Hot Iron 101

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It's easy to view distant horizons when you're standing on the shoulders of giants: this is where I come in with Hot Iron edition 101. The work that Tim Walford has put into Amateur Radio with his designs and kits have given thousands of Radio Amateurs a professional piece of electronic design; and has given many technical tips and kinks to all of us. I've had plenty of correspondence with Tim over the years, about – well, just about any RF design and construction aspect you can name; quite robust discussions too, I should add!

Tim and I worked for the same electronics company; he in high speed digital design, myself in semiconductor manufacturing machinery maintenance and Test Equipment. This gave us much common ground in RF and "nanosecond" design, but from opposite angles: Tim always looked for elegant and efficient design, I for the robust circuit which survived fault conditions and overload, easily repairable by a technician in the depths of a 12 hour night shift. We usually came to similar solutions: but where Tim had a handfull of components on a dinky circuit board, I had gear that you took a bag of spanners to! All in the "artistic appreciation", I'm told!

A common feature of canny electronic design: "no point in re-inventing the wheel" as my foreman taught me, so, to that end, I have spoken to some World class RF and electronics designers for permission to direct Hot Iron readers to their web pages. I give my grateful thanks to these people for their generous assistance and I hope readers of Hot Iron enjoy their amazing genius as much as I have over the years.

Hot Iron is the "Journal of the Constructor's Club", and that is exactly where I will take up the task. You will find in Hot Iron articles and designs specifically to build, and discussions about RF electronics construction. What you won't find are commercial equipment comparisons, nor references to commercial radio equipment. "Construction" is the key word: I have the advantage of a Technical Apprenticeship guided by the watchful eyes of ex RAF, Navy and Army veterans that would-be constructors of today don't have. I intend Hot Iron to be as construction orientated as possible: I apologise to the "old timers" who have superb construction skills – but for Amateur Radio to survive and prosper, I think we have to help those who want "real" Amateur Radio in their lives. Hot Iron holds out that helping hand by giving construction guides, tips and techniques; and I ask "old timers" to help newcomers by sending any and all construction tips & wrinkles they have accumulated over the years for inclusion in Hot Iron, no matter how large or small they may be, or basic. They are all valuable!

Finally Hot Iron is taking a different format, in that I'm creating sections for the fundamental topics of Amateur Radio design and construction: the Contents table shows the sections I've chosen (for now). Hot Iron is *your* Journal: I welcome any and every contribution relevant to Hot Iron's construction theme, and will take on board suggestions and requests for particular areas of RF interest. I have allocated space for "Letters to the Editor" so please feel free to sling brickbats or offer congratulations! A special section - "Tim's Topics" - is at the fore of the Journal. This is a mark of respect to the founder of Hot Iron, Tim Walford, and as long as Tim has anything to say to Hot Iron readers, he has a place here. My pleasure, Tim!

This edition features articles from my own notes and contributors. I (personally) believe valves are ideal for home constructed transmitters, but not all home constructors are happy with high voltages. I use transistors too – but have blown up more transistors than valves, by a big factor! Transistors win every time in receivers – they are naturally suited, and outperform valves in most receiver applications; they are also just right for lightweight, "SOTA" and QRP transmitters. Please use the Letters page to let me know what you think, and by all means send me any articles or ideas for inclusion. G6NGR, August 2018

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Circuits shown in Hot Iron may use potentially lethal voltages. It is your responsibility to ensure your own – and anybody else's – safety if you build or use equipment that employs hazardous voltages, currents or power. If in any doubt, you MUST get a competent person to check and approve the circuits, barriers and provisions to avoid any injury and electric shock. You MUST comply with your local Electrical Regulations and Safety Regulations.

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Tim's Topics

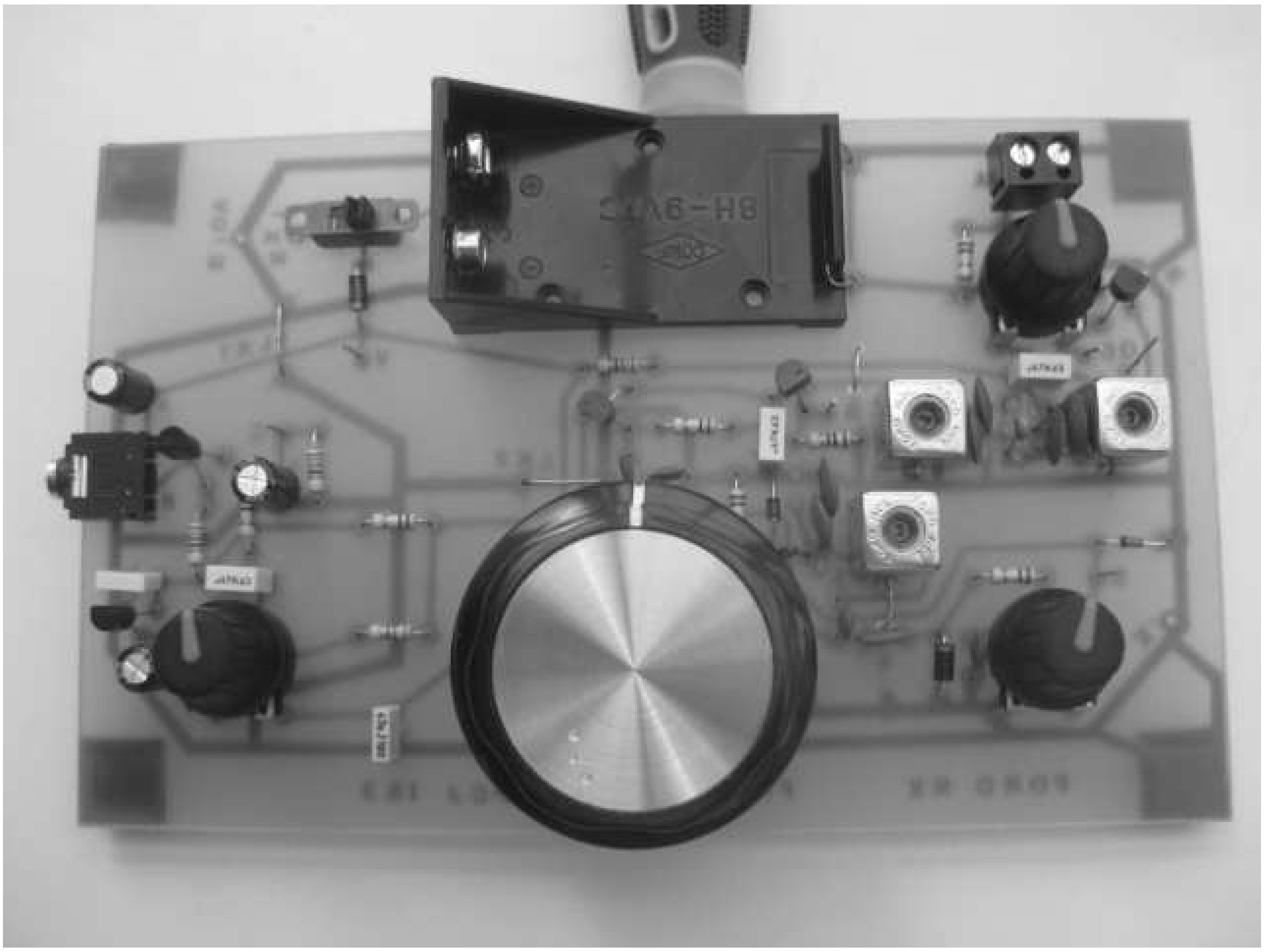
Kit news from Tim G3PCJ

The **Ford** is now available as a proper kit (instead of the original ugly built version and circuit information for you to build yourselves)! To remind readers, it is a relatively simple direct conversion receiver normally for 40m but with provision for either 20 or 80m. The kit has a single sided printed circuit board with plenty of space around parts. I am indebted to Steve G0FUV who encouraged me to turn the design into a proper kit and who has compiled the project's very smart construction manual – it is available from my website http://walfords.net/intermediate.htm The actual circuit is slightly improved compared that in Hot Iron 100 – I have added pads for the band options & a Zener supply regulator for the oscillator & Fine tuning. The other essential information – full circuit, layout, parts list and band options come with the physical kits. The design has a local oscillator running at band frequency for simplicity, ease of construction and setting up – but a consequence is any associated TX needs to be 'crystal controlled' as explained below!

The design is specifically for driving modern stereo 32R phones! This simplifies the output stage considerably and nowadays these phones are more readily obtained (if not already owned & cheaper!) than a small loud speaker! A simple audio amplifier to drive them is easily made using just two BS170 MOSFETs – see the circuit below. It has a high input impedance (~ 100K) with a bandwidth suited to phone signals. Both stages operate in the common source arrangement – the second stage having its source heavily decoupled for audio signals. Overall voltage gain with a 64R load is about x150. DC feedback from the output stage source lead stabilises the bias conditions; this can also provide a moderately stable DC voltage of about 2 volts for other stages if wanted. You may wonder why the second stage has a gate stopper resistor directly in series with its gate – this is to prevent VHF oscillation which can occur when a MOSFET (with its significant gate to source capacitance) drives a capacitive load on its source - it's a Colpitts oscillator!

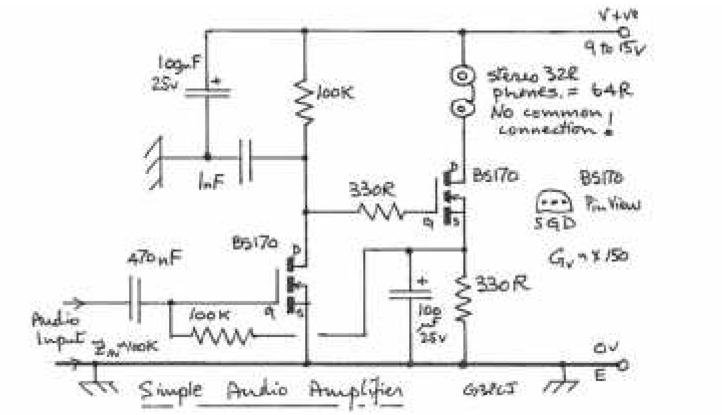
Shared impedances

Keen observers will have noticed that I changed the Ford from originally a dead bug style of construction on a continuous copper sheet to a single sided PCB without any ground plane. Aware that this can lead to problems, I increased the width and number of earthy/ground/0 volt tracks and also made several cross connections to minimise the track length for any particular part to the mass of other grounded parts. Somewhat to my surprise, when I came to peak up the RF filter inductors I noticed that it also shifted the local oscillator's frequency enough to move my 'tuning carrier', from a sig gen, out of the RX pass band! (To avoid this you should peak up the RF filters on band noise so the exact tuning is unimportant.) This effect was not present in the original dead bug version; the reason the local oscillator shifted is due to the RF and LO resonators somehow sharing an unintended common impedance – the most likely culprit being some part of the discrete earth tracks in the version with a PCB. I have since added many more wide earth tracks which may just be visible in the Ford Photo below. The effect is now much less pronounced and hence not a problem.



Interestingly, this sharing of a common impedance is the reason that simple CW transmitters chirp when their LO is running at the same frequency as the higher powered output stage – the output stage RF gets back into the VFO causing a slight change in frequency – in this case the shared impedance is less obvious but is actually the very small amount of unwanted coupling between the LO and output tank resonators – hence the usual solutions of running the LO at a different frequency or in modern rigs, using some sort of digital synthesis technique for the RF source!

“Ford” Audio section...



Radio Topics

My preferences...

Alright: I admit it. I'm one of those people who likes full carrier Amplitude Modulation, it's generation, reception, and simplicity. Sure, I'll never get any "real" DX and A.M. puts me in the corner where the oddities are, but, so be it! I know it's a fair slice of spectrum when I "Transmit", and I realise that only a quarter of my signal is for reception, but – and it's a big "but" for me - as I tune my receiver into an A.M. carrier, the crashing roar of the cosmos fades, and those gorgeous sidebands give sweet mellifluous tones, in beautiful clarity and intonation. The sheer ease with which you listen to full carrier A.M. signals is pleasant to my ear, easy on my mind. Whilst I do sympathise with contest competitors, and QRO SSB men running at full legal power, I *personally* like the sound of full carrier A.M. - and if radio isn't about listening, then what **IS** it about?

It's about "Digital Modulation Methods"...

Here's a historical fact: Samuel Morse didn't want his code to be transmitted by human hand – he designed his "transmitter" to be a semi-automatic stick of letters, which by dint of cam projections on the back of each letter, would automatically send the Morse for each individual letter, preserving the timing and spacing exactly. Similarly, the "receiver" was a printing mechanism, that produced hard copy for future reference and decoding in private – he didn't want his operators knowing the private business of his customers sending information via the telegraph. Sending and receiving by hand and ear was a later development that obsoleted the stick transmitter – as well as the privacy, security and automatic paper copy. The telegraph operators, having heard the code thousands of times, began "chatting" to one another with hand keys over the telegraph network – the text messaging and emails of the day? And the rest is history, as they say.

The advent of digital modulation (and similar related modulation methods) was heralded as the forthcoming wonder of the radio age, and so it has (mostly) proved. Whilst I like listening to nicely modulated speech, others prefer lines of text on a screen, or "waterfall" signal patterns - and more power to their elbows I say. This is because the digital modes more and more demand very high quality engineering - stable oscillators (thank goodness for DDS!), superb receiver technologies and digital filtering techniques that can out-pace anything analogue in just one chip. The onward march of digital methods can only be beneficial to all; and especially newcomers to the hobby, as the power of the system lies in the computing devices which pack in such massive processing power for very few pennies. The actual RF front end can be a USB "SDR receiver on a stick", yielding a "plug-n-play" radio solution. This to my mind is just as valid a "construction" project as bashing holes in chassis, or building a really neat loudspeaker enclosure for superb audio quality. "Here-Here" I say to digital technology, and I sincerely hope the esoteric methods used to dig out weak signals in the roaring maelstrom on the LF bands moves onto the HF, VHF and microwave bands for budding constructors to try.

This leaves, however, one outstanding challenge: the development of machine Morse using a PC keyboard to create the code, and an integrated receiving decoder that can decode ANY signal accurately - maybe teach us old laggards Morse without tears, by allowing us to use the significant advantages of CW? Learning the code would follow naturally, just as it did all those years ago with the telegraph operators. So, all you Android phone, Linux, Arduino, Raspberry Pi and PIC aficionados out there, how about it?

Back in the 1960's I recall (from an ARRL article) a "Morse Keyboard" that used "wonder chips" of the day - TTL - to generate Morse, but to date no effective Morse automatic receiver has ever been built, despite "fuzzy" logic and intuitive learning software. If a machine Morse transmission was prefixed by a timing sequence (like RS232 data frames are sometimes sent with "start" and "stop" bits) then the receive decoding could be simplified – "VVV" would be sufficient to synchronise a receive decoder, and let any human operators know that it was a machine transmitting, without wasting too much air time?

Some Requests...

Of the emails I received asking to be included in the circulation of Hot Iron (thank you!), a good percentage asked about valves. Valves, in my opinion, are the amateur's friend: they give years of valiant service, withstand abuse and come back for more. Valve circuits are simple; high impedance designs are less complex and far more suited (in some instances) to home constructed transmitters.

I used Wes Hayward's "Solid State Design for the Radio Amateur" when designing Test Gear for transistor test, and many times Wes had a design that slotted straight in and made my life much easier. I only disagree with Wes in one tiny regard: transistors (and mosfets) are nowhere near as rugged as valves under fault conditions. Professionally, I maintained power (up to 500kW) RF equipment: some using valves and others using solid state power devices – the solid state systems broke down much more frequently – and usually at some hour deep in the night shift.

A "seasoned" engineer gave me some advice: "Transistors? God bless 'em. We'll never be out of a job whilst transistors are around – fastest 3 legged fuses ever invented. Stick to valves, they are good friends and don't pop at the slightest whim". He being my mentor (thanks, Stan), he got me involved in amateur radio: the valves I changed out when their cathodes got a bit "lame", he happily put a kV on their anodes and had much fun on 80m. That's why I like valves just as much as transistors, and would advise any would-be constructor to watch Hot Iron for valve designs – fancy a one valve transceiver, then? That won't go "PHUTTT!" if you forget to connect an antenna?

The demise of an old friend...

It's only a few months now since Maplin Electronics (the UK equivalent of "Radio Shack" , or "Tandy" in the USA?) closed it's doors for good. Gone, those useful folded aluminium boxes. Gone, that convenient local source of electronic bits. Gone, those cheap and cheerful tools. And all the rest; you know the story, it's the familiar malaise of the High Street "shopping experience". Maplin went bust for many reasons, but the main one was that they didn't sell enough to pay for running a shop in today's markets – not many people build electronics any more. I get all the bits I want from electronics suppliers I know from my professional years – but not for new constructors, who might not have the first clue where to get parts for a design they want to try. Kits provide what a new constructor needs – but the next step's the big hurdle. Where does the new constructor go for parts? I would suggest subscribing to SPRAT, the G-QRP club of the UK, and their magnificent Club Sales, as a start! If you think it useful, please write (to the Letters page) and if sufficient requests warrant it, I'll compile a list of "amateur" suppliers for inclusion in the "Data & Information" section.

Oscillators

Different strokes for different folks...

The maestro of Arduino control for amateur DDS oscillators (and much, much, more) is Pete Juliano, N6QW. Take a look at his web page, http://www.n6qw.com, sit back, take your time. Pete has developed the Arduino for not only the DDS oscillator, but entire transceiver control – the whole shebang – and an analogue meter! A fascinating article follows, sent in by Pete – for which I'm very much obliged – and to add to that, if you want to see how Arduino technology can take amateur radio forward, then Pete's the man to watch. And listen to him, too: he's one of the presenters of the superb SolderSmoke podcasts, along with another "homebuild" stalwart of amateur radio, Bill Meara, N2CQR.

As always, for some folks, bells and whistles aren't their thing. For example, I need few frequencies to work A.M. – each band tends to have only one or two frequencies (if that) for A.M. curmudgeons – nor need complicated rig control, so a crystal or two and a couple of relays do the job nicely. Or should I say one of Terry Mowles' (VK5TM) PIC DDS controllers does the job! Terry is an ace at simplicity and low cost – PIC microcontrollers driving DDS, no frills, just a few push buttons for frequency "up" and "down" and one or two other functions. I asked Terry about discrete logic, or even BCD switches, to feed the control word into a DDS oscillator – any of these solutions would be far more expensive (and cumbersome) than a PIC! Take a look at Terry's web page, http://www.vk5tm.com/index.php and see what I mean. A single 5317kHz crystal recently cost me £7.30; I can get a DDS from my favourite auction house for under £8.50 that will cover every band from 2200m to 6m, and a PIC for £0.80 – what price crystal oscillators now?

And... how long will analogue VFO's survive? Drift of a few 10's of Hz (a remarkable figure for any analogue oscillator) would have complaints from users of modern commercial gear. DDS's are being retrofitted into boat anchors as an external VFO – is this the twilight of analogue VFO's?

Using the Arduino + Color Display as a Panel Meter

By Pete Juliano, N6QW n6qwham@gmail.com

About five years ago I got "hooked" on the Arduino as an element of a digital VFO system. At that time the display du jour was the one or two-line 'seasick green" LCD. But today we have a far greater latitude in our choice of displays. Adding color to a display with a choice of some 65,000 colors is staggering. $5 gets you one of these Color TFT displays delivered to your door.

For the longest time my displays were limited to showing frequencies. But there is much more hiding in the bushes insofar as the Arduino capabilities and today I would like to talk about Arduino Panel Meters.

First, I should start with the disclaimer – I am an amateur. My skill set is more of hacking, poking, trying, retrying, pulling my hair, drinking liquid sprits and more hacking. My results must seem crude to those illuminati who lurk the prestigious reflectors. But I suspect many of the Hot Iron readers are just like me and see half the fun is the learning.

Below is a Color TFT display with three bar graph type meters.

The top most meter is nothing more than a linear scale type meter which takes about 6 lines of code to implement. The first four lines draw the rectangular box and the next two lines generate the scale tick marks. Meter labeling that would add a couple of more lines.

[Don't worry I will providing the code on my website where you can "lift it" and embed it in your project. Please see http://www.n6qw.com for the code.]

This type of meter face would be useful for voltage measurements or perhaps level measurements. A remote rain gauge telling you how much it rained last evening is a good example of level measurement. Typically, I use a bar graph line on my displays where the bar itself is nothing more than instructing the Arduino to display a colored rectangle at a display location. The rectangle is long but not very wide. In specifying the rectangle code, one of the dimensions is a variable. This variable is detected by one of the analog ports and after suitable processing is inserted in the code. Thus, we have a "moving bar" display. The refresh rate is the speed of the Arduino loop.

The second and third displays as you will note have tick marks that are non-linear as in the top most display. The middle display shows a log scale and the bottom display while not a log scale is like the typical S Meter scales we see on various rigs. Again, these are moving bar graphs and the bar is generated in the same manner – read an analog pin, perform some math functions and then make that the variable in the rectangle display.

Let's talk a bit about the display of the "tick" marks in the displays. How the code works is that line 1 (below), is the typical range statement **for(int i = 0 < 18 i++) is a do loop,** where a process is actually carried out 19 times. The "int" means integer number. The second line specifies a very small rectangle to be built that is repeated 18 times beyond the first application but that same "i" is fitted into an equation that indexes the location of where the next rectangle is to be drawn.

The code for the top graph

```
for(int i = 0; i < 18; i++) {   // A Trick to add "Tick Marks"
display.fillRect(12 + 10* i,8,1,5,WHITE);}  //linear meter scale
```

Essentially the 1st line says do this process 19 times (0-18). The second line tells the Arduino to start at x position =12, y position = 8 and to draw the 1st rectangle 1 unit wide and 5 units vertical (downward) and that was when i = 0.

When i goes to 1, the rectangle is indexed 12 additional units in the x direction (12*1). When the i=3 the rectangle is drawn at 12 + 36 or X = 48. This continues all the way through the 19 counts.

Now when you go to meter faces 2 and 3 that involves some creative thinking **BEFORE** you write any code. Again, the same two lines (only modified) as above will put the log scale on the meter face.

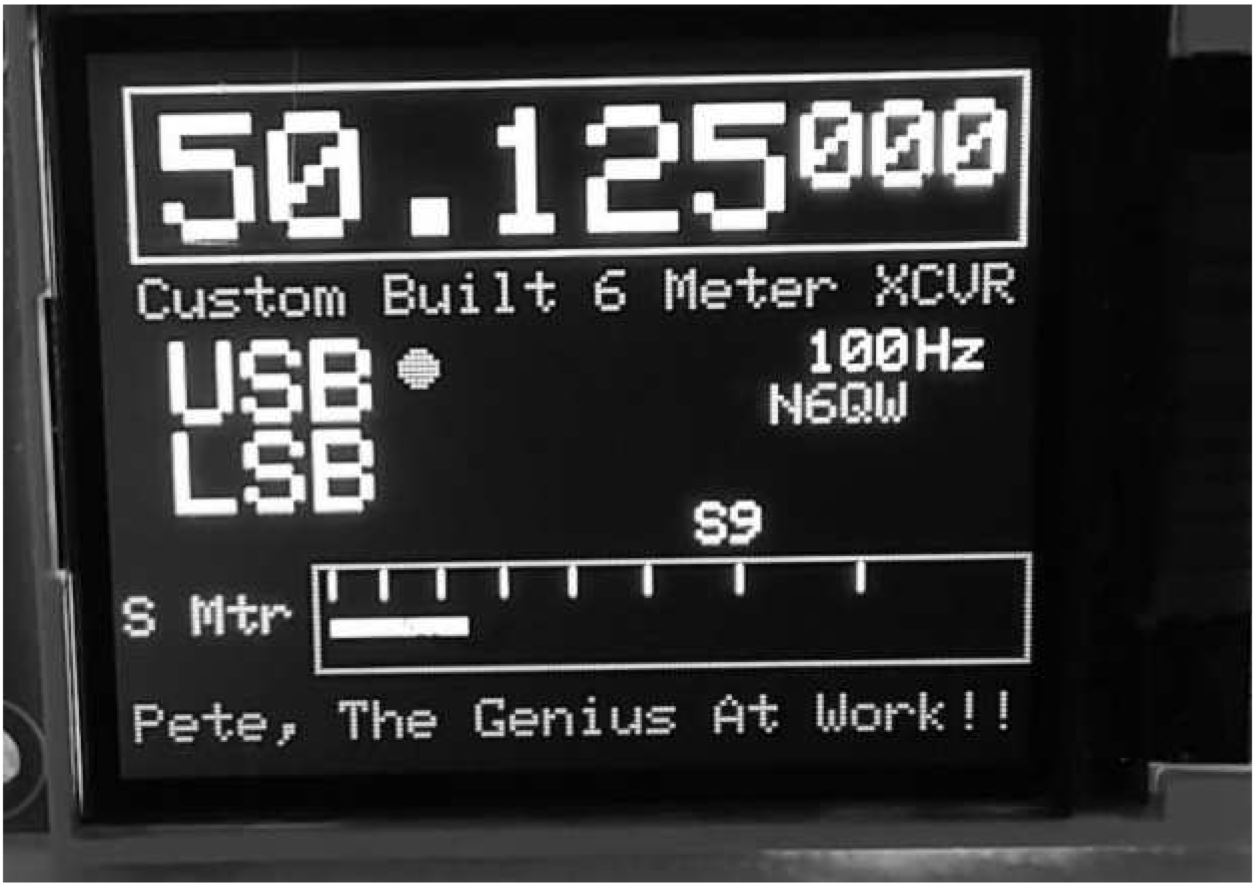
The code for the second meter is:

```
for(int i = 1; i < 5; i++) {   // A Trick to add "Tick Marks"
  display.fillRect( 14+abs(100*log( i)),54,1,6,RED); }
```

For this case we have a similar 1st line only this time we are asking for only 5 tick marks (1-5) and the reason we did not use i=0 is that we will get a value off scale and we also need to pick a “0” location which says that it will start at X = 14. Keep in mind the log(1) = 0. Another reason to start with 1. We also added for good measure the taking of the absolute value (abs). Let us see what happens as we increment i.

For I = 1 then the X value = 14. For i = 2 then the x value = 14 + 100 * log(2) = 44(nearest integer). Moving to i=3 we have x = 14 + 100*log(3) = 48 + 14 = 62. Next we have i=4 with x = 14 + 100*log(4) = 74. Finally we have i=5 where x = 14 + 100*log(5)= 84. Thus our x points are 14, 44, 62, 74, and 84. The “delta” change between subsequent values is getting smaller. Mind you (if you are watching closely,) only 4 tick marks actually are on the screen.

Finally, we have the last meter face which is an “S Meter”. This time the photo is taken with other display information. This one shows the integration with other data and the display bar.

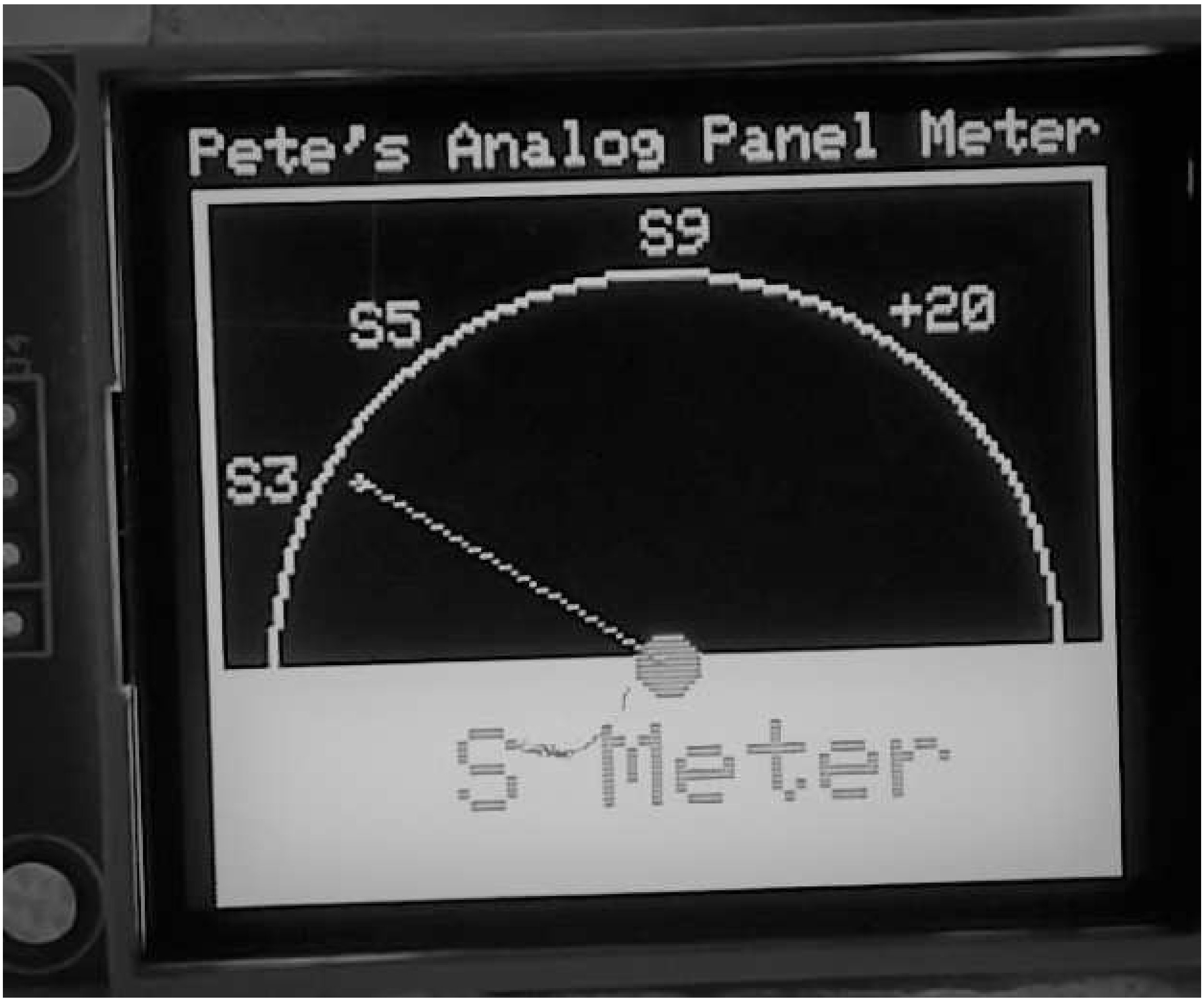


There is no sound basis for the code I am about to share, other than what is shown for the Tick marks "looks like" we see with S Meters. Since it too had to be non-linear I used a square root function with a multiplier. But there was also a visual trick at play here. In the case of our log scale the spacing between the tick marks got smaller as the tick marks went from left to right. So now how do reverse that so that as you go from left to right the spacing grows larger. The one-word simple answer is SUBTRACTION. For the X value we start with a large number for the baseline X and as the square root number gets larger the resultant X value gets smaller. The painting of the tick marks is from **right to left.**

```
  display.setTextSize(1);
  display.setTextColor(GREEN);
display.setCursor(2,95);
  display.println("S Mtr");
display.drawRect(35,90,125,20,0xF820); //S meter red rectangle
display.fillRect(36,97, 80,6, BLACK); //blank display of bargraph when there are changes

display.fillRect(38,100, val,3, YELLOW);  //S Meter bar graph

  display.setTextSize(1);
  display.setTextColor(WHITE);
  display.setCursor(102,80);
  display.print("S9");

  for(int i = 1; i < 9; i++) {   // A Trick to add "Tick Marks" to the S Meter
      display.fillRect(180-( 50*sqrt(i)),91,1,5,WHITE);}  // This is a non-linear scale pseudo log
scale
```

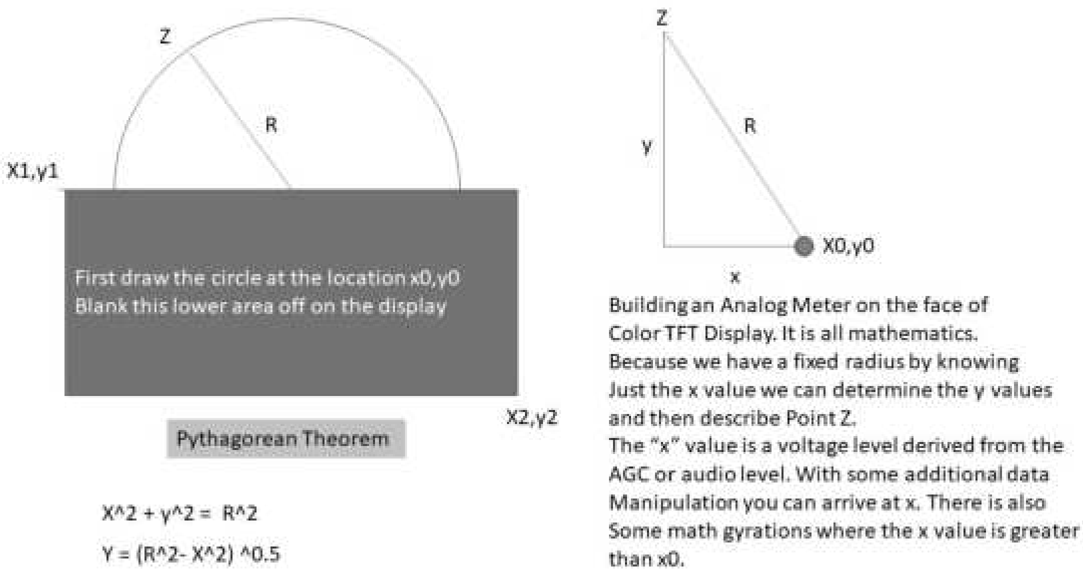
The important lines are the last two which shows that we will have 9 points and the second line shows the math equation that was pulled out of thin air. The 180 – (50*sqrt(1)) is the key.

How about something Round and “Old School”?



Now if you want to build circular type analog meters then, you need to know some advanced math to derive the equations. Hark back to the mathematics of the right triangle where if you know two of the triangle dimensions you can find the third. There was this Greek guy, Pythagoras who having nothing better to do came up with the concept. With our analog indicator meter, we have some already known information. Firstly, we can fix the hypotenuse (long side) and make that a constant equal to the radius of a circle. The next piece of information is the x value (base side) which is what we are measuring on one of the Arduino pins. The vertical side is then derived by squaring the hypotenuse and the squaring the value we measured and subtract that (x value squared) from our hypotenuse squared value. Next taking the square root of that result we have the “Y“ dimension. Don’t worry the Arduino math functions do this for you. The values x and y define a point on the arc of the circle. A line connecting the point on the circle to the center of the circle is “the meter movement”. One point of the line is fixed and the other moves.

Thus, you will have a moving meter needle. Now what I described is a simplistic approach, that is why I prefer the bar graphs. But additional considerations for the Analog meter would be to include some sampling delays where you have a sample and hold –just so the meter has a smooth movement. You would also need some range boundaries to limit the really wild excursion –i.e. pinning the needle. You will also need “blanking of the old meter location as you move to the next. Having a black background facilitates the blanking



Note the scales are arbitrary and would require calibration /modification. But this will get you started. Code for the four panel meter faces will be posted on my website www.n6qw.com

73's Pete N6QW

Well, it IS an oscillator of sorts….!

I've seen circuits for Morse training buzzers, continuity beepers and such, that had multiple transistors, uni-junctions, and even PIC microcontrollers! "Simple is as simple does" here; fancy electronics? Multiple transistors? No... a diode and a relay, and a capacitor if you want to get fancy!

Take your relay, jumper one end of the relay coil to one side of a normally closed contact. Feed power (enough to pull in the relay) via a Morse key to the other normally closed contact, and the open coil end. Result: a buzzer! To quench the sparking at the contacts, wire a diode (the diode cathode / bar end MUST go to the positive end of the coil) across the coil terminals.

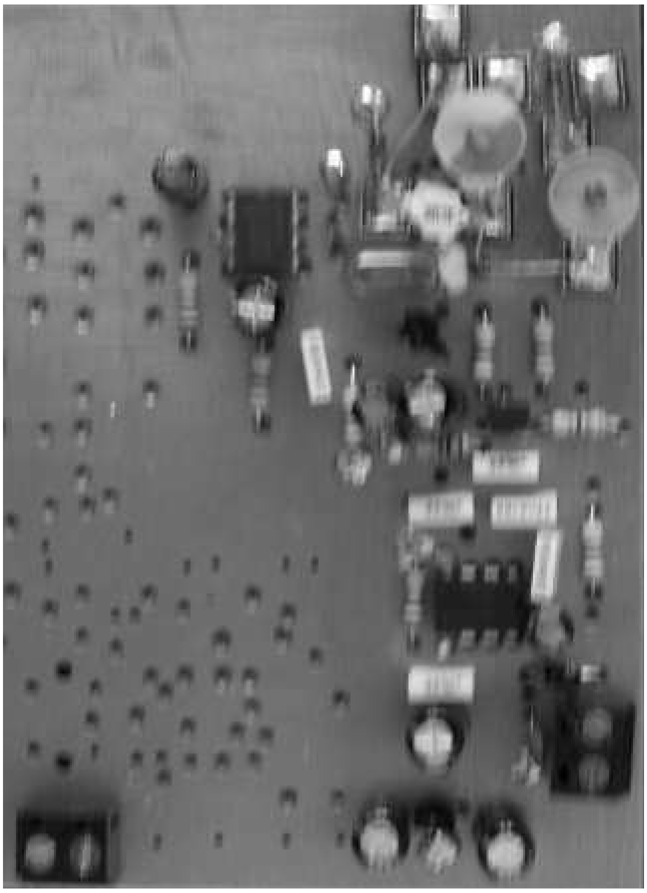
To increase the sound, connect a small loudspeaker with a capacitor in series across the normally closed contacts. The larger the capacitor, the louder the sound. Try a 47nF first and adjust as per requirements.

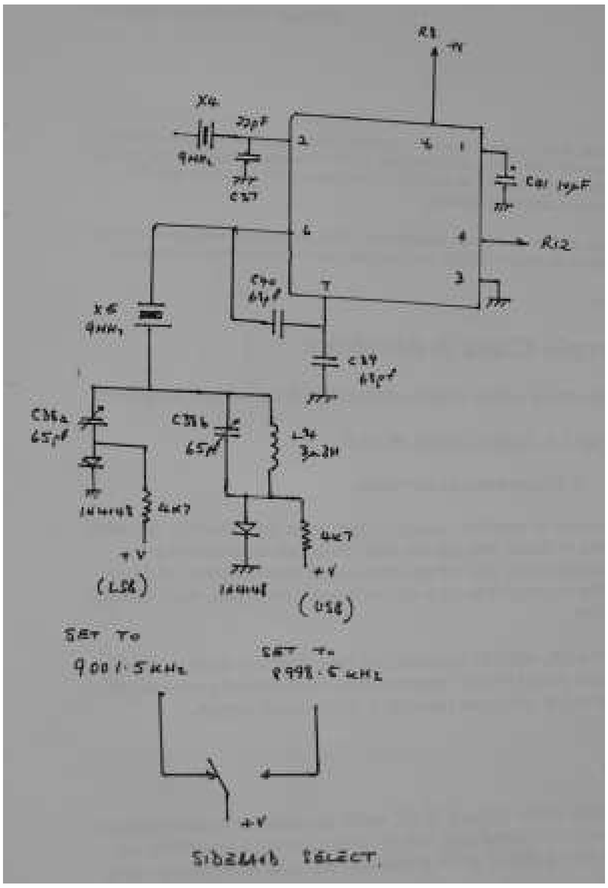
Rx's

Halse receiver mods by David, G8EMA....

David has sent pictures of the modifications he's made to the Halse receiver, with USB / LSB switching capability (pictures below, apologies for the "fuzzy"). This is an ongoing project, and

David is doing more modifications as time allows. As and when more information arrives, I will make sure it is included. I particularly like his “island” pad construction; it’s a favourite of mine too, and it allows easy access for servicing or changes.



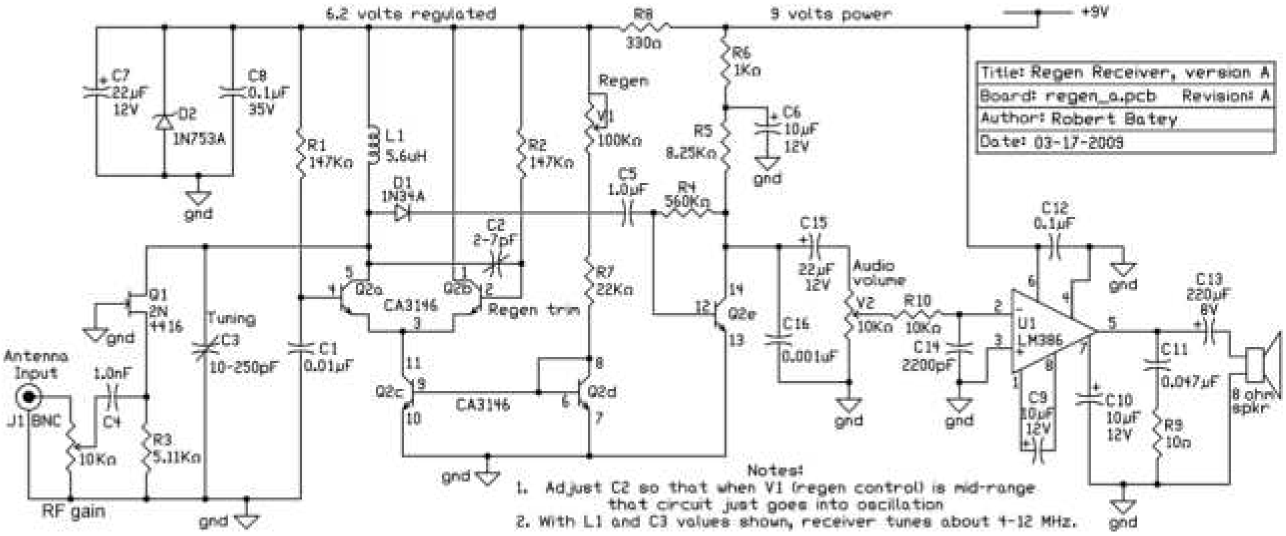


A very well behaved TRF receiver...

(By Robert Batey, KF7FTQ, from http://g3ynh.info/circuits/hi-fi_am.html)

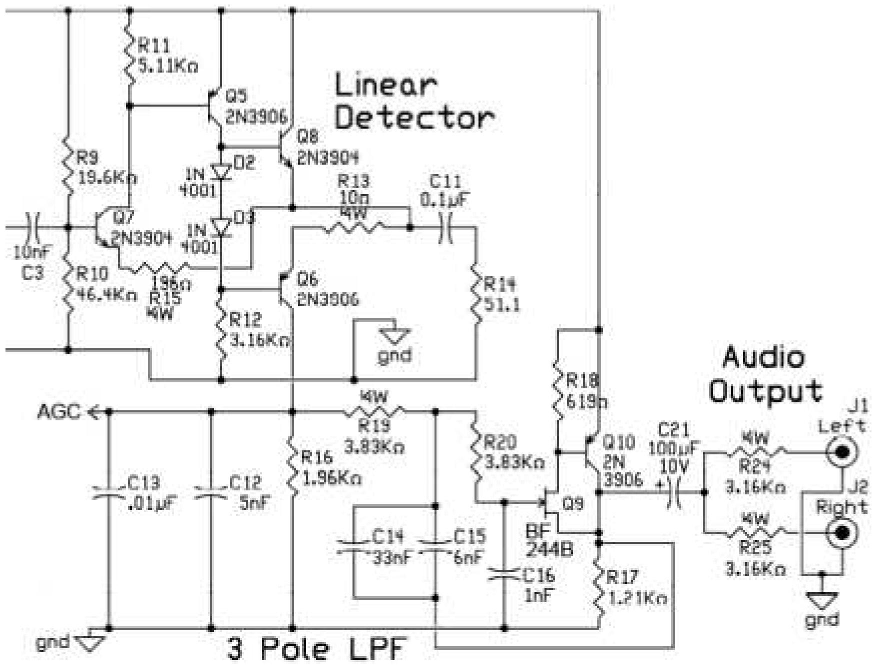
This receiver is an example of good design, as it eliminates a lot of the problems found in simpler designs yet retains easy construction and straightforward circuitry. The main problem with a simple regenerative receiver is the “hysteresis” in the regeneration control, the control having being been advanced into oscillation, has to be backed off a considerable amount to stop the oscillation. It’s almost impossible to just touch the “sweet spot”, as the receiver jumps into oscillation at the slightest perturbation. A feature of “long-tailed pair” differential amplifiers is that the amplifier’s overall gain drops as the signal levels within it increase; and in this design the control of regeneration is an active current source, isolated from the control potentiometer. This gives more or less perfect control, and is improved by using a transistor array, a CA3046 or CA 3146 as the transistors within it are very closely matched RF devices.

I’ve built quite a few of Robert’s designs, and every one has run “first-time”, and I can recommend them – you can see more of his designs on G3YNH’s web page referred to above – and Jim Kearman, KR1S, has adapted some of Robert’s circuits to his own requirements successfully.



The circuit works like this: Q1 is a conventional grounded gate j-fet isolation amplifier feeding the incoming RF directly into the tuning L/C circuit, comprising C3 (b'spread), C1 (main tuning) and L1 (can be any inductor, even a lossy RF moulded choke type). Q2a and Q2b form a differential (long-tailed pair) amplifier set up as an emitter coupled oscillator, the feedback set to optimum with C2, the oscillator feedback capacitor, and the "tail" transistor Q2c controlling the overall current through the long tailed pair and hence the gain of the stages. Any losses in L1 or C1, C3 or Q1 drain are cancelled by the Q multiplying effect of the long tailed pair emitter coupled oscillator being brought to the point of oscillation by the current in Q2c and Q2d. Q2c regulates the current via Q2d, which is set up as a temperature compensated identical (as near as wafer fabrication allows) PN junction to Q2c; these are transistors fabricated very close together under practically identical processing conditions, so the base-emitter volt drops are as near identical as is possible. So are the forward bias characteristics of each base–emitter diode: as current in Q2d's collector and base changes, then the current in Q2c's collector follows in an identical manner – but entirely (near as makes no difference) isolated from the current in Q2d's collector. This is a "current mirror" and is common in many linear IC's and employed for exactly this purpose. The amplified RF is taken from the L/C tuning junction via a 1N34A germanium diode demodulator, fed to a simple audio buffer stage with "top cut" elements C16 and C14) and thence to a ubiquitous LM386 audio driver amplifier.

Robert comments on the simple detector diode, the 1N34A, as being a germanium device, that has slight reverse leakage and thus auto DC biases itself; if (for example) a Shottky or Silicon PN junction diode is used, a DC path should be provided from the cathode of the detector diode to ground - a few µAmps are all that's needed - a value of 2M2 to 4M7 would be a good start.



For optimum A.M. performance, the Linear Detector as modified by Robert from another circuit would be a good idea. I’ve built one and the difference in audio quality (and hence readability of a poor signal) is profound. Robert’s detector is very well behaved due to the large amount of negative feedback, and is well worth building with whatever components you have to hand: the only critical parts are the notch filter resistors R16, 17, 18, 19, 20. For amateur communications receivers, the carrier heterodyne notch filters are probably not much use– amateurs don’t have to abide by 9kHz (10kHz in the USA) A.M. channel spacing – but might help if the bands are a bit crowded.

I would always recommend a decent Audio amplifier for audio output; I discuss this more in the “Audio” section of this edition of “Hot Iron”.

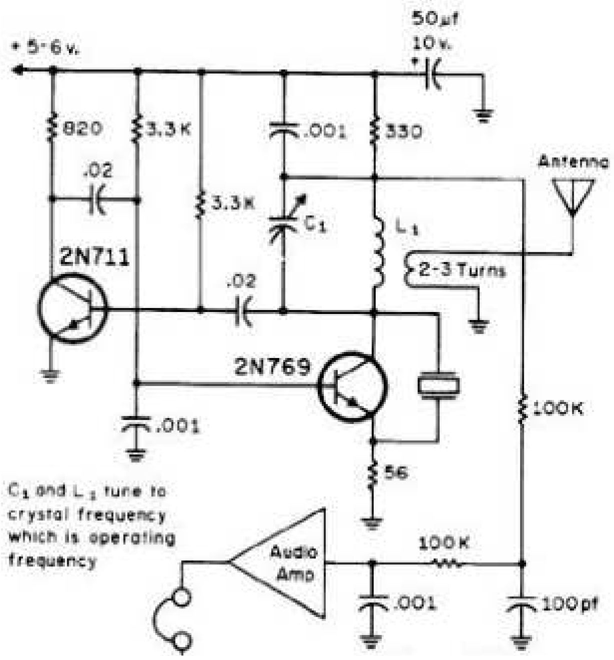
Super-Regens on HF...?

Being an A.M. curmudgeon, I have room in my repertoire for super-regenerative receivers. Usually thought to be fit for VHF local comms only, nothing could be further from the truth. A super-regen can be very effective for HF A.M., by using crystal control of the receiver bandwidth - see below for the “bare bones” circuit. Single channel fixed frequency HF operation becomes very simple and effective with crystal controlled super-regen receivers, offering simple tight bandwidth reception.

This diagram doesn’t show the RF isolation amplifier, mandatory to eliminate interference – I use an NPN grounded base or a j-fet grounded gate depending on the mood I’m in, from Chas. Kitchin’s (N1TEV) designs in the ARRL handbooks. Neither does the diagram show the shunt capacitor for trimming the crystal dead on the nail, or the high value resistor in parallel with the crystal to widen the receiver bandwidth for transmitters that drift a bit – try 470k, 1M or 1M2.

The circuit is a superb design: it’s a multi-vibrator, and employs the parabolic ramp of base voltage found in a multi-vibrator as a near ideal sawtooth quench waveform for the super-regen stage, the 2N769. Modern transistors fit readily into this circuit, and I run a crystal controlled super-regen on the 60m A.M. slot at 5317kHz with good results. It will run equally well on 80m, and 160m too, because the A.M. frequencies are (more or less) fixed I don’t need a VFO to tune across a band; but on the lower bands the bandwidth is very tight.

Don’t try a “self-quenched” super-regen with a crystal – the circuit won’t quench at anything like the required rate, as the Q of the crystal is so high. The oscillations can’t quench in time. You can however use this circuit as the oscillator for an accompanying transmitter, by disabling the multivibrator and taking a signal from the crystal oscillator section – it’s a common base oscillator.



UHF and water pipes...

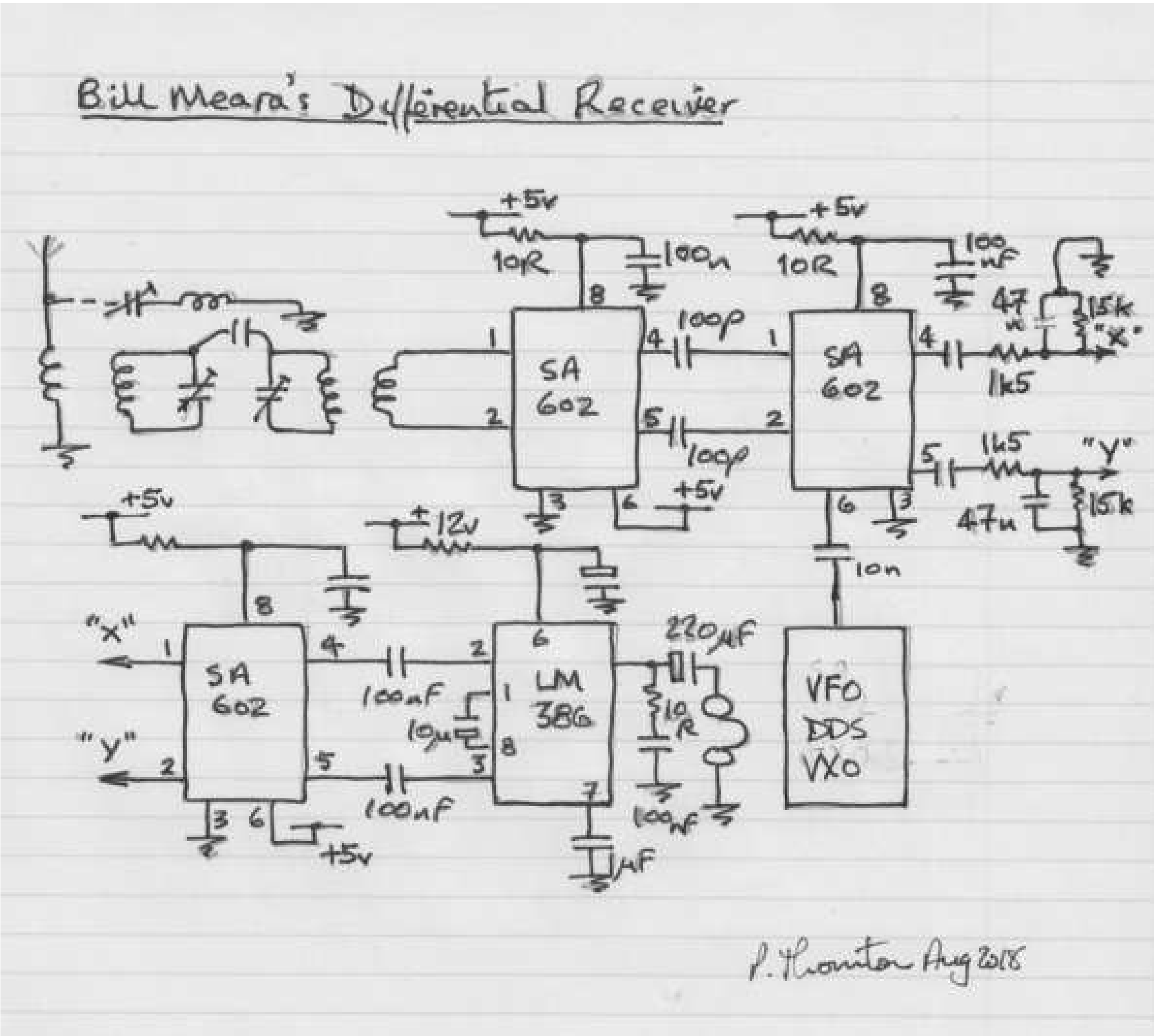
As you will have probably gathered, I’m often found wandering in the more curious corners of RF. One of the most interesting RF explorers I’ve come across is Harry Lythall, SM0VPO, who has hundreds of wonderful RF projects on his web pages. One which caught my eye when designing transistor Ft test rigs in my previous life (in a semiconductor wafer fab.) was Harry’s UHF resonator designs using copper water pipe; a quarter wave filter based on Harry’s design is in daily use measuring high Ft transistors to this day. The link shows a Colpitts and Hartley oscillator: http://www.ct2030swl.com/blog/articles/experimental-resonator-for-vhfuhf-by-harry-lythall/

Any radio amateur worth his milliwatts knows an oscillator equals a receiver so I thought it worth a go with Harry's Colpitts configuration. It works superbly: I could detect the factory Ft test rig running 2 Watts / 500MHz from a mile away, with a simple 3 element "bent wire" Yagi. Simply turn Harry's Colpitts resonator / oscillator into a regenerative receiver by varying the supply voltage, and extracting the audio from a 1k sense resistor in the +ve feed line. I used his idea for stabilising the Colpitts by supporting the centre line with an insulating bush. It held a steady note with a 500MHz signal generator for an hour, an amazing result for a TRF regen running at such frequencies.

Bill Meara's Differential SA602/612 receiver...

Bill Meara, N2CQR, of "SolderSmoke" fame, designed and built a true differential direct conversion receiver for HF that ran three SA602/612 chips: one as an RF amplifier, one for the mixer, and one for the buffer / diplexer. And very neat it is too! Such a differential circuit, powered by a battery to eliminate of the dreaded direct conversion "hum", will give superb results, as the differential signal paths automatically cancel common mode interference and noise. The circuit is easily understood, apart from one detail. Bill found it necessary to inlude a series trap on the antenna input, to eliminate broadcast breakthrough if I remember right, but it illustrates a good point we should all keep in mind: attract the signal you want (the double tuned top linked bandpass input filter – note the bottom of each parallel resonant section should be earthed) and reject what you don't want (the series resonant shunt filter).

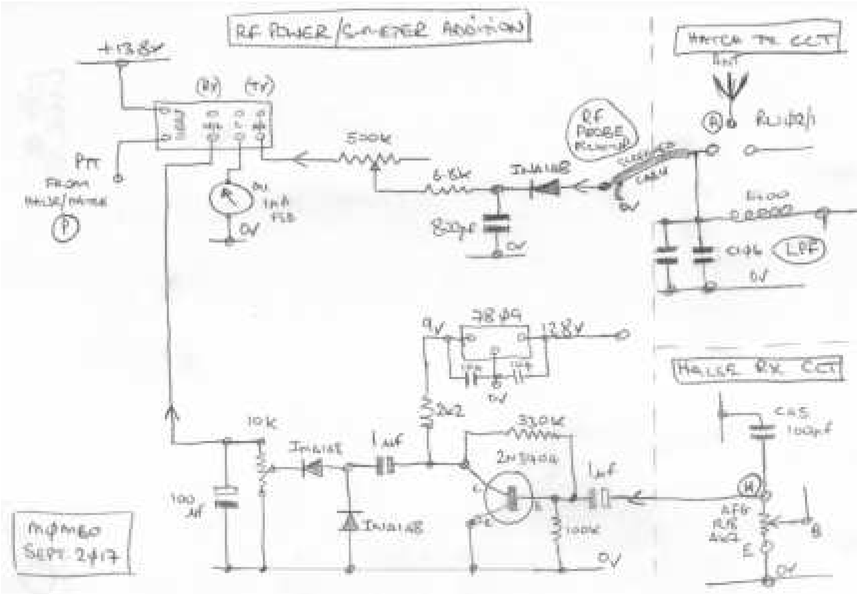
The local oscillator isn't shown – you can use any oscillator you want, so long as it can drive 300mV or more into pin 6 of the mixer. Needless to say, the local oscillator can be an SA602/612, if you like!

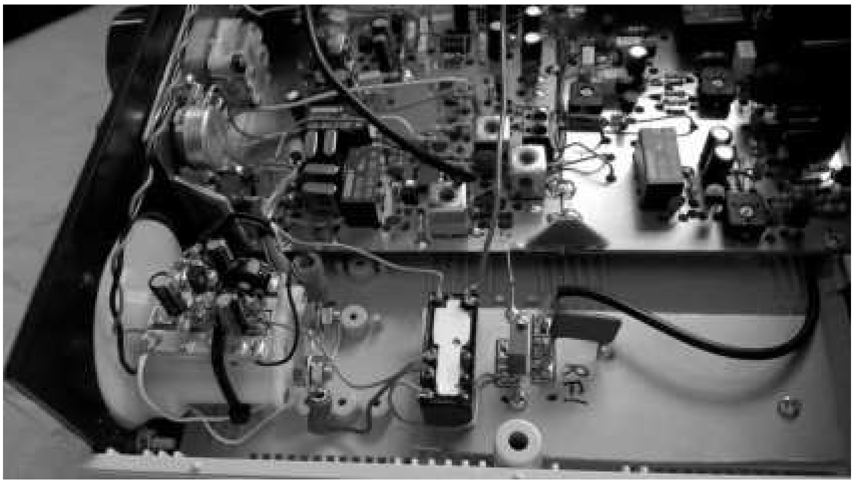


Pin 4, LM386 = ground, pin 5 = output. All supply resistors are 10R, capacitors 100nF/10µF.

Tx's

Hatch SSB transceiver mods by M0MBO....

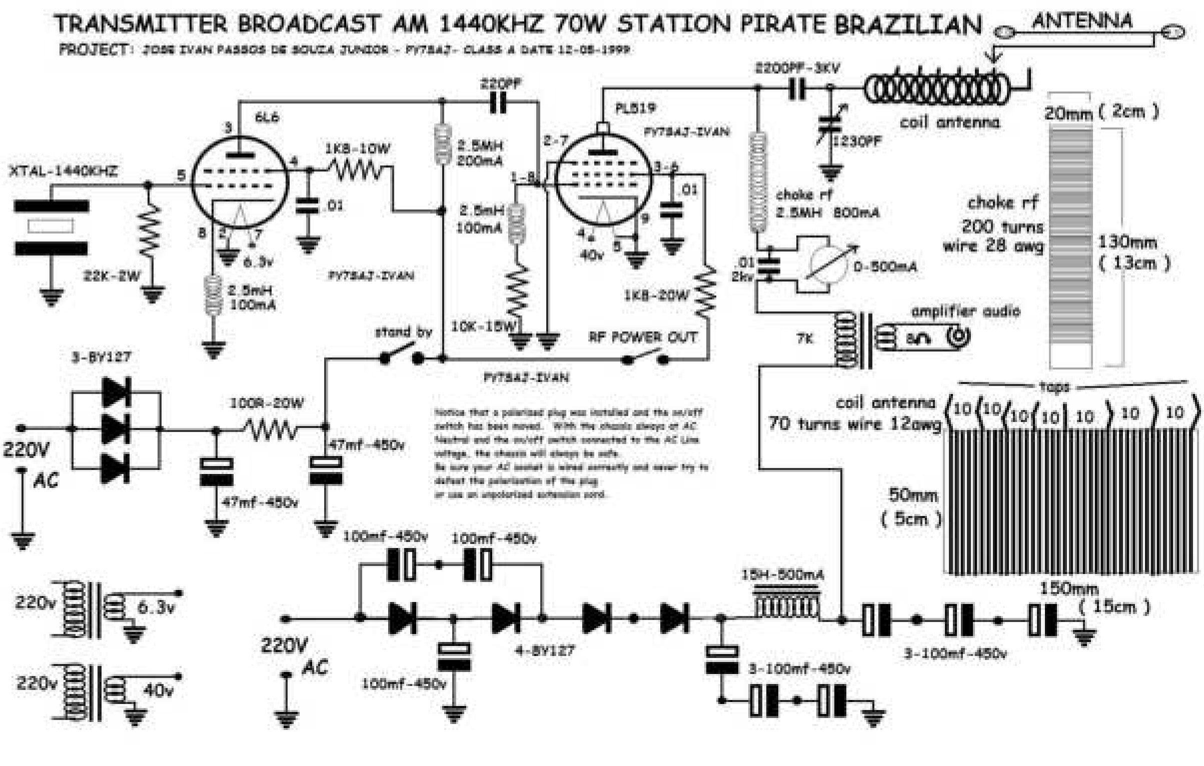




Here’s a very neat mod to the “Hatch” transceiver by M0MBO to add an RF power and “S” meter circuit. You can see the neat way the space has been adapted, and the effective installation. A good job well done!

The Pink Brazilian...

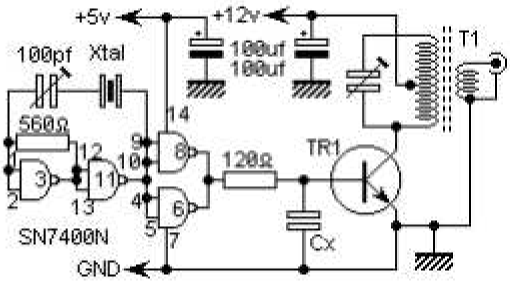
Here’s a design from Ivan PY7 SAJ, which illustrates the simplicity of valve circuits (for purposes I cannot condone). I intend to modify it for CW (cathode keying) and A.M. (plug-in MOSFET cathode modulator). I’ll be using a 6146B valve for the final, and high voltage transistors for the oscillator; a MOSFET for the cathode modulator, transistor screen grid drive and a transformer power supply (I’m not half wave tripling straight off the mains, and neither should you!). Power transformers are readily obtainable, 400v – 230v rms, 250VA or 500VA, from scrap industrial control panels. One of these, run “backwards” from 230v AC mains, feeding a full wave voltage doubler will yield 1kV DC – good for 50W from a 6146B (if you’re quick). Watch this space!



Incidentally, the name, “Pink Brazilian” will be explained when it’s up and running!

Harry’s 5 Watt transmitter...

Here’s a 5 watt transmitter, using TTL to drive a bipolar P.A. If you used CMOS NOR gates 4001B, with a supply of 9 or 12 volts, then an IRF 510 MOSFET would be a distinct possibility using a 4069B, all gates in parallel as gate drivers – and keying NOR gates is simpler. More can be found in Harry Lythall’s (SM0VPO) web pages. It doesn’t come any cheaper or simpler than this! (And... it’s easy to amplitude modulate the final.)



Audio Topics

Quality – or the lack of it...

As radio amateurs, we spend a lot of time working on improving receivers. We strive for “strong” mixers, controlled bandwidth IF amplifiers / crystal filters, pure oscillator tones, precision AGC control – then throw the whole shebang away by bunging our lovingly processed signals through a “minimal component” audio amplifier to present them to our ears! There’s no excuse for poor audio quality: technology and audio circuits have come a long way in the last 10 years. A distorted screech with added snap, crackle and pop has no place coming from a decent receiver! To that end, both transmitting and receiving audio should be as good as we can make it for effective communications. To see how Audio techniques have developed, visit Rod Elliott’s web pages, http://sound.whsites.net/index2.html and see how it’s done by a World class Audio expert. You won’t be displeased!

Microphones and such...

Transmitter microphones are often selected by price or availability – no thought of dynamic range, frequency response or noise – which if similar selection criteria were adopted in the RF design, would result in most unsatisfactory performance. But – quality microphones need not be expensive! The miniature “ear buds” much beloved nowadays make superb dynamic microphones, combined with a good impedance matched amplifier and a simple acoustically damped housing (my favourite is a roll-on deodorant bottle, with cut down foam pipe lagging as the acoustic damping). Alternatively, copper pipe fittings can be very effective (Internet search “Copperphone” for a commercial item that uses special damping for a “vintage” sound) combined with an electret microphone insert, pipe lagging dampers, are surprisingly good performers.

An internal 9 volt battery for microphone power eliminates a whole mess of RF and feedback problems from “phantom” power supplies and earth loops, as does feeding a good pre-amp: Rod Elliot’s Project #13 gives very good audio, http://sound.whsites.net/index2.html - where very low noise impedance matched microphone pre-amplifiers (and much more of interest to radio amateurs) will be found.

Power Supplies

Those usually “free” HV transformers...

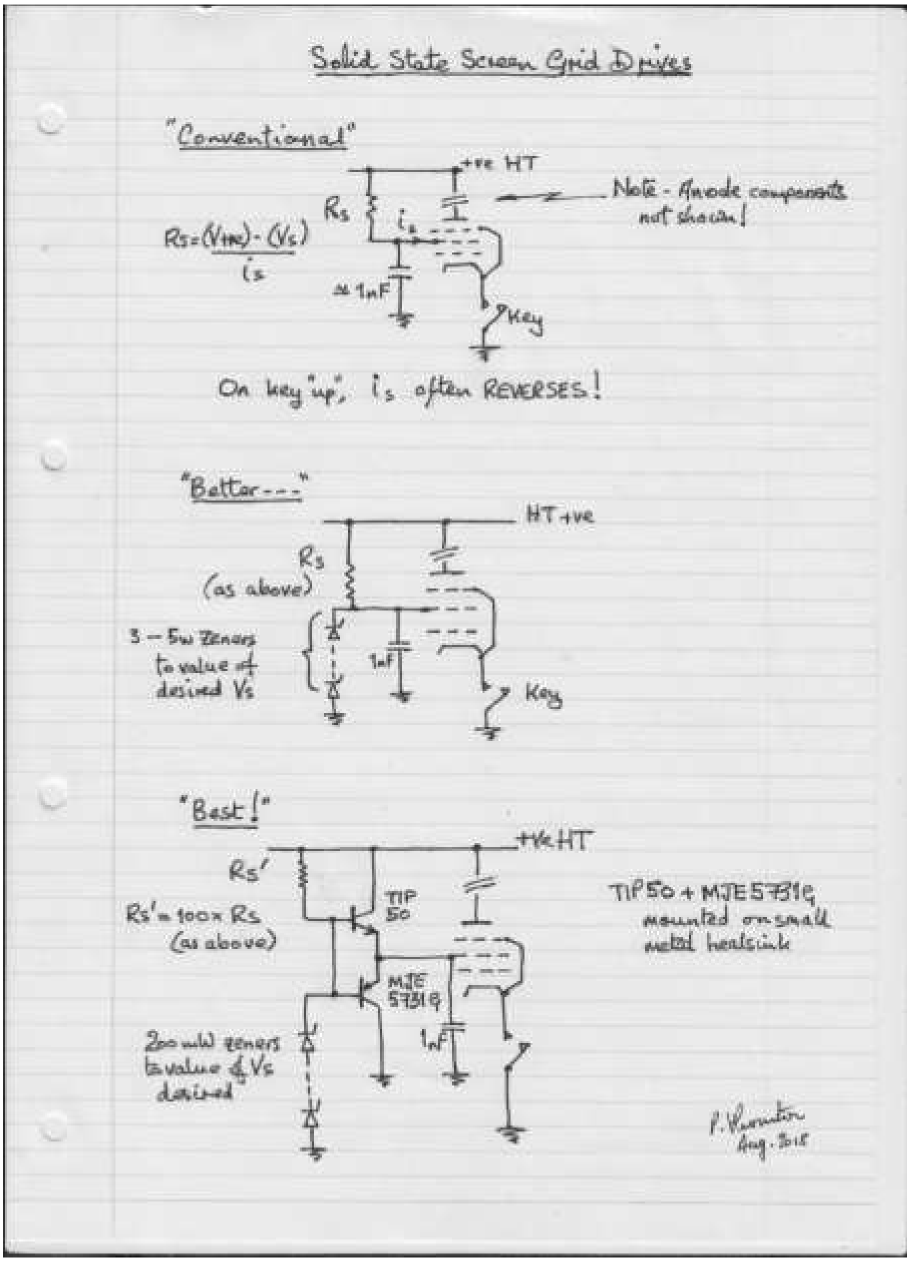
Microwave oven transformers are big chunky beasts, crying out for radio amateurs to use them in power supplies. They have an easily adaptable filament winding that can be tailored to requirements; they are tough as old boots and can be made more efficient by smacking out the magnetic shunts. These are fitted to prevent the DC current draw on the HV secondary feeding the half-wave voltage doubler causing failure (due to remanent magnetism core bias) - the core saturates on one half cycle. The really BIG snag is the HT wiring: one side of the winding is connected to the core. Assuming you can fit a primary (mains side) power controller to cut the output voltage to a more manageable level – they usually give 2kV rms on full mains - then these transformers make a useful valve power supply by mounting the entire transformer on stand-off insulators, and taking the secondary HV power from the winding and the (now floating) core! Obviously the primary to secondary winding insulation must be perfect, and flash tested to 4kV at least to make sure. Fitting in a substantial enclosure is an obvious “must” too, that core’s “hot”!

Of course, you can always chop out the HV secondary, and wind your own: at (usually) 0.5 – 1.0 volts per turn, it’s not a major rewinding job for a kVA rated low voltage, high amps power supply.

Screen grid power supplies & regulation...

Feeding a valve’s screen grid in a valve transmitter P.A. isn’t just a matter of a big resistor and an HV capacitor: with reactive loads, a screen grid can **source** current. The screen capacitor charges up, on key up, and key down the charge stored in the screen capacitor and space charge causes chirp, burnt out screen grid wires, and the cathode gets a battering. A neat way to avoid these maladies and reduce power wastage in screen resistors is to drive the screen with a stabilised voltage delivered by a complementary pair of HV transistors (designed for use in mains on-line SMPS’s). These have a Vce of >450v, and cost less than a £1 – look up TIP 50’s and MJE 5371G’s. The diagram below shows the idea: a bit more complicated than a resistor and capacitor, but delivers longer life from those hard working valves.

This method proved it’s worth in a 13.56MHz RF plasma asher, a machine used in semiconductor manufacture. The screen grid drives were modified this way, and the valves gave noticeably more hours running before needing replacement.



A "Robust" High Voltage Power Supply...

Here's a simple yet robust design for PSU's that employs large values of capacitors for smoothing. Capacitor input smoothing is notorious for large surge currents clobbering the bridge diodes. Only when the reservoir capacitors have charged up a fair bit can the relay RL1 coil energise – the lamp L3 drops the primary winding volts, slowly filling the capacitors until the primary voltage rises sufficiently to pull in RL1. The lamp L3 shown in the primary circuit can be a resistor, but you lose the non-linear limiting effect of a tungsten filament as it warms up, and the visual indication.

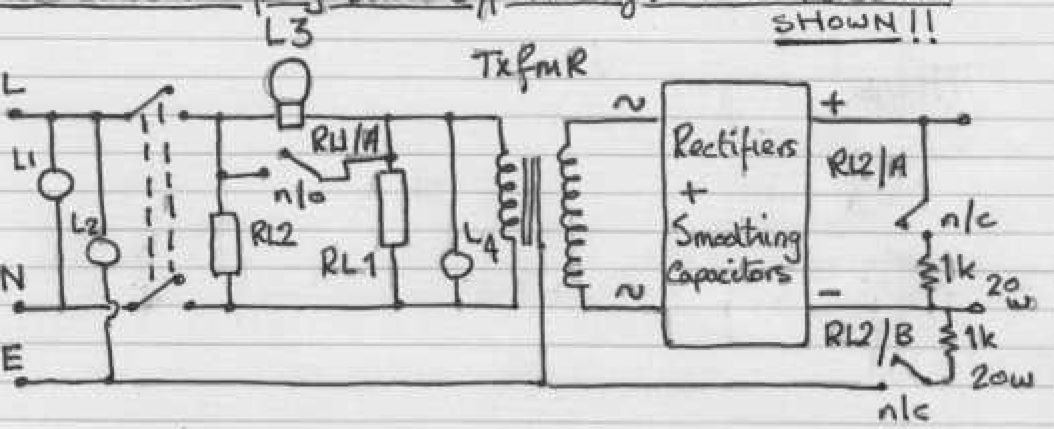
Lamps L1 and L2, rated at 240v rms for UK use, merit some explanation, as does L4.

L1 shows the presence of line power – you know the AC supply is "live". Lamp L2 is the "Earth" lamp. If L2 is NOT lit, when L1 IS lit, don't touch the power supply or anything connected to it: isolate the power supply and check the earth wiring, it's not functioning properly. Ideally L2 is a neon, so as not to trip sensitive Earth leakage circuit breakers. Lamp L4 shows the primary winding is energised, thus high voltage is present, avoiding an HV indicator lamp.

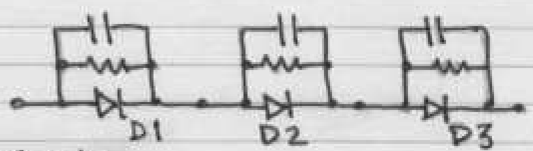
RL2 earths both sides of the smoothing capacitor’s charge immediately power is shut off: normally closed contacts short the HV output to ground via 1k power resistors, and open the instant power is applied to the primary. RL2/B isn’t always necessary if the negative output of the bridge is grounded; in that case, put RL2/B in series with RL2/A for higher voltage stand-off.

"Robust" High Voltage Power Supplies

Slow Start + Safety shut off Relays - NOTE FUSES NOT SHOWN!!



Each rectifier section is as follows -

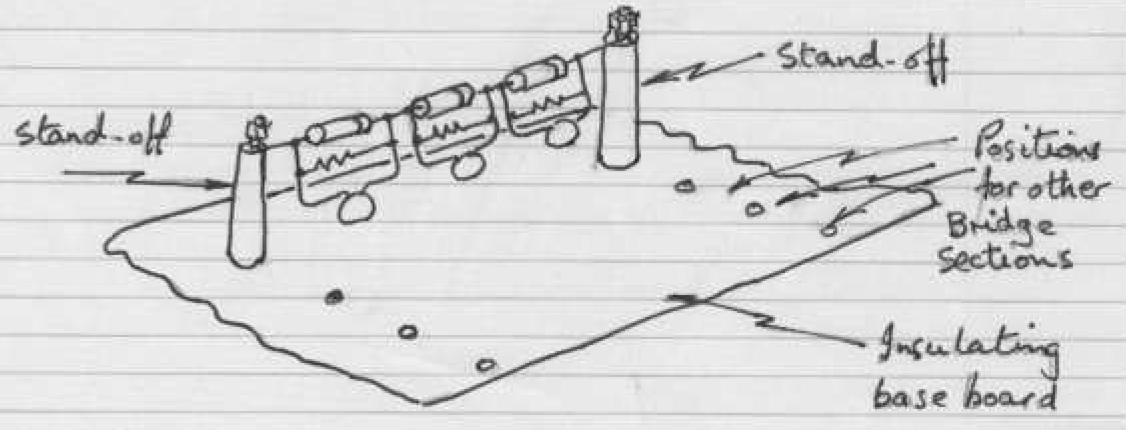


C = 10nF 1kV
R = 1MΩ 2watt
D1-3 = 1kV, 1A
(1N4007)

Design Guide

Make the total P.I.V. rating ≥ 3 × peak DC output
Forward current rating of each diode ≥ 5 × i max. load

Diodes mounted in clear open air for cooling

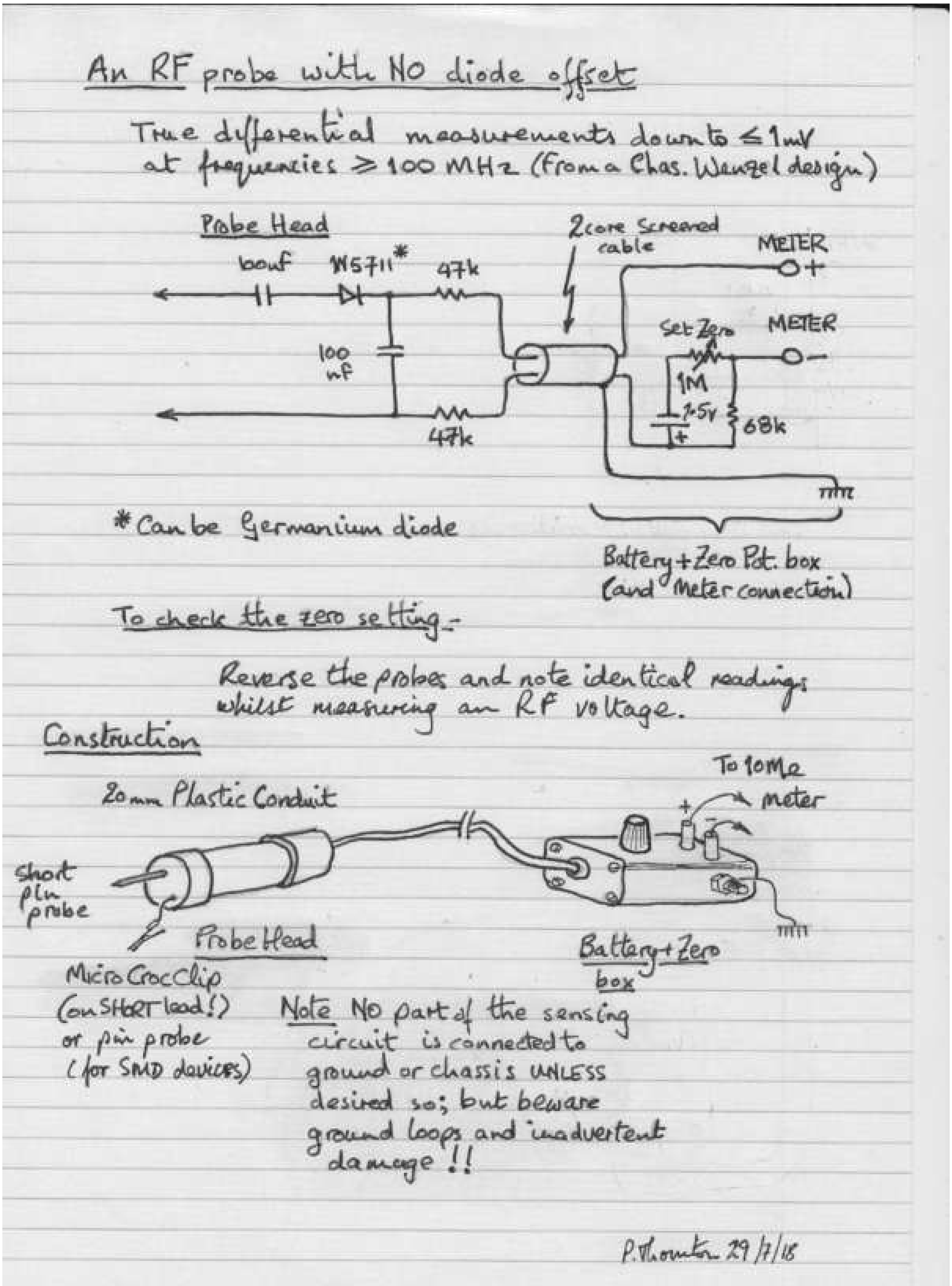


P. Thornton July 2018

Test Gear & Fault-Finding

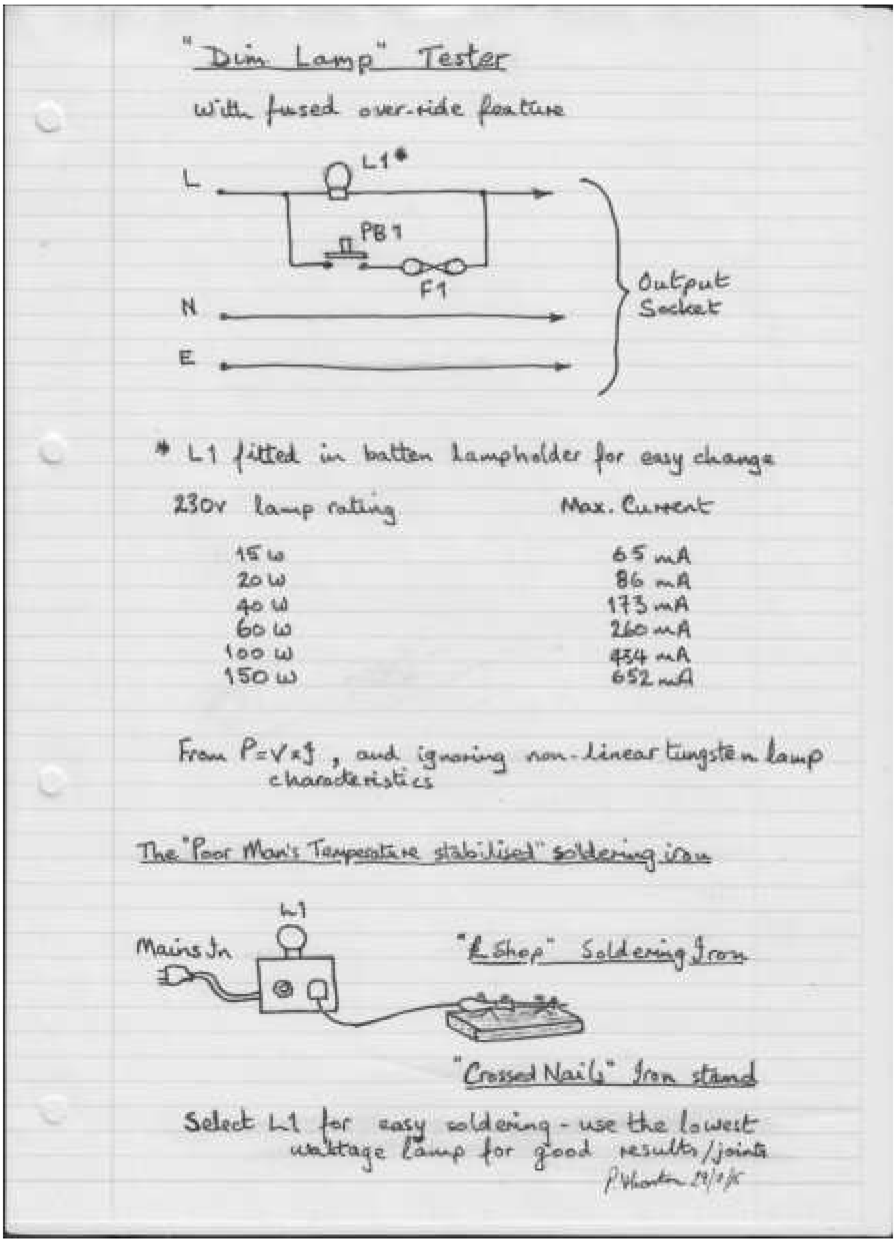
RF Probe WITHOUT diode offset voltage...?

From the amazing brain of Chas. Wenzel, comes a superbly simple and devastatingly effective way of measuring RF voltages down to mV, to above 100MHz, with 1N5711 Shottky or 1N60 Germanium diode. It's such a simple and elegant solution!



The Dim Lamp tester...

Here's a neat gadget every radio amateur should have. Use it to safely power up a new bit of kit, fault-find boat anchors bought at a boot sale, or run el-cheapo soldering irons (designed for 210v line voltages) on our 240v UK mains. The diagram says it all: make sure you have a good selection of filament lamps in stock!



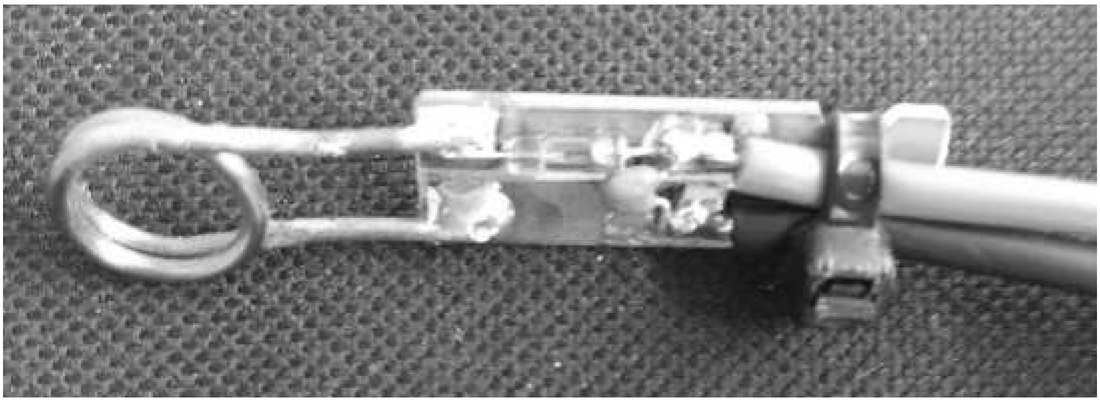
The iron's temperature is partially regulated by the non-linear resistance of the lamp filament: the lamp is working as a baretter, a non linear device used to stabilise current. Push button PB1 delivers 100% mains volts for fast warm-up: MUST momentary, NOT toggled!

More dim lamp applications to come, watch this space!

A useful device for finding parasitic oscillations – and much more...

If you take a two turn coil of thick wire, about 12mm / ½” diameter, solder the anode of a Germanium diode to one coil end, a red wire to the diode’s cathode - then a black wire to the other coil end with a 10nF capacitor between black and red wires - plug the red and black wires into your digital multimeter set to 10 mA DC, any RF near the coil will result in a meter reading.

Parasitics, oscillators, anything that creates RF will give a reading as the coil approaches. I made mine with enamelled wire, so it doesn’t matter if it accidentally touches a DC voltage; I mounted the coil and diode on a bit of FR4 pcb material and hold the wires ONLY for safety near high voltage, and NEVER touch a multimeter whilst HV is ON!



Components

Electrolytics...

Some years ago electrolytic capacitors changed: the fluid formula was “updated” by Japanese engineers, which gave us amazing miniaturisation. Gone were the huge chunky ‘lytics, in came tiny, pint sized jobs that promised excellent miniaturisation, longer life and excellent electrical properties. Hah! Those midget “devices of the Devil” plagued electronic maintenance engineers within months – any heat did for them, ad did “real” current in / out of them, they very soon gave up the ghost far faster than their older, more chunky brethren. The immediate result was to “replace all the ‘lytics” for a first fix, then locate and replace all the damaged components the dud ‘lytics had kyboshed.

To find what the current was doing after a bridge rectifier in a power supply, a neat trick with a clip-on ammeter (not the modern Hall effect devices, but the old fashioned current transformer type); if you clipped it onto a bridge DC output wire, the clip-on reads the DC ripple current. If a ‘lytic was drying up, losing it’s capacity, the ripple got worse – not a good thing in a 47,000µF / 50v lump. At least with a clip-on we had a way to catch these damn things degrading, and get replacements on order before any damage was done (and the plant’s production schedules down the tubes).

Surface Mount “Chip” High Voltage capacitors...

ATC (American Technical Ceramics) produce surface mount “chip” capacitors with a voltage rating of 500v, capacitances up to 1000pF. Interestingly, ATC offer series and parallel combinations to extend the voltage, power handling and capacitance to almost any level desired; but we being amateurs, know full well how to “stack ‘em and shunt ‘em”! Being SMD devices, it should be quite straightforward to assemble series or parallel combinations on scraps of pcb material, or make “sandwiches” always providing you can get in to solder both ends.

I don’t know who the UK distributors are of these beefy little capacitors – but the principle remains the same, no matter what make or rating: if you build in some “extra” capability by series / parallel strapping, then your beloved transmitter is going to withstand disaster that wee bit longer, until your carefully selected fuse protects the final.

Antennas & ATU’s

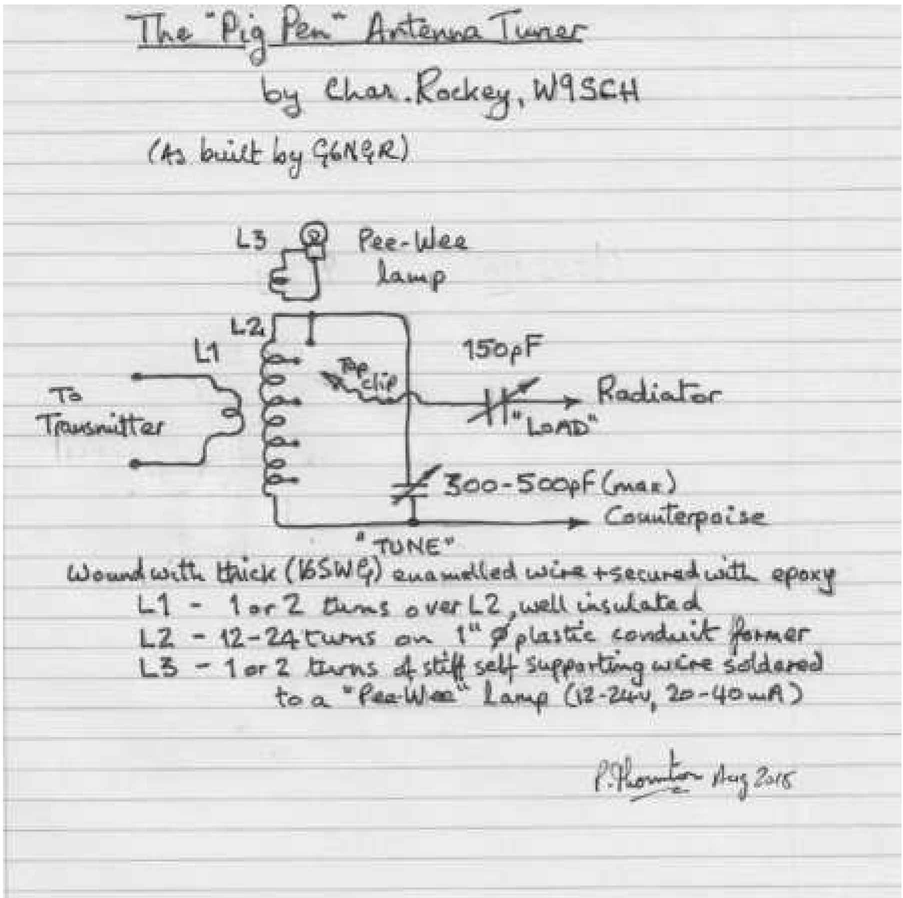
It’s not always possible to have a monster antenna, or even a dipole: but if you get as much wire “up and out” for the radiating element, and a “counterpoise” of some sort, draped near or on the ground then you’ll be able to get something out. Sure, a cut-to-resonance dipole, or multi-element beam, mounted 70’ or 80’ up will probably be better, but not everybody has the room, wallet or capability for such an antenna. The best idea is to get a piece of wire up and out as best you can, tune it to resonance with a very basic antenna tuning unit, and extend your counterpoise to get the best radiated signal. And that’s the conundrum: how do you know what the “best” radiated signal is? How do you adjust an antenna for best radiation?

You don’t really need an “SWR” bridge or other esoteric gear – just a germanium diode and a fairly sensitive (100µA - 1mA) meter. No, not a digital multimeter – a cheap and cheerful *analogue* (“VU” or similar) meter from your favourite online auction site, and wire up the meter thus:

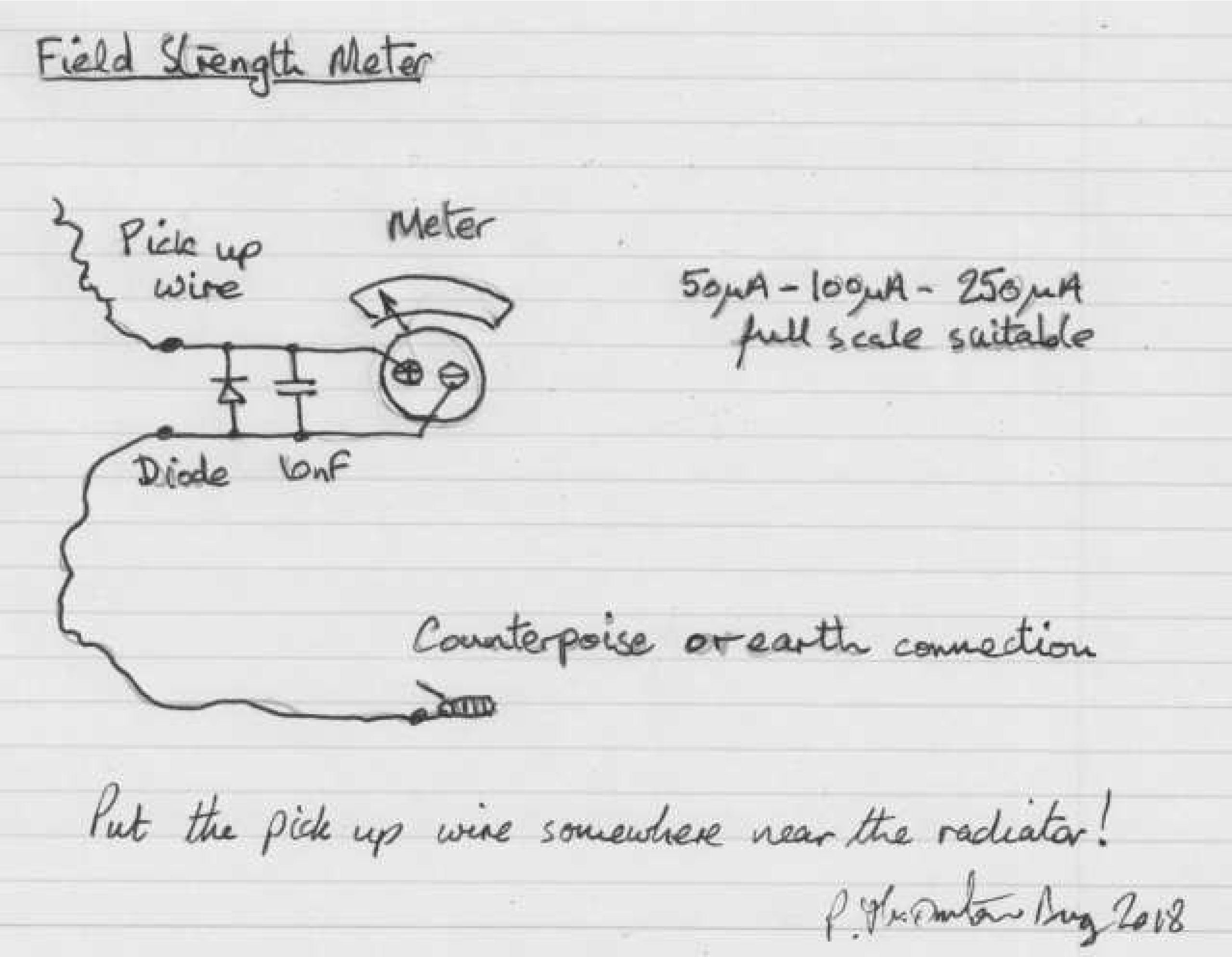
1. Connect the diode with 10nF in parallel to the analogue meter terminals – the “bar” end (cathode) to the meter +ve terminal, and the other (anode) end to the -ve terminal.
2. Connect a short (300mm?) length of wire as the “pick up” to the analogue meter +ve terminal, and a 2 metre length of wire to the -ve meter terminal and put a croc clip (or whatever you have to hand) on the far end.
3. Go outside to your antenna system, and clip the -ve lead with the croc clip to the counterpoise (or earth); and the 300mm wire is stuck up in the air near the radiating element as best you can. You now have a Field Strength Meter!
4. Set the transmitter output to low power, a watt or so, then key or “transmit”. Note the reading on the Field Strength Meter whilst the transmitter is energising the antenna. If the meter needle is pinned to the full scale end stop, move the 300mm pick up wire away a bit to reduce the reading. It helps if you can see the Field Strength Meter scale from inside your transmitting position, where your esoteric, “state-of-the-art” antenna tuning unit is placed.
5. Adjust your “state-of-the-art” tuning unit until the meter reading is maximum: turn off the RF, and re-arrange the counterpoise to get highest meter reading; re-arrange your radiating wire to get the highest meter reading.
6. Job done: remove the Field Strength Meter, turn up the wick, and blast away.

Nowhere have I mentioned impedance matching, SWR ratios or anything else: all you'll need to do is tweak your "state-of-the-art" tuning unit to get the highest reading on your Field Strength Meter. Since we're constructors, we can adjust the output link winding / transformer / coil tapping to get best radiated signal and who cares about impedances? This is where home-made scores over commercial gear: we can make it just how we like, it's far simpler and more fun to boot.

Below is your "state-of-the-art" antenna tuning unit, which was originally designed by Chas Rockey, W9SCH. It's superb and I cannot recommend it highly enough. Note that Chas's original L2 coil had 6 turns only for 7MHz to 30MHz coverage – I added turns to cover lower frequencies. You can short out sections of L2 to tune higher frequencies, if needs be. Use large, air spaced capacitors for anything above a couple of watts.



The tune up procedure: apply a small amount of RF, adjust the "TUNE" capacitor until the Pee-Wee lamp shows brightest (resonance), and your field strength meter reads highest. Then adjust the "LOAD" capacitor for best indication on your Field Strength Meter. You might have to change taps - turn the RF "off" before touching the tap clip! And that's it!



Mechanical & Construction

Strip Board Vs. Perf. Board...?

Beginners in constructing RF equipment tend to use copper strip board, sold under various proprietary names, and wonder why whatever they build is unstable, or just plain doesn't work. The answer is usually the layout. You *might* get away with strip board below 40m if the layout is (by chance) keeping instability at bay; but don't bank on it. Far superior is plain "perf. board", the insulating board with holes spaced every 0.1" horizontally and vertically, with no copper tracks that's wired directly point to point. The stray capacitance of perf. board component to component is very low, a few pF's at the most. Then, if the golden rule of "keep the input well away from the output" is followed, even though the structure is quite "chunky", the circuit will probably run fine – and above 10MHz I almost always build prototypes on perf. board for these very reasons. If an earth plane construction is required, self adhesive copper tape, up to 2" wide, can be bought. It's often used for wrapping round plant pots to prevent slug and snail damage, and can make that otherwise tedious visit to the Garden Centre a useful radio construction outing!

3D Milling Machines...

Pete Juliano, N6QW, the homebrew RF deity, has prompted me to *buy* (yes, that word is in my repertoire, occasionally...!) a desktop 3D milling machine / engraver that is controlled by computer and can cut precise areas of copper away to make pcb tracks, islands and the like. An imminent house move has prevented me from building the miller up and having a bash, but it will soon be in service once my new workshop studio is at the new place. Not only can pcb's be milled out without any chemicals and the associated safe disposal issues, but the copper swarf cut from the laminate can be vacuumed up, and saved for a weigh-in at the local scrappy.

The precision of these machines means that if a standard edge layout for power, signal and control lines is adopted, pcb's can be stacked together each "layer" being a section of the circuit being implemented – this is how Ivor Catt, the genius who, in the 1970's, showed how Maxwell fluffed it with Displacement Current, wanted to stack silicon wafers to produce pico-second logic computing cores. Heat dissipation in those TTL days kyboshed Ivor's idea, but on a pcb scale nowadays it could be feasible to construct a whole RF system and it's control a-la Arduino style, in stacked, plug together layers. The ease with which modifications and upgrades, possibly with programmable analogue chips via downloaded files, would make a very adaptable and flexible system; repairs and replacement would be very simple too, no de-soldering microscopic surface mount components, just plug-n-play. Dream on!

Tool Kits...

The picture below is my tool kit, small enough to be carried easily, but comprehensive enough to cope with most everyday "electronic" tasks. I haven't shown my metal bashing gear, power tools or other "heavy" tackle.

The small cutters and bent nose pliers are the most used: the ones shown are a famous Swedish make (L*ndstrom), with the white plastic handle grips removed (I don't like them, they make delicate work clumsy and insensitive). The screwdriver bits fit just about everything I come across, the only snag being the bit holder is a bit large to fit into some recessed screw heads. The 6" adjustable spanner (ideal for pot and rotary switch nuts) is from a Swedish flat-pack furniture assembly tool kit and the heavier cutters and pliers are from any decent tool store. A few hex keys, a small Stanley knife, a couple of small screwdrivers for terminal blocks; a jeweller's screwdriver (for tightening up my glasses...), a trim tool for tuning, a stainless steel spatula (for prying open those damn snap-fit plastic cases with little or no edges); a 3.5mm diameter twist bit for cutting copper tracks on strip board is just about it. You don't really need much more!

Letters

Well, what do you expect? It’s the first edition with a “Letters” page, so get your email up and running, and tell me what’s on your mind, at equieng@gmail.com, subject line “Hot Iron”!

You could post scheduled test transmissions, bits for exchange, or wanted; technical points, ideas for future editions, you name it, I'll read it and consider what you say!

Come on, what are you waiting for?

Data and Information

This information is for guidance only – you MUST comply with your local Regulations!

Wire Information...

AWG Table

```
1 AWG is 289.3 thousandths of an inch
2 AWG is 257.6 thousandths of an inch
5 AWG is 181.9 thousandths of an inch
10 AWG is 101.9 thousandths of an inch
20 AWG is 32.0 thousandths of an inch
30 AWG is 10.0 thousandths of an inch
40 AWG is 3.1 thousandths of an inch
```

The table in ARRL handbook warns that the figures are approximate and may vary dependent on the manufacturing tolerances. If you don't have a chart handy, you don't really need a formula.
There's several handy tricks:

```
Solid wire diameters increases/decreases by a factor of 2 every 6
gauges,
" " " " " 3 every 10 gauges,
" " " " " 4 every 12 gauges,
" " " " " 5 every 14 gauges,
" " " " " 10 every 20 gauges,
" " " " " 100 every 40 gauges,
```

With these, you can get around a lot of different AWGs and they cross check against one another. Start with solid 50 AWG having a 1 mil diameter.

```
So, 30 AWG should have a diameter of ~ 10 mils.

36 AWG should have a diameter of ~ 5 mils.       Dead on.
24 AWG should have a diameter of ~ 20 mils.      Actually ~ 20.1
16 AWG should have a diameter of ~ 50 mils.      Actually ~ 50.8
10 AWG should have a diameter of ~ 100 mils.     Actually ~ 101.9
```

If you are more interested in current carrying ability than physical size, then also remember that a change of 3 AWG numbers equals a doubling or halving of the circular mills (the cross sectional area). Thus, if 10 AWG is safe for 30 amps, then 13 AWG (hard to find) is ok for 15 amps and 16 AWG is good for 7.5 amps.
The wire gauge is a logarithmic scale base on the cross sectional area of the wire. Each 3-gauge step in size corresponds to a doubling or halving of the cross

sectional area. For example, going from 20 gauge to 17 gauge doubles the cross sectional area (which, by the way, halves the DC resistance).
So, one simple result of this is that if you take two strands the same gauge, it's the equivalent of a single wire that's 3 gauges lower. So two 20 gauge strands is equivalent to 1 17 gauge.

Wire Gauge Resistance per foot

4	.000292
6	.000465
8	.000739
10	.00118
12	.00187
14	.00297
16	.00473
18	.00751
20	.0119
22	.0190
24	.0302
26	.0480
28	.0764

Current ratings

Most current ratings for wires (except magnet wires) are based on permissible voltage drop, not temperature rise. For example, 0.5 mm^2 wire is rated at 3A in some applications but will carry over 8 A in free air without overheating. You will find tables of permitted maximum current in national electrical codes, but these are based on voltage drop. Here is a current and AWG table.

AWG	dia mils	circ mils	open air Amp	cable Amp	ft/lb bare	ohms/ 1000'
10	101.9	10380	55	33	31.82	1.018
12	80.8	6530	41	23	50.59	1.619
14	64.1	4107	32	17	80.44	2.575

Mils are .001". "open air A" is a continuous rating for a single conductor with insulation in open air.
"cable amp" is for in multiple conductor cables. Disregard the amperage ratings for household use.
To calculate voltage drop, plug in the values:
V = DIR/1000
Where I is the amperage, R is from the ohms/1000'column above, and D is the total distance the current travels (don't forget to add the length of the neutral and live together - ie: usually double cable length). Design rules call for a maximum voltage drop of 6% (7V on 120V circuit).

Resistivities at room temp:

Element Electrical resistivity (micro ohm-cm)

Aluminum	2.655
Copper	1.678
Gold	2.24
Silver	1.586
Platinum	10.5

This clearly puts silver as the number one conductor and gold has higher resistance than silver or copper. It's desirable in connectors because it does not oxydise so remains clean at the surface. It also has the capability to adhere to itself (touch pure gold to pure gold and it sticks) which makes for very reliable connections.

Thermal conductivity at room temperature

W/cm²/°C

silver	4.08
copper	3.94
gold	2.96
platinum	0.69
diamond	0.24
bismuth	0.084
iodine	43.5E-4

This explains why diamonds are being used for high power substrates now. That's man-made diamonds. Natural diamonds contain sufficient flaws in the lattice that the phonons (heat conductors) get scattered and substantially reduce the ability to transport the heat.

Copper wire resistance table

AWG	Feet/Ohm	Ohms/100ft	Ampacity*	mm^2	Meters/Ohm	Ohms/100M
10	490.2	.204	30	2.588	149.5	.669
12	308.7	.324	20	2.053	94.1	1.06
14	193.8	.516	15	1.628	59.1	1.69
16	122.3	.818	10	1.291	37.3	2.68
18	76.8	1.30	5	1.024	23.4	4.27
20	48.1	2.08	3.3	0.812	14.7	6.82
22	30.3	3.30	2.1	0.644	9.24	10.8
24	19.1	5.24	1.3	0.511	5.82	17.2
26	12.0	8.32	0.8	0.405	3.66	27.3
28	7.55	13.2	0.5	0.321	2.30	43.4

These Ohms / Distance figures are for a round trip circuit. Specifications are for copper wire at 77 degrees Fahrenheit or 25 degrees Celsius.

Wire current handling capacity values

A/mm2	R/mohm/m	I/A
6	3.0	55
10	1.8	76
16	1.1	105

25	0.73	140
35	0.52	173
50	0.38	205
70	0.27	265

Mains wiring current ratings

In mains wiring there are two considerations, voltage drop and heat build up. The smaller the wire is, the higher the resistance is. When the resistance is higher, the wire heats up more, and there is more voltage drop in the wiring. The former is why you need higher-temperature insulation and/or bigger wires for use in conduit; the latter is why you should use larger wire for long runs. Neither effect is very significant over very short distances. There are some very specific exceptions, where use of smaller wire is allowed. The obvious one is the line cord on most lamps. Don't try this unless you're certain that your use fits one of those exceptions; you can never go wrong by using larger wire. This is a table apparently from BS6500 which is reproduced in the IEE Wiring Regs which describes the maximum fuse sizes for different conductor sizes:

Cross-section area	Overload current rating
$0.5mm^2$	3A
$0.75mm^2$	6A
$1mm^2$	10A
$1.25mm^2$	13A
$1.5mm^2$	16A

Typical current ratings for mains wiring

Inside wall

mm^2	Amps
1.5	10
2.5	16

Equipment wires

mm^2	A
0.5	3
0.75	6
1.0	10
1.5	16
2.5	25

Wire sizes used in USA inside wall

For a 20 amp circuit, use 12 gauge wire. For a 15 amp circuit, you can use 14 gauge wire (in most locales). For a long run, though, you should use the next larger size wire, to avoid voltage drops. Here's a quick table for normal situations. Go up a size for more than 100 foot runs, when the cable is in conduit, or ganged with other wires in a place where they can't dissipate heat easily:

Gauge	Amps
14	15
12	20
10	30
8	40
6	65

PCB track widths

For a 10 degree C temp rise, minimum track widths are:

Current	width in inches
0.5A	0.008"
0.75A	0.012"
1.25A	0.020"
2.5A	0.050"
4.0A	0.100"
7.0A	0.200"
10.0A	0.325"

Equipment wires in Europe

3 core equipment mains cable

Current	3A	6A	10A	13A	16A
Condictor size(mm)	16*0.2	24*0.2	32*0.2	40*0.2	48*0.2
Copper area (mm^2)	0.5	0.75	1.0	1.25	1.5

Cable ratings for 3A, 6A and 13A are based on BS6500 1995 specifications and are for stranded thick PVC insulated cables.

Insulated hook-up wire in circuits (DEF61-12)

Max. current	1.4A	3A	6A
Max. working voltage (V)	1000	1000	1000
PVC sheat thickness (mm)	0.3	0.3	0.45
Conductor size (mm)	7*0.2	16*0.2	24*0.2
Conductor area (mm^2)	0.22	0.5	0.75
Overall diameter (mm)	1.2	1.6	2.05

A.M. Frequency slots in Amateur HF Bands

All Frequencies in MHz

160 Metres: 1.885, 1.900, 1.945, 1.985 (USA)

1.850 (W. Europe)

1.933, 1.963 (UK)

1.843 (Australia)

80 Metres: 3.530, 3650 (South America)

3615, 3625 (in the UK)

3705 (W. Europe)

3.690 (AM Calling Frequency, Australia)

75 Metres: 3.825, 3.870 (West Coast), 3.880, 3.885 (USA)

60 Metres : 5.317

40 Metres: 7.070 (Southern Europe)

7.120, 7.300 (South America)

7.175, 7.290, 7.295 (USA)

7.143, 7.159 (UK)

7.146 (AM Calling, Australia)

20 Metres: 14.286

17 Metres: 18.150

15 Metres: 21.285, 21.425

10 Metres: 29.000-29.200

6 Metres: 50.4 (generally), 50.250 Northern CO

2 Metres: 144.4 (Northwest)

144.425 (Massachusetts)

144.28 (NYC-Long Island)

144.45 (California)

144.265 (Los Angeles, CA)

Other AM Activity Frequencies

AM activity is increasingly found on a number of other bands, in particular: 5317KHz, 7143KHz, 14286KHz, 21425KHz and 29000 - 29150KHz.
There are several local AM nets in the UK on top band.

FM Frequencies

For mobiles working into VMARS events, 2m calling in on 145.500MHz (S20) is usual, before QSY to a working frequency. At event locations where military equipment is in use, suggested FM "Centres of Activity" on VHF are 51.700Mhz, 70.425MHz (70.450MHz calling).

VMARS RECOMMENDED FREQUENCIES

3615 Khz	Saturday AM net 08:30 – 10:30
3615 Khz	Wednesday USB net for military equipment 20:00 – 21:00
3615 Khz	Friday LSB net 19:30 – 20:30
3615 Khz	Regular informal net from around 07:30 - 08:30
3577 Khz	Regular Sunday CW net 09:00
5317 Khz	Regular AM QSO’s, usually late afternoon
7073 Khz	Wednesday LSB 13:30; Collins 618T special interest group
7143 Khz	VMARS AM operating frequency
51.700 MHz	VMARS FM operating frequency, also rallies and events
70.425 MHz	VMARS FM operating frequency, also rallies and events

Hot Iron 102

Contents Hot Iron 102

CQ-CQ-CQ

Modules (# 1)

When constructing an amateur radio receiver it's a "backwards" sequence that usually wins the day: begin with the audio section (knowing roughly the input and output levels, source and load impedances, thus power supply capacity desired), then build and test the audio section to be sure it functions as expected. Then comes the "tidy up" - you build the now proven section on a pcb, strip board, "perf" board, tag strip or whatever method does it for you.

Probably next in line is the demodulation stage: a product detector, BFO, discriminator or any one of many A.M. detectors. Designed with the input impedance of the audio stage in mind, this section is now tested with a signal generator or similar oscillator to mimic the IF output and prove the design. Then it's a repeat of above: transpose the design onto the construction medium you desire, but now, since it operates way above audio frequencies, test again to be sure no unwanted feedback or stability problems occur.

The IF amplifier – the highest gain stage, the most likely unwanted feedback culprit - is much the same: the design is prototyped, proven, and transferred to the final assembly medium then tested once more for stability. There's nothing worse than assembling an entire system to find it's unstable – fault finding an individual section, especially one that's conditionally stable – is almost impossible when it's embedded in a sequential chain, or closed loop system, believe me!

We arrive in our backwards design excursion at the mixer, or more accurately, the diplexer almost always required to ensure stable and effective termination of the mixer output port "DC to daylight" – and the testing of such at various frequencies, amplitudes and impedances. Once proven, the design goes onto the desired construction medium, and is tested to be sure it performs as desired.

The RF amplifier(s), filters, AGC system is built up similarly, and finally a local oscillator of whatever sort you like, VFO, DDS, whatever. The testing and proving completed, the entire receiver is assembled: if the ionosphere is smiling upon you, then it will sing like a bird with a µV or two from the signal generator, and even with the signal generator output turned up full, right on top of the receiver thus assembled, no blocking or distortion noted.

So far, so good: a standard routine for many in industrial electronics, and amateur radio projects in our limited facilities. Every section of the receiver is designed and proven – so why, oh, why, do we repeat all the hard work time and time again, on the next project to be approached? The input and output levels, impedances, frequency responses, power supply requirements, are all "standard" values – typically 50 ohms, 12v supply and "line level" (now, there's a term open for discussion!) for audio sections. This means I could build standard modules that simply fitted together, for testing new ideas and receiver designs by substituting the new bit in a chain of proven modules and noting the output: so as amateurs, we could build a library of subsystems to plug together, building up receivers as and when we want, to suit the requirement of the moment?

If I had all of these signal processing modules connected by reed relays (or, possibly, digitally controlled analogue switches), I could programme an entire receiver (or *any* RF system) digitally via a computer, enabling active switching to find the best receiver structure for whatever the ionospheric conditions demand? Is this the "programmable radio receiver", or am I describing something the microwave community and NASA have been doing for years? Fully programmable receivers (not just the frequency / mode)? Perhaps our Arduino aces might take a look at this....!

Modules (# 2)

I'll bet you have a favourite pair of headphones, yes? And I'd say you'd not buy a new pair of 'phones for every project you build? This interchangeability can be extended further, thinking as we are about modules: I have a favourite loudspeaker I use for testing purposes; I have a known and proven power supply (12v, 24v & 50v) that I always turn to for powering my trial designs; similarly I design my test gear to work with my power supply, loudspeaker, and all the rest of my home-made gear, all designed to be "universal" as far as I can. Some bits of test gear I modify slightly so they can be "universal": for instance I don't add the usual 4M7 resistor to my shunt diode RF probe to read r.m.s. on a 10M-ohm multimeter, thus I can use it with my Signal Tracer (described later in this edition) for RF fault finding from 10kHz to 150MHz or more.

The moral is this: when you have a studio of known, proven pieces of test gear and RF modules you're on home ground: territory you are familiar with and fully conversant with. The psychological benefits of knowing that your test gear and RF modules are 100% functional is a massive boost to your design and experimental work, and will yield good results and a peaceful mind. Such an approach reduces clutter, encourages tidy and logical work whilst delivering a flexible and adaptable approach to Amateur Radio experimentation: the core of our hobby.

Antennas and Interference

The over-riding effort toward the development of transmitting antennas since radio began would seem to be over: developing technology needs to concentrate on receiving antennas that can reject the disruptive influence of broadband noise and interference. The old adage of "select what you want, reject the rest" must (by nature of the broadband nature of noise and interference nowadays) begin right at the receiving antenna. When broadband noise and interference signals hit a mixer stage, the resultant mixer products will be broadband – in hefty amplitude, too. Superhet designs suffer from image responses, and if the noise is truly broadband, then these will walk straight through the IF amplifier and overwhelm the desired signals. It seems nowadays that separate Transmit and Receive antennas will yield the best signal to noise results – the most µV's incoming isn't always the best answer if those µV's are mostly noise. It would be nice if someone could design a circuit that could infallibly separate the desired signals from noise in the µV's coming from an antenna, but, to date, only the human brain and ear is capable of doing that! The human brain has superb "adaptive" learning systems built in, that, to date, are nigh on impossible with digital implementations today.

Receiving antennas that can reject interference demand a whole different approach to extract those precious µV signals we seek from the sky, than the transmit antenna that launches our kW's(!) of RF skyward. I'll not go into the sources of the interference and noise here, suffice to say anyone who has listened to LF, 160m or 80m will know the crashing roar that drowns out amateur signals; it's how to cope with this noise and yield a signal that's readable.

Most amateurs know that a "loop" antenna can null out noise from one orientation – but what if the noise is coming from all points of the compass, and at various tilt angles too? The old-fashioned noise cancelling circuits using variable gain inverting amplifiers, delay / phase adjust, invert and add the noise with the combined (noise) plus (wanted) signal to knock out the noise, have no real hope unless the noise is a single fixed position source. There may be partial answers though: if the "noise" antenna is broadband, truly "omnidirectional" in three dimensions, then the noise signal incoming can be processed via broadband amplifiers both at RF and audio frequencies; the required phasing and delays processed by multiple all pass filters in parallel to cover the entire noise spectrum. The summing to cancel the incoming noise can take place within broadband RF amplifiers, audio amplifiers, or, indeed, in the headphones themselves, al-la "noise cancelling" headphones from high end audio suppliers. A system using audio noise cancelling is presented, in the "Antennas" section of this edition.

It would seem that in the continuing battle against noise overwhelming fragile amateur signals, a holistic approach is mandatory. Every section of the receiving chain has to be designed following low noise and noise cancelling technologies – audio adaptive and "learning" technologies are available today. AMS Technologies, an Austrian audio company, have an integrated noise cancelling chip, described in the data sheet at:
https://ams.com/documents/20143/36005/AS3415_35_DS000299_1-00.pdf/3cf70528-ebbe-b1c9-7607-04af31b150ae

This chip, with it's digital adaptive techniques, could well form the basis of a very advanced RF noise cancelling unit, that can rapidly shift and sum out in the RF spectrum using appropriate RF active devices combined with the existing digital adaptive techniques. Just how high the frequency of this design can be pushed remains to be seen; but taking the technology shown in the chip's block diagram and implementing it at IF or even RF frequencies could well be a step forward in the battle against the overwhelming odds interference noise possesses.

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Circuits shown in Hot Iron may use potentially lethal voltages. It is your responsibility to ensure your own – and anybody else's – safety if you build or use equipment that employs hazardous voltages, currents or power. If in any doubt, you MUST get a competent person to check and approve the circuits, barriers and provisions to avoid any injury and electric shock. You MUST comply with your local Electrical Regulations and Safety Regulations.

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If in doubt, don't do it: get professional, competent, qualified expert advice and help.

Tim’s Topics

Muting and avoiding clicks & thumps - from Tim G3PCJ

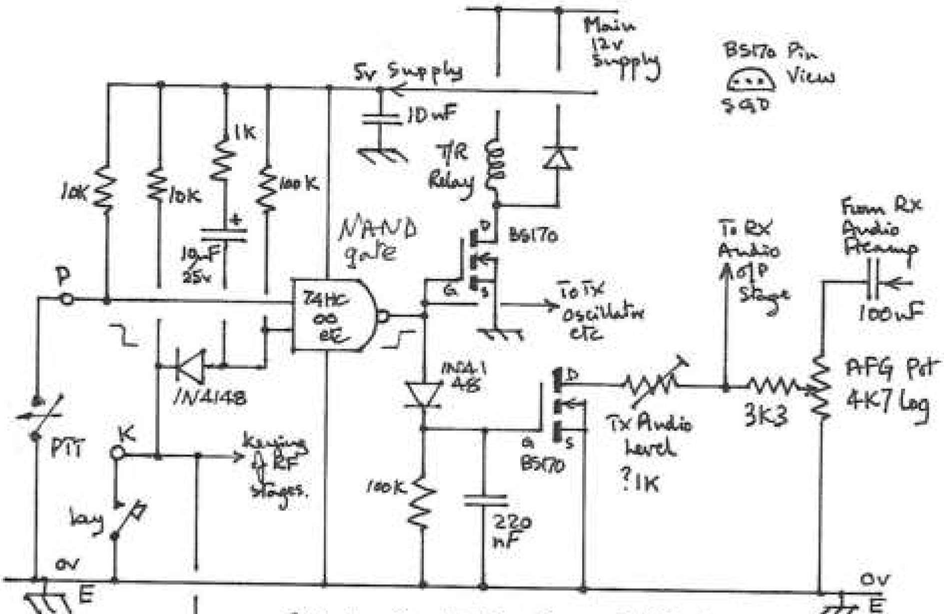


FIG 1: RX Muting to avoid TR thumps © G3PCJ

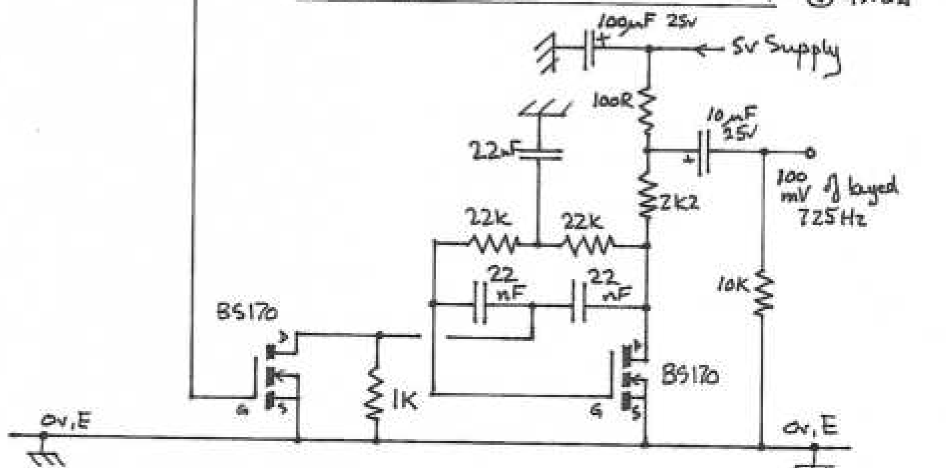


FIG 2: Sidetone keying to avoid thumps © G3PCJ

In very simple designs of receivers, with simple aerial relay change-over arrangements between transmission/reception, and vice-versa, it is common to experience a nasty ‘splat’ occurring at every change, which gets very annoying when using headphones! The cause of this is the TR aerial change-over relay, which puts a relatively heavy demand on the supply line when turning on;

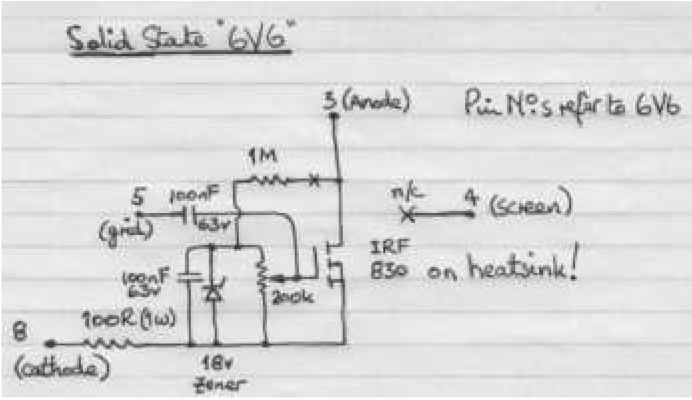
this makes the supply dip suddenly and translates through the early RX audio stages into a thump or splat in the phones. Because this is due to the relay current building up through its inductance over a few milli-seconds, the solution is to apply muting to the RX audio path before this relay current gets going, ie in micro-seconds after the PTT or key line is activated. Luckily this is not difficult as shown in Fig 1 which uses a BS170 MOSFET to apply a short across the output of the AFG pot just before the output audio amplifier – hence masking the thump. I usually include a small series resistance with the AFG pot slider to improve the attenuation factor when the very small 'resistance' (a few Ohms) of the MOSFET is turned on by the transmitter control circuits. On reverting to reception, the relay turning off also causes a supply transient (despite it having a protective diode to clamp/conduct the positive going reverse voltage spike), so the answer is to delay turning the muting MOSFET off until all these disturbances are over – hence the diode and CR network which hold the MOSFET on for a few mS after relay release by the PTT switch, or the end of CW key up delay. When you want to listen to transmitted RF to provide a keying sidetone, this can be done by having rather less attenuation when the MOSFET in on. Just add a preset in series with the MOSFET, and adjust for the desired beat note reception level. A little experiment may be needed to find the right value for this preset because it will be dependent on the circuit impedances to which the muting MOSFET switch is connected.

The keying of audio oscillators, for sidetone in a CW transmitter or for CW audio demonstrations, is often another source of annoying transient thumps or clicks. One solution is to have the audio oscillator run continuously but it is strange how its audio manages to get into active receiver stages where its not supposed to be! It is better to actually stop and start the oscillator. Very simple designs often just alter the DC bias conditions (in some crude manner) to turn the amplifier part of the oscillator either hard on or off – this is no good as the DC level change comes through as a large thump! A much better arrangement is to alter the AC loop gain (under key control) so that when the key is up, the loop gain is insufficient to maintain oscillation. The twin T network between drain and gate of my favourite BS170 MOSFET makes an excellent simple audio oscillator. Using a 5 volt supply, this self biasing arrangement will cause the drain to sit at just over 2 volts DC with the audio (4v p-p) superimposed on that when oscillating. (Keep the AC gain only just sufficient for oscillation and the waveform will be near sinusoidal due to limiting as the MOSFET 'bottoms'. The loop gain at the network peak of nominally 725 Hz can be easily reduced enough to stop oscillation by placing a 'short' across the 1K to 0 volts in the capacitive arm of the twin T network – inevitably this is a job for another BS170 as shown in Fig 2! If a low Z (even adjustable) audio output is needed, this is easily done with an attenuator in the drain load. (The build up and decay times of the audio 725 Hz output signal are equal but are quite good enough for most homebuilt rigs!)

Radio Topics

Valve bits

I've had some interesting emails from readers about valve circuits: it seems some folk like having their "getters" fired as much as I do! I build transmitters (and an occasional regenerative receiver) using valves as they seem to do the job better and more reliably than transistors: but that, I have to admit, is in the RF side of things. A simple IC audio amplifier can produce a very decent watt of audio in such a tiny area of chassis, compared to the valve equivalent - think of the output transformer, another cathode to heat, you get the idea. One recent note I received (from Brad, see the "Letters" section) caught my eye especially: the use of power mosfet's as replacements for 6V6 beam pentodes. Power mosfets can offer equal or better linearity than valves; but I doubt if this scheme will run above Top Band or 80m, as the gate - source stored charge of hefty power mosfets is high. Note the screen isn't connected; for those applications needing a true screen connection, feed the gate potentiometer from the screen terminal (marked X). Not quite the same, admitted; but it will allow the screen to control the device's conduction to a certain extent.



I've long been interested in j-fet / NPN cascode connected replacements for "ECC" twin triodes, which was a task I had as an apprentice years ago; but I could never get them to run as well as valves above 30MHz. The same goes for modern power mosfets: until that huge gate charge storage is vastly reduced, they will struggle to get anywhere above HF in power terms. So, vive le vacuum! I'll keep to a mixture of valve and solid state technology, I'm currently building a hybrid version of the magnificent "Radio Rotor" receiver, with added p-zazz in the form of automatic regeneration control.

Oscillators

LOCO and the Ceramic Resonators

For those of us who have tried PIC and similar microcontroller programming, and given up in disgust at the madcap software programming "suites" the manufacturer provides (who are the people these abstruse software systems are aimed at?), a different approach that might be an easier to digest (but first, check out Terry's (VK5TM) web page and see if one of his PIC + DDS solutions might fit your bill, though) are *clock multipliers*, which are digital chips often used in computer systems which take a clock signal and multiply it in frequency by programmed ratios. x2, x3, x5, x7, x8 are typical multiplication factors, but others are available and clock multipliers can be cascaded for a whole range of frequencies if desired - up to 200MHz in low cost chips.

A clock multiplier has onboard PLL's, feedback divider chains, VCO's and output buffers, designed to feed clock busses in a digital system with minimal clock skew - which means a generous output drive capability, always a welcome feature in an amateur design. Typical of the breed is the LOCO, from IDT. The chip has an internal oscillator, merely requiring a crystal to be connected, but for the highest multiplications, an external oscillator driving the LOCO is required: thus driven, frequencies of (at least?) 200MHz can be achieved. For HF purposes, a few of these chips would cover the harmonically related bands, and with a bit of adroit "multiply 8 then divide by 3" (and the like) juggling ratios could get the WARC bands and others you might like.

A simple web search for “LOCO clock multipliers” will bring up many of the IDT chips, with different features for various jobs - pick the one that fits your purpose. The are cheap (as you would expect for PC computer construction) and available World-wide.

Instead of a crystal (or crystal oscillator) driving the LOCO, you could try a ceramic resonator, as these beasties offer easy “pulling”, far further than a quartz crystal. If two identical ceramic resonators are run in parallel, in a “super VCO” design, some remarkable frequency shifts can be achieved, but at what stability? That’s the $64,000 question: so I tried a few from my junque box (of very dubious parentage and age) in a breadboard lash-up to see what a hovering hot soldering iron would do to the output frequency - my assumption being that temperature would be one of, if not the biggest factor in drift.

I found a mixture of results, and it varied with the amount of “pull” I had applied, too. Suffice to say, some “pairs” of “pulled” ceramic resonators shifted high with heat applied; other “pairs” went low - or stayed within spitting distance of the ambient temperature response. Those “pairs” that stayed near enough I put on one side for further tests; I then combined them in different pairs and tested again, to see if it was an intrinsic feature of each individual ceramic resonator, or the combination of the two.

The answer? Some pairs stayed put, and others drifted readily. Therefore I take it that it’s the pairs working together.... or is it a near field effect that one resonator’s electrical field interferes with the adjacent resonator’s functioning, and they lock into each other?

My feeling at present is that I’ve opened a right can of worms here, and it would be a long term study project to undertake! Unless.... you know different?

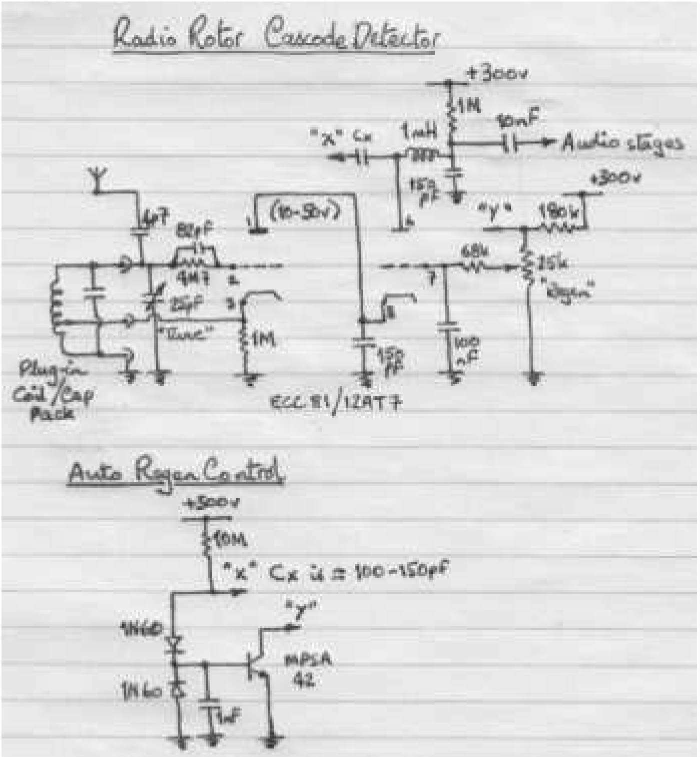
My advice: have another go at the PIC + DDS module approach. If you have the hex files and basic PIC blowing firmware from Terry’s (VK5TM) web pages, you have it sorted; but for those who defiantly eschew digital methods, then by all means try the “super VCO” crystal / ceramic resonator feeding a LOCO clock multiplier, but be sure you try a touch of heat to see how the drift looks after a trip through the LOCO!

Rx’s

Hybrid TRF receiver...

The Radio Rotor is a superb design (for circuit and notes, please email equieng@gmail.com), that has been built by many amateurs for 160 / 80 / 40 / 30m, and with a cascode RF amplifier for isolation, performs very well indeed. Using valve or transistor cascodes give extra capabilities like AGC at the RF amplifier; superb isolation of the tuned circuit from the audio section, good sensitivity (sub μV if you really try) and strong, stable audio gain. I saw a design from “Antentop” (www.antentop.org), of a loop antenna TRF receiver that had fully automatic regeneration control - the detector is kept hovering right on the edge of oscillation with a simple feedback system:

(http://www.antentop.org/016/files/autodyne_016.pdf). This prompted me to investigate if the idea was viable for a Radio Rotor receiver, as one snag with a TRF receiver is the need to trim the “regen” control as you tune across the band - a common “feature” of most TRF receivers. The diagram of the detector stage and proposed auto regen control is below:



The principle is as follows. The lower section of the ECC81 double triode forms a Hartley oscillator / detector, in a cascode - the top section is the grounded grid stage being cathode driven. This give a big dose of gain, the audio thus detected being taken from the lower end of the 1M resistor from HT+ve. The voltage applied to the Hartley oscillator stage is controlled by the “regen” control potentiometer, fed from the HT+ve via a 180k resistor for fine control. So far, all standard stuff: now consider the points marked “X” and “Y”.

Point “Y” is the voltage feed to the regen control potentiometer, and lowering the voltage here will control the ability of the Hartley stage to oscillate. Point “X” samples the output anode signal via a low value capacitor - which passes RF but rejects Audio. If the stage is oscillating RF is fed to the MPSA42 via capacitor Cx and 1N60 Ge diode doubler which adds to the tiny bias from the 10M-ohm to turn the MPSA42 “on” harder. This pulls down the voltage feeding the regen control potentiometer, stopping oscillation. The detector is therefore held right on the edge of oscillation.

Due to variations in construction, gain of the triodes and Q of the coils, some set-up will be required; the lowest value capacitor feeding point “X” and the 10M bias resistor may need adjustment. Disconnecting point “Y” returns the circuit to “manual” control, so you can easily see the effect of the feedback loop.

No oscillation (but held right on the edge) means the Hartley stage will be at it’s most sensitive for A.M. reception; for SSB/CW some oscillation is required for detection, in which case some base current has to be bled away from the base of the MPSA42: a 1M resistor to ground means more RF is required at the anode for the MPSA42 to throttle oscillation. This gives automatic control of the oscillation, so tuning the band won’t need constant adjustment of the “regen” control during SSB / CW reception.

To set the system up, advance the “regen” control until A.M. is received clearly; for SSB/CW (switch in a 1M base bleed resistor) advance the “regen” control a touch more to give the feedback loop some “room for manoeuvre” as the band is tuned. Once the loop has control, adjusting the “regen” control upwards should make very little difference to the detected audio.

Needless to say, an RF amplifier is recommended to reduce spurious emissions: a cascode amplifier is ideal for that job!

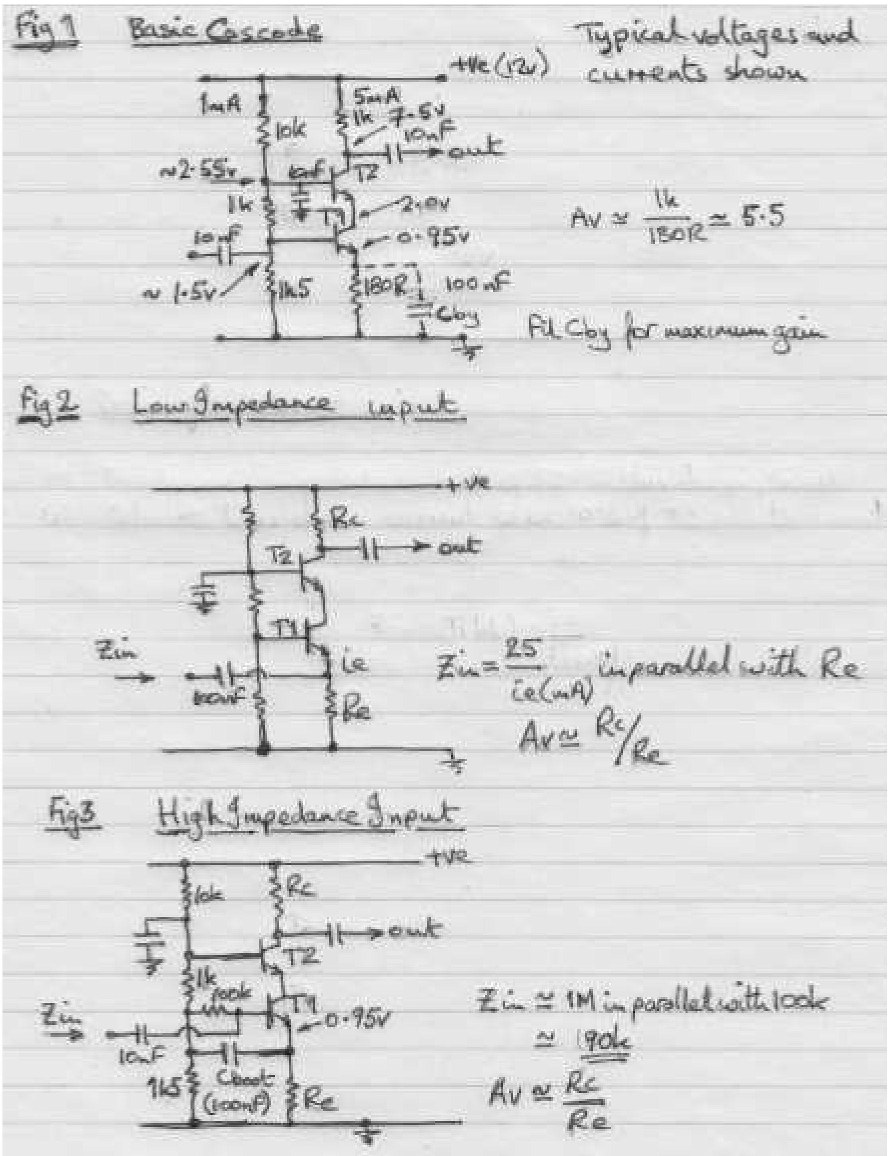
The Cascode [1]

Cascodes built with transistors give reliable and repeatable designs, as bipolar transistors have far less variable parameters than, for instance, j-fets. Bipolar cascodes are easy to design, rarely give stability problems, so much so, you can build input tuned / output tuned amplifier stages without them turning into remarkably powerful oscillators!

The design of a basic cascode RF amplifier runs like this. First choose the standing current you want to flow in the cascode, this gives the top transistor's collector load resistor - this resistor should hold the top transistor collector just above half the supply voltage with no signal. Next, aim for the voltage at the lower transistor's emitter to be about a volt; this allows reasonable emitter resistor values and aids stability. You now have the lower transistor's base voltage: it's 0.55v above the emitter voltage. Since the current gain of both transistors can be assumed to be >10, you now have the current flowing in the base bias chain - it's the standing current in the cascode divided by 10 which should give a reasonably "stiff" base bias. Set the upper transistor base voltage to be a volt or so above the lower transistor base; this gives a bit of space for the emitter of the top transistor to run linearly. You now have the middle resistor value: 1 volt divided by the bias chain current.

You now know the voltage between the supply and the top transistor's base: Ohm's law now gives the top resistor in the bias chain.

The general idea is to set the top transistor's collector voltage at a point that gives the best voltage swing under large signal conditions: the voltage on the collector of the lower transistor is (in effect) "wasted" as it's fixed and cannot change more than a few mV's as the top transistor's emitter clamps it to the bias chain voltages, less the base - emitter drop (0.55v, or thereabouts).



You have several choices now, depending on the input impedance you want. In Fig.1, you have the lower two bias chain resistors in parallel with the base-emitter dynamic resistance which is approximately (hfe) x (emitter resistor) - typically a few k-ohms.

Fig.2 shows a low impedance input: you'll get a good match to 50 /75 ohms, and superb isolation and bandwidth: the circuit is a common base amplifier feeding another common base amplifier. The input impedance is the emitter resistor in parallel with the emitter-base dynamic resistance: roughly $25/i_e$ (i_e in mA's).

Fig.3 shows how to get a high impedance input should you need it. The bias chain for the lower transistor base is bootstrapped from the emitter, so the input impedance will be more or less the centre bias chain resistor.

Tx's

A Digital Interface

By Pete Juliano, N6QW n6qwham@gmail.com

So, Ok, you are an entrenched homebrew, CW QRP, minimalist enthusiast and here is this guy from California trying to lead you to the digital dark side. Yes, that is exactly what I am doing but maybe only to share some of my experiences and information with you. Disclaimer: upfront you must have an SSB rig tuned to USB to have this work on the several digital modes that are mentioned.

I have been at this hobby a long time and aside from doing the WSPR thing several years ago with my Softrock V6.3, I am not deeply involved with digital operations. But seeing as I have a few SSB rigs available for experimentation coupled with some new digital modes I felt it time to once again test the waters. Coincidentally a new program from K1JT, Joe Taylor, called WSJT-X has many of the digital aspects rolled into a single program which are simply menu selected. You must download this free program to the computer you will use.

Two of the currently popular digital modes are WSPR (Weak Signal Propagation Reporting) and FT8. WSPR has been around a long time and essentially has you tune a specific frequency and listen for other stations. Periodically your transmitter, under computer control, is turned on and other stations listen for you. Most often stations run QRP power levels like 30 dBm signals (1 watt), some even less. I have been spotted 10,000 miles away running 500 MW.

The key feature to this program is the real time database where you can see who you have spotted and who spotted you. Today 40 Meters is a DX band and spots spanning great distances is often the common experience. WSPR uses a two-minute time block and so you can watch your lawn grow during the two-minute intervals. Thee 40 Meter WSPR frequency in 7.038600 MHz USB. Included on the WSPRNET webpage is a world map which captures the spots specific to your station. I learned a lot about my antenna as the spots are consistent NE SW

FT8 is a new addition to the digital array and this format is much quicker as each pass is 15 seconds and is more QSO like. A station sends an CQ call and the computer screen shows the station who sent it. Boom, double click on that call and the computer takes over by responding and then listening for a return. The computer will continue doing this until the person responds back OR another station picks him up. Once the connection is made the computers on each end exchange signal reports, confirm the reports and send 73's. It is the latest craze; but some naysayers have likened it to remote quickie sex. A variant called FT8CALL now adds to the sequence by letting the operator add text and other information, so it is more like a QSO. The FT8 frequency is 7.074 MHz USB.

When I was using the Softrock V6.3 much of the interconnect to the rig and the computer program was done entirely in software within the computer. With a standalone rig, this requires some hardware to do the interconnect. A little time with the Internet resulted in a configuration that will do that task. Pre-made inexpensive circuit boards are readily available; but also, there had to be some adjustments made to work with modern computers.

The first board is a sound card interface kit from KF5INZ available on eBay for around $7 USD. This board has a couple of 600:600 Ohm modem transformers and some keying circuits that trigger and opto-isolator switch from either a DTR or RTS signal via computer Serial Port. That is the first issue as most modern computers don't have a Serial port as everything has shifted to USB. That was one of the first nuts to crack. Although initially I did use the Serial port on an old Windows XP Pro computer; but then later shifted to the USB. Knowing what I know today I would not buy the kit, but just build the modem isolation part. Essentially, I have abandoned the Serial Port keying.

I also have abandoned the XP Pro machine and now the system is running on a small form factor Windows 10 NUC computer that is about the size of a CD case and 1 inch high. This computer has only an earphone output, so I added a plugin USB Sound card Dongle from Sabrent (about $7) as that provides the audio in/out capability. For the triggering of the PTT, Adafruit Industries makes a small USB to Serial board that is quite small (CP2140). One of the outputs is RTS –perfect. But the output logic is only 3.3 volts whereas the Serial Port is 10 Volts. So, I needed a way to trigger the PTT from 3.3 Volts. A simple 2N3904 transistor switch, a SPDT relay, isolating diode and one small resistor handles that chore. I have successfully loaded an earlier version of WSJT-X on to a Raspberry Pi3B but am having a bit of difficulty with the current version that has the WSPR and FT8. Just need a bit more time. But think of the possibilities.

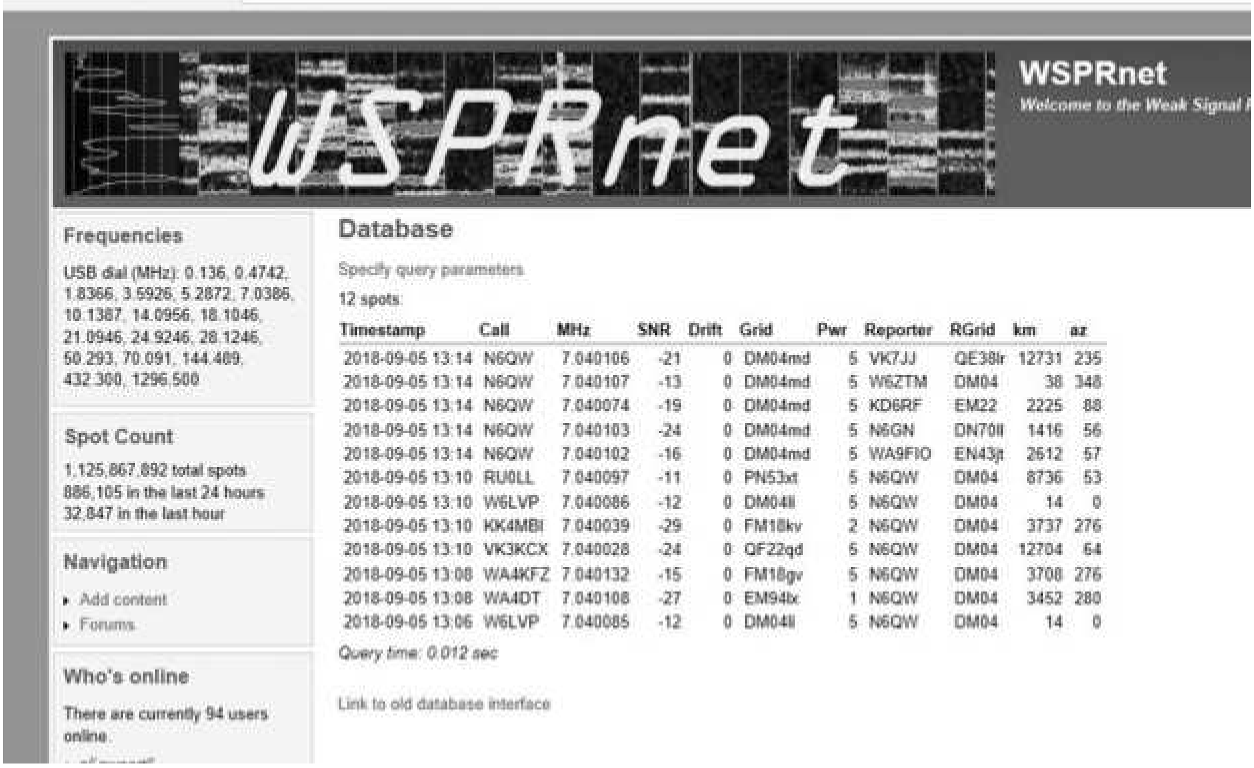
The WSJT-X has a settings tab that requires you to enter your call sign, grid square and the method of keying (RTS) and the COM Port to be used. There are some other items that require checking the block, like double click to automatically respond to a CQ and to disengage the transmitter once your computer sends 73's. Spend a little time with this setup and look at all of the tabs. I didn't and then wondered why nothing worked.

Oh, a cool feature of the WSJT-X –it is linked with hamlib. When you call a station, it tells you the azimuth (like if you have a beam) and the distance from you. Pretty cool

I am happy to report that my interface box has been in operation for about a week now and works perfectly.

73's
Pete N6QW

Below is a page from the WSPR database. I was running 5 watts (37 dBm) with a droopy dipole. Imagine being heard 12000 km away with that kind of lash up. But that is a significant bonus to digital operations, especially FT8, as it levels the playing fields running low power and modest antennas. So that may be a real appeal to those with QRP rigs who have antenna restrictions or live in apartments. Following that is a photo of the actual interface hardware.



WSPRnet

Welcome to the Weak Signal

Frequencies

USB dial (MHz): 0.136, 0.4742, 1.8366, 3.5926, 5.2872, 7.0386, 10.1387, 14.0956, 18.1046, 21.0946, 24.9246, 28.1246, 50.293, 70.091, 144.489, 432.300, 1296.500

Spot Count

1,125,867,892 total spots
886,105 in the last 24 hours
32,847 in the last hour

Navigation

- Add content
- Forums

Who's online

There are currently 94 users online.

Database

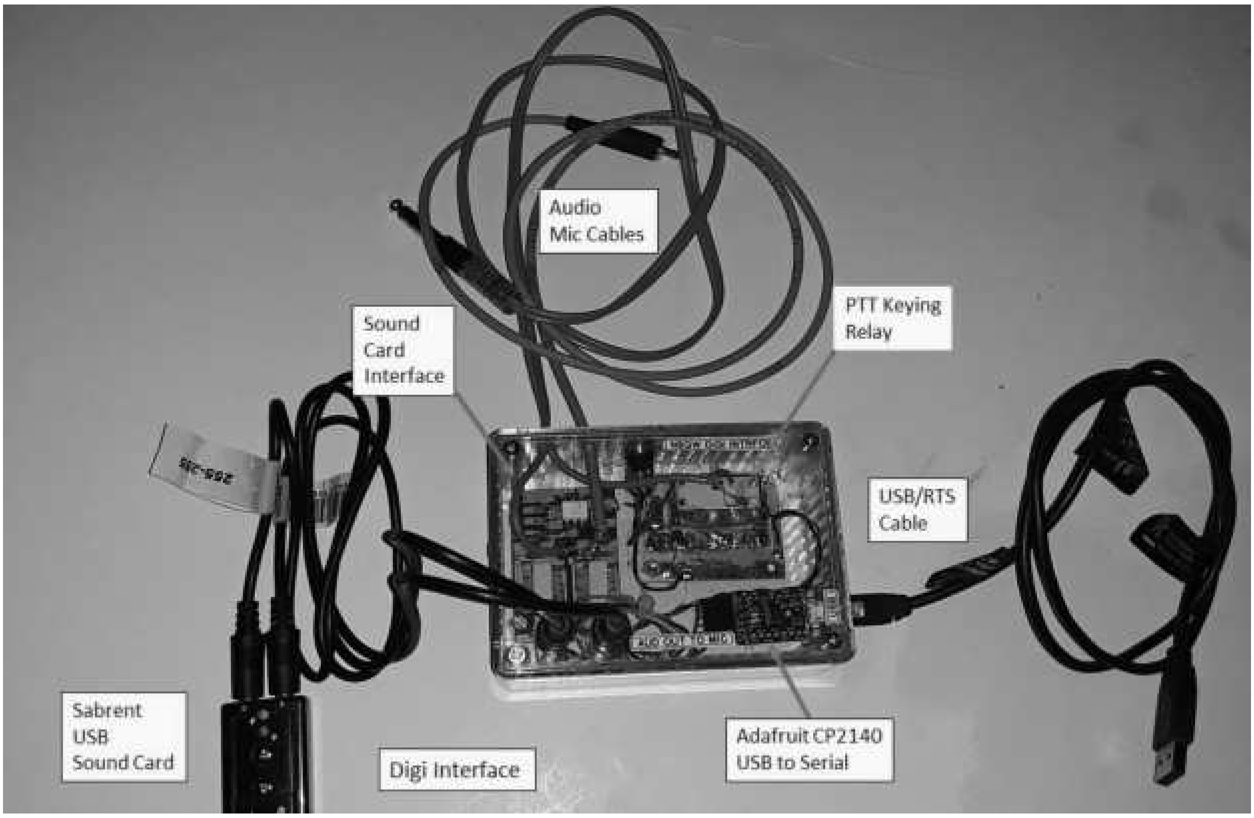
Specify query parameters

12 spots:

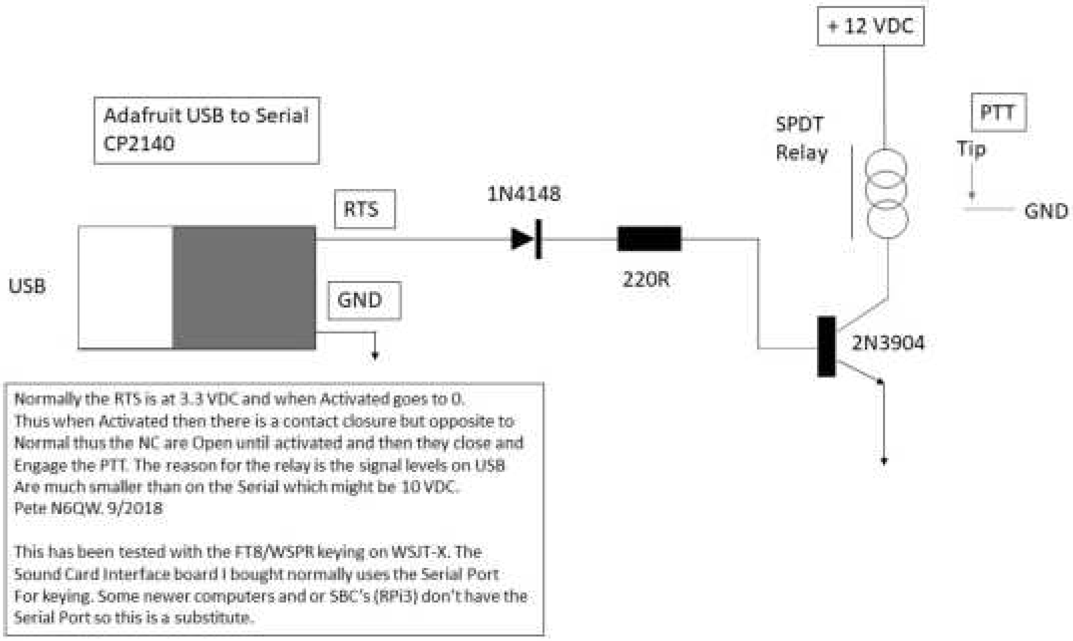
Timestamp	Call	MHz	SNR	Drift	Grid	Pwr	Reporter	RGrid	km	az
2018-09-05 13:14	N6QW	7.040106	-21	0	DM04md	5	VK7JJ	QE38lr	12731	235
2018-09-05 13:14	N6QW	7.040107	-13	0	DM04md	5	W6ZTM	DM04	38	348
2018-09-05 13:14	N6QW	7.040074	-19	0	DM04md	5	KD6RF	EM22	2225	88
2018-09-05 13:14	N6QW	7.040103	-24	0	DM04md	5	N6GN	DN70ll	1416	56
2018-09-05 13:14	N6QW	7.040102	-16	0	DM04md	5	WA9FIO	EN43jt	2612	57
2018-09-05 13:10	RU0LL	7.040097	-11	0	PN53xt	5	N6QW	DM04	8736	53
2018-09-05 13:10	W6LVP	7.040086	-12	0	DM04li	5	N6QW	DM04	14	0
2018-09-05 13:10	KK4MBI	7.040039	-29	0	FM18kv	2	N6QW	DM04	3737	276
2018-09-05 13:10	VK3KCX	7.040028	-24	0	QF22qd	5	N6QW	DM04	12704	64
2018-09-05 13:08	WA4KFZ	7.040132	-15	0	FM18gv	5	N6QW	DM04	3708	276
2018-09-05 13:08	WA4DT	7.040108	-27	0	EM94lx	1	N6QW	DM04	3452	280
2018-09-05 13:06	W6LVP	7.040085	-12	0	DM04li	5	N6QW	DM04	14	0

Query time: 0.012 sec

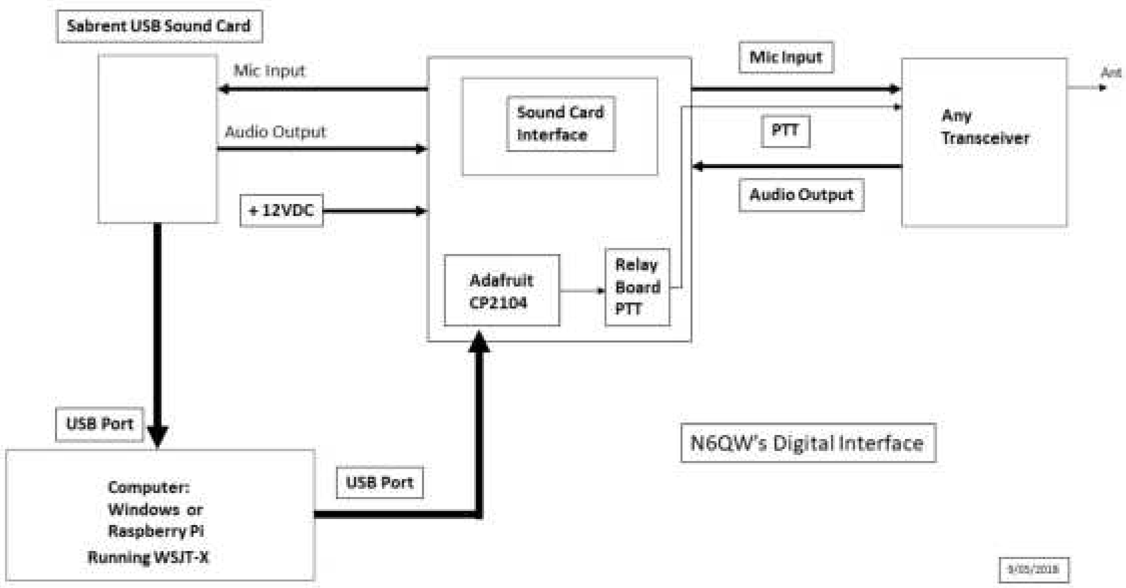
Link to old database interface



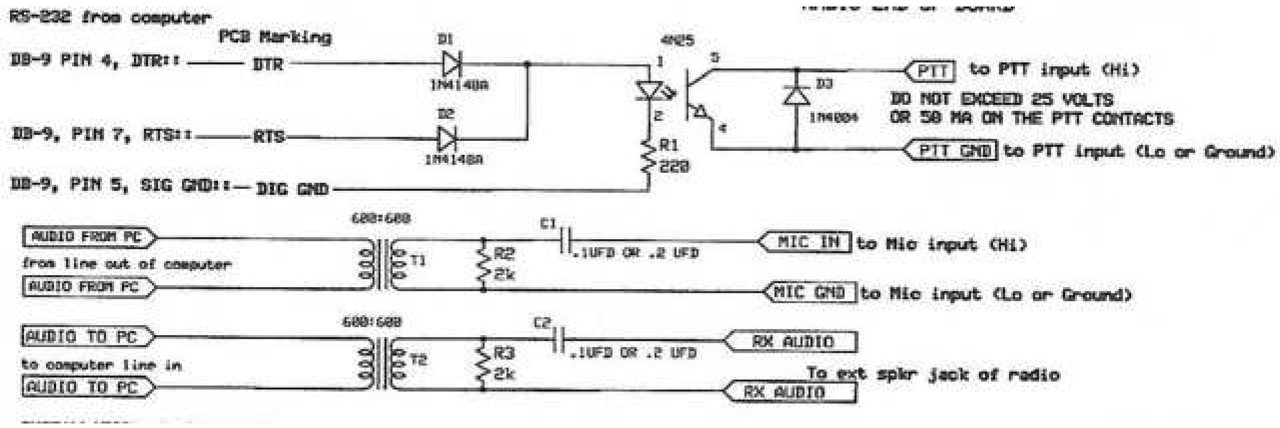
This is the modification to the Adafruit CP2140 to key the PTT on the transceiver



Below is a pictorial of the component/board interconnects.



Finally, this is the schematic of the Sound Card Interface board. Based on my current experience I would just build the modem interface which is two transformers, two resistors and two capacitors. A friend in the UK was going to purchase the board from the US and the shipping cost was $20 for a $7 board. So, skip the Serial Port Interconnect and go with the USB.



A couple of cautions. Upon initial setup with the Adafruit board connected to your computer using the control panel, find the COM port associated with the USB as you will need that to enter information into the settings page. The next caution involves the computer, which by the way had me baffled for about an hour or two. I could see the signals on the waterfall; but they were not being registered on the panel and neither was anyone copying me when I transmitted. Like a ton of bricks, it hit me. My automatic update of the computer clock was not updating automatically. A synchronization with Internet Time and all was good.

Unlike other programs and since my rigs are homebrew I must physically tune the rig to the WSPR or FT8 frequencies. With other software auto tuning of the rigs to the frequencies is done automatically. Appliance operators would consider this an inconvenience but as a home brew guy it is just another day in the shack.

I should note that you will need a super stable VFO to work the digital modes. My homebrew rigs (nearly two dozen) all use the Si5351 PLL or AD9850 DDS. It may be possible to use an analog VFO but unless it is using a X Lock 3 frequency stabilizer (from G4GXO) your results may be marginal.

I will be looking for your signals on WSPR or FT8.

Zener Clamps and mosfet Gate - Source charge storage

Most modern power mosfets have inbuilt +/- 30 volts gate protection diodes; however, some designers prefer to clamp gate signals much lower than this. One problem amateurs face using power mosfets is the gate - source charge storage. It’s too high as it is, let alone adding the pF’s contained in back to back zener diode junctions, not counting noise generated in zener (really “avalanche” diodes, if above 3.3v rating).

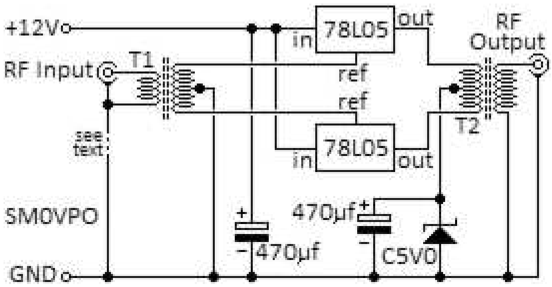
A simple answer is to add a fast (silicon) signal diode in series with each zener, in such a way the zener action isn’t blocked by the signal diode. Result: the capacitance of the signal diode is far lower than the zener diode, so represents the effective capacitance of that leg of the clamp, when back biased: a few pF’s in the case of a 1N4148 / 914. The zener clamps at ~ 0.55v higher than the rated voltage due to the added silicon signal diode, but much lower overall capacitance is the benefit.

Push-Pull Voltage Regulator Amplifier

by Harry Lythall - SM0VPO

Introduction
Now this is a circuit that is interesting. It is a push-pull power amplifier mis-using voltage regulators as active devices. The circuit can be used for audio or radio frequencies. This unit will deliver over 250mW before the 78L05's begin to restrict the current to 100mA (peak). If you use 1-Ampere bypass transistors then you can get a nice comfortable 2.5-Watts out.

Circuit Description
This is simply a pair of 78L05, +5V, low-power voltage regulator chips, each of which will amplify one half of the input waveform. Transformer T1 isolates the input to the amplifier and gives two anti-phase signals to drive each of the voltage regulator inputs (reference inputs).



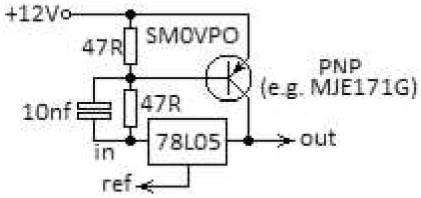
The 5V regulators each deliver +5V, which is fed though the output transformer T2, with the centre-tap connected to a 5V Zener Diode. The Zener will not conduct (much) until the voltage rises above +5V DC. The two +5V out pins of the regulators are modulated with the input waveform, so either side of the transformer is driven in antiphase.

5.0V is not a prefered value, but I had a few in my junk box from one of these "mixed bulk packs" you get at radio rallies. 1N5222 is a 400mW 2.5v Zener diode, and you could use two of these in series. You could alternatively use A 5.1V Zener and use a germanium diode to raise the T1 centre-tap by 130mV.

The amplifier itself has a fantastic power-rail ripple rejection, due to the action of the 78L05 regulators. They are simply voltage followers with a +5V bias.

Gain
The active stages give absolutely no voltage gain whatsoever, but they give about 100x current gain. The transformer T1, on the other hand, can be used to realise voltage magnification. The input impedance to each regulator ref pin is about 5,000 Ohms, so using a 50 Ohm input you can have a step-up turns ratio of 1:10+10. This means you can easily realise a power gain of 20dB or so (100x the power).

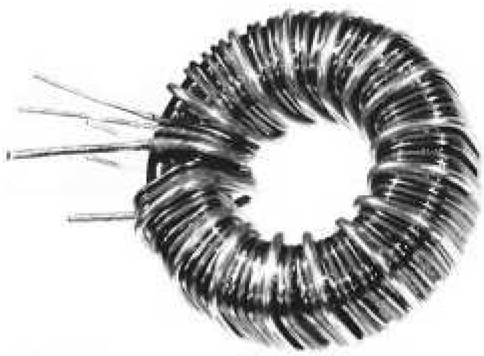
If you use the technique of bypassing the 78L05 with a power transistor, then you can get over 30dB of gain. This is how it is done:



The current drawn by the regulator also pushes current into the base of the PNP transistor. This causes it to conduct, and the collector current is added to the output current from the regulator. The regulator therefore draws less current, and the bypass transistor does all the work.

The 10nf capacitor prevents the 47 Ohm resistors and other capacitances from forming a time-constant that could reduce the response time at higher frequencies.

Transformer T1
T1 is simply a 1:10+10 (turns ratio) transformer. This can be wound on a very small ferite toroidal ring. The secondary winding should be "biflar" wound (two bits of wire twisted together before winding). This will make a nice broadband transformer. 5 + 50 + 50 turns will work fine for around 100kHz to 5MHz, but 2 + 15 + 15 will be perfect for up to 30MHz.



Any ferrite should work fine, but you may need to adjust the number of turns, depending on the ferrite you use. I have used small ferrite beads designed for VHF in this application, and I even used some unmarked ferrites robbed from a computer power unit.

For audio work you will need something a little different. Two small speaker transformers from ye-olde transistor radio can have the speaker coils connected in parallel and the driver coils in series. Alternatively you can perhaps re-wind one of the dinky ferrite transformers used in your old Black-&-Decker drill charger after the batteries died.

Although I have grounded the input transformer T1, you could have the input winding isolated from ground, and perhaps use a transistor driver stage ("see text" in the circuit).

Transformer T2 (250mW)
If you are building the 250mW version then T2 must be chosen for the correct impedance, depending on your application. The transformer input is 4V AC at 70mA = 50 Ohms. T2 turns ratio should therefore be 3:1 (1.5 + 1.5 : 1) to driver an 8-Ohms speaker, or 1:1 (1 + 1 : 2) to drive a 50 Ohm load. 50Hz or 60Hz mains transformers can be selected for audio circuits.

You need to wind your own coils on ferrite rings for RF work. At 100mA a ferrite ring in the region of 2.5cm Diameter is more than adequate. The primary should be "biflar wound" so that you can ensure the two halves are identical. See below for a better description.

Transformer T2 (2.5-Watts)

If you are building the 2.5-Watt version then T2 must be modified for the correct impedance, depending on your application. If you use the regulator bypass transistors then the output of the amplifier is 4V AC at 700mA = 6 Ohms. To drive a 10-Ohm speaker you can use a 50Hz or 60Hz mains transformer that has a 1:1 ratio, such as 6-0-6 and 12-0 outputs, and ignore the 115V / 230V windings.

To drive a 50 Ohm load you need a turns ratio of 1 + 1 : 6 step-up transformer. A total of about 30 turns is ok for 1MHz to 30MHz, and about 100 turns total for 100kHz to 5MHz. If you have a load of those cheap ferrite rings from computer power units (about 2cm Dia.) then you can stack 3 or 4 of them to form a bigger tube, using super-glue.

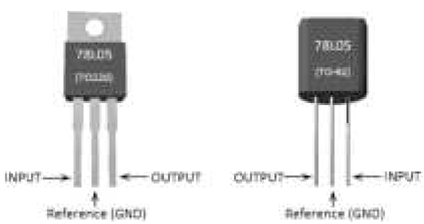
You could alternatively stack 2 + 2 of them, using glue, to make what looks like a pair of mini spectacles: one turn is in one ring and out through the other. You can get 2-hole ferrites ready made from Maplins, Mouser or Conrad, if you do not want to go to the trouble of making then with cheap rings and super-glue.

Ready-made 2-hole ferite

For RF up to 30MHz you should select the power transistors for an ft of 150MHz or more. CB output transistors should work fine, as long as they are PNP devices.

78L02 Pin-outs

Here are the pin connections to the 78L05:



Device pin-outs

I have not tried using a higher-current TO-220 version of these devices in these applications, but you may like to experiment a little for yourself. I have 1000's of these devices in the TO-92 (100mA) version and for me it is no problem to add a power transistor when needed.

Stability

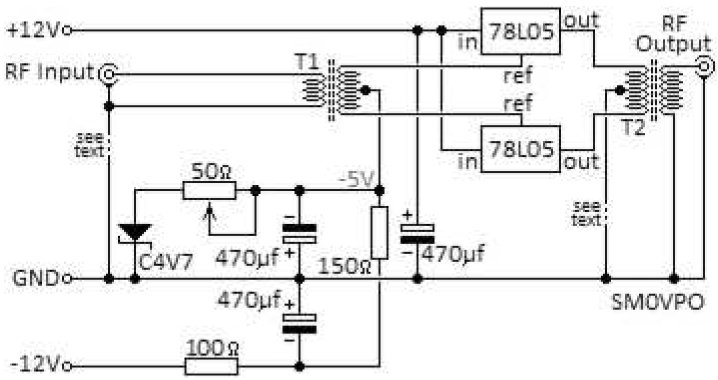
If you intend to use this project as an RF power amplifier then I strongly suggest you:

1. Add an output band-pass filter between the amplifier and the antenna (mandatory)
2. Put a capacitor across the output of T1 and T2, impedance = 10x the load impedance.
3. Neutralise the PA devices to prevent parasitic oscillation

Use a 10nf capacitor in series with a 10k-Ohm resistor between 78L05#1-out and 78L05#2-ref, and another 10nf capacitor in series with a 10k-Ohm resistor between 78L05#2-out and 78L05#1-ref. If there is a tendency to self-oscillation at RF then reduce the value of the 10k resistors.

Biasing

The idea presented is somewhat over-simplified, but you can get more than double the output power by changing the biasing. If you use a 12V AC transformer and rectifier PSU then you will also have -12V DC available by adding a single diode and a low-current regulator. This allows the possibility of giving the 78L05 chips a -5V reference, so the output of the amplifier will rise from 4V AC to 7V AC. This can be done with a simple Zener diode and a control pot, plus a couple of capacitors thrown in.



Note that this doubles the output power, but will also increase the output impedance by 50%. This means that you have to add 50% more turns to T2 primary. Double the power is only 3dB, or 1/2 and "S-point", so it is debatable whether there is anything to gain, other than better stability from the operational aspect.

The benefits of this method are:

1. The output transformer is referenced to ground
2. The bias level can be set so the PA draws about 3mA under no signal
3. The spuruious emissions at RF will fall

You will also get an improved crossover distortion figure, but the prototype was so low that I could hear nothing, even at very low audio levels where crossover distortion is most noticed.

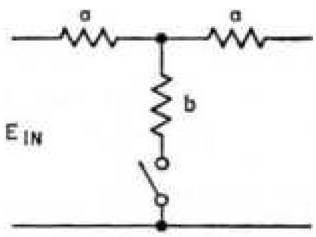
I never cease to be amazed by the ingenuity and diversity of Harry's designs! G6NGR

Audio Topics

Quality, or the lack of it - Soft Limiters

It's a common sight in RF and AF designs: a pair of back to back "clipper" diodes to limit a signal ("clamp") to acceptable levels. Much used in impulse noise gates and the like, diode clamps are a useful feature – but cause gross distortion of the signal. Trying to dig out a tiny signal awash in a sea of noise is hard enough; now add swathes of harmonic distortion to the signal and the intelligibility by the average listener is dramatically reduced. What's required is some sort of limiting circuit that doesn't slice off the tops of signals, but introduces limiting attenuation that gets progressively stronger the higher the input signal: and can act on fast impulse noise too.

One implementation that does just this is a series of TEE audio attenuators, in series, that introduce more and more attenuation as the input signal rises giving a "soft" clamping effect rather than a cliff edge clamp. One such circuit is described by George Schleicher, W9NLT, and he describes it for RF but the principle can be used equally at audio frequencies. Below is a single attenuation cell (courtesy W9NLT's web page):



Note the switch in the TEE leg: when open, the attenuation is minimal (if the load is much greater than resistors "a") and this is where back to back diodes are used to switch the attenuator cell into or out of circuit. The design of such a TEE attenuator cell can be found in many references; W9NLT gives his design equations (again, courtesy W9NLT's web page):

"Only four simple formulas are needed in designing T attenuators; they are as follows:

Loss (expressed in db.) = $20 \log \frac{1}{\frac{I_{out}}{I_{in}}}$ *{1}*

n = $\frac{I_{out}}{I_{in}}$ *{2}*

a (the series resistor value) = $Z \frac{1-n}{1+n}$ *{3}*

b (the shunt resistor value) = $Z \frac{2n}{1-n^2}$ *{4}*

(Z is the characteristic impedance of the attenuator).

As an example of the use of these formulas, assume that you are designing an attenuator of 150 ohms impedance with a loss of 6 db.:

$$6 = \frac{20 \log \frac{1}{I_{out}}}{I_{in}}$$ ***{from 1}***

$$6/20 = \frac{\log \frac{1}{I_{out}}}{I_{in}}$$ ***{from 1}***

$$0.3 = \frac{\log \frac{1}{I_{out}}}{I_{in}}$$ ***{from 1}***

antilogarithm of 0.3 = 2.0 } from slide rule or log table

$$2.0 = \frac{\frac{1}{I_{out}}}{I_{in}}$$

$\frac{I_{out}}{I_{in}}$ ***= 1/2 = n = 0.5 {solving for n}***

a = 150 $\frac{(1 - 0.5)}{(1 + 0.5)}$ ***= 150*** $\frac{0.5}{1.5}$ ***= 50 ohms {from 3}***

b = 150 $\frac{(2 \times 0.5)}{(1 - 0.5^2)}$ ***= 150 (1/0.75) = 200 ohms {from 4}***

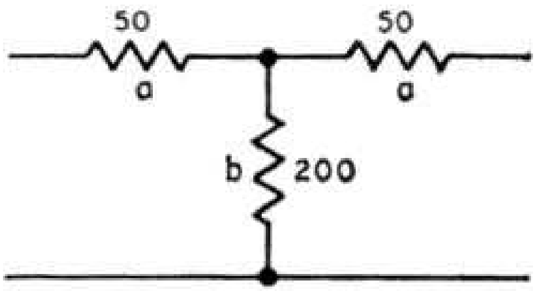


Fig. 5 - Attenuator used as an example for calculation as described in the Appendix.

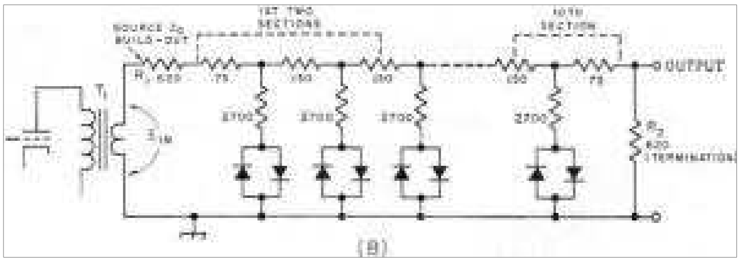
A single attenuator section of 150 ohms impedance and 6 db. loss is shown in Fig. 5 (above).

Some representative attenuator section values are shown below. They are included as an aid in designing limiters of the kind described here.

Loss, db.	*a* resistance	*b* resistance
1	57.5	8500
2	115	4310
3	171	2840
4	224	2100

These values are based on an attenuator impedance of 1000 ohms. For other impedances the values should be increased or decreased proportionately.”

W9NLT shows a series attenuator:



As the input signal rises in amplitude, more and more attenuation automatically cuts into the circuit. This is NOT an “AGC” system: it is capable of performing at many MHz (construction allowing), typically the only delay being the time it takes for signal diodes to switch – in the case of 1N4148 / 914’s, a couple of nSecs. Compare this to the time constraints an AGC loop must observe to avoid irritating “pumping”, or constantly changing audio levels.

In these circuits, W9NLT emphasises the diodes should be as near matched as possible for reduction of distortion; modern packaged twin diodes will easily and cheaply save the amateur hours of meter work and eliminate the cost of factory selected matched devices. It should be noted that the matching is only required in the diodes for each attenuator cell – cell to cell matching is irrelevant as far as I can see. The system is of course, lossy, but a stage or two of (low noise!) amplification will readily bring the signal levels back up.

Sub-Audio control?

The output of a receiver connects to the human ear, and therefore any frequency above or below the threshold of hearing is inaudible, and will not detract from the intelligibility of the audio signal (be this CW, SSB or AM in the transmitter). Here, then, is a possible means of synchronisation for automatic Morse decoding, DSB carrier re-insertion (which yields a 6dB improvement over SSB if a synchronous DSB demodulation is used) and many of those esoteric modulation methods much beloved by our LF brethren. Ignoring the “higher” audio option, as bandwidth limits prevent upwards spectrum expansion, sub audio could be a way. If, for instance, 100 cycles of 10 Hz sub-audio signal are added a transmission, with a gap of a few cycles every hundred, a counter can be synchronised to the transmitter which is self correcting as the counter will reset on the next cycle “gap” and the count resume. By this means synchronous decoding / demodulation can be implemented; historically “coherent CW”, the pre-cursor of WSPR and many other digital methods, foresaw the rise of similar digital synchronous transmissions.

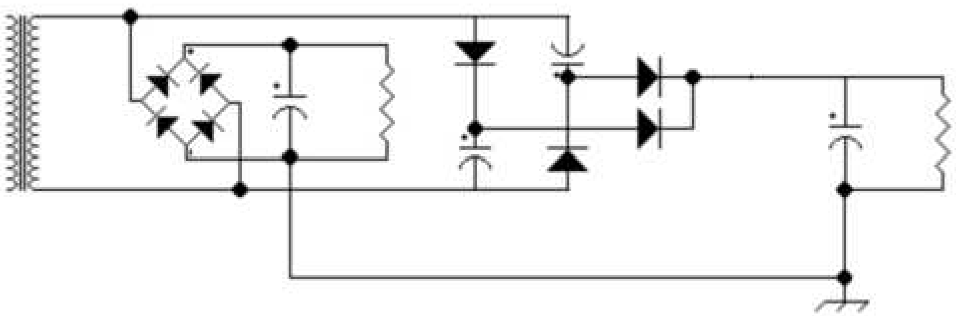
The proposition is this, consider the CW first. If the monotonic carrier is 20% amplitude modulated with a sub 10Hz tone, two sidebands, a 10 Hz displaced from the carrier will be present in the received signal during every key “down”. The carrier will be dominant by a factor of 4 (standard AM carrier / sideband relationship), so the main signal will be the CW; the sidebands will be much reduced, but selectable by an 8 pole digital filter (which can respond much faster than an analogue filter, without the inherent analogue problems) and used to synchronise a phase locked loop, maintaining the synchronisation signal during key “up” no carrier periods, maintaining the count until the next 2 cycle “gap” comes along to synchronise.

The sub-audio frequency is thus used to control the timing, both in the transmitter and the receiver, of the CW signals in a set pattern – a simple matter for an electronic keyer using logic or a microcontroller, similarly a CW decoder in the receiver, as the CW carrier and sidebands will have identical path delays. A hand key could feed “semi random” (apologies to you expert CW fists!) sequences into a digital counter and comparator system – the comparator decides whether the key down period is “over” or “under” for dits and dahs and “gates” the sub-audio cycle counts according to the speed setting of the system. The receiver phase locked loop will capture the sub audio frequency and lock onto it; detecting accurate “dits”, “dahs”, “short” and “long” spaces. Being sub audio, the speed of synchronisation is necessarily limited; but would yield a semi-automatic Morse system with easily obtainable current technologies, that would be usable by “hand fists” too.

Power Supplies

The power supply(s) shown in this section require a working knowledge of High Voltage practices and safety. I cannot be held responsible for any accident, injury or other nasty event, as I can’t supervise your construction, testing or use. ***If in doubt, don’t do it!*** *Get expert help from a capable and qualified competent person. This is a MUST! Don’t even think of “winging it”!*

The Pink Brazilian - the doubler / rectifier



Shown above is a very efficient and effective power supply rectifier (note: fusing and safety / soft start equipment NOT SHOWN). The secondary of the transformer feeds two sections: the *bridge* section, and the *doubler* section. The magnificent advantage of this design, which I first met working on EHT diode stack test fixtures some years ago, is that the bridge and doubler both have *a common negative* making it ideal for replacing the now rare centre tapped HV power supply transformer.

The Pink Brazilian transmitter is aimed at a 6146/B valve final which requires ~ 620v on the anode, and ~ 300v on the screen grid, the recommended operating values so this transformer and rectifier circuit will suit perfectly using a single 240v secondary winding; a common winding on control panel transformers which are far more available than a centre tapped HV transformer. An added benefit, the bridge section eliminates the lossy screen dropper resistors, dropping ~ 300v from a 600v rail, at a good few mA's for "stiff" screen regulation. 240v rms bridge rectified gives a healthy 310v DC on load (depending on the transformer regulation); so doubled by the efficient (true full wave) doubler section gives ~ 620v DC.

Another common "control panel" transformer is the 415 - 425 - 435 - 480v rms to 110v or 230v rms; this, run "back'ards", when rectified with a bridge / doubler would yield 585v DC and 1350v DC. This is getting seriously near the voltages the bigger beasts in the Radio Transmitter country consume - like a 4CX250B. I think a neat HF or VHF linear around 100 - 200 watts could be put together very economically using this doubler system.

Since the Pink Brazilian is designed for full amplitude modulation, the ability to drive the screen grid with audio (and the control grid for better audio quality and depth of modulation) is an option using a power mosfet to control the screen potential at audio frequency. The original idea to avoid a modulation transformer was the mosfet version of the "plug-in" cathode modulator, the proven and very efficient (if that word's applicable to an A.M. transmitter!) system that applies a combination of anode and grid modulation but allows full power CW to be transmitted by switching to keying in the cathode.

On any high voltage power supply I fit a soft-start relay, and an earthing relay (as shown in Hot Iron 101), which has dual function: the earthing relay uses normally closed contacts to short circuit the HV outputs to ground when AC mains supply shuts off (for whatever reason). The soft start relay system employs a dropper resistor (or a light bulb...!) in series with the primary that is shorted by normally open contacts of the soft start relay whose coil is energised by the output of the transformer via a trimming resistor to set the pull-in point - the secondary voltage has to rise to 80% of maximum before the soft-start relay coil pulls in the armature, shunting out the primary side dropper resistor. The entirely eliminates any large surges which can not only blow open circuit (UK technical term.... "nadger") the rectifier diodes, but severely strains the electrolytics used for smoothing and reservoirs. I fit low ohms resistors as deliberate fusible links, which double as the RC filter low pass element between the smoothing capacitor and the reservoir capacitor on the power supply's outputs.

Back-to-Back transformers - a transformer designer's opinion

Hot Iron is all about amateurs building radio equipment: we are a diminishing crowd, but the spirit and will lives on, despite every effort by manufacturers to discontinue our favourite parts and abandon those amateurs who home build gear. One of the major issues is HV transformers for valve projects: once common place, these are as rare as hen's teeth nowadays, and no easy substitutes are to hand – same goes for those really useful audio transformers, 8k→8 ohm, that often inhabit valve receivers. Of course, you could use a quality semiconductor audio amplifier (check Elliott Sound Products webpages for eminently suitable designs). You can use "100 volt line" audio transformers, but they are touch expensive and bulky, so I'd plump for a modified LM386 circuit as the very minimum, or one of Rod Elliott's designs for a proper job.

Now: back to that power supply problem. I've tried connecting transformers "back-to-back", for instance, 230v primary to 12v secondary (that feeds ECC 81/2/3 series wired heaters very nicely) then driving the 12v into the second transformer's 12v winding, and gathering 230v rms for rectifying / doubling from the "primary". But the scheme never seems to deliver the volts on the rating plate; it's always a good bit low, and several correspondents have asked me why.

I decided to get the whole truth on this matter; to get to the root of this method of generating a floating, earth free AC supply, so I asked Martin Boardman, the magnetics magician who runs

Boardman’s Transformers, with whom I have done (professional) business for many years. Martin winds transformers for virtually all the major electronic distributors in the UK and Europe, and is a most helpful chap indeed. Here’s his comments on running “back-to-back” transformers for HV power supply purposes, quoting to him a 200VA 415v → 230v control transformer I want to run “back’ards”:

“Hi Peter

Good to hear from you.

In principle there is no problem running a Transformer the other way round.

The only real issue is the output voltage that you will achieve. Yes the turns ratio is broadly ok but depending on the VA rating of the Transformer, 200VA in your case, the output voltage will be a little down because the regulation is working against you.

Around 6% for a 200VA unit.

The normal approach when designing a Transformer is to modify the turns, reduce them on the primary and increase them on the secondary to allow for the dc resistance of the winding, therefore allowing for the regulation and achieving the correct voltage under full load.

So, to cut the story short, no problem whatsoever to use the Transformer in reverse, you will probably just find you are a little down in output volts, maybe 400V or less, instead of 415V.

I hope that helps.

Best Regards

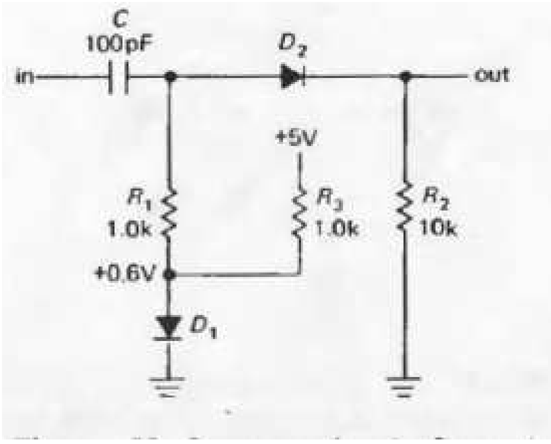
Martin Boardman”

So there you have it: it’s essentially the winding resistances at play that cause the lower than expected output. The transformer designer builds the magnetics to deliver sufficient flux, cutting sufficient turns, to create the rated output *at full load* – he puts a few more turns on the secondary and a few less on the primary to compensate for the winding resistances. We run the transformer back’ards, so we have to overcome the winding resistances. Going off Martin’s comments, we’re not doing anything disastrous but it might be an idea to run a 230v →15v rms “driver”, feeding a 12v→230v “driven” transformer to get the full rated 230v rms output. All that remains is to use a small value resistor to drop the 15v “driver” transformer secondary output to 12v ensure our delicate ECC81 filaments don’t get toasted!

Test Gear & Fault-Finding

RF Probe WITHOUT diode offset voltage [# 2]

Another biased diode RF probe:



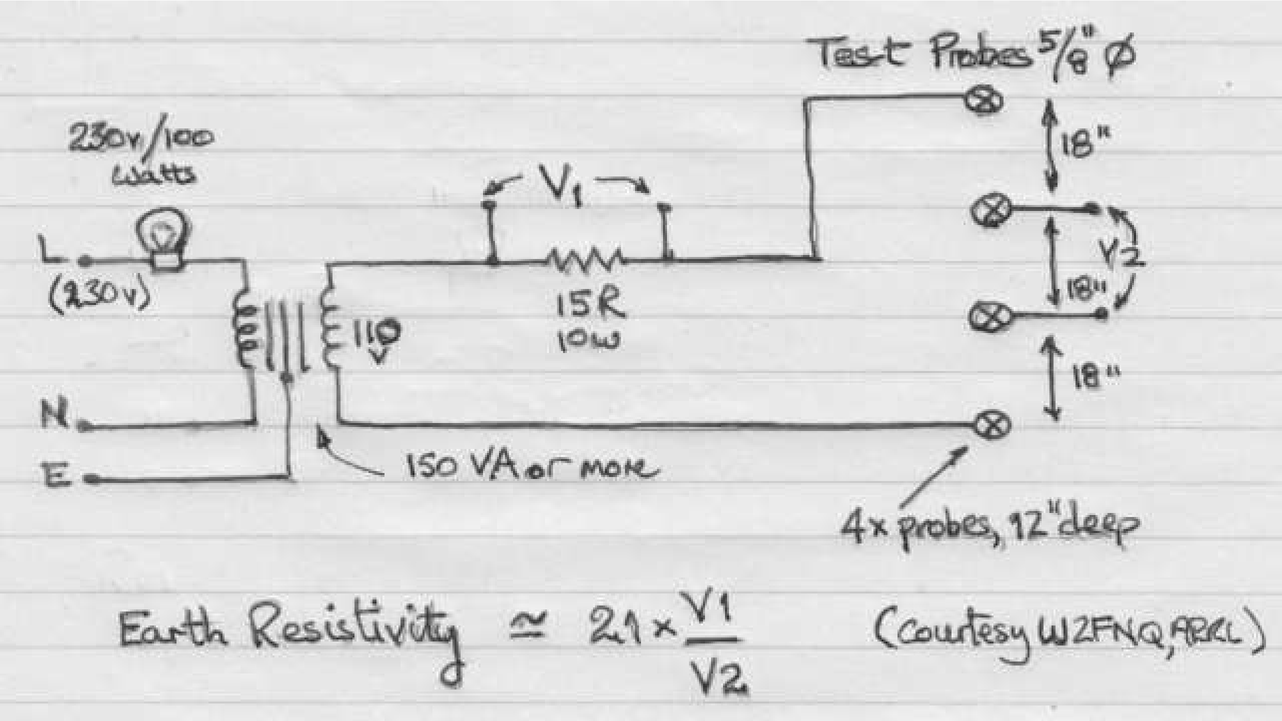
This is from a diagram in “The Art of Electronics” by Horowitz & Hill; one of the “Bibles” no professional Industrial Electronics Engineer should be without. You can modify the values up or down as you like. The only drawback is the need for a bias supply; but almost any voltage above a 1.5 volts will do nicely. It’s a good idea to make the R3 a combination of 470 ohm and a 2k-ohm preset rheostat so you can adjust the bias current though the diode D1 to adjust the bias voltage generated by D1. Set up the bias with the “in” terminal shorted to ground via a 50 ohm resistor, whilst monitoring the output with your multimeter (set on low mV’s) and adjust Di current for zero indicated volts.

The Dim Lamp tester... (2) Vertical Antenna Ground Conductivity testing

More cautious readers might like to read this article whilst wearing rubber gloves and Wellington boots: it’s a classic from yesteryear when “Health & safety” was of little or no concern! The more safety conscious of us would use an isolating transformer to generate a safe supply for this test – which might prove useful for those Radio Amateurs who need earthworms for fishing (or other?!?) purposes...

The measurement method is an illustration of the “four point probe” technique, much beloved by those of us with a silicon device manufacturing background, that measure the *Conductivity* (NOT resistance) of the ground under your vertical antenna. In simple terms, you inject a test current into the ground (AC to eliminate electrolysis effects) via the outer probes, and measure the voltage between the inner probes – the higher the conductivity, the more efficient your vertical antenna will be. Fans of “Time Team” will recall the Geo-Physics surveyors using such probes to search the ground to discover archaeological structures below: this method really does drive current well below the surface.

The physics of the measurement technique is not simple – the maths is particularly “non-amateur” - but the rule is simple if you stick to the spacing and depth given. For the more technically minded, WIKIPEDIA has an excellent article, and describes the two methods of interpreting the results; Wenner and Schlumberger. We don’t need to bother too much about these esoteric methods: W2FNQ came up with this simple method, below:



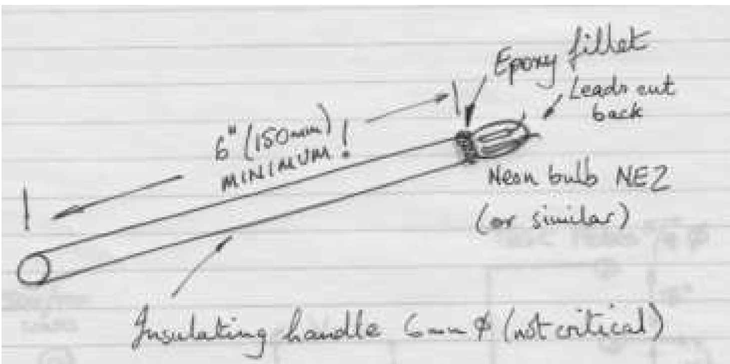
The 100W incandescent lamp limits the applied power; V1 is proportional to the current flowing and V2 is the generated voltage measured in the earth. By using the dimensions shown, the maths simplifies to 21 x V1/V2, approximately.

Chucking a few buckets of water around the probed area, then measuring again, will show if your soil is too dry: if the conductivity rises then the soil needs wetting regularly. This is rarely a problem in the UK; despite the song about mad dogs and Englishmen, we can go out in the midday "sun" as it's usually hiding above the massed Cumulo Nimbus!

A useful device for finding parasitic oscillations... [2]

A neon bulb "wand" like the one below can detect the presence of RF energy, by touching just one of the cropped wire leads on a "hot" terminal; if the RF is more than a watt or two, mere proximity will illuminate the neon. The colour of the glow is useful: a red / orange is LF / HF present; purple tinge indicates VHF, 40MHz and up (assuming you're using a genuine NE2 neon, test it on your 2m txcvr antenna). I culled mine from a "£-shop" mains indicating screwdriver that had seen better days!

The insulating handle is for safety; any good insulating plastic, fibreglass or similar rod with a dab of epoxy serves very nicely (a large knitting needle is ideal, but don't let on I told you that...!)



Signal tracers

A very useful multi-functional tool for fault finding and prototyping is a bench audio amplifier, fitted with a high input impedance pre-amplifier and an RF probe, making a Signal Tracer, used to track signals in an RF or AF section. A DC biased probe head can also locate that most elusive fault, the “noisy” (leaky) capacitor, feed-through insulator, co-ax cable using a bias DC supply.

To find those leaky capacitors / insulators, the idea is this: the signal tracer probe tip has a +ve DC bias voltage applied (via a small switch on the probe body), so when you touch the D.U.T. test point, it has a +ve DC bias applied (the opposite end of the D.U.T. is grounded temporarily to stress ONLY the D.U.T.) which shouldn’t make any sound in the signal tracer, it’s AC coupled - the only audio you’ll detect is if the capacitor is breaking down.

For obvious reasons, the polarity of the capacitor must be observed; always ensure you fit the grounding lead FIRST, at the CORRECT end, or you’ll unnecessarily stress other adjacent semiconductors. Touch the test point with the probe (switch set to “noise”). Make ABSOLUTELY SURE the adjacent semiconductors are either grounded / shorted out or disconnected / unplugged. Semiconductors are nowhere near as tolerant as valves when it comes to voltage stress!

If the capacitor is “leaky” then you’ll hear a scratchy “noise” as the DC bias breaks down the insulation. The old Heathkit valve Signal Tracer put +150v DC on the probe tip (high impedance for a touch of basic safety), ideal for valve jobs, but definitely not recommended for modern semiconductors! I have checked discarded lengths of co-ax using this technique and chucked away plenty that had been water damaged, but otherwise looked perfect: the Signal Tracer with DC bias will find these problems and the like in a jiffy, where a multimeter on ohms won’t show a fault (the test voltage is too low).

With a well designed germanium diode probe head, you can trace an RF modulated signal injected from your handy μV RF source from antenna socket right through to the audio section of a receiver.

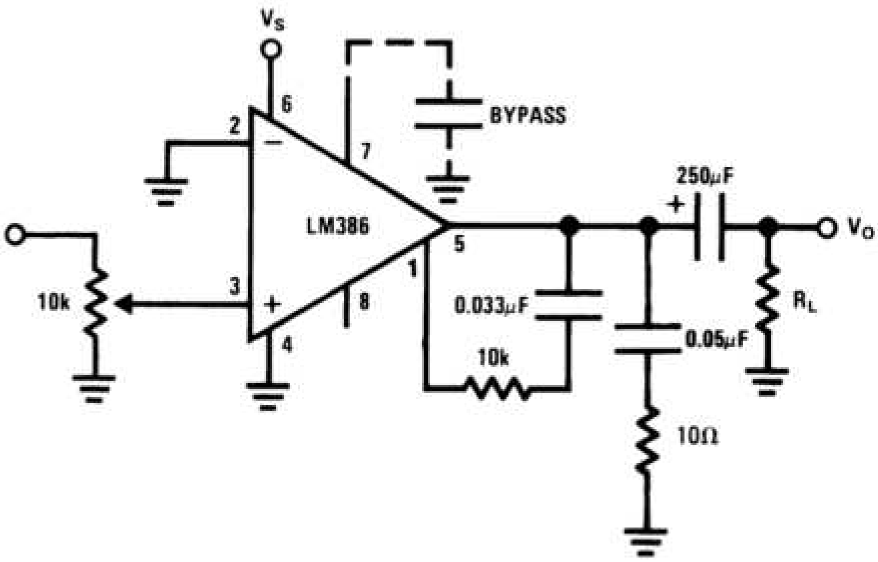
In short, you’ll find the section of a “deaf” receiver that is giving trouble very quickly and easily, as most receivers can be split into sub-systems and then divided further as the results become known. Typically the sequence of sub-systems in a receiver is: RF amp → Mixer → IF amp → Product detector/BFO → Audio; the local oscillator can be checked using the RF probe feeding your 10M input multimeter and ensuring steady output volts as the oscillator is tuned across it’s range(s); the output from the local oscillator buffer amplifier should test similarly.

“Interesting” faults like instability in a stage (dried-up decoupling electrolytics are a favourite culprit for this) show up as an output, with power applied to the receiver, when no signal input is present as a warbling, wavering sound.

The circuit of the Signal Tracer is quite straightforward: a >1M-ohm input impedance pre-amp feeds a 250mW amplifier (think LM 386 with hiss and distortion killer components fitted). It’s important to use a good quality DC blocking input capacitor in the RF probe head; be generous with the voltage rating (500V isn’t excessive) so you can test an HV power supply for ripple. This capacitor needs to be able to pass RF and AF into 1M-ohm, but not be so big as to cause excessive start-up charging delays - 15nF is a good value.

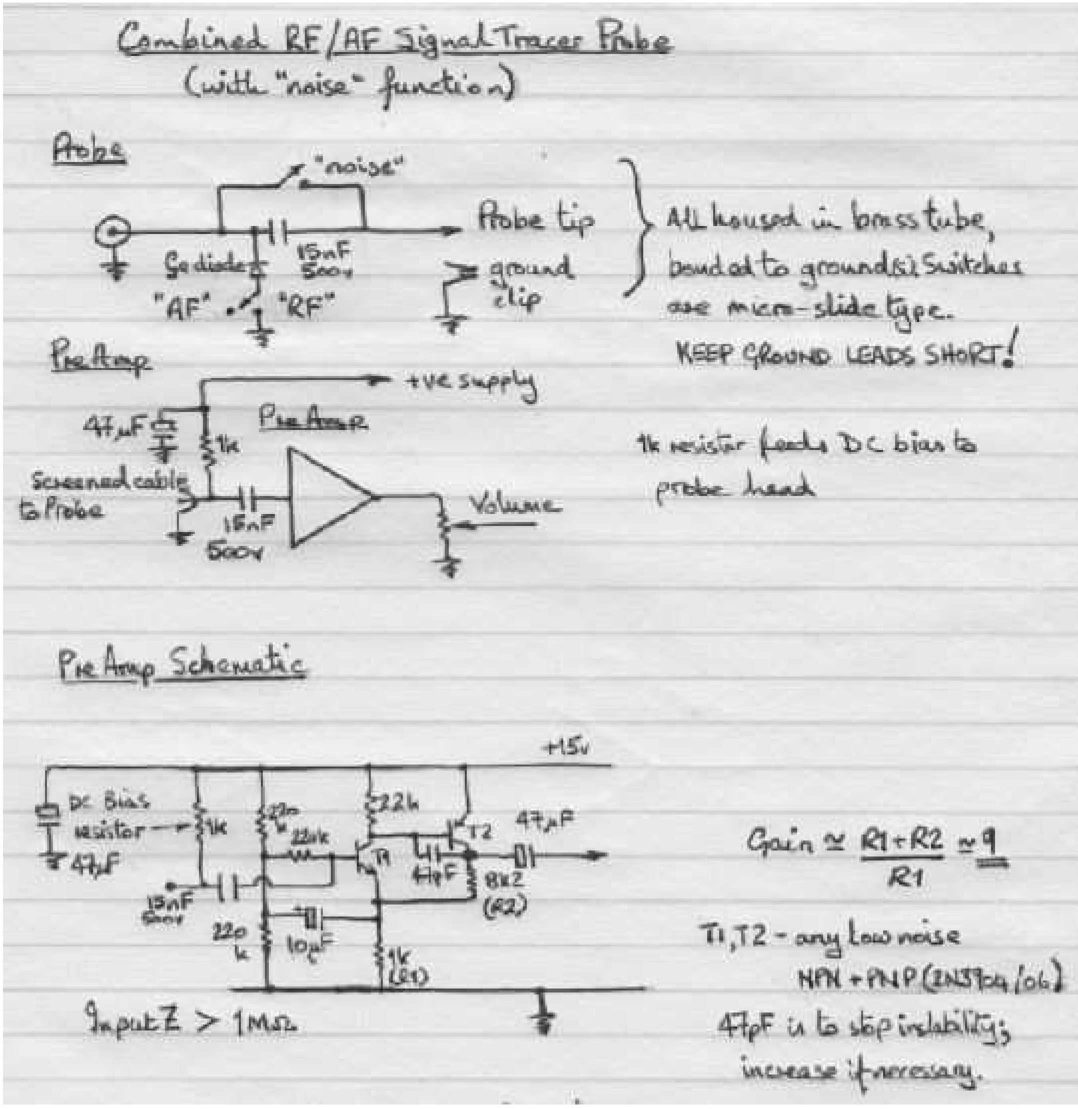
The pre-amplifier I prefer is “bootstrapped” bipolar transistors, to gain very high (>1M ohm) input impedance to eliminate loading effects on the circuit being tested. You could use a j-fet or mosfet, but I prefer the repeatability and robust performance bipolar silicon transistors offer; especially if an accidental charge / discharge of the RF probe coupling capacitor when checking high voltages (in a valve circuit for instance). Shown in the diagram is a design that offers >1M ohm input impedance that can run happily on any supply voltage between 9v. to 15v. The gain is just above 9; combined with an LM386 set to maximum gain (200) results in an overall gain of around 65dB, enough to reliably hear weak µV signals yet remain reasonably low noise and stable.

For the main amplifier I bought an LM386 pcb “plug-n-play” amplifier module with volume control from an on-line auction site: this was considerably cheaper and smaller than I could make with individual parts! I fitted the hiss killer components (33nF + 10k, pins 5 to 1) on the top side of the SMT pcb. You can find dozens of variations for improving the LM386 on the web, below is National Semiconductor’s applications note circuit with “bass boost” (i.e. hiss killer) which I find acceptable, cheap and robust:



Fit a 47µF capacitor between pin 1 (+ve) and pin 8 for gain = 200, rather than the gain of 10 (open circuit) as shown. The “bypass”capacitor is 100nF. Grounding pin 7 mutes the beast should you need that function.

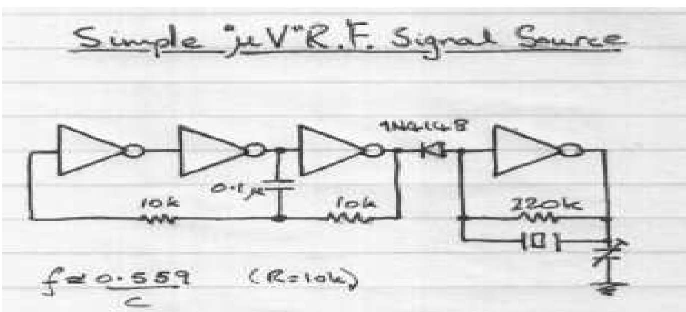
The RF probe with switched RF / AF function and “Noise” setting is shown below. I personally use the standard “shunt diode” RF probe for most functions; it works just as well on AF as far as I’m concerned, for most jobs and means I can use it for metering purposes too, indicating peak RF.



A modulated μV RF signal source

To use a Signal Tracer, you need a low level signal source. I was shown how to make this when constructing an AC pA pre-amplifier for photo-diode checks, whilst working as an technician apprentice in a (once-famous) UK electronics manufacturer.

The left hand gates form an audio oscillator, roughly 550Hz, which switches the crystal oscillator on and off via the diode. The effect is A.M., easily found in a receiver under test. I built this “in the open” and found it could be detected from some yards away! Then my mentor showed me how to get the output



down: “put it into a diecast box, with integral battery supply. Make sure the box lid is bonded with thick wire to the box and supply negative / ground. Unscrew the box lid, and open it half way - switch it on, find the signal on the detector / receiver, and close the lid until the signal all but disappears; you’re now down to less than a µV”.

Any crystal between 1MHz and 10MHz will run easily with a CMOS / 74HC hex inverter package with appropriate supply; the trimmer is to adjust the crystal dead on frequency should you wish. Use any audio frequency you like, it’s not critical. Just as Stan told me, open the lid, put it near the antenna socket, power up and find the signal. Close the lid progressively by sliding it shut until the signal disappears in the noise. Job done!

What if you can’t find the signal on the receiver...? You’ve just built an RF signal tracer, use that until you locate the faulty section, starting at the antenna input; use plenty of signal (open the lid...) to get a result and move through the receiver until you get to the “dud” stage. Fault found!

Components

Electrolytics – again...

Electrolytic capacitors work miracles; let there be no doubt about that. To squeeze all those µF’s into such a small size, delivering current millions of times yet still remaining leakage free (more or less) is a technological marvel. But... as we have seen previously, they are a common cause of breakdowns, trouble and general bad behaviour. One feature I have observed over the years is value and voltage rating “creep”. This occurs typically when an electrolytic is run below it’s nominal rated voltage; i.e. a 450v rated capacitor running on rectified 230v AC rms, typically ~ 310v DC.

What happens is the capacitance creeps UP; and the voltage rating FALLS to match the applied voltage. Not all electrolytics do this; I’ve seen it in signal coupling capacitors, and in the DC bus reservoir capacitors in 10kW motor inverters running at 20kHz. There seems to be no rhyme nor reason why one capacitor will show this “creep”, yet it’s neighbour, of apparently identical parentage, remains exactly as marked on the tin.

The effect (I guess?) is caused by the insulating layer becoming thinner as the lower than rated applied voltage doesn’t maintain the electric field in the electrolyte required to create the insulation; the layer becomes thinner to match the voltage applied. Since $C = \varepsilon * A/D$, and “D” is getting smaller, then C rises proportionately.

The moral is this: if you put a bit of kit on another supply, higher in voltage than the one you usually run it on, then beware: odd results after a day or two might point to an electrolytic going off to the land of it’s fathers, after suffering “creep” and the voltage rating has fallen, the now higher voltage is breaking it down.

“Real or Fake”, the curse of Scam devices

Terry, VK5TM, gave some advice recently about scam devices for sale on our favourite on-line auction house; it’s a sensible check and test method, and I recommend it. Terry says:

* “*Always assume they are fake (they are more often than not).*
Doesn't help when you need some for a project/job I know, but the majority of RF transistors for sale on the auction sites haven't been made for quite some time now.

* *Do a photo search using the photo's from the ad, quite often the same picture will show from multiple sellers, usually a sign of no good.*

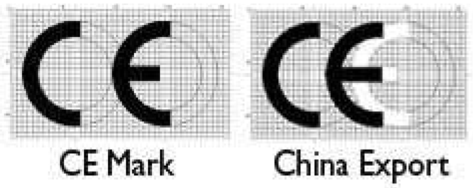
* *If the price seems too good to be real - well, you know the saying.*

* *Search using the sellers name to see if there has been any comments outside the eBay system, good or bad, about the products from that particular seller.*

Terry VK5TM”

I had another input from Alan Gale, G4TMV, who commented on the “Chinese Export” marking: it certainly looks uncannily familiar to me! An extract from a Marine Radio article Alan directed me to is below. This is one to look very carefully for, an obvious rip-off of the Euro “CE” marking. Will we see USA “UL” and “CSA” marks similarly ripped off? Ditto, SEMKO in Scandinavia?

Chinese companies printing close replica of European standards logo on products



In recent years we in the UK have got used to the fact that if a product bears the CE mark, it’s Kosher. The reason for this is that goods with CE marking demonstrate that they meet relevant and strict EU standards. This marking brings benefit to all in the supply chain and most notably, the consumer.

Unfortunately, there exists a very similar mark which the majority of consumers and even sellers may see as the CE mark of the European Union but actually is something completely different. This “CE” mark means “China Export” and only means that the product was manufactured in China. It is believed by various organizations that this similarity is not a chance coincidence and that this expresses an aggressive approach to sell into the European market without the right standards.

On this page are examples of both logos. As you can see that the letters in the “China Export” logo are sitting very close to each other and bear a striking resemblance to the official European marking. This is the one to watch out for. It wouldn’t be too difficult to mistake it as the genuine Euro standard mark. The China Export logo is not registered; it does not confirm positive test results and is placed by Chinese manufacturers arbitrarily.

Ft measurements for the amateur

In the past I have been involved in the manufacture of silicon devices and microcircuits, and the measurement and test of these devices was a major part of my employment, as was the designing and building the test equipment. One job that always interested me was the measurement of “Ft”, the transition frequency where the power gain of a device fell to unity. This can be adapted for amateur checks of RF devices, assuming you can attenuate your transmitter output to a suitably low level or have a signal generator that can deliver 0.5v to 1.0v rms of RF.

For quick checking devices, you measure the voltage gain in common emitter configuration at various frequencies – the gain multiplied by the test frequency (in MHz) yields a fair approximation of the Ft value. The reason for this is that in common emitter configuration, the gain rolls off with increased frequency almost linearly, due to the Miller effect (as well as many other factors...).

For example, supposing you measure the voltage gain (using a peak reading RF probe to measure the drive voltage and output voltage) using 30 MHz as the test frequency. You record a gain of ~ 5 at various drive levels (careful not to clip the output by over-driving).

The Ft is roughly (gain) x (frequency) which gives 5 x 30MHz ~ 150MHz. Repeat the test at 10 MHz and note the gain: say 16, which gives an Ft ~ 160MHz. Up the frequency to 60MHz, measure the gain again: 2.3 (say) which gives Ft ~ 138MHz.

You can assume this transistor is good for most low HF duty; if you need it to run above 30MHz then I'd say you need common base configuration to get useful gain from it!

Antennas & ATU's

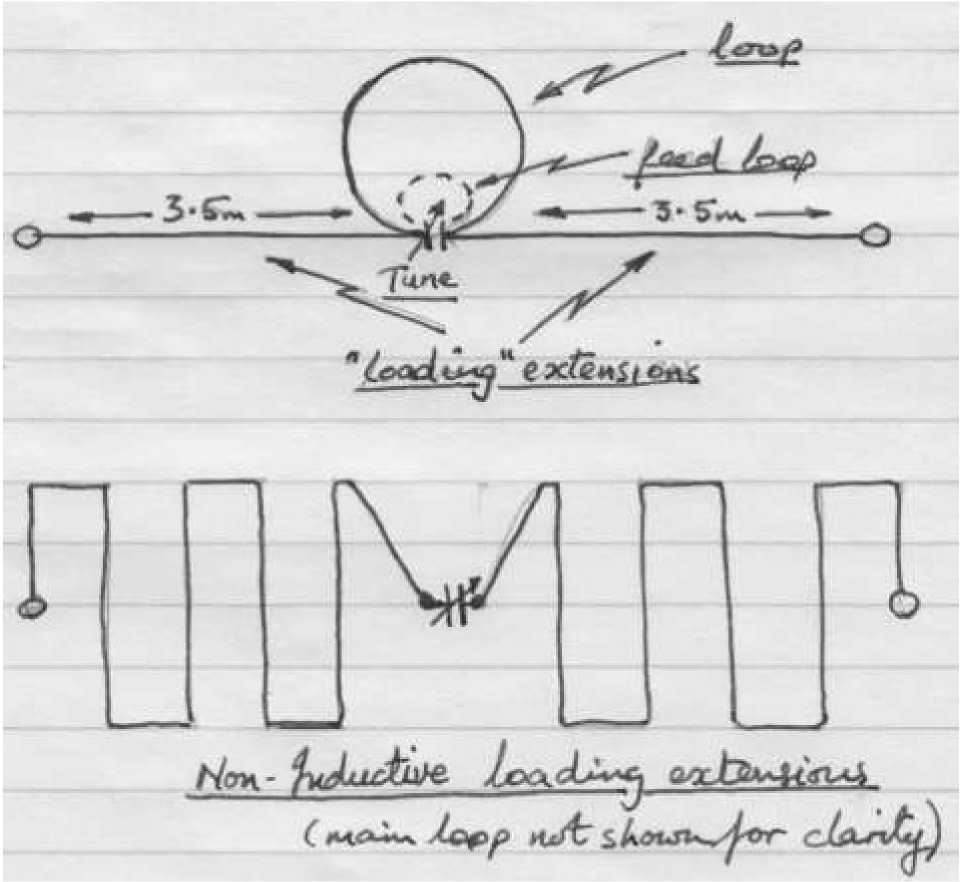
A Mag Loop – with a difference

From Aleksander Grachev, UA6 AGW, comes an idea which caught my eye - a tuned loop antenna that has reasonable bandwidth without losing efficiency. The "mag loop" is very useful in places that suffer from electric field noise, as it's sensitive to the "B" field, rather than "E" field, and is very useful for those with limited space. The "elephant in the room" is the loop tuning capacitor, it's retuning every few kHz, and the huge voltages across the plates usually requiring vacuum variable capacitors, motorised for remote tuning.

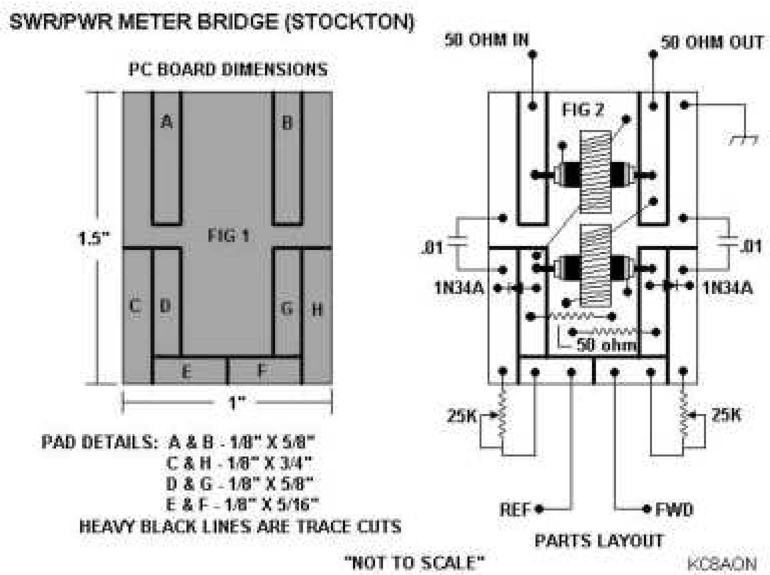
UA6AGW has found a potential answer to this "elephant" in the form of a standard antenna technique that is simple and well proven: capacitive loading.

A capacitance "hat" works wonders with short vertical antennas and the like; lowers end voltages, widens bandwidth and generally does a power of good in every respect. Aleksander uses 3.5m lengths of wire, strung out horizontally from the open "ends" of the mag loop where the usual vacuum variable capacitor sits (to supporting insulators) in the plane of the mag loop to maintain the directional properties. Whilst I have no definitive measurements of the improvement, UA6AGW quotes VSWR ratios below 2.0 for 40m to 10m using capacitive loading, and bandwidth opened up to 100kHz or more before needing re-tuning. RU1OZ reports using WSPR reports that show the "loaded loop" to be more effective than a conventional wire antenna; but under what ionospheric conditions, sunspot counts and so on I don't know. It needs further study in varied installations; mag loops are ideal "attic" antennas, but good for exposed outdoor work too: the low wind loading and thin capacitive loading wires would make a tidy and low profile installation.

It struck me that "non-inductive" folded loading wires would keep the directivity and get more capacitance in a smaller space, meaning lower voltages and losses - but this will need trials in different installations to prove one way or t’other, and supporting the capacitive loading structure might introduce cross fields, disrupting the main loop radiation. But... why does every improvement “idea” create at least a dozen more questions?!



SWR measurement without tears



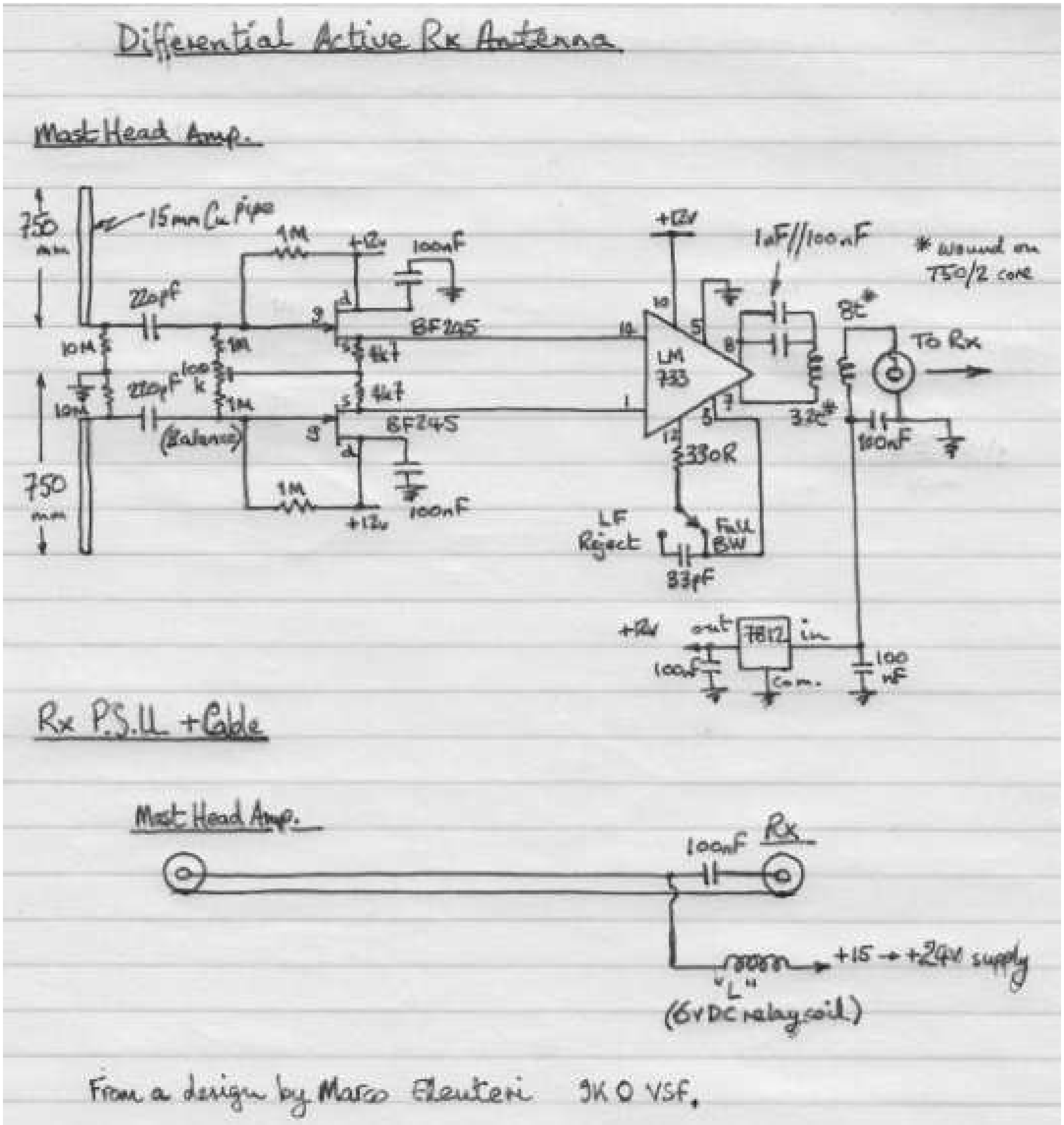
This is a simple PCB for the ever-popular Stockton SWR Bridge, by Richard S. McKee, KC8AON, with this superb layout that I saw recently. What attracted my attention was the symmetrical layout Richard has achieved: this is the key to measurements like this, maintaining balance and minimising stray capacitances. The PCB can be cut with a craft knife or small hand grinding tool, but I like self adhesive copper foil; perf board gives a neat grid for designing symmetrically and is extremely low capacitance too - as good as Manhattan style.

At the moment I'm experimenting with some short lengths of brass tube and two filament lamps to give a visual indication of matching and SWR; this is a work in progress and more on this topic will come later. The Stockton bridge above will be very useful to double check such simple lamp measurements, to make sure I'm measuring what I think I am!

An Active Antenna for Dx

Here's an active Rx antenna that combines several elements of very good antenna design. Originally from IK0VSF, it has balance (to reduce common mode noise), has the sharp "nulls" of a dipole (assuming the dipole is horizontal; vertical = omni-directional, of course); has a differential to single ended low noise output link and can be powered from the Rx via the signal co-ax. Just for good measure, it can reject strong medium wave broadcast transmissions from local stations by tailoring the frequency response of the buffer amplifier, a well-respected and rugged video amplifier, the LM733. The gain is preset via internal resistors as is the bandwidth (see the LM733 data sheet) and the LM733 features complementary outputs - ideal for common mode noise cancelling and driving a simple transformer to couple the signal into the co-ax down lead.

It is quoted as being able to withstand over 0.5v of RF on the input, something I've not tried at G6NGR, and the balance adjuster allows balancing the input for best results. I use BF245 j-fets because I have them to hand; no doubt other j-fets will run, with suitable bias adjustments. The positive gate bias is the key to the large signal capabilities; again, altering these bias levels isn't something I've done at G6NGR, I'm good with the design "as is". You don't need massive elements in the dipole: indeed longer elements than quoted may detract somewhat. The response throughout 80m to 6m with the setting on "LF Reject" is excellent, it's possibly capable of 2m results, but is (quite reasonably) getting a bit breathless, as the quoted maximum bandwidth is 120MHz. It will perform very happily on 160m and below, if used in the "Full BW" mode - kW Medium Wave B/Cast stations live there, so if you're a MW Dx-er, this is the antennas for you!



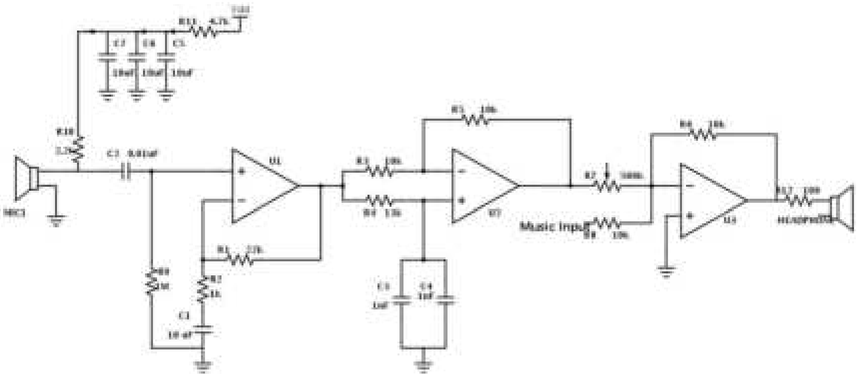
Allied to this antenna, the schematic following is an “noise cancelling” audio section, designed for “noise cancelling” headphones comprising buffer amplifier, an all-pass filter section (for delay / phase adjustment) and a summing amplifier for cancellation. Noise cancelling at RF is not at all easy; and once the wideband noise is in the IF stages it’s the very devil for creating havoc as the stages can be driven into clipping on transients and cross-modulation with wideband noise.

A wideband receiver with an omni-directional “noise” antenna, rather than trying to cancel the “noise” from the “signal” at RF, can feed this circuit: you could do far worse than look at the design by Chas. Wendel - the “Amazing All Band Receiver”, especially the adapted circuit by Paul Beaumont, G7VAK) which would be ideal.

The principle is straightforward: the active dipole antenna captures the signal you want plus as little noise as possible in your location (by using the dipole nulls); the “noise” signal from the all-band receiver is fed to the noise cancelling circuit to be amplified (variable gain), phase shifted / delayed (variable delay) then summed (adjustable ratio) with the active dipole receiver audio output to cancel as much noise as possible over a full spectrum.

Feed the “noise” audio into the microphone input, and the Rx audio into the “music” input via potentiometers to set the best level. Thus phase / delay control cancellation takes place at audio frequencies, much easier to manipulate and engineer than at RF or IF frequencies.

Using a twin pot control in the “all-pass” delay element as part of the feed-in resistors in the centre op-amp, a variable “delay” can be generated, allowing adjustment of cancellation to be achieved. maybe simple, not perfect; but effective when required and able to reduce (if not eliminate entirely) interfering noise.



Mechanical & Construction

Earth plane construction

Many construction techniques have been discussed over the years, but the most reliable, for both serviceability, alteration and ruggedness (vital for mobile applications) is un-coppered “perf board” (sometimes called “Lektrokit” board). the components are laid out more or less as per the circuit diagram, and interconnections made by using the component leads bent to meet each other and soldered. This results in short interconnects, and very low capacitance, component to component, with the components held sturdily in place. Should earth planes be required, self-adhesive copper tape, available in 1” and 2” wide strips (garden and nursery suppliers, for anti-slug / snail bands round plant pots) is ideal. Any holes through the perf board where an earth isn't required is made with a 1/8" diameter drill; the drill point removes the copper all round the hole for clearing the component lead.

As an alternative, very thin flexible, FR4 single side copper pcb can be bonded to perf board using super glue for mechanical rigidity. Holes for through leads can be made as before, with a 1/8" drill bit, or alternatively the circuit built over a ground plane by bonding small "island" squares of thin FR4 (cut with scissors) to the earth plane for each circuit node.

Another useful adjunct is salvaged tin-plate from food cans. This is readily cut with light tin snips (or heavy scissors) and makes excellent screening material. Tin plate is a good material because (1) it's ferrous, thus features permeability much greater than air so containing magnetic fields effectively; and the tin plating ensures no corrosion, keeping a low resistance surface to catch any electric fields. Both of these are the "near fields" of any current carrying conductor, which if current is flowing, must have potential differences across it causing the electric field. Tin plate is also far cheaper than FR4, and is very readily soldered for sound earth connections and forming into covers and box-like structures to completely cover sensitive areas. But... beware! Tin plate, cut with scissors or snips, has a devilish sharp edge: knock the edge burrs off by a quick rub with a small smooth file to blunt those would-be razors.

Letters

"Hi Peter, as far as a gear bartered page I have a Ten Tec Century 22 for disposal £ 100 notes, or swop. In excellent condition could do with a peak up on transmit, rx f/b."
73 Adrian, G4GDR QTHR or 01793 762970.

~~~~~~

Peter, Many thanks for Hot Iron 101. Very good work. Just one comment...
Those component values. 5.11k, 147k, 8.25k, 4.64k, 19.6k, 3.83k etc.
E24 values is as far as I go.

Sorry if that sounds like a complaint. It wasn't intended to be. Just a comment.

73,
Paul Smith, G4BJG

Hi Paul, yes, point taken; people who design filters and the like have access and funds to procure such components that "amateur" constructors can't source. I've found that by series // parallel connecting I can get very close... but of course the size of the parts becomes enormous! Or, just go with the nearest you have: in my experience the trick is to look for identical values in the filter network and substitute those tin an identical manner. The filter might not be dead on the centre frequency or have the "Q" the designer wanted, but it will be close, and work (generally) fine. I like to keep life (and circuits) as simple as possible!
~~~~~~

I'd like to include your email (and my reply) on Hot Iron 102 letters page, if that's OK? It's a very good point you make, and I'm sure others will be just as flummoxed.

Kindest regards, Peter Thornton G6NGR

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I spotted an advertisement for an interesting transformer on the “Glowbugs” page by Brad Thompson, AA1 IP, and after discussing this and that, he sent me a diagram for a 6V6 MOSFET substitute, below. I had been trying multiple IRF 510 devices to get to 1 kV drain / source rating, to cope with mis-matched loads, and had some background information on solid state “valves” I thought he might find useful.

~~~~~~

Hello, Peter--

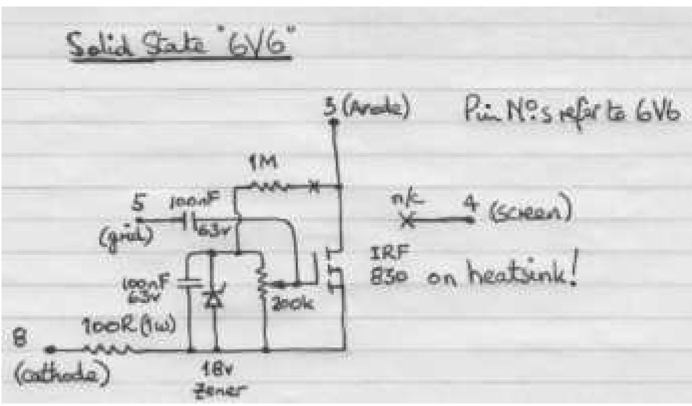
Thank you for the FETRON circuit-- I'm unfamiliar with the BF459, but I looked it up on line. That device might make a good QRP final amplifier transformer since its fT is reasonably high and the breakdown voltage rating *might* make it somewhat resistant to unpleasant loads.

In exchange, I'm attaching a couple of files describing a "solid-state 6V6" circuit and description.

As for purchasing anything from the U.S. that's heavy (e.g., a power transformer), the shipping cost quickly spoils any sense of a bargain.

Thanks again, and 73--

Brad AA1IP



Re: the cascode RF circuit, I wonder whether it would be possible to implement a distributed amplifier using power MOSFETs?

(Handwaving mode OFF)

Thanks again, and 73--

Brad AA1IP

Now here's another line of investigation opening up! P.Th. G6NGR

~~~~~~

Hi Peter,

I have a question that potentially could spur an article for hot iron.

I am thinking about having a go at constructing my own standalone software defined radio and took a look at the Icom 7300 to see how it works. In summary it has a 14bit analogue to digital converter with a 1.5 volt peak to peak input (LTC2208-14). I make this to be 91.5uV per quantisation level. There is a 20db gain amplifier (LTC6401-20) ahead of the ADC so best case this would give 9.1uV per quantisation level.

Wikipedia gives for HF a S5 signal to be 3.2uV (rms relative to 50R). Equivalently this is 9.1uV peak to peak, resulting at best in a S5 signal at most only changing the Least Significant Bit of the ADC. Not much can be hoped to demodulate from this surely?

By the same logic, S9 would only move between 15 levels.

As the 7300 works very well, clearly I am missing something but I don't know what. Can any member of the hot iron audience fill me in?

Regards,
Richard Fearnley

This is a fascinating topic, and one that needs thoroughly investigating – SDR is definitely a now and future technology that could bring amateur radio to many more people, and open up new digital communication protocols. More than anything, the question of noise and the intrinsic noise floor of an SDR is very much an unknown at the present moment. If any Hot Iron readers can give the definitive explanation of SDR bit definitions then please feel free!

P.Th. G6NGR

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Data and Information

This information is for guidance only – you MUST comply with your local Regulations! I have included information about AC power systems and conventions, as equipment can often be bought from overseas nowadays and it's important that we know exactly how to connect it to our "home" supplies - but

suffice to say, if there’s any doubt - - - GET PROFESSIONAL, COMPETENT HELP BEFORE YOU CONNECT TO ANY ELECTRICAL SUPPLY!

Wire Information...

AWG Table

1 AWG is 289.3 thousandths of an inch
2 AWG is 257.6 thousandths of an inch
5 AWG is 181.9 thousandths of an inch
10 AWG is 101.9 thousandths of an inch
20 AWG is 32.0 thousandths of an inch
30 AWG is 10.0 thousandths of an inch
40 AWG is 3.1 thousandths of an inch

The table in ARRL handbook warns that the figures are approximate and may vary dependent on the manufacturing tolerances. If you don't have a chart handy, you don't really need a formula.
There's several handy tricks:
Solid wire diameters increases/decreases by a factor of 2 every 6 gauges,
" " " " " 3 every 10 gauges,
" " " " " 4 every 12 gauges,
" " " " " 5 every 14 gauges,
" " " " " 10 every 20 gauges,
" " " " " 100 every 40 gauges,

With these, you can get around a lot of different AWGs and they cross check against one another. Start with solid 50 AWG having a 1 mil diameter.
So, 30 AWG should have a diameter of ~ 10 mils.

36 AWG should have a diameter of ~ 5 mils.	Dead on.
24 AWG should have a diameter of ~ 20 mils.	Actually ~ 20.1
16 AWG should have a diameter of ~ 50 mils.	Actually ~ 50.8
10 AWG should have a diameter of ~ 100 mils.	Actually ~ 101.9

If you are more interested in current carrying ability than physical size, then also remember that a change of 3 AWG numbers equals a doubling or halving of the circular mills (the cross sectional area). Thus, if 10 AWG is safe for 30 amps, then 13 AWG (hard to find) is ok for 15 amps and 16 AWG is good for 7.5 amps.
The wire gauge is a logarithmic scale base on the cross sectional area of the wire. Each 3-gauge step in size corresponds to a doubling or halving of the cross sectional area. For example, going from 20 gauge to 17 gauge doubles the cross sectional area (which, by the way, halves the DC resistance).
So, one simple result of this is that if you take two strands the same gauge, it's the equivalent of a single wire that's 3 gauges lower. So two 20 gauge strands is equivalent to 1 17 gauge.

Wire Gauge Resistance per foot

4	.000292
6	.000465
8	.000739
10	.00118
12	.00187

14	.00297
16	.00473
18	.00751
20	.0119
22	.0190
24	.0302
26	.0480
28	.0764

Current ratings

Most current ratings for wires (except magnet wires) are based on permissible voltage drop, not temperature rise. For example, 0.5 mm^2 wire is rated at 3A in some applications but will carry over 8 A in free air without overheating. You will find tables of permitted maximum current in national electrical codes, but these are based on voltage drop. Here is a current and AWG table.

AWG	dia mils	circ mils	open air Amp	cable Amp	ft/lb bare	ohms/1000’
10	101.9	10380	55	33	31.82	1.018
12	80.8	6530	41	23	50.59	1.619
14	64.1	4107	32	17	80.44	2.575

Mils are .001". "open air A" is a continuous rating for a single conductor with insulation in open air. "cable amp" is for in multiple conductor cables. Disregard the amperage ratings for household use.
To calculate voltage drop, plug in the values:
V = DIR/1000
Where I is the amperage, R is from the ohms/1000' column above, and D is the total distance the current travels (don't forget to add the length of the neutral and live together - ie: usually double cable length). Design rules call for a maximum voltage drop of 6% (7V on 120V circuit).

Resistivities at room temp:

Element	Electrical resistivity (micro-ohm-cm)
Aluminium	2.655
Copper	1.678
Gold	2.24
Silver	1.586
Platinum	10.5

This clearly puts silver as the number one conductor and gold has higher resistance than silver or copper. It's desirable in connectors because it does not oxidise so remains clean at the surface. It also has the capability to adhere to itself (touch pure gold to pure gold and it sticks) which makes for very reliable connections.

Thermal conductivity at room temperature

	W/cm²/°C
silver	4.08
copper	3.94
gold	2.96
platinum	0.69

diamond	0.24
bismuth	0.084
iodine	43.5E-4

This explains why diamonds are being used for high power substrates now. That's man-made diamonds. Natural diamonds contain sufficient flaws in the lattice that the phonons (heat conductors) get scattered and substantially reduce the ability to transport the heat.

Copper wire resistance table

AWG	Feet/Ohm	Ohms/100ft	Ampacity	(mm^{2})	Meters/Ohm	Ohms/100M
10	490.2	.204	30	2.588	149.5	.669
12	308.7	.324	20	2.053	94.1	1.06
14	193.8	.516	15	1.628	59.1	1.69
16	122.3	.818	10	1.291	37.3	2.68
18	76.8	1.30	5	1.024	23.4	4.27
20	48.1	2.08	3.3	0.812	14.7	6.82
22	30.3	3.30	2.1	0.644	9.24	10.8
24	19.1	5.24	1.3	0.511	5.82	17.2
26	12.0	8.32	0.8	0.405	3.66	27.3
28	7.55	13.2	0.5	0.321	2.30	43.4

These Ohms / Distance figures are for a round trip circuit. Specifications are for copper wire at 77 degrees Fahrenheit or 25 degrees Celsius.

Wire current handling capacity values

mm2	R/m-ohm/m	I/A
6	3.0	55
10	1.8	76
16	1.1	105
25	0.73	140
35	0.52	173
50	0.38	205
70	0.27	265

Mains wiring current ratings

In mains wiring there are two considerations, voltage drop and heat build up. The smaller the wire is, the higher the resistance is. When the resistance is higher, the wire heats up more, and there is more voltage drop in the wiring. The former is why you need higher-temperature insulation and/or bigger wires for use in conduit; the latter is why you should use larger wire for long runs. Neither effect is very significant over very short distances. There are some very specific exceptions, where use of smaller wire is allowed. The obvious one is the line cord on most lamps. Don't try this unless you're certain that your use fits one of those exceptions; you can never go wrong by using larger wire. This is a table apparently from BS6500, reproduced in the IEE Wiring Regs which describes the maximum fuse sizes for different conductor sizes:

Cross-section	Overload current
CSA / area	rating

$0.5mm^2$	3A
$0.75mm^2$	6A
$1mm^2$	10A
$1.25mm^2$	13A
$1.5mm^2$	16A

Typical current ratings for mains wiring

Inside wall

mm^2	Amps
1.5	10
2.5	16

Equipment wires

mm^2	A
0.5	3
0.75	6
1.0	10
1.5	16
2.5	25

Wire sizes used in USA inside wall

For a 20 amp circuit, use 12 gauge wire. For a 15 amp circuit, you can use 14 gauge wire (in most locales). For a long run, though, you should use the next larger size wire, to avoid voltage drops. Here's a quick table for normal situations. Go up a size for more than 100 foot runs, when the cable is in conduit, or ganged with other wires in a place where they can't dissipate heat easily:

Gauge	Amps
14	15
12	20
10	30
8	40
6	65

PCB track widths

For a 10 degree C temp rise, minimum track widths are:

Current	width in inches
0.5A	0.008"
0.75A	0.012"
1.25A	0.020"
2.5A	0.050"
4.0A	0.100"
7.0A	0.200"
10.0A	0.325"

Equipment wires in Europe

3 core equipment mains cable

Current	3A	6A	10A	13A	16A
Conductor size (mm)	16*0.2	24*0.2	32*0.2	40*0.2	48*0.2
Copper area (mm^2)	0.5	0.75	1.0	1.25	1.5

Cable ratings for 3A, 6A and 13A are based on BS6500 1995 specifications and are for stranded thick PVC insulated cables.

Insulated hook-up wire in circuits (DEF61-12)

Max. current	1.4A	3A	6A
Max. working voltage (V)	1000	1000	1000
PVC sheat thickness (mm)	0.3	0.3	0.45
Conductor size (mm)	7*0.2	16*0.2	24*0.2
Conductor area (mm^2)	0.22	0.5	0.75
Overall diameter (mm)	1.2	1.6	2.05

Common Cable colour Codes

American electrical contractors and electricians are required to follow the National Electrical Code ("NEC") with regard to wiring colours. NEC imposes the following electrical wiring colour standards:

- **Ground wires:** green, green with a yellow stripe, or bare copper
- **Neutral wires:** white or gray

In theory, wiring conducting live current in the U.S. is permitted to be any other colour, although in practice, electrical contractors and electricians follow these local conventions:

- **Single phase live wires:** black (or red for a second "hot" wire)
- **3-phase live wires:** black, red and blue for 208 VAC; brown, yellow, purple for 480 VAC

Most countries in Europe, including the U.K., now follow the colour conventions established by the International Electrotechnical Commission ("IEC"). These colour conventions are as follows:

- **Earth wires** (called ground wires in the U.S. and Canada): green with a yellow stripe
- **Neutral wires:** blue
- **Single phase live wires:** brown
- **3-phase live wires:** brown, black and gray

Electrical wiring in Canada is governed by the Canadian Electric Code ("CEC"). The following wiring colour requirements apply in Canada:

- **Ground wires:** green, or green with a yellow stripe
- **Neutral wires:** white
- **Single phase live wires:** black (or red for a second live wire)
- **3-phase live wires:** red, black and blue

It's important to remember that the above colour information applies only to AC circuits.

A.M. Frequency slots in Amateur HF Bands

All Frequencies in MHz

160 Metres: 1.885, 1.900, 1.945, 1.985 (USA)

1.850 (W. Europe)

1.933, 1.963 (UK)

1.843 (Australia)

80 Metres: 3.530, 3650 (South America)

3615, 3625 (in the UK)

3705 (W. Europe)

3.690 (AM Calling Frequency, Australia)

75 Metres: 3.825, 3.870 (West Coast), 3.880, 3.885 (USA)

60 Metres : 5.317

40 Metres: 7.070 (Southern Europe)

7.120, 7.300 (South America)

7.175, 7.290, 7.295 (USA)

7.143, 7.159 (UK)

7.146 (AM Calling, Australia)

20 Metres: 14.286

17 Metres: 18.150

15 Metres: 21.285, 21.425

10 Metres: 29.000-29.200

6 Metres: 50.4 (generally), 50.250 Northern CO

2 Metres: 144.4 (Northwest)

144.425 (Massachusetts)

144.28 (NYC-Long Island)

144.45 (California)

144.265 (Los Angeles, CA)

Other AM Activity Frequencies

AM activity is increasingly found on a number of other bands, in particular: 5317KHz, 7143KHz, 14286KHz, 21425KHz and 29000 - 29150KHz.
There are several local AM nets in the UK on top band.

FM Frequencies

For mobiles working into VMARS events, 2m calling in on 145.500MHz (S20) is usual, before QSY to a working frequency. At event locations where military equipment is in use, suggested FM "Centres of Activity" on VHF are 51.700Mhz, 70.425MHz (70.450MHz calling).

VMARS RECOMMENDED FREQUENCIES

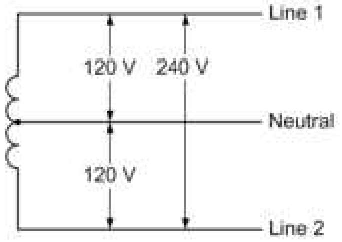
3615 Khz	Saturday AM net 08:30 – 10:30
3615 Khz	Wednesday USB net for military equipment 20:00 – 21:00
3615 Khz	Friday LSB net 19:30 – 20:30
3615 Khz	Regular informal net from around 07:30 - 08:30
3577 Khz	Regular Sunday CW net 09:00
5317 Khz	Regular AM QSO’s, usually late afternoon
7073 Khz	Wednesday LSB 13:30; Collins 618T special interest group
7143 Khz	VMARS AM operating frequency
51.700 MHz	VMARS FM operating frequency, also rallies and events
70.425 MHz	VMARS FM operating frequency, also rallies and events

Electrical Supplies - Courtesy LEGRAND equipment

Common Electrical Services & Loads

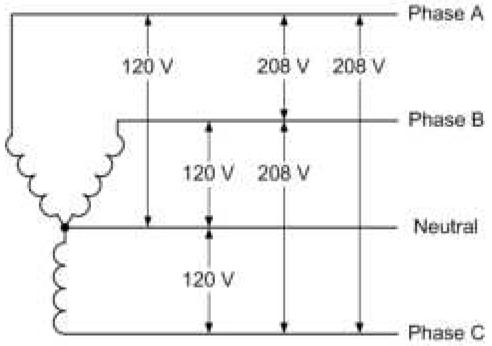
In the following drawings, the coil symbols represent the secondary winding of a utility service transformer or other step down transformer. Electrical code regulations in most jurisdictions require that the neutral conductor be bonded (connected) to the earth safety ground at the electrical service entrance.

Single Phase Three Wire



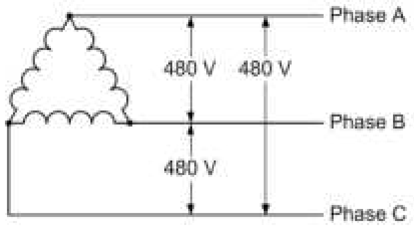
Also known as an Edison system, split-phase or centre-tapped neutral. This is the most common residential service in North America. Line 1 to neutral and Line 2 to neutral are used to power 120 volt lighting and plug loads. Line 1 to Line 2 is used to power 240 volt single phase loads such as a water heater, electric range, or air conditioner.

Three Phase Four Wire Wye



The most common commercial building electric service in North America is 120/208 volt wye, which is used to power 120 volt plug loads, lighting, and smaller HVAC systems. In larger facilities the voltage is 277/480 volt and used to power single phase 277 volt lighting and larger HVAC loads. In western Canada 347/600V is common.

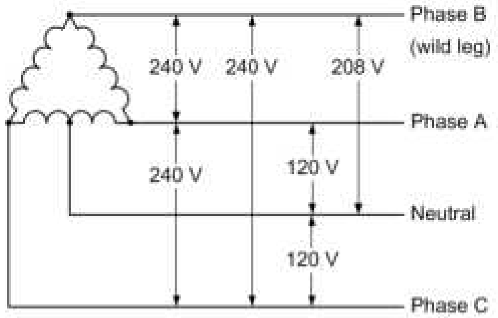
Three Phase Three Wire Delta



Used primarily in industrial facilities to provide power for three-phase motor loads, and in utility power distribution applications. Nominal service voltages of 240, 400, 480, 600, and higher are typical.

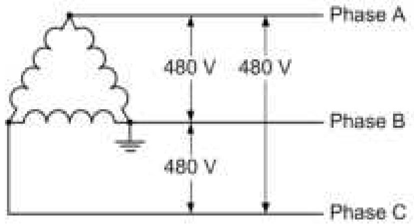
Uncommon Electrical Services

Three Phase Four Wire Delta



Also known as a high-leg or wild-leg delta system. Used in older manufacturing facilities with mostly three-phase motor loads and some 120 volt single-phase lighting and plug loads. Similar to the Three Phase Three Wire Delta discussed above but with a centre-tap on one of the transformer winding to create neutral for 120 volt single-phase loads. Motors are connected to phase A, B, and C, while single-phase loads are connected to either phase A or C and to neutral. Phase B, the high or wild leg, is not used as the voltage to neutral is 208 volt.

Three Phase Two Wire Corner-Grounded Delta



Used to reduce wiring costs by using a service cable with only two insulated conductors rather then the three insulated conductors used in a convention three phase service entrance.

International Electrical Distribution Systems

Description	L–N Vac	L–L Vac	Countries
1-Phase, 2-Wire 120 V with neutral	120	–	US
1-Phase, 2-Wire 230 V with neutral	230	–	EU, UK, Scandinavia
1-Phase, 2-Wire 208 V (No neutral)	–	208	US
1-Phase, 2-Wire 240 V (No neutral)	–	240	US
1-Phase, 3-Wire 120/240 V	120	240	US
3-Phase, 3-Wire 208 V Delta (No neutral)	–	208	US
3-Phase, 3-Wire 230 V Delta (No neutral)	–	230	Norway
3-Phase, 3-Wire 400 V Delta (No neutral)	–	400	EU, UK, Scandinavia
3-Phase, 3-Wire 480 V Delta (No neutral)	–	480	US
3-Phase, 3-Wire 600 V Delta (No neutral)	–	600	US, Canada
3-Phase, 4-Wire 208Y/120 V	120	208	US
3-Phase, 4-Wire 400Y/230 V	230	400	EU, UK, Scandinavia
3-Phase, 4-Wire 415Y/240 V	240	415	Australia
3-Phase, 4-Wire 480Y/277 V	277	480	US
3-Phase, 4-Wire 600Y/347 V	347	600	US, Canada
3-Phase 4-Wire Delta 120/208/240 Wild Phase	120, 208	240	US

3-Phase 4-Wire Delta 240/415/480 Wild Phase	240, 415	480	US
3-Phase Corner-Grounded Delta 208/240	–	240	US
3-Phase Corner-Grounded Delta 415/480	–	480	US

Note: regional variations may exist: if in ANY doubt, consult your Electrical Supply Authority.

Hot Iron 103

Feb. / Mar. 2019

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CQ-CQ-CQ

SSB, AM and the end of "Amateur" Radio?

The advent of commercially available amateur SSB transmitters and transceivers in the 1960's and 1970's saw off the then common "phone" mode of AM; the marketing being particularly aggressive and pricing was - to say the least - keen, ensuring SSB dominated the "phone" mode after a few years. Quite rightly, for "phone" Dx the wider bandwidth of AM and lower efficiency did cause problems in the congested amateur bands then available. No WARC bands in those days meant the bands were (and still are) somewhat overloaded. This led to many amateurs, who would happily tackle building an AM transmitter but not an SSB transmitter, buying ready made technology in the form of a "black box". Thus the vast majority of Radio "Amateurs" of today, following this "easy" answer are largely "Equipment Users" , with no real desire or motivation to build home-made gear.

This is not to admonish such Equipment Users: not every amateur can build their own equipment for any number of reasons; but this is the road to eventual destruction of Amateur Radio as we know it. Sure, it won't happen for years; sure it won't affect those with commercial gear. But Radio Amateurs, to comply with their licenses, are meant to be constructors; otherwise how (apart from antenna and propagation studies) can any "experimental" or "self teaching" role be fulfilled?

Hot Iron is the journal of the Constructor's Club, that solid core of Radio Amateurs who appreciate building home made RF equipment is a fascinating and rewarding process that is not too expensive or impractical. Home construction of RF equipment teaches the constructor the techniques that Equipment Users pay stacks of moolah for: the design, alignment, trimming, and... the manufacturer's profit expectations. For those with limited resources, kits are available: superb technology at very low prices compared to a "plug-n-play" Black Box. You get excellent technology for minimal outlay, and the pleasure of setting up and operating equipment you've built yourself: this is the self-teaching aspect of our licenses at it's best.

Our brothers-in-arms, the GQRP club, and the QRP movement in general throughout the World, have a growing membership devoted to low power RF techniques, deriving great pleasure from simple equipment designed and built at home in most instances. It's fair to say most GQRP constructors probably have commercial RF equipment alongside their home made gear, and this I think represents the best combination - the commercial balanced by the home made amateur gear. Best of both Worlds! But - if you want to transmit more than 5 watts, QRP isn't perhaps the bestfor you: certainly 5 watts will get you a long way if the conditions are right, but the overwhelming choice of SSB / CW operating power is more likely 100+ watts in order to be heard above the rising tide of man-made noise and interference. Add to that creating a 100 watt transmitter at home, from scratch, is for most a daunting prospect. So out comes the credit card, cheque book or whatever: several £/$ thousands change hands and it's "plug-n-play".

A darker side of this is worth mentioning. Equipment "users" are inadvertently promoting the destruction of amateur radio bands, as they are not "experimenting" but simply operating commercial equipment. The commercial manufacturers of domestic electronics that create disruptive wideband interference therefore have a semi-legitimate claim that the amateur bands are no longer being used for their original purpose - experimentation - nor yielding any furtherance of RF technology, the very core of the Radio Amateur ethos. This means rising wideband noise is not an issue to those who generate the interference: hence no need to make any effort to accommodate the needs of Radio Amateurs.

If you want to see where Amateur Radio is leading by following the “Black Box” route, look at current “amateur” Photography magazines. No home made gear there? And look at those toe-curling prices on the cameras, lenses and all the other optical paraphernalia that get punted out by “experts”. Now that does make you shiver!

CW and my mobile phone

My Android mobile phone converts speech to text and vice-versa, via it’s built in microphone and loudspeaker. Here’s a challenge to all the Android software developers out there: how about converting to speech to Morse, and vice-versa, on the fly, in real time? All the advantages of CW for a speech channel! Voila!

You speak a phrase into the mobile phone microphone, the output is a series of perfectly spaced and timed Morse characters (at, say 500Hz) “on the fly” and via a external isolating acoustic interface, fed to the transmitter’s keying input. The Morse incoming from the receiver is fed into the mobile phone’s microphone via acoustic link isolation to be decoded, and the speech displayed.

This means plain speech can take advantage of CW propagation! The CW generated from my voice keys the transmitter; and the reply drives the text to speech function, thus my mobile phone’s “voice” tells me what the distant CW transmitter is replying. It might be a bit slower than normal speech, but 30wpm is not unknown on amateur bands, without infringing bandwidth limits, so “CW” speech could be quite practical. What’s not to like?

Noisy Neighbours?

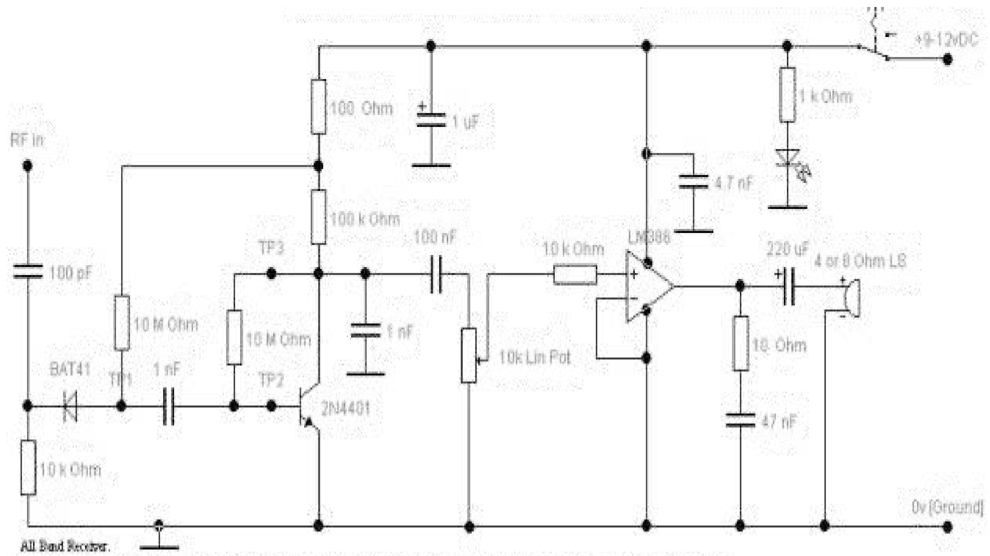
Reports of constant S8 / 9 background in urban areas are to be seen in various Amateur Radio orientated publications: this is a problem which causes blocking, obliterating and noise jamming of amateur signals. OFCOM take a stand well askance from amateurs, after all, we’re only “playing” radio seems to be the current opinion, forgetting that amateur experiments with esoteric modulation methods, signal reception reporting and the like are often taken up by commercial factors; but still the onslaught from Wi-Fi routers et al goes on unabated.

Is it any wonder? Computer and smart phone users demand ever more flexibility, range and bandwidth - and don’t think fibre optic cable will help. Domestic Wi-Fi will still be RF based. Recent advertisements proudly proclaim “the most powerful Wi-Fi router available today”; and whilst the frequencies used by Wi-Fi aren’t supposed to interfere with any “domestic” electronics, nobody has told base - emitter junctions that, so they happily capture the Wi-Fi GHz signals, rectify them and thus we have the overwhelming noise and clatter on low band HF. Now routers are proclaiming 50m ranges, “in domestic environs”, which I take to be through a brick wall or two, through several wooden floor and ceiling structures. What power do these routers emit? How “clean” is the signal? But - I think the trouble is the ever-rising data bandwidth demands. Routers do not emit a single tone, but complex streams of quadrature modulated signals, pulsed transmissions, all comprising carriers, sidebands, wideband edges, all of which lead to the saturation of amateur signals by interference.

Simple experiments with my mobile phone at G6NGR show I can hold my router connection to nearly 40m away from my house in one direction, 20m in another; this indicates the capability of the router to get signals through 18” thick gritstone walls. I have no simple way of reducing the router power, either; it’s on or off. Throw in the recent TV set installed - quite legitimately - in a neighbour’s bedroom adjacent to my favourite receiver location, I now have multiple switched mode power supplies kicking out wideband hash. Let’s count them: the TV, the accompanying video recorder, “wall wart” power supplies for LED table lamps, mobile phone chargers - the list gets ever longer - all of which spit out a wideband electrical racket, showing on low HF bands as S8 / 9 noise..

An interesting addendum to this is the current rise in Wi-Fi house control gear: Google “Alexa” and the like, “Hive” home control equipment, et al. I’ve not tried a low band HF receiver near any of these devices yet - but welcome any and all comments from those who have these devices and are active on low HF bands as to any ill effects or blocking noticed. It would be wise advice for all amateurs to build a simple wideband RF detector, to help locate the source of any interference.

Chas. Wenzel’s design - “The Amazing All-Band Radio” is an ideal project for this job. Shown below is a version by Paul Beaumont, G7VAK, as reproduced from Chas’s web page.



Tim’s Topics

Dipole Dilemma!

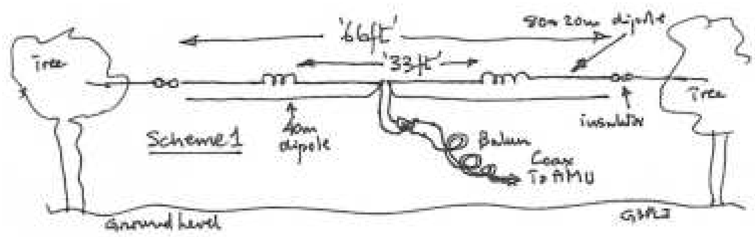
Many of you will know that we are a farming family, and have been in this part of Somerset for a long time! (See www.uptonbridgefarm.com for some amusement!) Our son is now doing most of the physical work so he needs to be living in the old Victorian farmhouse in the midst of all the farming activity! So with much anguish over what to chuck away, we have just moved into a new house just around the corner but it lacks the room space and large trees that were near the old house! Apart from what used to be called the ‘Lab’, I have had to give up my lovely big antenna – a half wave dipole for 160m fed by open wire line, as well as an internal roof dipole (for about 6.5 MHz) that was handy for day to day experiments. So what should I erect here?

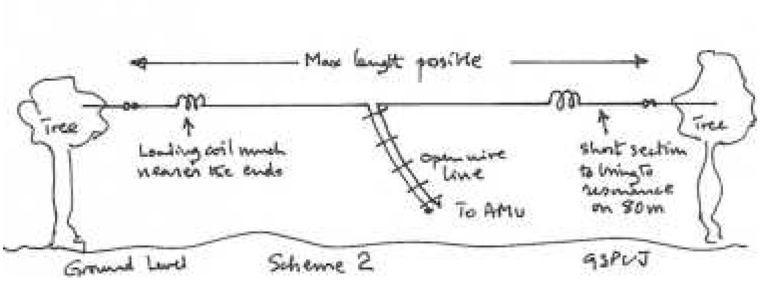
I want to be able to use at least 20, 40 and 80m; and there are two smallish trees about 70 ft (22m) apart some 30 ft (10m) from the house. Having nearly always used a balanced antenna system for serious contacts, I would much prefer that again. The gap between the trees might allow a quarterwave on 80m (nominally 66ft – 20.1m) but it would be end fed and so not be properly balanced. The classic Zepp with open wire feeder at one end comes to mind but the high Z 'connection' to the feeder has never appealed to me, and it would only suit 40m as an end fed half wave. It could be used with 'strapped feeders' as an end fed long wire for 80m but it would need some form of RF earth, which does present its own challenge too! Counterpoises work well but need to be similar (in length) to the radiating element; the alternative of earth stakes (possibly many or even a matt) to obtain a low Z connection to the real RF earth is not terribly convenient either. Concrete house foundations, a large garage and layers of stone a few inches thick about 2 ft (0.6m) down don't help! So I come back to the desirable centre fed radiating wire as being preferable.

33ft (10m) on each side centrally fed by a balanced low impedance feeder will work as a half wave on 40m nicely (and so also work on 15m) – but it is not long enough for 80m. How about a dipole of less than a full half wave but with loading coils somewhere towards the outside ends? A bit of web browsing suggests that adding loading coils can compensate for the missing outer end radiating sections so bringing the shorter span back to resonance. This approach could even work if the overall length is half the normal span. In principle a loading coil of impedance near 950R at the half way point of each side, would be needed to make the reduced length of 33 ft (nominally on each side) resonant on 80m. With a bit of luck, the middle section between the loading coils (also being 33 ft apart) would then be resonant as a half wave on 20m! The loading coils should 'isolate' the outer ends of the overall span so the inner section can function as a 20m dipole; hence this arrangement should cater for 20 and 80m leaving only 40m to be resolved!

How about adding a plain 40m half wave dipole directly in parallel with the above scheme? Both wires will only have a low Z feed point impedance on their own band(s) so they should not interfere with each other. The 40m dipole will have the same overall length as the loaded 80m wire so can be easily erected with a little separation between them. This scheme 1 is shown in the top diagram and has the advantage of being compatible with a coax feed line – ideally having a few turns to form a choke balun immediately below the centre point.

Some people might say this is a bit complex! Why not just get up the maximum possible length for a 80m dipole fitted with loading coils near its ends (scheme 2 lower diagram) and then accept whatever performance it gives on the higher bands? If this simpler arrangement is used, the feed point impedance is most unlikely be in the 50 to 100R range for 20 and 40m, so it would be sensible to use open wire line in conjunction with a versatile AMU – nor will it need the unsightly wound coax balun! Have any readers any helpful comments? Tim G3PCJ Feb 20th 2019





Audio Topics

Microphones - common misconceptions & design notes

From an article by Richard Knoppow, for which many thanks. His article explained some misconceptions I'd come across in the past - AM with poor audio quality is not a thing of beauty and I believe it only appropriate to use the very best audio that I can achieve. Richard's notes tell, in simple terms, why microphone audio can be compromised. Please read on!

"It may help to understand that the impedance usually given for a microphone is its internal impedance, not the expected load impedance. Nearly all "generator" microphones are designed to be loaded by an impedance considerably higher than the rated impedance so as not to drop the voltage much.

By "generator" I mean microphones like dynamic, crystal and ceramic mics. They convert energy in a sound wave to an electric signal. Dynamic included all microphones that use some sort of magnetic generator such as moving coil, ribbon and magnetic microphones. In each the voltage output will be halved when operated into an impedance, perhaps resistance is more accurate, that is equal to the rated one. That reduces the signal to noise by half. It was BBC practice to use microphones terminated with their rated impedance but never in the U.S.

So, impedance can be misleading. If you measure the impedance of a microphone of the dynamic type you will generally come up with a value of about the rating. For non-directional types the acoustical-electrical circuit is generally highly damped to the internal impedance looks like a resistance and is generally fairly uniform with frequency. Crystal and ceramic microphones have almost purely capacitive internal impedance so they behave somewhat differently. They require a resistive load many times higher than the capacitive reactance. When loaded with a lower resistive value the resistance and internal capacitance form a high pass filter causing the low frequencies to be rolled off. To avoid this may require many megohms effective load. A capacitance in parallel with the mic such as the cable capacitance, acts like a shunt reducing the overall level so crystal and ceramic mics should be used with the lowest value cable capacitance possible.
A ceramic microphone has essentially the same characteristics as a crystal microphone but the piezoelectric material is a lot more rugged: it is not sensitive to high temperatures (crystals are permanently damaged by exposure to around 125F or higher) and are much less sensitive to moisture. They still can be damaged by mechanical shock. Their drawback is having about 10 db less sensitivity but, since both types have quite high output its not usually a serious problem.

Crystal microphones, and to a lesser extent ceramic ones have very high output levels for "generator" types. They became popular at a time when electronic amplification was expensive. A crystal microphone or phonograph pickup could save the cost of a stage of audio amplification. They are also relatively simple and economical to manufacture. Condenser and carbon microphones are not generators. Rather they control an external source of voltage. The condenser microphone is kept charged with a constant voltage. As the diaphragm moves it changes the *capacitance and hence the charge and varies the voltage across the microphone. This variation is coupled to the outside world by an isolation amplifier with the highest possible input resistance. It may be any gain desired because its main purpose is coupling the varying voltage across the mic. Condenser microphones can also be used as a varying capacitance across the resonant circuit of an oscillator. It then produces FM which is detected and put out by the detector. This has the advantage of eliminating the usually fairly high voltage needed by condenser microphones operated by DC bias. Carbon microphones are variable resistors. They have a DC bias or power source. The variation of resistance caused by motion of the diaphragm causes a varying voltage at the output.*

There are a number of ways of coupling carbon microphones, probably the most common is a transformer with the microphone and its power source in the primary and the output taken from a secondary winding. However, a carbon microphone can also be used as a variable cathode resistor in a tube amplifier or emitter resistor in a transistor amplifier. Carbon microphones are amplifiers! That is one reason they were so common in telephones. They can put out more power than they absorb from sound waves.

Electret microphones are a variation of the condenser microphone. They work by causing a changing voltage across the mic because of the change in capacitance just as in a condenser mic. However the dielectric is not air but some other material that can be charged up and holds the charge for an indefinite period. They still need an impedance translating device, usually a transistor, but do not need either a DC bias source of an oscillator. For the most part they have the characteristics of condenser mics, i.e. simple construction and excellent acoustic performance. They are not quite the equal of a standard condense mic in their ability to handle very high sound levels but this is mostly of importance in sound measurement applications. Also, it is possible to calculate the exact characteristics of a condenser microphone from its mechanical dimensions so they are very useful as standards for measuring sound.

In general, a condenser or electret microphone does not have a characteristic impedance as a generator does, rather it is the characteristic of the attached amplifier that is given. Since this is an active circuit it can be designed to have any source impedance desired and work into any terminating impedance desired.

Carbon microphone are somewhat similar. They can be designed to have a fairly wide range of resistance, typically somewhere around 50 ohms to perhaps 500 ohms but are used with either a transformer or electronic amplifier so can be designed to be used with any range of impedance desired.

Dynamic microphones of the moving coil or magnetic type have a coil which can be made to have a fairly wide range of impedance directly (without a transformer). Moving coil microphones are typically wound to have voice coil impedances of from around 30 ohms to around 200 ohms. Most of the older designs used very low impedance coils (20 to 50 ohms) either connected directly where a low impedance was desired or stepped up to cover medium impedance (150 to 500 ohms about).

More modern microphones are often designed for the 150 ohm range and have voice coils of about that impedance designed to be connected directly. Dynamic microphones intended for high impedance loads generally have in internal step up transformer, typically with an output of around 10 to 100Kohms. Some microphones, typically ribbon and cardioid moving coil microphones, do not have a constant source impedance. That is because the acoustical and mechanical network is reactive and its varying impedance is reflected in the electrical side. These microphones often have a low frequency impedance peak in the same way (and for the same reasons) a moving coil loudspeaker does. If terminated in a resistance equal to the source impedance at mid frequencies there will be a roll off of bass due to the impedance mismatch there. As an example, the famous RCA 44-BX ribbon microphone has a rated output impedance of around 150 ohms (actually it is selectable) but the impedance at the low frequency peak is somewhere around 5 Khz so it really wants to work into a quite high impedance. Many moving coil cardioid microphones are similar. The rise in impedance coming from the acoustical network that gives them the directional pattern. Note that this is NOT true of the Electro-Voice cardioid microphones using their patented "Variable-D" principle for reasons too complex to explain here. These mics have essentially resistive source impedance that is relatively constant with frequency. The input impedance of vacuum tube audio amplifiers without matching transformers is typically fairly high. The input to the Drake T4XB puts the mic across a 3.3 Megohm grid resistor so the load impedance seen by the microphone will this plus whatever the tube produces, probably about the value of the grid resistor. This should be high enough for nearly all crystal and ceramic microphones although Astatic shows flattest response from the D-104 with a load of 4.5 Megohms. It certainly should not affect any moving coil or ribbon microphone.

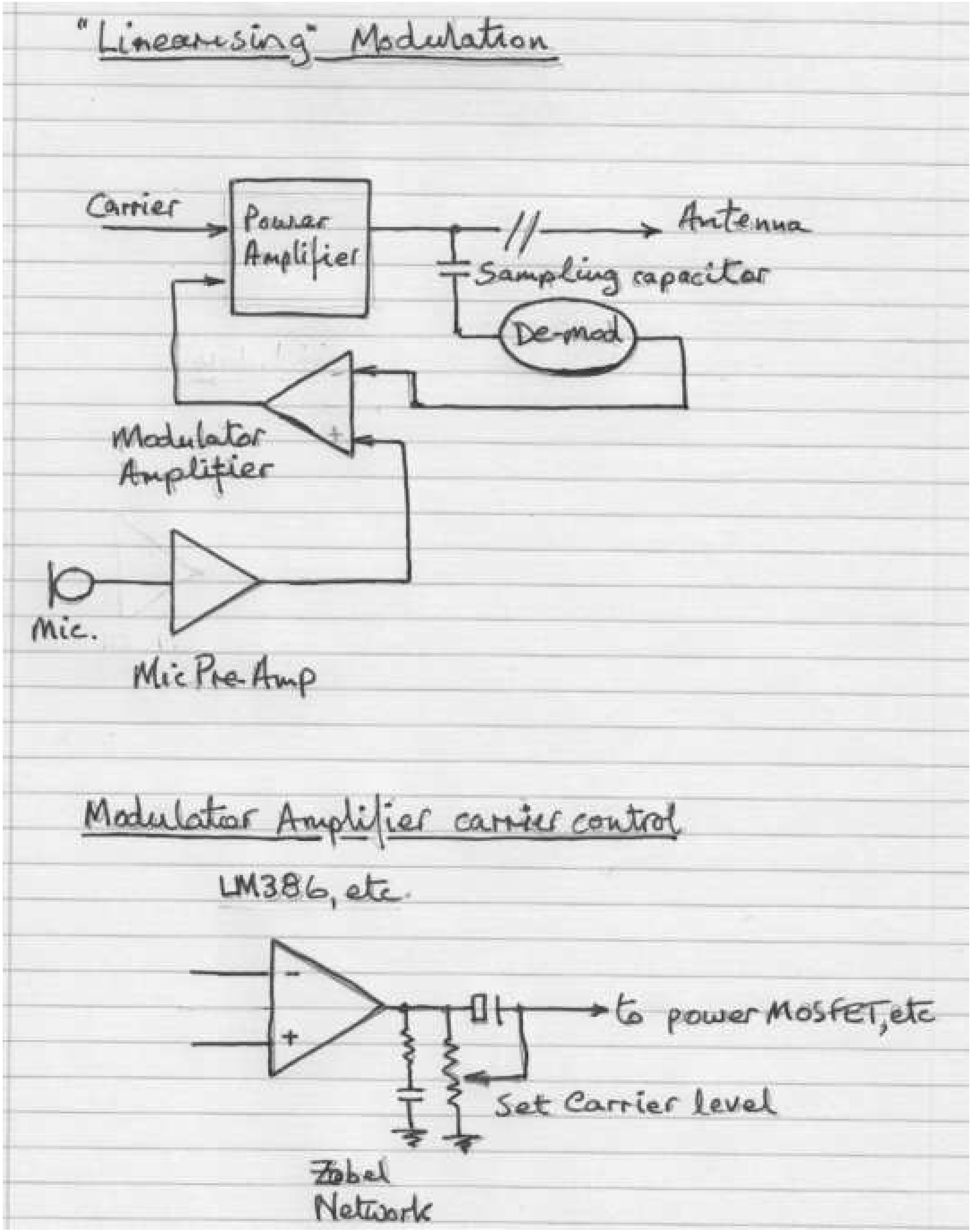
To use a low impedance broadcast type microphone requires a step up transformer. Typically these have an output impedance of somewhere around 50Kohm when connected to a 200 ohm source."

My grateful thanks to Richard Knoppow for these notes.

RF demodulation feedback

Using "efficiency" modulation to create AM can introduce considerable audio distortion as the P.A. device electrode used for modulation isn't always a "linear" multiplier, which is a requirement for quality audio. The "cathode" style modulator is well known for producing good audio (in both valve and transistor / mosfet P.A. stages), as it applies both grid and anode (base / gate and collector / drain) modulation automatically which does help improve the quality of audio transmitted.

A simple scheme to truly linearise the transmitted audio is shown below in block diagram form: since there are so many ways to create A.M. (or DSB / SSB, for that matter: you have the carrier oscillator(s) to hand in the transmitter to for RF audio recovery via a product detector) so I can't give a detailed values or designs. But... that's amateur radio! Try improved transmitted audio, and note the very distinct edge over those stations running poor audio in Dx contacts. If the distant receiver's "ears" can't hear your speech clearly and understand you readily, they can't - or won't - respond!

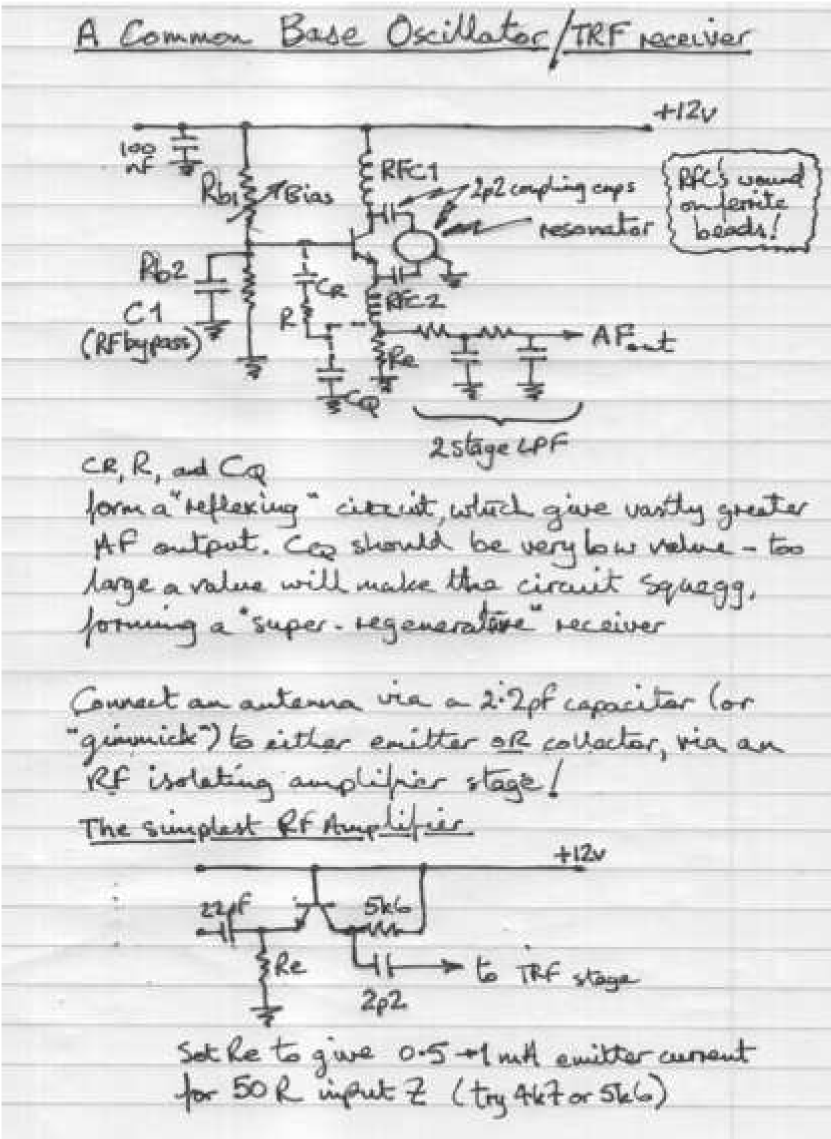


Rx's

VHF / UHF Coffee Cans...

This uses one of Harry Lythall's amazing designs that is easily built at home, and is well worth trying especially if you have a 2m transmitter. I wanted to use Harry's VHF quarter wave resonator in a common base oscillator as the frequency selective feedback element, thus eliminating the resonator's losses and improving Q. By adding a gain control to the oscillator, a TRF regen or super-regen receiver can be created - add an RF amplifier for isolation and audio amplifier stage and it’s a dead simple VHF all-mode receiver. Yes, I know the selectivity is as wide as a barn door, but it’s a simple way to receive a local VHF signal, or monitor the output of a 2m FM transceiver by slope detection, and even SSB/CW as you would in an HF TRF. Ideal for 2m “black box” users!

Harry’s design is on his web page “Projects”, click “Receiver Circuits” and look down the left hand side list for “Cavity RX”. I didn’t use a diode in the resonator; just two coupling loops.



Using SLAB’s for noise free Rx power

A “sealed lead acid battery” can make a very potent “electrolytic capacitor” as mentioned recently by Bill Cromwell, and is ideal for supplying “noise free” DC power. He comments that sealed lead acid batteries can give real improvements in hum noise elimination, and uses them often for B+ supplies and heaters / filaments in valve circuits. This last is an often dismissed point: although the capacitance between heaters and other electrodes is minimal, it still represents a way for hum and noise to enter the signal path.

The best arrangement is to have the SLAB recharging when the receiver isn’t required: when transmitting, for instance. The usual way to float charge a SLAB is to use a “boosted” 7812 regulator - aim for 13.5v to 13.8v output, conveniently procured by using an LED in the "common" leg of the 7812 to ground. That way you get a free "charging" indicator light; or 3 x 1N4148 diodes, or similar if you don't want to waste an LED.

Humbuckers...

Valve audio (guitar) amplifiers often featured a circuit called a "humbucker". This effectively reduced power line "hum" heard in the output by balancing the heater feeds about earth, so cancelling any induced or coupled "hum" signals. This was a low value pot, the track connected across the heater supply lines, the wiper to earth / common, then adjusted for minimal hum.

I recently noticed an article which discussed a very similar - but not quite the same - technique, in which a bench power supply was being used to power a receiver whilst the original power supply was being checked to see if it was faulty.

"I was using the supply to power my valve receiver to figure out where an awful hum that (had) just developed was coming from. The good news is that I found the culprit was a broken wire to a connector that was carrying the regulated 150 volts power to the HF oscillator and half the tubes had no filament voltage.

I had split the filament transformer duties between the 5 amp supply in the main power supply transformer and an auxiliary 6.3 volt filament transformer.

Following the advice on one of the audiophile web pages I put a ***100 ohm resistor in series with the centre tap to ground*** *on the Triad [heater] transformer and increased the winding twist on the [heater] wiring snaking through the chassis. It was unbelievable how improved the sound was."*

Many years ago the routing of filament (or any other AC power lines) was an important detail when building new Test Gear or finishing off repairs to equipment; especially sensitive items like valve voltmeters, electrometers, mass spectrometer heads and the like. The lack of such power lines amongst modern signal chassis (or on PCB's) is a forgotten art - and it's only when the design steadfastly refuses to co-operate does the "hum" issue raise it's ugly head once again. The best advice is to wire such AC power circuits in "twisted pair", and avoid enclosing loops of wire.

Tx's

Peter Parker's AMOXO

A very welcome dash of simplicity from that most ingenious and capable builder of radio gear in Australia, Peter Parker, VK3YE! He has used a TL431 active "zener" as an audio amplifier to drive the "P.A." transistor in an OXO transmitter. He's had very good results from his flea power A.M. transmitter, and has run field trials with it to check audio quality and reception range.

Peter's A.M. OXO are shown on:

https://www.youtube.com/watch?v=ARhiSUl8-5w

Which leads nicely into the "simplicity" discussion for continuing use (locally and not-so-local) of HF bands for A.M. The bandwidth taken by A.M. is double that of SSB; and A.M. has that whacking big carrier (FOUR times the power of each sideband). DSB eliminates the carrier, and with it, to pay the price for improved efficiency, the ability for simple receivers and demodulation to use the signal. When you add up the complexity, extra components, setting up and all the other requirements that SSB requires, then add in a receiver Product detector, Carrier Insertion Oscillator (that needs very good frequency stability, matched to the IF) then you've got a big box of bother for the average home constructor. By this I mean the person who has limited soldering experience, few if any spare components to hand, no workshop, a very basic multimeter, you get the picture. If home construction that leads to self learning, experimentation, discovery and (most important) pride in building something that sends / receives a signal from miles away via home-made radio equipment is to survive and prosper, then the whole spectrum of abilities has to be encouraged: and Hot Iron seeks to do just this.

If somebody puts together a simple transmitter / receiver from a kit or home made from whatever parts are to hand in the ubiquitous "junque box", runs a few CW contacts, *even if it's only across town* this is a mighty stepping stone to further success, prototype building and eventual finesse: confidence that "you CAN do it" is a positive feedback signal that re-enforces itself. Adding a simple modulator for a phone contact is the next step on, and with that success, you have a life-time home constructor making his own path through the wonderful World of Amateur Radio - another very satisfied Radio Amateur in the making, gaining far more satisfaction and pleasure than the "equipment user"!

I do understand not all Amateur Radio license holders want to (or are remotely interested in) home built radio equipment, and I wish them the best of luck - but I have no interest in your telling me of your latest all-band Sky-Sticker Super Thrutch vertical antenna, or your £5k Yaestrioken all bands every mode computer controlled receiver with waterfall displays and more functions than can be used in the heat of the moment on a fading signal. Sorry 'bout that - but I have little (if any) interest in "amateurs" spouting (usually "quoted-from-adverts") specifications, wonderful options and whizz bang functions that 99.99% of the time you don't need - or use. So go build an A.M. OXO or a Michigan Mighty Mite - I modulated one with "cathode" modulation from an LM386, and got 15 miles (across Manchester) with it on 80 meters - or take your pick of any other simple CW transmitter with modulation applied any which way you fancy, A.M. or DSB, or whatever takes your imagination (and is covered by your license of course).

Hot Iron will happily publish any reader's radio circuits they've built themselves, A.M., (or, if you must - sorry Pete J.! - DSB / SSB) or CW transmitter kit. I think it's important to encourage home construction as much as possible. Those HF band users worried about being bothered by a few milliwatts of A.M. perhaps should consider the future of Amateur Radio lies not in buying Japanese Technology, but in building and discovering the pure joy of that first successful transmission and reception between two like-minded amateurs using their home made gear. And take heart: if such an accomplished radio amateur as Peter Parker can play with basic transmitters as per an OXO, then it behoves us all to get something built and have a bash with the soldering iron.

Yes, I'm a curmudgeon; yes, I like simplicity; yes, I want to see more license holders building pip-squeak transmitters chucking out a few hundred milliwatts of clean, stable CW, A.M., DSB and SSB from a 10 yard length of wire strung out over the washing line. Because - that, to me, is real Amateur Radio, and that's how we build a future !

FT241/3 & HC6-U crystals...

Wiring "Octal" sockets to take FT241, 243 & HC6-U crystals

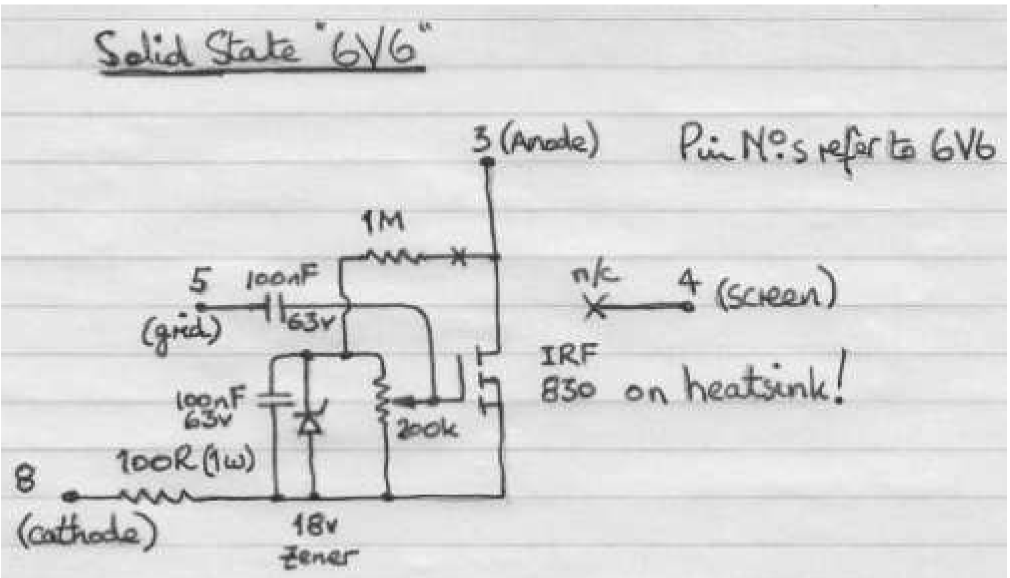
“*Wire Pins 1, 2, 5 and 6 are connected together and connect to one side of the crystal; pins 3, 4, 7 and 8 are connected together and go to the other side of the crystal. Now plug an FT-243, FT-241 or HC6-U into the octal socket, in any position that takes the crystal’s pins without any strain or bending for a secure placement.*

Alternatively: pins 2, 3, 6 and 7 are connected together and pins 1, 4, 5 and 8 are connected together and go to the other side of the crystal.”

(As seen on a web page by N2EY)

The spacing of the crystal pins ensures you hit the right socket hole combinations. This works well too for those “octal” relay bases (those with minimal wiring inside) and makes a neat job if you mount the socket (after wiring) through a nip clearance hole in the front panel using the screw holes in the relay base. This allows a short section of DIN rail to be mounted on the rear of the “crystal socket”, allowing “industrial” switches, fuse holders, indicators, etc., to be mounted through the front panel, for a robust job well suited to “ham” fisted operators...!

This prompts another thought that might help budding constructors to get some wire, a few components and “have a go”. If the crystal for an oscillator circuit can be mounted in a screw terminal “octal” base, as can an octal power device (6146B for instance, or a mosfet set up as an RF power pentode) then a transmitter can be put together *without any soldering*. Below is the diagram I was sent for a mosfet “Tetrode”



(I believe this was originally from Electronics World April 2001)

Note: the n/c “screen” on pin 4 above could connect to the right hand end of the 1M ohm resistor, not to pin 3, anode: this would give an approximation to the effect the screen grid has in a real 6V6 tetrode, by varying the bias voltage fed to the IRF 810 gate and thus the transconductance of the device; but that would be a definite “suck it and see” experiment!

If this circuit was built as an assembly mounted on the salvaged base of a dud “octal” valve, you could construct a transmitter *without soldering* by plugging the assembly into an octal relay socket as above: the tank coil and other components required could all be assembled and wired on parallel choc-bloc screw terminal strips, mimicking a parallel terminal tag board. For obvious reasons you couldn’t use this method above 40 metres or so as the extensive wiring could cause instability.

A Rig in a Bottle

Pete Juliano n6qwham@gmail.com

As a kid I often marvelled at how a small ship was placed inside of a tiny bottle. The ships were often intricate containing many sails and very observable detail. It was a mystery. Some said everything was in a collapsed condition wherein all was passed through the neck of the bottle and then hoisted into place once inside the bottle. Still others like my Dad said the bottom of the bottle was removed and then once the ship was inside applying high heat via very pointed "blowtorch" the bottle was sealed. No matter the method –it was always a mystery.

Fast forward to 2018 when I spotted a bottle in a supermarket that looked like the right size and was filled not with spirits; but chocolate candy infused with Champagne. In an instant my mind raced toward a project I had dreamed of for many years – a SSB transceiver inside a bottle. Boom! Here we are with a fully functioning, dual VFO, USB/LSB selectable 40 Meter QRP transceiver inside a bottle.

I should note that the company who make this bottle filled with chocolates is the Defaille Company located in Belgium. They have a website but do not show this bottle. I sent them a feedback email – great chocolates but an even better bottle! The bottle has a screw off base, so you can gain access to the inside of the bottle and noteworthy the plastic bottle is very durable and easily drilled without cracking.

The rig itself uses a 9 MHz four pole filter from INRAD and it is a bilateral design employing the Plessey amps as Found in EMRFD. The Microphone amp is a single 2N3904 and the Audio amp is a 2N3904 driving a LM386. For the RxTx Mixer and the Product Detector/Balanced Modulator we have the TUF-1 at both places. This rig does not use a Rx RF Amp stage and is quite sensitive. As usual I am using an Arduino Nano and Si5351 for frequency control and to provide a 988 Hz TUNE Tone. You got to love those Microcontrollers.

Outboard are the Transmit Pre-driver, Driver and Final Amp stages which deliver 5 watts to the antenna. There is only so much you can cram into a bottle. As is, it will do microwatts. The rig has been air tested and gets high marks.

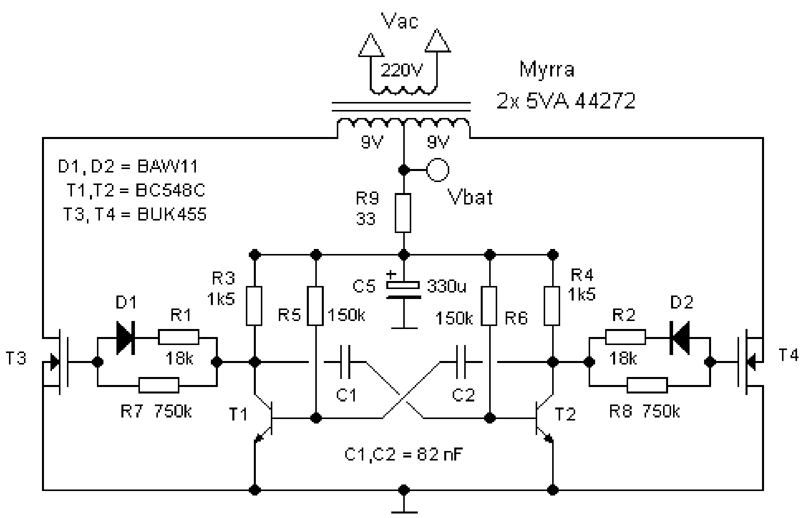
We are in the Holiday season and hopefully you have kept those cookie tins and metal boxes that initially carried some Christmas treasure –so time to think out of the box to inside the bottle. It would have been fun to say that the bottle was initially filled with spirits and fun to consume; but it was not –although the chocolates were quite good.

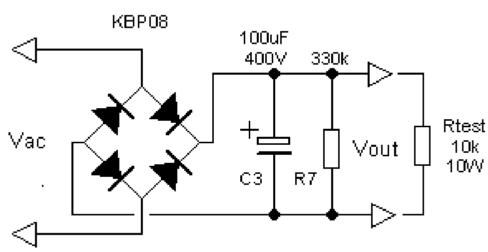
Keep an open mind for possible rig enclosures.

73's
Pete N6QW

I'm most grateful to Pete J. for his contributions; always superbly presented and built. What an imagination! Much appreciated!

Power Supplies





steering diode and 18k - much faster turn off, but again, nowhere near the mosfet's capabilities. The nett result is controlled switching edges, by using the gate - source capacitance as a low pass filter.

Testing an unknown transformer

I replied to a letter asking about testing an "unknown" transformer to see if it was useful as a filament (heater) supply for a pair of 813 valves - 10 amps at 10 volts rms. My reply is below:

"I would first use a 500v or (preferably) 1kV Megger Insulation tester to make sure the old girl still has effective insulation windings to core and primary to secondary. Once you're happy the old girl can take the pressure, energise the primary from your mains outlet, via a 40 Watt lamp, with no load attached to the secondary. This will tell you if you have shorted turn in either primary or secondary, as the lamp should only light dimly with the core magnetising current; a fault (like a shorted turn) will merely light the lamp to full brilliance ("dim lamp" test), and not blow any fuses.

Size up the core, comparing it to known VA rated transformers (catalogues with weights and dimensions are useful): the core size indicates (give or take) the VA rating, being the iron creating the secondary current. Next measure the open circuit secondary voltage and note it down. Add some secondary loading resistors and note down the loaded secondary volts. This indicates the regulation of the windings - most transformers (above 10VA or so) are usually wound to give less than 10% volt drop on full load, a real gem, 2%.

Thus if you draw a couple of amps and the secondary rms voltage sags 1 or 2%, gradually load her up more, let her run for an hour, or until the core gets slightly warm to the touch - emphasise "slightly". This will give you fair indication of the old girl's capabilities, and you'll have a good estimation of the regulation under load - in your case, a pair of 813's, which will pull 10 amps at 10 volts rms. Once you're driving 10 amps at 10 volts rms for an hour or two, with no excessive core heat (i.e. more than 50°C), and no furious "buzzing", indicating core saturation, you're good to go.

I reckon you'll not be far off with those tests. All that remains is to wish you good luck in finding some lively 813's!

Kindest regards, Peter Thornton, G6NGR"

This follows the format I used many times in testing power transformers, from 100VA to 15kVA in high vacuum equipment power supplies. It's about as simple as it can be done, and using a thermal on-load "soak" test lets heat get right through the windings and core, finding elusive "intermittent" faults, or those that only occur on full power - caused by metal parts expanding with heat.

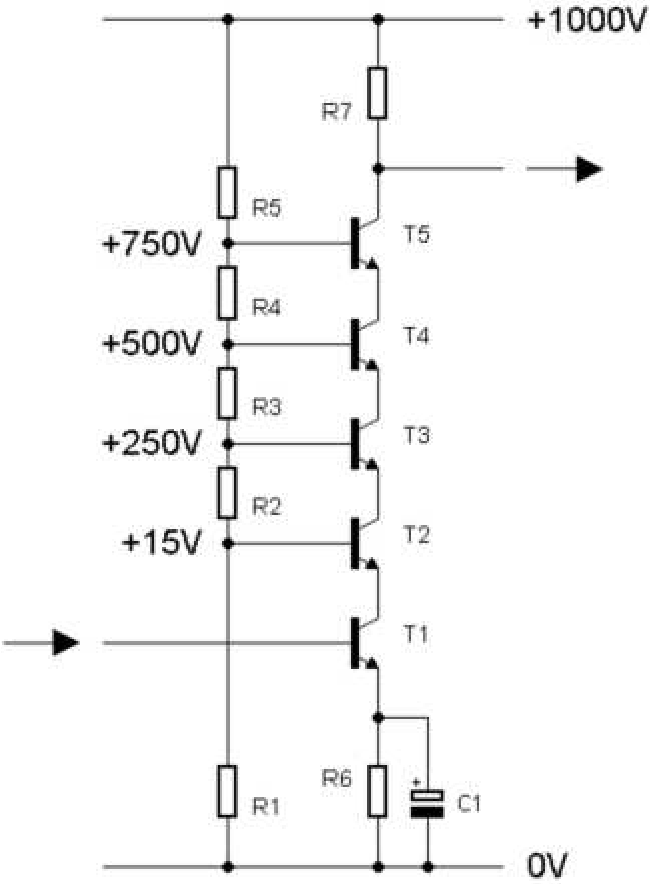
The Cascode (2)

In a previous Hot Iron I discussed the cascode connection for transistors, mosfets and valves as a high isolation, stable gain block for RF small signal service: cascodes can be adapted very easily for HV and power work too - far above the normal voltage limits of each device in the connection. The most common service I've seen cascodes used for HV service is in shunt regulator circuits for 1kV and above; but the principle can be adapted for any voltage or current.

It used to be common practice to add a "ballasting" resistor to load up HV DC supplies, as the biggest change in output voltage is from no load to mid load. A large resistor is clamped across the DC supply, to always draw some current and thus eliminate the soaring "no load" voltage rise; but it's far more economical in power terms to only draw the minimal current necessary to eliminate the off load peak. Shunt regulator circuits are a favourite in this role: whilst wasting power when the load is idling or on standby, when running near full output current the shunt regulator draws very little power compared to the load. Obviously for a very disjunct load (like a transmitter running QRSS) the voltage fluctuations can be significant, whereas running A.M. with steady carrier draws a much steadier current and thus the PSU has a quieter life.

The shunt regulator works like this: a sample of the output voltage is compared to a stable reference voltage, and the difference between the sample and the reference(the “error” voltage” used to drive a shunt load made from transistors, mosfets or valves. Should the output rise, the shunt load conducts more, causing the output voltage to sag, as the resistance of the transformer windings and rectifier forward losses drop more voltage. The net result is the output voltage remains more or less constant. A neat description I once heard was the shunt regulator acted like a giant adjustable Zener diode across the supply!

Shown below is the basic structure of the HV cascode connection.



(Diagram from
Wikipedia, for which many thanks)

T1 base is the error signal drive point: driven positive as the output rises, the entire ladder is turned on by T1 conducting, pulling down T2’s emitter. Since T2’s base is held at a more or less constant voltage, T2 turns on harder, lowering the voltage on T3’s emitter, and so on, so on. In a shunt regulator, the resistor R7 would be a low value, to give some protection to the ladder transistors, and the base drive potential divider taps would be decoupled to ground to eliminate noise and instability.
This circuit can be designed with mosfets too; but be aware the mosfet’s combined gate / source charge storage in each device might make the ladder a tad sluggish in response!

Test Equipment & Fault Finding

Dim lamp [3]

Smps testing with a dim lamp: diagnosing an ill-mannered SMPS. My response to a query about repairing a specialist SMPS:

Hi XXXX, your SMPS: first things first, before you go diving into the innards of a complex (and high voltage) IC, set up as follows and note the results of these tests.

(1) Any sign *at all* of any physical damage, like burned resistors, discoloured windings, bulging cases on an electrolytic capacitor, transistor, diode, IC?

(2) What's the ripple voltage on load? [*To measure ripple, attach a dummy load to run plenty of current, at least 75% of full rated output, and measure with your digital meter on "AC" or your analogue meter on a low AC volts range in series with a 2.2 or 4.7µF non-polarised capacitor, to see the AC component of the DC output.*]

(3) Does the SMPS make any "odd" or random, audible noises, possibly a "buzz", "sizzle", or regular clunking noise?

(4) With the dummy load connected, and after running for a good few minutes, unplug the mains, wait a minute to let the HV capacitors discharge and using your free Infra-Red heat detector - a finger tip! - quickly touch all the components. You'll know when you've found the problem, *very* quickly... OUCH!! Alternatively, run the SMPS whilst monitoring output voltage / current, and spray freezer on IC's, transistors, etc., and watch for a sudden change in output when you freeze a particular component. Another sneaky trick is to drip iso-propyl alcohol (on a cotton bud?) onto all the electronic components in turn: any hot parts will instantly evaporate the alcohol drop. Gotcha!

(5) Wire a 25W or 40W lamp in series with the mains input (I have a lamp holder and socket ready wired specially for these jobs), keep your dummy load connected and power up: note how the lamp reacts as power is applied. The lamp should light quite bright, then dim down as the reservoir and smoothing capacitors charge up.

Answers

(1) Anything "fried", swollen or otherwise looking out of sorts is worth replacing and trying again. It's a good chance that will fix it; but let it run a good few hours into a dummy load to be sure.

(2) Any ripple over a hundred or two mV's is a good sign the main smoothing reservoir electrolytics are dried up / "naquerred". Replace with high temperature types of equivalent value - typically 105°C caps.

(3) A power transistor / mosfet suffering or intermittently breaking down results in all sorts of odd noises as the transformer core gets a hammering and acts like a loudspeaker. The twin Schottky rectifier diodes (looks and meters like a big bipolar transistor) are another culprit, especially when hot - but semiconductors generally go open circuit or short. It's possible one of the diodes in the pair has gone; the control IC is sensing low output and bunging up the volts to try and compensate.

(4) Self explanatory!

(5) The lamp in the mains feed shows the line current being drawn on start-up. It's common for the lamp to glow as the SMPS tries to start, then cuts out due to under-voltage feed as the lamp filament warming up limits the current. This shows a functional IC usually; and the high value start-up resistor is still functional.

Lastly, build a 5 volt crowbar with a fuse, 4.3v zener, and a hefty SCR. Wire the SCR anode to +ve output via the fuse (important!); cathode to -ve output; zener from anode to gate. Anything over 4.3v plus the gate-cathode drop (typically ~1.0V) - even a glitch or ripple - will pop the fuse, protecting your load from damage. Any decent SMPS for a fixed voltage should have a crowbar fitted; but many (cheap and nasty!) Chinese designs don't.

Simplest Audio / RF sig gen

Sometimes it's necessary to inject a low level audio signal into a circuit for test or trials. An audio signal generator, of low distortion and variable frequency isn't available: so what to do? Make one! A simple method is to make a CMOS / TTL gate square wave oscillator (of which the internet has millions) then convert the square wave into something without "corners". How best to do this?

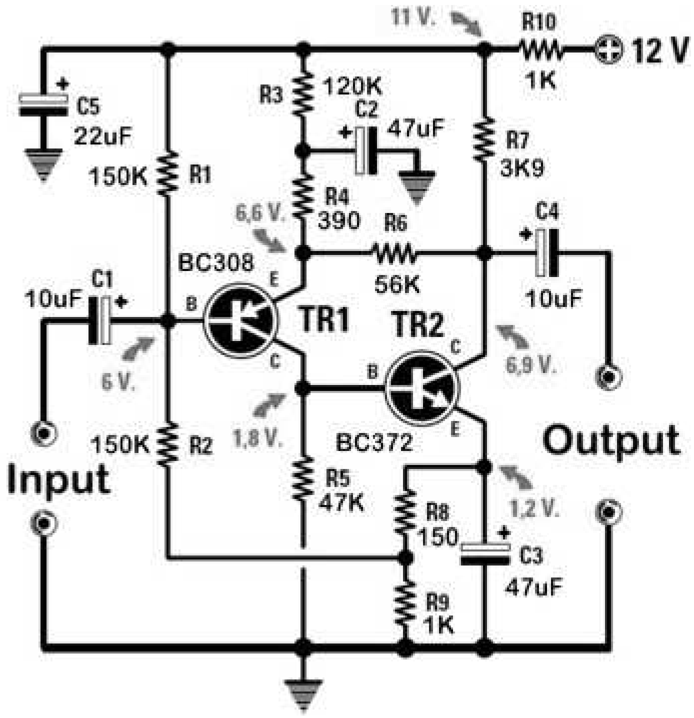
You could use a single series resistor feeding a shunt capacitor as a one section low pass filter; but far better - and easily lashed up - is multiple R-C low pass filters cascaded in series. You then have a choice of taps down the cascaded low pass filter sections, for different output voltage levels and distortion characteristics. Six sections of (say) 8k2 feeding a shunt 47nF ceramic disc capacitor yields a few mV of pure (enough) 1kHz sine wave at ~50k impedance, perfect for feeding into a hi-input Z microphone pre-amp or similar. The actual values depend on frequency and your requirements, but it's an easy and cheap way to get a clean sine wave.

You can apply the same principle to an RF signal generator: make a CMOS or TTL crystal oscillator, feed the output into multiple RC low pass filters built with series 47R resistors and 47pF shunt capacitors (scale as appropriate for the frequency of your choice) and you'll have a µvolt or two of RF for test purposes.

Note: none of the component values mentioned above are critical. Use whatever you have to hand, or can get in 10 off quantities cheaply. It will work like a charm, and be your own design!

Pre-amp for signal tracer, more gain required?

The signal tracer described in Hot Iron 102, whilst suitable for the job I had on the bench, really needed more pre-amp gain, wrote Neil Simmonds. I can understand this: for detecting very low levels of signal a fair bit more gain could well be more effective. The circuit below offers a gain of over 100 and is stable with good construction practices, and shows the simplicity achieved with complementary PNP and NPN devices in a feedback amplifier.



Restarting / Using old electrolytics...

Much utter tripe, waffle, or bunkum has been written about "ageing" and "reforming" electrolytic capacitor plates or insulation, especially by the "audiophool" web pages I come across occasionally. The simple truth is that electrolytics **must** have volts applied to create the insulating layers between the plates, and **must** leak a mA or two for the electrolyte (the clue is in the name...!) to form the oxide insulation layers. Most manufacturers form the "plates" during test: if put into service within a year or two of manufacture, you'll have no bother. The problem comes in an electrolytic that's been in storage (or otherwise unused) for years: the thing is condemned to the rubbish bin as it leaks like a sieve when first re-powered. Easy answer: set up a DC power supply to stress the electrolytic capacitor to ~70% of it's rated voltage, and feed the volts to it via a 15 watt lamp (yes, I use a lot of incandescent lamps - they are cheap, and **do what they say on the tin**) or lamp plus a power dropper resistor if the voltage is greater than the lamp spec.

The lamp will probably glow dimly on applying the 70% volts volts: the plates start "forming" and you should see (if the electrolytic capacitor's half decent) the glow fade after a short time. Ramp up the applied volts (a Variac or lamp dimmer are useful to control the AC volts to the DC bias supply), noting how the lamp glows brightly again, then fading as the leakage drops. Finally apply full rated volts, plus a few extra, to really thicken up the insulating layer. If the lamp glows brightly and doesn't fade after a while, the old electrolytic capacitor's not up to the original rating and shouldn't be trusted unless you've absolutely nothing else to replace it - but expect it to go !BANG! at the most inconvenient time!

I had an interesting fault on a 5kW motor inverter; using a bank of electrolytic capacitors for the "DC link" power. The capacitors (9 x 1500μF, 750 volt DC, 100 amp ripple, arranged in a 3 x 3 square formation) were suspected, as an indicated DC link over-current error (even under no load) definitely pointed to a electrolytic capacitor going down on full volts. Testing each electrolytic capacitor individually found no culprit: but after 30 minutes testing at full link volts did the culprit show itself. The leakage current flowing in the DC link suddenly went sky high - the electrolytic capacitor in the centre of the 3 x 3 was far hotter than all the electrolytic capacitors round it (finger touch test), and breaking down, even under no load. The whole bank of electrolytic capacitors duly replaced, the inverter ran a test full load for 48 hours non-stop without any signs of distress. Job done!

QRO power supply builders might keep that repair in mind - leave lots of cooling air space around your power supply electrolytic capacitors. Heat breaks down electrolytic capacitors quicker than you can say “what the h3ll was that !BANG!” ?

Servicing without a schematic diagram

In a previous reincarnation (of employment!) I spent 6 months “servicing” electronic equipment: mostly power electronics: inside motor drives, inverter welders, spot welders, and the like, electronic components **wear out**. It was very educational: repairing circuit boards that ran many hundreds of amps, some with applied RF to ionise the welding cover gas to start the arc was a fascinating experience - especially since I didn’t have any circuit diagrams or manuals!

Most people don’t understand the need for modern electronics to be “serviced” - as opposed to “repaired” - but industrial electronics, working in more extreme environs and at full load almost all the time, wears out components that in domestic electronics would rarely, if ever, be seen.

I soon found the parts that commonly needed replacing; not because they had ceased to function altogether, but had either depleted so far as to render the gear unable to achieve the output usually expected, or protection circuits kicking in to prevent burn-outs or other damage.

These replacement patterns are equally applicable to elderly or over-stressed radio gear that’s past it’s best perfomance. Below is a list of jobs in roughly the right order of attack; but as always, don’t take it as Gospel. Most important, have a thorough look-see for signs of burning, be aware of the acrid smell of burned resistors and transformer windings, and any loose or “wobbly” connectors.

- Clean the entire thing from top to bottom, an old paint brush or two and a vacuum cleaner with a thin nozzle helps. Take pictures in a good light from every angle for future reference. Replace, in roughly this order: electrolytics after noting value, voltage and polarity; relays; other electromechanical bits; all burnt components - if you can still see the value or make an educated guess!
- Check all resistors, especially high value or SMPS start-up resistors, and capacitors (if you can, that is: “in circuit” tests do a reasonable job, but still throw odd red herrings around Schottky diodes and the like); reflow vulnerable soldered joints (typically those that interface with the World outside the enclosure), switch terminals, IC leads and power transistor joints.
- Make sure all screws, etc., are tightened appropriately. Check everything is as per original photographs - no missing parts. Be especially suspicious of previous (unknown quality) repairs, they are likely to be the cause of many maladies - wired up incorrectly or wrong components fitted that did further damage.

Now try it again in service!

Components & Construction

From a well known artificer in Amateur Radio, Roger Lapthorn, G3XBM, points out from his employment days that magnetic fields should ALWAYS be kept well away from iron dust toroids and ferrite rings - see the PF8 UHF transceiver manual for more; but I think common sense says that these items could well have remanent magnetic fields in them after near approach of a magnet. Now where would I find a magnet in close proximity to ferrites and iron dust cores / toroids? Temperature controlled soldering irons are my first thought, and the number of times I've repaired equipment containing such cores and not batted an eyelid!

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The resistance of thoriated tungsten cathodes increases as tungsten is "sputtered" off the cathode surface by electron bombardment. It's quite common in high power RF generators to increase the filament volts in proportion to the operating hours to maintain efficiency and RF power output, by applying a primary "bucking transformer" on the filament transformer's primary. Typically a directly heated thoriated cathode filament runs between 10 - 20 times the anode current: if the anode current drops, and the filament current drops too, it's sure sign the filament is is ageing. Up the filament volts a touch and lo and behold: full output power restored.

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Starting up "NOS" ("new old stock") valves is another of those jobs that sometimes needs a bit of over-drive to restore performance. The coating on the cathodes inside these venerable beasts gets a little bit "poisoned" whilst not working - the normal heat and back bombardment by electrons whilst running drives off the surface contaminants; and before a valve can deliver the goods, the cathode has to be "cleaned up" a bit. TV service engineers who worked with "dull picture" faults in cathode ray tube days repairs will recognise what's coming!

The following article is largely as it appeared in the book "TV Data Publications" in 1966. The voltages involved are potentially lethal and hence the procedures used should only be attempted by people with suitable experience and competency working with such voltages. IF IN DOUBT, DON'T DO IT. GET COMPETENT AND EXPERIENCED HELP! The procedure outlined is not dissimilar to that used during the production of CRT cathodes during manufacture.

"During the life of a cathode ray tube, the cathode emission will fall gradually. Eventually this slow deterioration will reach a point where it begins to have an adverse effect upon the brightness of the picture. Providing no other defect has developed within the tube, it can probably be rejuvenated when it reaches this stage by one of two methods.

The first is perhaps the simplest method and is the one most likely to give the best results. It is to increase the heater voltage by about 15%. This may well extend the life of the tube by several months, whereupon a further small increase to, say 25% may be tried. Generally, these increases in heater voltage will provide a very worthwhile extension in the tube life, and only in a few isolated cases will the heater wire fuse due to the overload. C.R.T. "booster" heater transformers are commercially available, their function being to increase heater voltage in this way. They may be temporarily plugged in between the receiver circuits and the tube base.

The other method of rejuvenating tubes is the procedure which is usually termed "reactivation". This involves temporarily overrunning the heater whilst, at the same time, a positive potential is applied to the tube electrodes (usually a grid). The result of this procedure is that a new supply of emitting oxides are formed on the surface of the cathode, and the tube should then be good for a further period of use under its normal working conditions. A simple cathode booster could consist of a heater transformer which is capable of providing a voltage which is about 30% in excess of the working heater voltage of the tube. The positive potential for the electrodes is obtained from a separate power supply, or directly from the a.c. mains via a suitable rectifier and potentiometer. This voltage is fed to the tube electrodes via a current limiting resistor (in my case almost always a 15 watt lamp!) and milliamp meter to read the current flowing cathode to grid.

These supplies are fed to the tube which is undergoing treatment, and if the procedure is going to be successful the emission will be initially low, but will rise gradually until it reaches a peak as shown on the meter. The time required for this part of the operation may be anywhere between a few minutes and an hour or so, but once the peak has been reached, the booster should be disconnected and the tube heater run at its normal voltage for at least half-an-hour with no voltage on the electrodes. After this, the tube may be returned to its normal operating conditions and, if the exercise has been successful, a good picture will be obtained."

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6BA screws

The very common screw sizes of my youth - "BA" sizes - were used in the vast majority of UK radio and electronics gear. 6BA is identical (as near as makes no difference) to ISO 3mm; UNC as used in the USA is very close to UK "Whitworth", and UNF (in some sizes) is near enough to "BSF" to be useful. The nomenclature sizing of USA screws is a little confusing to some; the table below shows useful information:

UNC - Unified Coarse Threads

Major Diameter *(in)*	**Threads per inch**	**Major Diameter *(in)***	**Major Diameter *(mm)***	**Tap Drill Size *(mm)***	**Pitch *(mm)***
#1 - 64	64	0.073	1.854	1.50	0.397
#2 - 56	56	0.086	2.184	1.80	0.453
#3 - 48	48	0.099	2.515	2.10	0.529
#4 - 40	40	0.112	2.845	2.35	0.635
#5 - 40	40	0.125	3.175	2.65	0.635
#6 - 32	32	0.138	3.505	2.85	0.794
#8 - 32	32	0.164	4.166	3.50	0.794
#10 - 24	24	0.190	4.826	4.00	1.058
#12 - 24	24	0.216	5.486	4.65	1.058
1/4" - 20	20	0.250	6.350	5.35	1.270
5/16" - 18	18	0.313	7.938	6.80	1.411
3/8" - 16	16	0.375	9.525	8.25	1.587
7/16" - 14	14	0.438	11.112	9.65	1.814
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Major Diameter *(in)*	Threads per inch	Major Diameter *(in)*	Major Diameter *(mm)*	Tap Drill Size *(mm)*	Pitch *(mm)*
1/2" - 13	13	0.500	12.700	11.15	1.954
9/16" - 12	12	0.563	14.288	12.60	2.117
5/8" - 11	11	0.625	15.875	14.05	2.309
3/4" - 10	10	0.750	19.050	17.00	2.540
7/8" - 9	9	0.875	22.225	20.00	2.822
1" - 8	8	1.000	25.400	22.85	3.175
1 1/8" - 7	7	1.125	28.575	25.65	3.628
1 1/4" - 7	7	1.250	31.750	28.85	3.628
1 3/8" - 6	6	1.375	43.925	31.55	4.233
1 1/2" - 6	6	1.500	38.100	34.70	4.233
1 3/4" - 5	5	1.750	44.450	40.40	5.080
2" - 4 1/2	4 1/2	2.000	50.800	46.30	5.644
2 1/4" - 4 1/2	4 1/2	2.250	57.150	52.65	5.644
2 1/2" - 4	4	2.500	63.500	58.50	6.350
2 3/4" - 4	4	2.750	69.850	64.75	6.350
3" - 4	4	3.000	76.200	71.10	6.350
3 1/4" - 4	4	3.250	82.550	77.45	6.350
3 1/2" - 4	4	3.500	88.900	83.80	6.350
3 3/4" - 4	4	3.750	95.250	90.15	6.350
4" - 4	4	4.000	101.600	96.50	6.350

UNF - Unified National Fine Threads

Major Diameter *(in)*	Threads per inch	Major Diameter *(in)*	Major Diameter *(mm)*	Tap Drill Size *(mm)*	Pitch *(mm)*
#0 - 80	80	0.060	1.524	1.25	0.317
#1 - 72	72	0.073	1.854	1.55	0.353
#2 - 64	64	0.086	2.184	1.90	0.397
#3 - 56	56	0.099	2.515	2.15	0.453
#4 - 48	48	0.112	2.845	2.40	0.529
#5 - 44	44	0.125	3.175	2.70	0.577
#6 - 40	40	0.138	3.505	2.95	0.635
#8 - 36	36	0.164	4.166	3.50	0.705
#10 - 32	32	0.190	4.826	4.10	0.794
#12 - 28	28	0.216	5.486	4.70	0.907
1/4" - 28	28	0.250	6.350	5.50	0.907
5/16" - 24	24	0.313	7.938	6.90	1.058
3/8" - 24	24	0.375	9.525	8.50	1.058
7/16" - 20	20	0.438	11.112	9.90	1.270
1/2" - 20	20	0.500	12.700	11.50	1.270
9/16" - 18	18	0.563	14.288	12.90	1.411

Major Diameter *(in)*	Threads per inch	Major Diameter *(in)*	Major Diameter *(mm)*	Tap Drill Size *(mm)*	Pitch *(mm)*
5/8" - 18	18	0.625	15.875	14.50	1.411
3/4" - 16	16	0.750	19.050	17.50	1.587
7/8" - 14	14	0.875	22.225	20.40	1.814
1" - 12	12	1.000	25.400	23.25	2.117
1 1/8" - 12	12	1.125	28.575	26.50	2.117
1 1/4" - 12	12	1.250	31.750	29.50	2.117
1 3/8" - 12	12	1.375	43.925	32.75	2.117
1 1/2" - 12	12	1.500	38.100	36.00	2.117

Antennas

Gerscht transformers - Terry Ritter & A Simple Variable Ratio RF Transformer

Using a tapped coil to match different AC impedances is quite common in radio techniques: feeding a very low impedance antenna for instance from a high impedance anode circuit is one example. Once the taps are found, then the job’s done: turns ratios don’t age or drift, so once set up, voila! Now there’s the rub - it’s very easy to say, but difficult to do - “once set up”. Using today’s miniature toroids, even 2” sizes, having to resolder taps until a good match is made can be a right pain.

An answer might be to study some devices Terry Ritter describes on his web page: http://ciphersbyritter.com/RADELECT/RATIOTRN/RATIOTRA.HTM and make them suitable for RF matching by using the appropriate iron dust toroid cores for the frequency and power to be handled.

Terry’s web page describes Gerscht Variable Ratio Transformers for instrumentation use. They are very similar to rotary “Variac” style transformers: a toroid is close wound with wire and a rotary wiper picks off the turns one by one. It would be a neat solution to save one of those elderly 2” diameter chunky rheostats, and use the mechanics of the wiper but replace the resistance wire and support with the wound toroid - thus we could have a variable ratio transformer that could match virtually any impedance to another, just by turning the control knob. Far simpler and easier than soldering / de-soldering taps!

An interesting design could be the feeding of power to the centre of the winding, rather than an end. Thus the wiper, starting at the lowest contact point, represents high impedance to low; moving the wiper up to half way round the winding give a one to one impedance; moving the wiper further towards the top gives low impedance to high ratios.

The only snags I see with this are the requirement of any transformer to have sufficient inductance so as to not draw too much magnetising current and have sufficient insulation and turn separation to avoid flash-overs. The first can be arranged by stopping the wiper going too close to either end of the winding with mechanical limits; the second needs quality enamelled wire of suitable gauge and ensuring the wiper’s contact can carry the RF currents. Another issue, especially on lower frequencies, is the Tesla coil action of an open-ended winding energised by RF - maybe some blue spark fireworks if running a good few watts! 80m and above should have sufficient stray capacitance to prevent Tesla coil action; but I'd be a bit wary below 80m, and on LF, beware!

Apart from that, I foresee a useful new role for those chunky wire wound rheostats that are often found for pennies at radio rallies!

3/8ths wave monopole

An interesting note that reduces considerably the need for "lower than low" earth resistance for vertical antennas is the folded monopole of various forms longer than the usual ¼ wave size. If a ¾ wave wire is folded in half, and set up vertically with the fold uppermost, either end near the ground being the feed point with respect to ground (the rising wire ~ 30cms from the descending wire) this results in an elevated current maxima, and a feed point impedance of some 450 ohms - thus relieving the need for acres of copper mesh earth mats as ground currents are much lower due to the higher impedance. Mechanically too, the resulting ⅜ "monopole" structure is not too demanding: roughly 7 metres high is fine for 20 metres working, and of course becoming shorter as the frequency rises. The antenna is well behaved, giving omni-directional radiation, and can be made with thin wire as the current is much lower than the ¼ wave Marconi, so is quite "stealthy".

Tx/Rx auto changeovers...

Timing an antenna change-over switch is important: it's very easy to have a powered transmitter feeding into an open circuit if care isn't taken in the design of the switching. Relays are very useful in these circuits, and whilst a relay provides the ultimate in electrical isolation, you trade off isolation for speed - break in keying (QSK) MUST be electronic, which means many additional problems - how to isolate against HV appearing on the key, or guaranteeing a minimum (electrically) safe opening gaps of contacts, to name but a few.

A popular circuit - due to it's low cost and simplicity - is a double pole change-over contact relay: the antenna connects to the moving contact, receiver to the normally closed contact and transmitter to the normally open. The other set of contacts control the power to the transmitter P.A. and the receiver muting on transmit. The transmitter keying / Push to Talk switch (PTT) drives the relay coil to effect the transfer; the relay contacts (on HF and low VHF at least) offer excellent isolation so the transmitter power never gets near the receiver's front end. Simple? Yes. Effective? Well.... no, not always.

As the relay armature moves from the normally closed position, switching to "transmit", the transmitter is powered up when the relay completes it's action; but the receiver's input is open circuited for the switching transition and this can produce loud squawks or crashes. On switching back to "receive", the transmitter's capacitors are fully charged, so the transmitter sees an open circuit load until the capacitors discharge - maybe not an issue on QRP but above 10 watts, you've a recipe for disaster, especially if you're using solid state P.A. devices. Might not be every time, but a transmitter feeding an open circuit is asking for very high RF voltages to appear around the P.A. device.

It's very simple to add another relay and a few timing components - and the sequencing can be done safely and reliably, for powers up to kW's if desired. RL1 is the ANTENNA change-over relay; RL2 is the Tx POWER control relay. The sequences are below: system initially in "receive".

RECEIVE→[PTT / Key down]→ RL1 pulls in → RL2 pulls in → TRANSMIT active

Note: RL1 has changed over BEFORE RL2 pulls in, the ANTENNA is connected to the Tx output BEFORE power is applied to the Tx P.A. Now the PTT / key is released at the end of the "over":

PTT / Key UP → RL2 drops out → RL1 drops out → RECEIVE active

Note: The instant the PTT / Key is released, the power to the Tx P.A. is cut - BUT the ANTENNA relay RL1 DOES NOT drop out until the Tx decoupling capacitors are discharged. That's the trick: the time delay between the power to the Tx P.A. being cut, and the antenna being switched over to receive. The Tx P.A. never "sees" an open circuit load until safely shut down, as the antenna is still connected.

You'll have noticed from the above you'll not run QSK / break in keying; the relays cannot move quickly enough (nor would they last very long!) if you tried. This system is perfect for phone operation, and assures safe conditions are presented to the Tx P.A. at all times (assuming, that is, your antenna is reasonably matched and in good fettle!)

In this day and age it's policy to reduce power consumption wherever possible. I agree with that, and it's possible to reduce the current draw of relays significantly without reducing switching capabilities. I had two "Octal" industrial relays to hand, and from experience, these are tough as old boots and very reliable, so I chose those for the job. They had, however, AC coils: you can't just apply DC drive to an AC coil, it will burn out as they have significantly less wire turns in the coil, relying on the inductance to limit the current, not the copper wire resistance as in a DC relay coil. You can use AC coils on DC circuits providing you apply only enough DC voltage to draw the same coil current as when operating on AC. It's a relatively simple procedure requiring some bench testing - you apply a variable DC voltage to the coil until the coil draws the same DC current as if using AC(rms), or try a series resistor and a 12 volt supply until you get reliable pull-in.

Typically you need 50% of the rated AC (rms) volts of DC to operate reliably; but test before committing to a design. You can calculate the rms current draw from the maker's specified power consumption figure, usually quoted in VA's, by dividing the nominal AC (rms) operating voltage by the VA consumption quoted. That will get you a safe working value to base your calculations on.

An interesting Web article by Peter Hand....

"AC and DC relays are constructed differently. An AC relay usually has a split pole - the iron core where it comes out of the coil is slotted, and half the pole is surrounded by a thick copper D-ring known as a shield. The purpose of that is to create a lag - the shorted turn has a current induced in it as the AC voltage rises, which delays the rise of the magnetic field on that side. Then as the AC voltage falls, along with the magnetic field in the unshielded pole, the current in the D ring gives back its energy to magnetize the shielded pole. That means the armature is always attracted to the core, even during the drops and reversals of the current, so it doesn't buzz. If you apply AC to a relay designed for DC, it won't have that continuity of field and will buzz and possibly not close.

You can however operate an AC relay with DC, but you must use less than the rated voltage. The current in an AC relay is limited by inductive reactance as well as DC resistance, so a 24V AC relay with a 100 ohm coil may only draw 100mA or so instead of the 240mA you would expect. However, if you apply 24V DC, it will pull a full 240mA and probably burn out. As a rule of thumb, you shouldn't drive an AC relay with more than half its rated voltage DC.

But we're not done yet with the differences. Because, as I said, the current in the AC relay is partly limited by reactance, when you first apply power and the magnetic circuit is not closed - the relay is not pulled in - the reactance is much less than it will be after the relay is closed. So the initial current is higher than the steady state, which makes the magnetic field stronger, so the AC relay pulls in much more sharply than a DC relay. If you drive it with half its rated voltage DC, it may be quite slow to close and even not close at all.

The final problem you may encounter is that an AC relay driven with DC may stick in the ON position due to magnetic remanence. DC relay cores are made of specially soft iron that loses all its magnetism when the current is removed, but that iron is expensive. AC relays are often made with cheaper iron, since the constantly reversing current keeps it demagnetized. When you power it with DC it tends to become a permanent magnet and hold the armature closed when you want it released."

[A useful solution to the "sticking" problem above is to artificially introduce a gap in the magnetic circuit, to increase the reluctance. A few thousandths of an inch is sufficient. Cigarette papers were an old favourite; nowadays, 2 or 4 thou. Mylar tape is a good solution, as is a thin sliver of thin self adhesive PVC insulating tape.]

TYCO Electronics and Relay coil suppression article also gives some useful advice:

"**The application of relay coil suppression with DC relays**

This application note has been written in response to the numerous application problems resulting from improper relay coil suppression. The typical symptom is random "tack" welding of the normally-open contacts when switching an inductive load or a lamp load with high inrush current.

When an electromechanical relay is de-energized rapidly by a mechanical switch or semiconductor, the collapsing magnetic field produces a substantial voltage transient in its effort to disperse the stored energy and oppose the sudden change of current flow. A 12VDC relay, for example, may generate a voltage of 1,000 to 1,500 volts during turn-off. With the advent of modern electronic systems, this relatively large voltage transient has created EMI, semiconductor breakdown, and switch wear problems for the design engineer. It has thus become common practice to suppress relay coils with other components which limit the peak voltage to a much smaller level.

Types of Transient Suppression Utilized with Relays

The basic techniques for suppression of transient voltages from relay coils are shown in Figure 1. (*TYCO's Fig 1 shows a relay coil with various components connected in parallel*). As observed here, the suppression device may be in parallel with the relay coil or in parallel with the switch used to control the relay. It is normally preferred to have the suppression parallel to the coil since it can be located closer to the relay (except in the case of PC board applications where either may be used). When the suppression is in parallel with the relay coil, any of the following may be used.

A. A bilateral transient suppressor diode that is similar in V-I characteristics to two zener diodes connected cathode to cathode (or anode to anode).

B. A reverse-biased rectifier diode in series with a zener diode such that their anodes (or cathodes) are common and the rectifier prevents normal current flow.

C. A metal-oxide-varistor (MOV).

D. A reversed-biased rectifier diode in series with a resistor.

E. A resistor, when conditions permit, is often the most economical suppression.

F. A reversed-biased rectifier diode.

G. A resistor-capacitor "snubber". Generally the least economical solution and no longer considered a practical solution.

H. A bifilar wound coil with the second winding used as the suppression device. This is not very practical since it adds significant cost and size to the relay.

Suppression used in parallel with the switching element is likely to be either a zener diode or a resistor-capacitor "snubber". The comments associated with the "parallel to coil" application are also applicable to this circuit.

Effects of Coil Suppression on Relay Dynamics and Life

Even though the use of coil suppression is becoming more significant, relays are normally designed without taking the dynamic impact of suppressors into account. The optimum switching life (for normally-open contacts) is therefore obtained with a totally unsuppressed relay and statements of rated electrical life are usually based on this premise. The successful "breaking" of a DC load requires that the relay contacts move to open with a reasonably high speed. A typical relay will have an accelerating motion of its armature toward the unenergised rest position during drop-out. The velocity of the armature at the instant of contact opening will play a significant role in the relay's ability to avoid "tack welding" by providing adequate force to break any light welds made during the "make" of a high current resistive load (or one with a high in-rush current).

It is the velocity of the armature that is most affected by coil suppression. If the suppressor provides a conducting path, thus allowing the stored energy in the relay's magnetic circuit to decay slowly, the armature motion will be retarded and the armature may even temporarily reverse direction. The reversing of direction and re-closing of the contacts (particularly when combined with inductive loads) often leads to random, intermittent "tack welding" of the contacts such that the relay may free itself if operated again or even jarred slightly.

Based upon the impact on armature motion and optimizing for normally- open contacts, the best suppression method is to use a silicon transient suppressor diode. This suppressor will have the least effect on relay drop- out dynamics since the relay transient will be allowed to go to a predetermined voltage level and then permit current to flow with a low impedance. This results in the stored energy being quickly dissipated by the suppressor. Transient suppressor diodes are available as bi-directional components and permit the relay to be non-polarized when installed internally. Note that if a uni-directional transient suppressor is used, a rectifier diode must be placed in series with it to block normal current flow and it has little advantage over the use of a zener diode. The transient suppressor should be selected such that its pulse energy rating exceeds any anticipated transient such as coil turn-off or motor "noise" found in the application.

A metal-oxide-varistor will provide results similar to those of transient suppressor diode, but will have a higher "on-state" impedance and will thus allow a higher voltage to be developed. As an example, a 33 volt transient suppressor diode may have a "clamping" voltage between 30 and 36 volts. In comparison, a 33 volt MOV will likely clamp the relay at 45 to 55 volts (based on a typical automotive relay with 130 mA coil current). When the additional voltage is no problem, an MOV may save cost over the transient suppressor diode and will also provide a non-polarized relay. The use of a reversed-biased rectifier diode in series with a zener diode will provide the best solution when the relay can be polarized. This suppression is often recommended by Siemens Electromechanical Components (SEC) for use in automotive circuits.

The impact on release dynamics is minimal and poses no loss of reliability. This is normally a low-cost method and the only design precaution is to select a zener with an appropriate breakdown voltage and impulse power specifications adequate for the relay in its application. In printed circuit board applications with transistors used as relay drivers, the zener diode can be placed "across" the transistor; that is, for a common emitter circuit, cathode connected to collector and anode connected to the emitter (the series rectifier diode is not used in this type of circuit). A reversed-biased rectifier in series with a resistor may be used successfully with some relays when maximum load switching capacity is not required. Care must be taken to use a resistor large enough in value to quickly dissipate the relay's stored energy but yet stay within the desired peak voltage transient. The required resistor value may be approximated from the following equation:

R = V peak /I coil   where;

R = resistor value in Ohms

V peak = peak transient voltage permitted

I coil = steady-state relay coil current

The actual voltage peak observed will be lower than calculated by this formula due to energy losses in the resistor. When using this type of suppression it is best to consult the relay manufacturer for recommended values.

A resistor may also be used by itself as a transient suppressor when the additional power dissipation and resulting heat generated by the resistor can be tolerated. In most situations, this will provide the least expensive suppression method (assuming the resistor value can be properly sized to minimize its impact on relay performance). This method is normally recommended by SEC when the application requirements permit.

Many engineers use a rectifier diode alone to provide the transient suppression for relay coils. While this is cost effective and fully eliminates the transient voltage, its impact on relay performance **can be devastating**. Problems of unexplained, random "tack welding" frequently occur in these systems. In some applications, this problem is merely a minor nuisance or inconvenience and the controller or operator will cycle the relay until the proper response is obtained. In many applications; however, the first occurrence may cause a complete system failure or even present a hazardous situation. It is important that these systems be designed with another method of relay suppression.

To illustrate the impact of various coil suppression on the relay response time, consider the following data that was recorded using an automotive ISO type relay with a 55 ohm coil and with 13.5VDC applied to the coil.

Method	**Time (mS)**	**Transient (V)**
Unsuppressed	1.5	-248
680Ω Resistor	1.9	-167
470Ω Resistor	2.3	-143
330Ω Resistor	2.8	-115

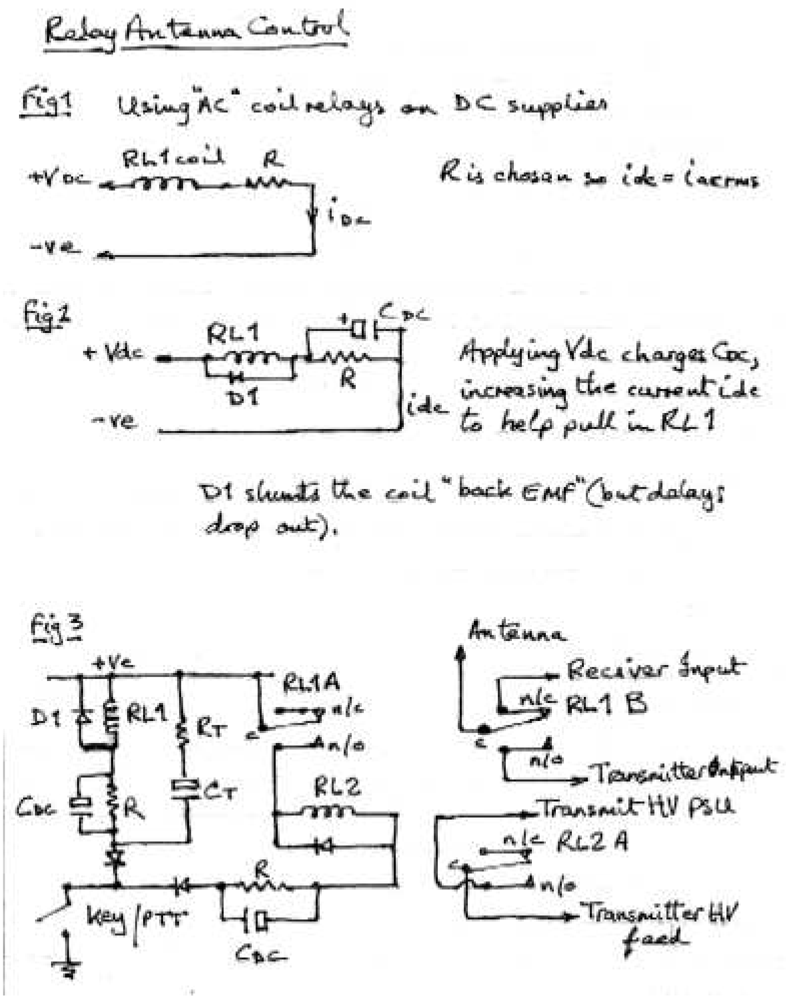
220Ω Resistor	3.2	-81
100Ω Resistor	3.7	-54
82Ω Resistor	4.0	-37.1
70Ω Resistor	6.1	-20.1
Diode & series 24v zener	5.5	-24.6
Diode	**9.8**	-0.8

Note how slow the single diode makes the relay drop-out! This can be used as a useful feature.

From the standpoint of physics, the suggested technique for relay coil transient suppression is to use a reversed-biased rectifier diode and series zener diode in parallel with the relay coil. This permits the relay to have optimum release dynamics and normally-open contact life.”

Taken with thanks from **TYCO Relay Application Notes** web pages.

So here is the final relay circuit, with my notes from the time (please forgive the extraneous scribbles!). I do believe in fitting a snubber (100R in series with 47nF) across the Tx DC power contacts: it reduces arcing dramatically. Appropriate indicator lamps can be fitted if desired to show the presence of power if none are fitted to the Transmitter; and appropriate fusing / safety devices to comply with your local electrical codes MUST be employed appropriately!



And you thought relays were simple devices.... Hah!!

Reflections...

I’d like to set out a fairly “offbeat” idea here, which has relevance to all sorts of things “electronique”. Let me start with a transmission line: a co-ax line, with an inline SWR meter, is a familiar scenario - but what is *really* happening inside that line? You know that reflections come from unmatched loads. The gist is that if it’s unmatched, you get “reflections”, showing up as a non-unity SWR on the meter. So far, nothing new. You might ask yourself how “standing waves” in a transmission line occur; considering the line is made of highly conductive copper; how can voltage differences occur without huge currents flowing? The answer is that the voltage apparent in a standing wave doesn’t exist IN the copper; it’s *outside* the copper conductors, as anyone who has known voltages to appear on the (earthed!?) outer screen of co-ax will vouch for!

Let’s consider a voltage being fed into a parallel wire transmission line, open circuit at the far end. This could be a single step voltage from a logic gate, or the front of a sine wave from an RF generator. The nett effect is a potential difference exists between the conductors making up the transmission line, and that potential difference is moving down the transmission line at the speed of light (applicable to that transmission line insulating medium) towards the far end.

The potential difference creates a *transverse electromagnetic* (TEM) field which moves down the line, between the wires, at the speed of light (for that particular line); it very rapidly arrives at the open circuit far end, and *reflects*. The TEM inverts at the far end open circuit, and starts travelling back toward the feed end. When it reaches the feed end, it reflects again. The result is yet another reflection racing down the line towards the open circuit far end, where it will reflect, inverted, back to the feed end, over and over again, at the speed of light for that transmission line. A TEM wave front is oscillating at the speed of light between the feed end and the far end as no energy is delivered to an open circuit load, and the only losses are those of the line itself: not a lot!

It surprises some that such reflections race back and forth in a mismatched line; but as radio amateurs we are all familiar with unmatched loads not absorbing power. These oscillations do exist: the exact same TEM wave is used in klystrons and magnetrons to create GHz oscillations in coupling cavities and the like.

Let’s now take a step forward. Consider two flat conducting rectangular plates, spaced apart just like our 2 wire transmission line above. Apply a potential difference (DC or RF, it doesn’t matter which) to the centre of these plates, and study as above. The TEM spreads out in the insulating medium between the plates until it hits the plate edges, (open circuit) and reflects back to the feed point, and there reflects once more, setting up an identical situation as above. As the TEM inverts in polarity at every reflection, the driving voltage at the feed point is somewhat cancelled by the reflection; the voltage doesn’t rise quite as fast as the driving voltage would try to effect. It’s only as the voltage slowly increases at the feed point, the reflected TEM’s cancel more and more of the driving point potential difference, until the transmission line has an equal voltage at all points to the driving point potential difference. The TEM waves, that oscillated back and forth at the speed of light (for that transmission line) slowly diminish to nothing as the potentials on each plate become equal and opposite.

Radio amateurs have another name for conducting plates spaced apart with voltages applied: we call them capacitors. And when we apply a voltage to capacitors, we are taught that a “displacement current” flowed through the insulating medium between the plates - the capacitor’s charging current. Current in an insulator? It doesn’t exist! But - - - a TEM wave DOES. That’s why you find all the exponential terms in capacitor (or inductor) theory for currents and voltages: the reflections cancel the incoming driving voltage (current in inductors) proportional to the difference between the applied and reflected potentials. After a time, these are equal, the reflected TEM waves cease, and the capacitor (or inductor) is at steady state, charged, (or magnetised if we’re talking about currents). Any current flowing into the parallel wire or plates manifests as the magnetic component of a TEM wave: and this effectively puts paid to Maxwell’s Equations Displacement Current theory!

If this explanation of exponential charging currents and other related phenomena interests you, you can find far more on this subject by reading the work of Ivor Catt: his demolition of Maxwell’s equations is a fascinating and easily understandable explanation of many practical electrical effects using simple examples that any competent electrical / electronic technician can digest.

Perhaps this is how a “capacitance hat” on an antenna produces much more radiation, via TEM waves?

A selection of Ivor Catt’s work include:

Electromagnetic Theory, C.A.M. Pub., 1983, ISBN 0-906340-03-9

Death of Electric Current: Wireless World Articles and Letters, C.A.M. Pub., 1987, ISBN 0-906340-06-3
The Catt Anomaly: Science Beyond the Crossroads, Westfields, 2001, ISBN 0-906340-15-2

Data and Information

This information is for guidance only – you MUST comply with your local Regulations! I have included information about AC power systems and conventions, as equipment can often be bought from overseas nowadays and it’s important that we know exactly how to connect it to our “home” supplies - but suffice to say, if there’s any doubt - - - GET PROFESSIONAL, COMPETENT HELP BEFORE YOU CONNECT TO ANY ELECTRICAL SUPPLY!

Wire Information...

AWG Table

1 AWG is 289.3 thousandths of an inch
2 AWG is 257.6 thousandths of an inch
5 AWG is 181.9 thousandths of an inch
10 AWG is 101.9 thousandths of an inch
20 AWG is 32.0 thousandths of an inch
30 AWG is 10.0 thousandths of an inch
40 AWG is 3.1 thousandths of an inch

The table in ARRL handbook warns that the figures are approximate and may vary dependent on the manufacturing tolerances. If you don't have a chart handy, you don't really need a formula.
There's several handy tricks:
Solid wire diameters increases/decreases by a factor of 2 every 6 gauges,
" " " " " 3 every 10 gauges,
" " " " " 4 every 12 gauges,
" " " " " 5 every 14 gauges,
" " " " " 10 every 20 gauges,
" " " " " 100 every 40 gauges,

With these, you can get around a lot of different AWGs and they cross check against one another. Start with solid 50 AWG having a 1 mil diameter.
So, 30 AWG should have a diameter of ~ 10 mils.

36 AWG should have a diameter of ~ 5 mils.	Dead on.
24 AWG should have a diameter of ~ 20 mils.	Actually ~ 20.1
16 AWG should have a diameter of ~ 50 mils.	Actually ~ 50.8
10 AWG should have a diameter of ~ 100 mils.	Actually ~ 101.9

If you are more interested in current carrying ability than physical size, then also remember that a change of 3 AWG numbers equals a doubling or halving of the circular mills (the cross sectional area). Thus, if 10 AWG is safe for 30 amps, then 13 AWG (hard to find) is ok for 15 amps and 16 AWG is good for 7.5 amps.
The wire gauge is a logarithmic scale base on the cross sectional area of the wire. Each 3-gauge step in size corresponds to a doubling or halving of the cross sectional area. For example, going from 20 gauge to 17 gauge doubles the cross sectional area (which, by the way, halves the DC resistance).
So, one simple result of this is that if you take two strands the same gauge, it's the equivalent of a single wire that's 3 gauges lower. So two 20 gauge strands is equivalent to 1 17 gauge.

Wire Gauge Resistance per foot

4	.000292
6	.000465
8	.000739
10	.00118
12	.00187
14	.00297
16	.00473
18	.00751
20	.0119
22	.0190
24	.0302
26	.0480
28	.0764

Current ratings

Most current ratings for wires (except magnet wires) are based on permissible voltage drop, not temperature rise. For example, 0.5 mm^2 wire is rated at 3A in some applications but will carry over 8 A in free air without overheating. You will find tables of permitted maximum current in national electrical codes, but these are based on voltage drop. Here is a current and AWG table.

AWG	dia mils	circ mils	open air Amp	cable Amp	ft/lb bare	ohms/1000’
10	101.9	10380	55	33	31.82	1.018
12	80.8	6530	41	23	50.59	1.619
14	64.1	4107	32	17	80.44	2.575

Mils are .001". "open air A" is a continuous rating for a single conductor with insulation in open air. "cable amp" is for in multiple conductor cables. Disregard the amperage ratings for household use.
To calculate voltage drop, plug in the values:
V = DIR/1000
Where I is the amperage, R is from the ohms/1000' column above, and D is the total distance the current travels (don't forget to add the length of the neutral and live together - ie: usually double cable length).
Design rules call for a maximum voltage drop of 6% (7V on 120V circuit).

Resistivities at room temp:

Element	Electrical resistivity (micro-ohm-cm)
Aluminium	2.655
Copper	1.678
Gold	2.24
Silver	1.586
Platinum	10.5

This clearly puts silver as the number one conductor and gold has higher resistance than silver or copper. It's desirable in connectors because it does not oxidise so remains clean at the surface. It also has the capability to adhere to itself (touch pure gold to pure gold and it sticks) which makes for very reliable connections.

Thermal conductivity at room temperature

	W/cm²/°C
silver	4.08
copper	3.94
gold	2.96
platinum	0.69
diamond	0.24
bismuth	0.084
iodine	43.5E-4

This explains why diamonds are being used for high power substrates now. That's man-made diamonds. Natural diamonds contain sufficient flaws in the lattice that the phonons (heat conductors) get scattered and substantially reduce the ability to transport the heat.

Copper wire resistance table

AWG	Feet/Ohm	Ohms/100ft	Ampacity	(mm$^{2)}$	Meters/Ohm	Ohms/100M
10	490.2	.204	30	2.588	149.5	.669
12	308.7	.324	20	2.053	94.1	1.06
14	193.8	.516	15	1.628	59.1	1.69
16	122.3	.818	10	1.291	37.3	2.68
18	76.8	1.30	5	1.024	23.4	4.27
20	48.1	2.08	3.3	0.812	14.7	6.82
22	30.3	3.30	2.1	0.644	9.24	10.8

24	19.1	5.24	1.3	0.511	5.82	17.2
26	12.0	8.32	0.8	0.405	3.66	27.3
28	7.55	13.2	0.5	0.321	2.30	43.4

These Ohms / Distance figures are for a round trip circuit. Specifications are for copper wire at 77 degrees Fahrenheit or 25 degrees Celsius.

Wire current handling capacity values

mm2	R/m-ohm/m	I/A
6	3.0	55
10	1.8	76
16	1.1	105
25	0.73	140
35	0.52	173
50	0.38	205
70	0.27	265

Mains wiring current ratings

In mains wiring there are two considerations, voltage drop and heat build up. The smaller the wire is, the higher the resistance is. When the resistance is higher, the wire heats up more, and there is more voltage drop in the wiring. The former is why you need higher-temperature insulation and/or bigger wires for use in conduit; the latter is why you should use larger wire for long runs. Neither effect is very significant over very short distances. There are some very specific exceptions, where use of smaller wire is allowed. The obvious one is the line cord on most lamps. Don't try this unless you're certain that your use fits one of those exceptions; you can never go wrong by using larger wire. This is a table apparently from BS6500, reproduced in the IEE Wiring Regs which describes the maximum fuse sizes for different conductor sizes:

Cross-section CSA / area	Overload current rating
0.5mm^2	3A
0.75mm^2	6A
1mm^2	10A
1.25mm^2	13A
1.5mm^2	16A

Typical current ratings for mains wiring

Inside wall

mm^2	Amps
1.5	10
2.5	16

Equipment wires

mm^2	A
0.5	3
0.75	6
1.0	10
1.5	16

2.5	25

Wire sizes used in USA inside wall

For a 20 amp circuit, use 12 gauge wire. For a 15 amp circuit, you can use 14 gauge wire (in most locales). For a long run, though, you should use the next larger size wire, to avoid voltage drops. Here's a quick table for normal situations. Go up a size for more than 100 foot runs, when the cable is in conduit, or ganged with other wires in a place where they can't dissipate heat easily:

Gauge	Amps
14	15
12	20
10	30
8	40
6	65

PCB track widths

For a 10 degree C temp rise, minimum track widths are:

Current	width in inches
0.5A	0.008"
0.75A	0.012"
1.25A	0.020"
2.5A	0.050"
4.0A	0.100"
7.0A	0.200"
10.0A	0.325"

Equipment wires in Europe

3 core equipment mains cable

Current	3A	6A	10A	13A	16A
Conductor size (mm)	16*0.2	24*0.2	32*0.2	40*0.2	48*0.2
Copper area (mm^2)	0.5	0.75	1.0	1.25	1.5

Cable ratings for 3A, 6A and 13A are based on BS6500 1995 specifications and are for stranded thick PVC insulated cables.

Insulated hook-up wire in circuits (DEF61-12)

Max. current	1.4A	3A	6A
Max. working voltage (V)	1000	1000	1000
PVC sheat thickness (mm)	0.3	0.3	0.45
Conductor size (mm)	7*0.2	16*0.2	24*0.2
Conductor area (mm^2)	0.22	0.5	0.75
Overall diameter (mm)	1.2	1.6	2.05

Common Cable colour Codes

American electrical contractors and electricians are required to follow the National Electrical Code (“NEC”) with regard to wiring colours. NEC imposes the following electrical wiring colour standards:

- •**Ground wires:** green, green with a yellow stripe, or bare copper
- •**Neutral wires:** white or gray

In theory, wiring conducting live current in the U.S. is permitted to be any other colour, although in practice, electrical contractors and electricians follow these local conventions:

- •**Single phase live wires:** black (or red for a second “hot” wire)
- •**3-phase live wires:** black, red and blue for 208 VAC; brown, yellow, purple for 480 VAC

Most countries in Europe, including the U.K., now follow the colour conventions established by the International Electrotechnical Commission (“IEC”). These colour conventions are as follows:

- •**Earth wires** (called ground wires in the U.S. and Canada): green with a yellow stripe
- •**Neutral wires:** blue
- •**Single phase live wires:** brown
- •**3-phase live wires:** brown, black and gray

Electrical wiring in Canada is governed by the Canadian Electric Code (“CEC”). The following wiring colour requirements apply in Canada:

- •**Ground wires:** green, or green with a yellow stripe
- •**Neutral wires:** white
- •**Single phase live wires:** black (or red for a second live wire)
- •**3-phase live wires:** red, black and blue

It’s important to remember that the above colour information applies only to AC circuits.

A.M. Frequency slots in Amateur HF Bands

All Frequencies in MHz

160 Metres: 1.885, 1.900, 1.945, 1.985 (USA)

1.850 (W. Europe)

1.933, 1.963 (UK)

1.843 (Australia)

80 Metres: 3.530, 3650 (South America)

3615, 3625 (in the UK)

3705 (W. Europe)

3.690 (AM Calling Frequency, Australia)

75 Metres: 3.825, 3.870 (West Coast), 3.880, 3.885 (USA)

60 Metres : 5.317

40 Metres: 7.070 (Southern Europe)

7.120, 7.300 (South America)

7.175, 7.290, 7.295 (USA)

7.143, 7.159 (UK)

7.146 (AM Calling, Australia)

20 Metres: 14.286

17 Metres: 18.150

15 Metres: 21.285, 21.425

10 Metres: 29.000-29.200

6 Metres: 50.4 (generally), 50.250 Northern CO

2 Metres: 144.4 (Northwest)

144.425 (Massachusetts)

144.28 (NYC-Long Island)

144.45 (California)

144.265 (Los Angeles, CA)

Other AM Activity Frequencies

AM activity is increasingly found on a number of other bands, in particular: 5317KHz, 7143KHz, 14286KHz, 21425KHz and 29000 - 29150KHz.
There are several local AM nets in the UK on top band.

FM Frequencies

For mobiles working into VMARS events, 2m calling in on 145.500MHz (S20) is usual, before QSY to a working frequency. At event locations where military equipment is in use, suggested FM "Centres of Activity" on VHF are 51.700Mhz, 70.425MHz (70.450MHz calling).

VMARS RECOMMENDED FREQUENCIES

3615 Khz	Saturday AM net 08:30 – 10:30
3615 Khz	Wednesday USB net for military equipment 20:00 – 21:00
3615 Khz	Friday LSB net 19:30 – 20:30
3615 Khz	Regular informal net from around 07:30 - 08:30
3577 Khz	Regular Sunday CW net 09:00
5317 Khz	Regular AM QSO’s, usually late afternoon
7073 Khz	Wednesday LSB 13:30; Collins 618T special interest group
7143 Khz	VMARS AM operating frequency
51.700 MHz	VMARS FM operating frequency, also rallies and events

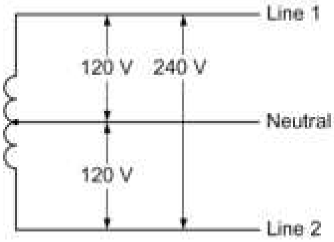
70.425 MHz VMARS FM operating frequency, also rallies and events

Electrical Supplies - Courtesy LEGRAND equipment

Common Electrical Services & Loads

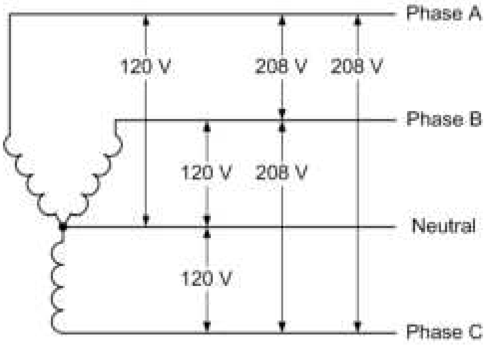
In the following drawings, the coil symbols represent the secondary winding of a utility service transformer or other step down transformer. Electrical code regulations in most jurisdictions require that the neutral conductor be bonded (connected) to the earth safety ground at the electrical service entrance.

Single Phase Three Wire



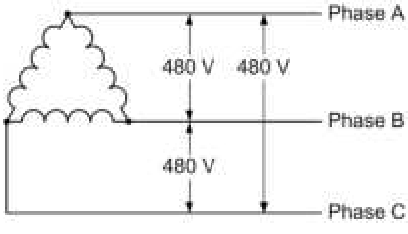
Also known as an Edison system, split-phase or centre-tapped neutral. This is the most common residential service in North America. Line 1 to neutral and Line 2 to neutral are used to power 120 volt lighting and plug loads. Line 1 to Line 2 is used to power 240 volt single phase loads such as a water heater, electric range, or air conditioner.

Three Phase Four Wire Wye



The most common commercial building electric service in North America is 120/208 volt wye, which is used to power 120 volt plug loads, lighting, and smaller HVAC systems. In larger facilities the voltage is 277/480 volt and used to power single phase 277 volt lighting and larger HVAC loads. In western Canada 347/600V is common.

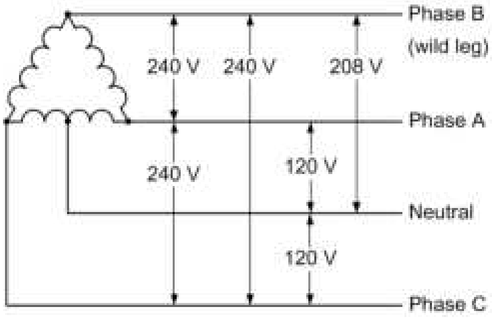
Three Phase Three Wire Delta



Used primarily in industrial facilities to provide power for three-phase motor loads, and in utility power distribution applications. Nominal service voltages of 240, 400, 480, 600, and higher are typical.

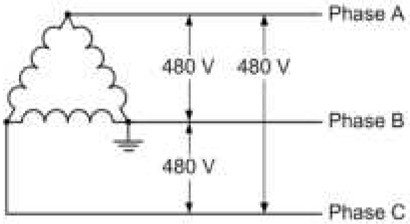
Uncommon Electrical Services

Three Phase Four Wire Delta



Also known as a high-leg or wild-leg delta system. Used in older manufacturing facilities with mostly three-phase motor loads and some 120 volt single-phase lighting and plug loads. Similar to the Three Phase Three Wire Delta discussed above but with a centre-tap on one of the transformer winding to create neutral for 120 volt single-phase loads. Motors are connected to phase A, B, and C, while single-phase loads are connected to either phase A or C and to neutral. Phase B, the high or wild leg, is not used as the voltage to neutral is 208 volt.

Three Phase Two Wire Corner-Grounded Delta



Used to reduce wiring costs by using a service cable with only two insulated conductors rather then the three insulated conductors used in a convention three phase service entrance.

International Electrical Distribution Systems

Description	L–N Vac	L–L Vac	Countries
1-Phase, 2-Wire 120 V with neutral	120	–	US
1-Phase, 2-Wire 230 V with neutral	230	–	EU, UK, Scandinavia
1-Phase, 2-Wire 208 V (No neutral)	–	208	US
1-Phase, 2-Wire 240 V (No neutral)	–	240	US
1-Phase, 3-Wire 120/240 V	120	240	US
3-Phase, 3-Wire 208 V Delta (No neutral)	–	208	US
3-Phase, 3-Wire 230 V Delta (No neutral)	–	230	Norway
3-Phase, 3-Wire 400 V Delta (No neutral)	–	400	EU, UK, Scandinavia
3-Phase, 3-Wire 480 V Delta (No neutral)	–	480	US
3-Phase, 3-Wire 600 V Delta (No neutral)	–	600	US, Canada
3-Phase, 4-Wire 208Y/120 V	120	208	US
3-Phase, 4-Wire 400Y/230 V	230	400	EU, UK, Scandinavia
3-Phase, 4-Wire 415Y/240 V	240	415	Australia
3-Phase, 4-Wire 480Y/277 V	277	480	US
3-Phase, 4-Wire 600Y/347 V	347	600	US, Canada
3-Phase 4-Wire Delta 120/208/240 Wild Phase	120, 208	240	US
3-Phase 4-Wire Delta 240/415/480 Wild Phase	240, 415	480	US
3-Phase Corner-Grounded Delta 208/240	–	240	US
3-Phase Corner-Grounded Delta 415/480	–	480	US

Note: regional variations may exist: if in ANY doubt, consult your Electrical Supply Authority.

Hot Iron 104

May / June 2019

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Back issues availability

Back issues of the “electronic” editions, 89 to 103 are available. Please let me know which you would like and I’ll email them to you but please be patient, as I’m a bit pushed for time. This doesn’t include the “paper” editions; I believe they are being scanned and stored as PDF’s for easy emailing by an operator in Australia, but I don’t have any further information as to exactly which issues are available or when the scanning will be complete.

Scanning isn’t a particularly quick job (that’s experience talking....) and it’s very easy to miss or duplicate a page or two, but as soon as I have more information I’ll make sure it’s known to all.

Amateur Radio: relevance today

I had an interesting email recently that prompted me to take a sideways look at amateur radio today, in view of the easy and cheap world-wide communications offered by mobile phones and “voice over Internet protocol” (VOIP) systems.

As some of you might know, my interests lie in several areas: amateur radio, rock climbing, and motorcycling. I contacted a colleague who’s climbing in Spain, simply dialled the number on my mobile phone here in Northern England. Within seconds I was connected, and the call answered: the audio quality was at least equal to calling locally, crystal clear with no particular bandwidth limiting or distortion. It cost just £0.09p per minute! This call was followed by a VOIP call to South Africa, via a VOIP application (I refuse to call them “Apps”) on my mobile phone. Result - clear speech, no obvious bandwidth clipping, low noise. Cost? FREE, as it used my “already-paid-for” Internet connection - which is getting cheaper every year because fibre optic cable connections render copper cables unfashionable, and so prices are falling - the copper cable typical data rate of 6 - 10 Mb/s is plenty good enough for me.

This raises the question: what does amateur radio mean to me? As the above illustrates, not impromptu long distance communications at any time of day; no - to me, it's the chance to experiment with different circuits; to try old technologies built with modern components; to exercise my "grey matter" in finding optimum designs, fault finding bits of dud gear. I don't find the communications side of amateur radio particularly interesting - once I've tested a circuit, antenna, or whatever, made a contact or two, my interest wanes. If I want to talk with (non radio amateur) climbing friends I keep in touch with them all over the globe via mobile phone or VOIP communications.

That doesn't mean I don't understand or appreciate other interests in amateur radio. I noted recently Peter Parker's (VK3YE) amplitude modulated "OXO" transmitter, the much beloved (quite rightly) midget gem of QRP amateur operators. "Simple is as simple does" is an excellent motto, and producing quality A.M. with just 10 extra components is a triumph on Peter's part. Another fine example of this elegant thinking is Nyle Steiner's (K7NS) "Easy Ten" transmitter: 6 parts gets you onto 80m CW, and his antenna notes in the same article are priceless, in their simplicity and down-to-earth common sense (more on that later in "Antennas"). This illustrates another aspect of amateur radio: doing the most with the least.

The simple beauty of doing the job with the minimum of parts (and expense) is, to me, an "elegant" solution: consider, for instance, Pete Juliano's (N6QW) magnificent Arduino controlled SSB rigs, or the superb RTL / SDR receivers conjured up using very cheap and easily available parts that plug into the USB port on a PC. It's not just the technology; it's not just the complicated designs in the silicon that power these projects; it's the sheer visionary elegance and beauty of the final result, wringing superb results from a few components. That the components might have millions of transistors in them (in some cases) isn't the point: it's the amazing human ingenuity and imagination that makes the design stand out and work so well.

This being the Journal of the Constructor's Club the emphasis is on "construction" of radio equipment and ancillary support items. As you might know from previous Hot Iron editions, I readily accept the ability of CW / Morse to get the long distance "Dx" - but "Dx" communication doesn't particularly interest me, as outlined above. Morse code, generated by hand, cannot (to date) be accurately and reliably machine decoded, yet man has walked on the Moon, and machines are, at this moment, digging holes on the surface of Mars. There is a staggering gap just waiting to be filled here with asynchronous, random, hand made CW signals being interpreted reliably: such technology would have huge opportunities in communications systems for digging digital data signals out of noise and phase error faulted transmissions, or, for blind or deaf amateur radio operators. Yet, to date, nobody has come up with anything nearly as good as a human ear and brain for the job!

It's when simplicity meets ruggedness, the application demanding the utmost from the design, the power efficiency being engineered to give best performance in desperate situations, for a build price shaved down ("Muntzed") to the absolute minimum that impresses me - as a good example of that, I'll close this with a reference to the WW2 clandestine transceivers, "Parasets", "TRD's" and their ilk. To my mind they were perfect examples of amateur radio ingenuity shining through (these

WW2 sets were almost exclusively designed by radio amateurs in the armed services) under the most trying circumstances imaginable, that proved themselves (although the TRD's of the "stay-behind" British resistance groups were never used in anger - as far as we know...!) time after time and saved countless lives, by courageous operators who risked their own lives just turning them on. They had to be battery powered to avoid detection by cutting off the mains electricity, able to be set up, tuned and run into any "bit of wire" - even bedsprings - yet be reliable, simple to fix, small enough to be inconspicuous, yet still able to transmit and receive over path lengths of many hundreds of miles reasonably reliably. An article later in this edition shows some of the amazing engineering and marvellous spirit of the Dutch engineers who developed the EF50 as an illustration.

Puts the modern kilo-bucks all-singing, all-dancing, multiple "bells and whistles" transceivers (now a much promoted "fashion" item in the amateur radio World) in a different light, perhaps? This isn't to decry the amateurs who have no construction desire, nor facilities to construct electronic circuits and associated paraphernalia who buy in the R&D, engineering, manufacturing and testing of RF equipment: amateur radio is whatever you want it to be - so long as you stay within the terms of your license, it's entirely up to you!

George Dobbs, G3RJV

George Dobbs, G3RJV, now a "silent key", steered the G-QRP amateur radio movement for many years in a most professional yet personal manner. By both amateur and professional RF engineers, George was well respected; his designs illustrated elegance in every respect. He will be sadly missed; and I would recommend all Hot Iron readers look out for the future publication(s) of his circuits and articles. They shine like a beacon of common sense and practical application in this World of gimmick marketing, fake, invented "problems" and "snake oil technology" ("SNOT" is an old term for this malevolence). George proved incontrovertibly you don't *need* a professional receiver or transmitter to enjoy amateur radio: you don't *need* every option inside a receiver to be adjustable. To mimic a professional station's standards is a fine aim, but that's all: we are *amateur* radio enthusiasts, and George's work showed how *amateurs* could derive far more pleasure from building and operating home-made radio gear, rather than being merely operators of black boxes. No matter how technically (or otherwise) competent these black boxes are, the pleasure in operating an all "bought in" station soon palls - it's the satisfaction of building your own gear and de-bugging it that "educates, informs and entertains" (as Lord Reith declared) for far more years.

"Community" amateur radio

In the USA "part 15" radio transmitters are allowed, unlicensed, to transmit low power A.M. and F.M. in the broadcast bands, for not only voice (or other "sound" applications) but other useful things like baby monitors, security devices, remote controls, and the like. The Part 15 scheme is - as far as I'm aware - used for "Campus Radio" services and "Carrier Current" distribution, which means RF injected into the mains electricity cables to link into local broadcasting areas, limited to 61 metres around the originating transmitter. There is no specification as to what is transmitted: you can transmit whatever you wish, in any form you wish (but I assume you've got to observe copyright requirements?). USA readers who know different please feel free to tell me if this is truly the case, and how effective "Part 15" local radio services really are.

Perhaps to create a wider community based appreciation for radio amateurs, would a UK version of “part 15” operation suit? Amateur radio would become a useful and cheap radio communication in helping those who are alienated in this progressively uncaring society: the blind, disabled, lonely elderly people could have some personal connection via Part 15’s local radio service. Citizen’s Band in the UK did prompt some operators to become licensed amateurs, to escape the on-air lunatic asylum CB is here in the UK; but CB here was never a properly organised, voluntary radio service - here I’m thinking of voluntary Hospital Radio and the like - which in remote areas could be a very useful system indeed for disseminating community local information.

I confess to an interest myself here: in rock climbing and mountaineering circles in the UK, local conditions can vary a great deal within a few miles: the UK hills and mountains attract bad weather like a magnet, and as a radio amateur, I’d love to “stick it to the man” who profits from mobile phone telecoms (which are not always functional in mountainous regions, anyway) by using MW ground wave and / or VHF mountain top transmitters to give on-the-spot climbing condition reports. But... we don’t have any freedom to do that; and I suspect the low power outputs of “part 15” would need increasing a wee bit to get coverage. So... in true amateur style, why can’t we use “time division multiplexing” - transmit a some watts for a few minutes every hour? The average power (calculated per hour) would then be miniscule, representing no continuous interference threat to anyone?

Added to that, a “carrier current” service could use the existing mains electrical distribution system in a mountain village (where one power transformer feeds the entire community, so all in the village have free access) to alleviate the need for a medium wave antenna, not an insignificant beast, this could bring amateur radio to the attention of many more people, and attract more UK licensed amateurs to the bands?

The whole aspect of truly open, free speech, unlicensed radio operations here in the UK needs a proper dose of looking at!

The marketing of SSB...

I use “SSB” as an example of the commercialisation of amateur radio. I should add I have absolutely no objections or complaints about amateur radio use of SSB; if that’s what “flops your mop”, then so be it! But... there are many alternative modulation methods: to ascribe one as the “be all and end all” phone modulation method is short-sighted and inaccurate in my opinion.

The standard technique to make money is to find something many people find useful that they do for themselves, convince them that they can’t do it “properly” by quoting some imaginary (or semi-genuine) problem: in other words, guilt trip them into thinking they would be pariahs if they built their own gear, substantiated by inventing spurious “problems” - then sell back to them what they used to do for themselves. So, just what IS “sufficient carrier suppression”? If you reduce the carrier by -40dB, who says “that’s not enough”? WHERE did these figures come from, and by what authority were they given? Certainly, the elimination of heterodyne interference from carriers is a good thing: that’s why (I guess?) the A.M. slots - voluntarily I should add - are unique frequencies in each band. Operators therefore know “there be carriers here”, much akin to the dragons marked on Mediaeval maps!

I have a small ICOM HF transceiver; it has more twiddles, multi-function buttons, menus and other switches, display modes, than some of the machines I've repaired that made the silicon chips inside the darn thing! It's akin to a piano with a dozen pedals and five keyboards - you can't possibly use all of them "on the fly". Humans have two hands, two eyes: I'm not counting feet but it won't be long before somebody comes up with foot pedals for yet more functions on a transceiver!

In the heyday of amateur radio, you used CW or AM phone. The crowded bands of those days welcomed SSB; SSB started as a mathematical curiosity until amateurs engineered it and make it "do-able" by amateur constructors. Then the marketing men got wind of it, the hype began, and SSB suddenly became the best thing since sliced bread, but only if you bought it ready engineered in a commercial box. But still some phone operators kept using full carrier A.M.; so the vilification campaigns began, with forceful, overwhelming advertising budgets and marketing which eventually (almost) pushed A.M. into extinction - but not quite, thank goodness. That the bands were full to the brim in those days, yes: but nowadays? For local and not-so-local communications, A.M. is fine: IF you listen first, a good few kc's either side of your carrier that the frequency is clear, and your A.M. signal bandwidth is within the limits (bandwidth **and** band edges) set by your license, then off you go: you're not doing anything wrong; you're not an outcast; just keep to your license terms and everything's hunky dory.

It's a very simple matter for a CW transmitter to be converted to A.M. phone. Use a modulated supply to the driver and final; or the wonderfully simple "cathode modulator" that plugs into the key socket and away you go. A superb example of the simplicity (listen to Peter's joy in describing his design) A.M. affords is Peter Parker's (VK3YE) amplitude modulating an "OXO" QRP CW transmitter - 10 extra components and the job's done. The delight in Peter's voice as he demonstrates his TL431 voltage regulator A.M. transmitter (on U-Choob) says all.

Here's a quote from R.A. Penfold's book, "How to build advanced short wave receivers", published in 1977 by Babani, which neatly sums it up:

"*The reason that commercially produced equipment has increased in popularity is probably largely due to the high standard of finish that is achieved. It must be admitted that it is difficult for the home constructor to equal commercial standards in this respect, but if due care and attention is taken, it is possible to obtain a standard which will satisfy even the most critical. As far as performance is concerned, there is absolutely no reason why a home constructed receiver should not have a level of performance which is at least equal to that of a commercially built receiver of similar complexity. Furthermore, the home constructed receiver is likely to cost very much less than its ready made equivalent.*"

It doesn't *need* to be "state of the art" - but of course it could be! Just your best efforts, in a receiver or transmitter you built, and your "bit of wire" antenna is all you need to sample the true wonder of amateur radio. And that's something the marketing men can't put in a black box and flog back to you!

Hot Iron contributions & ideas

Hot Iron is your journal: I need you to tell me what you want to see, and for you to show me the wonderful gear you've built, or the intriguing antenna you've designed that runs all HF bands at 1:1 up to a kW, 95% efficient and doesn't need an earth plane the size of Wales.

Please send all your ideas, designs, thoughts, pictures, scribbles and questions to me (equieng@gmail.com) for Hot Iron. All are welcome; if you are writing to me "not for publication" please make that clear, otherwise I'll assume you're happy with me reproducing it in Hot Iron.

About email security

Hot Iron is distributed by email and I hold a list of email addresses to send it to, using the "BCC" (Blind Carbon Copy) emailing facility for privacy. Recipients have to ask to be included on the distribution list; I will NEVER put anybody's email address on the distribution list that has not specifically asked me to do so. I do not keep actual names or physical addresses for any recipients. Your email address will NEVER be used for any commercial purposes, sold, distributed or otherwise used for anything other than distributing Hot Iron; nor will any access by a third party be given.

SAFETY NOTE:

Circuits shown in Hot Iron may use potentially lethal voltages. It is your responsibility to ensure your own – and anybody else's – safety if you build or use equipment that employs hazardous voltages, currents, power or any other injurious element. If in any doubt, you MUST get a competent person to check and approve the circuits, barriers and provisions to avoid any injury and electric shock. You MUST comply with your local Electrical Regulations and Safety Regulations.

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If in doubt, don't do it: get professional, competent, qualified expert advice and help.

Tim's Topics

A new project - maybe?

The advent of cheap and capable computer driven DDS style RF oscillators for a receiver, means that analogue multi-band RXs are a thing of the past! Consequently I am always on the look out for other interesting projects to add to my line-up. A good customer in Wales suggested I might consider a small Amplitude Modulated (AM) transceiver for 10m – hence these deliberations! It would need better selectivity than a single plain Tuned RF stage so I first considered a fairly conventional superhet; the usual IF range of up to a few MHz would mean a first tunable local oscillator probably over 20 MHz – not going to be frequency stable! Instead I considered a 'converter' ahead of the main tunable RX which would also provide the selectivity. This appeals because the converters could be for 'any single band' with different crystals driving its mixer – so allowing for the keen 40m AM fraternity. So what form should the main tunable and selective RX take? It could be a superhet but it then becomes triple conversion overall – complex and with potentially many unwanted spurs! The obvious choice is a Regen RX – simple with much gain and good stability if its frequency range is in the low MHz range. The Regen allows reception of CW or SSB as well as AM which might be an added attraction. Some might say they are fiddlesome and difficult to use – a fair criticism unless specifically addressed; so this needs a restricted tuning range, Regen stage gain control (either side of the critical point at which oscillation starts) without a change in frequency and which is very smooth. These are (normally) addressed by using a low MHz Regen stage frequency and a control pot with added presets on its 'top' and 'bottom' leads to turn it into a 'fine' form Regen control. A tuning offset can also be added just in case that is needed when switching to transmit, this is because the Regen oscillation needs to be quite large for that and this might lead to a small jump in frequency when it is forced to oscillate somewhat more strongly! (I happen to know that our Editor has been investigating Regens with automatic gain control, so maybe he will come up with other solutions, especially for really weak CW that appear challenging for a conventional Regen!) This project's potential block diagram (Fig 1) looks like this:-

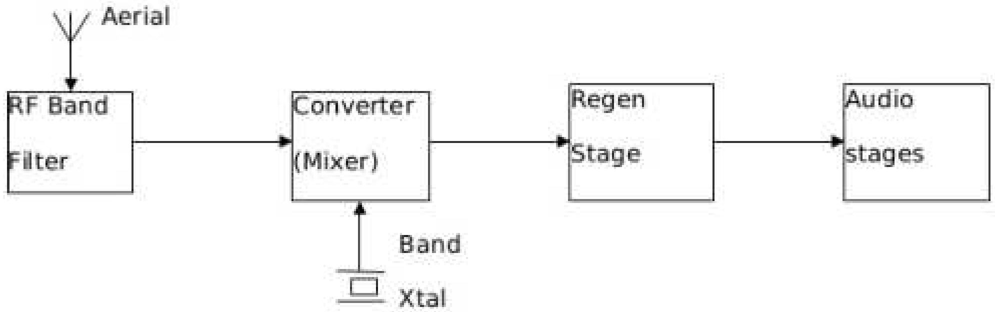


Fig 1 – RX Block Diagram

There are two obvious choices for the modulation method to produce AM – conventional superimposition of the audio onto the RF final's supply rail (plate modulation) or superimposing the audio onto the gate of a MOSFET RF final stage which is nearly as good at producing AM as plate modulation. The latter is much easier nowadays because suitable audio power transformers are hard to find, and it needs an audio driver stage capable of half the carrier power!

A more interesting design point is how to implement the reversed RF signal flow through the RX converter's mixer? My initial thought was to use a SA612 mixer with its integral oscillator stage; and to then switch the inputs and outputs using an extra relay controlled by the PTT switch. Not very elegant and the in/out impedances are a bit high for comfort when working on 10m for transmit! How about diode or FET mixers which can be arranged in an inherently bi-directional arrangement to avoid the in/out switching problem? They also usually operate at nearer 50 Ohms in the conventional twin transformer doubly balanced arrangement. Mixers using switches like the fast 74HC4066 don't need huge driving power and can be driven by an easy crystal oscillator and chain of digital gates for best alignment of the desired complimentary driving waveforms and their sharp edges.

References on such mixers suggest that proper wide band termination of in and out ports is highly desirable to avoid unwanted responses, so maybe one should add small resistive attenuators (or maybe diplexers) on in and out ports; this would normally lead to a noticeable loss of sensitivity, but don't forget that the RX aerial signal is coming via the transmitter bypass route during reception – so why not give this route a strong wide band RF amplifier which will make up for the loss of gain in subsequent RX stages (RF filter, mixer and possibly two attenuators). This leads to a partial block diagram as in Fig 2. Problem solved! Could this scheme work?! If it does, the RX might be called the Hurst and the TX will be the Heale.

Tim G3PCJ May 4th 2019

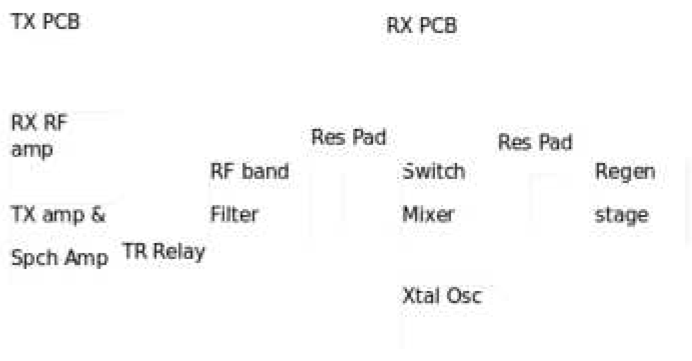


Fig 2 – Partial overall block diagram

Apologies for the diagram - the outline boxes are very feint; conversion from Microsoft "docx" format to "jpeg" was nigh on impossible due to the way Windoze handles graphics, and I didn't have the time to re-draw the diagram out. You can see Tim's reasoning of the bi-directional nature of the design; and yes, I'll be looking at auto-regen detection of weak signal CW in the future.

Audio Topics

Microphones...

For those who like to build their own microphones for commercial equipment, or repair "bargain buys", an absolute gem of a web page is by G4WPW: https://www.qsl.net/g4wpw/date.html

My sincere thanks to G4WPW for his magnificent work and the QSL.net group for presenting the information in the public domain (internet).

You'll find hundreds of mic schematics, notes and details referring to just about every commercial transceiver - a veritable gold mine of useful information. And for me, this is the core spirit of amateur radio: helping others, do-it-yourself and building a network of co-operation.

Copper Water pipe fittings and sweet sounds

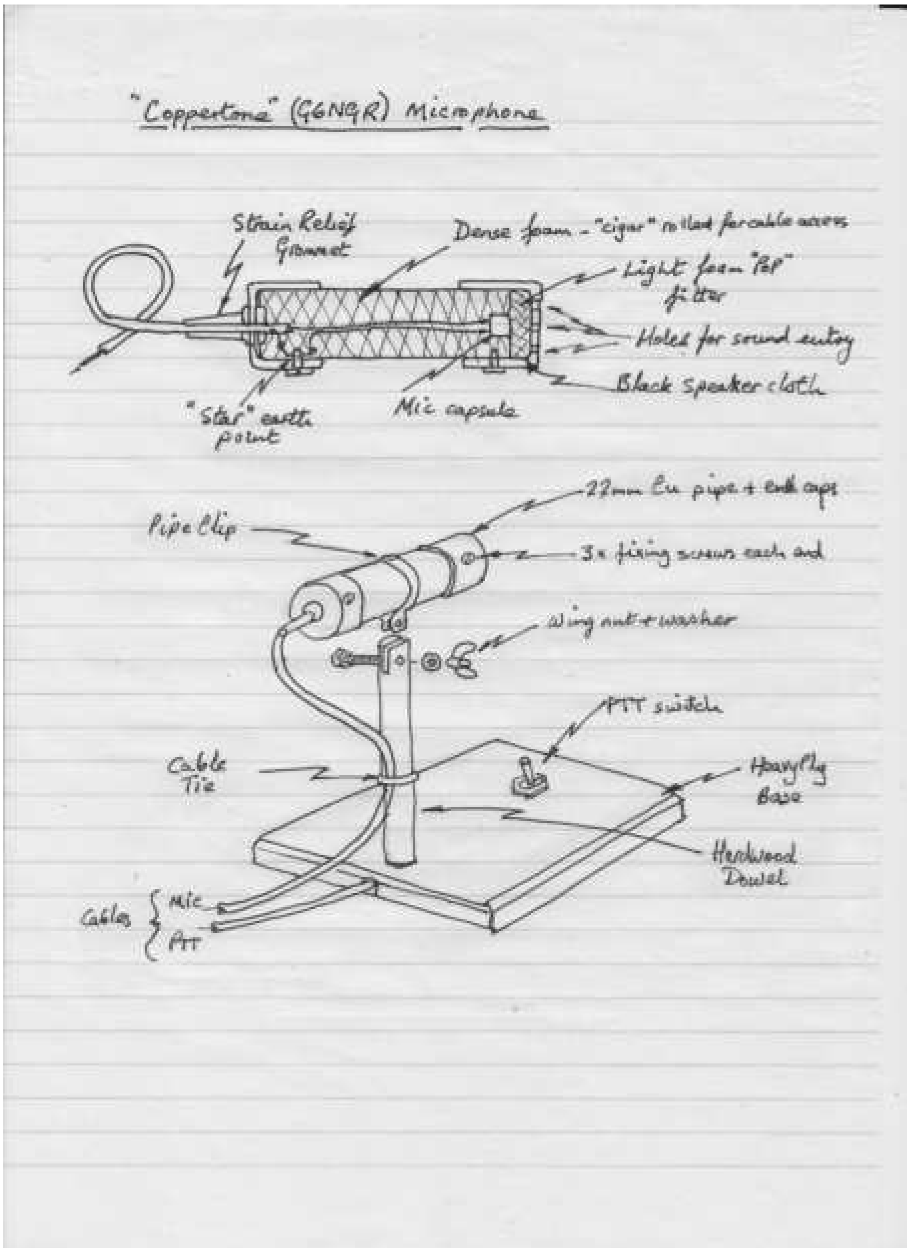
A microphone deliberately designed and engineered to have an "old time" sound is the "Copperphone" from Placid Audio (https://www.placidaudio.com/products/copperphone/). If you look closely at the beast, you'll observe it's akin to a short length of copper water pipe with "end feed" caps on the ends, the caps held in place by annular screws - no heavy soldering and easy servicing. The holes in the front cap can be marked and drilled with elementary geometry, and a small piece of black speaker cloth glued in place inside the cap makes for a neat finish. Polish the outer metal with some auto chrome polish, then apply some well thinned clear nail varnish to protect the now shiny copper surface.

The beauty of this design that caught my attention for radio amateurs isn't the "old time" engineered sound the Placid Copperphone achieves, it's the superb "all-over" electrical shielding the construction creates: this solid metal cover gives just about the best Faraday screen money can buy. You are, after all, generating μV to mV audio signals in close proximity to watts of RF; it's a good idea to make your microphone as "RF proof" as you can. If you build your own version of the "Copperphone" you can experiment with foam damping, positioning and other such variables until you get the quality of audio you want - mics are much like antennas, being a similar "black art", requiring a fair bit of cut and try, but always a pleasure to build and use.

Internally, an electret microphone capsule is supported with a tight fitting, "cigar rolled" dense foam plug, which damps and centres the electret, provides rear sound absorption yet allows tiny rearward air flow to avoid damping the diaphragm, with consistent yet flexible shock absorbing support. The front face of the electret will need covering with a few millimetres of light foam to create a "windshield", eliminating the breathy "pops" found on certain letters, "P" and "D" for instance. If you're prone to s-s-sibilance, then a double layer of front foam and a touch up on the mic gain can help.

For those on the tightest of budgets, an ear bud scrounged from the lightweight earphones now found - literally, often discarded - makes a good dynamic microphone, in place of the electret; but remember that you'll need a low input impedance input amplifier of about 80 to 350 ohms, pointing to either a common base or High Z input amplifier slugged with an input resistor to get the best results from an "earbud" dynamic mic. The electret has an internal pre-amp and needs "phantom" powering, the ear bud, no; however for ultimate sound quality mic pre-amplifiers look to: http://sound.whsites.net/index2.html, and have a wander through some of the finest audio pages you’ll find on the planet. Don’t forget too that the microphone amplifier is the best place to apply treble roll off and bass cut with feedback capacitors and coupling capacitors, respectively, and make sure you use single point “star” earthing wherever possible to eliminate earth loops.

A brass “Ring” type pipe clip very neatly supports the copper pipe body, which can be easily set into a slotted piece of dowel using the Ring clip securing screw hole, matching bolt, washers and a wing nut, morticed in a small plywood plinth, nicely sanded, chamfered, painted black, looks the real deal in any amateur shack - and costs but little.



For the most “rigorous” microphone enthusiasts

Don’t say I didn’t warn you. Acoustic design makes RF antenna analysis look like a Sunday School picnic! The maths is full-on abstruse, things like the “acoustic Ohm” and similar, commonplace. Yes, mechanical objects have resistance, capacitance and inductance, believe it or not - it’s the only way you can realistically analyse an acoustic system.

Right, that’s the hard bit done: I refer you to a web page where you can download all you’ll ever need to know about microphones. It was originally written in the 1950’s by that wondrous organisation, the BBC, and, whatever you consider their faults, poor quality sound is NEVER one of them - it is, literally, World Class sound engineering, so is well worth a good dose of looking at.

I’ve always made my own microphones by thinking of them as loudspeakers in reverse: you’re aiming for an infinite baffle, so the sound has no rear reflections, yet anything infinite in this World isn’t really a practical proposition so we use damping material behind the loudspeaker and a nice box for it to live in, so the desired sound is squirted out where we want to hear it - a direct transposition into our ears of the original voice, music or whatever.

You want the full experience of microphone design? You want to know the real engineering “ins and outs” of the acoustic / electromechanical interface device? Here:- https://www.bbceng.info/additions/2016/BBC%20Engineering%20Training%20Manual%20-%20Microphones%20(Robertson).pdf

This is an openly available public document on the web; and is truly a *magnum opus*. Doubt ye not; this is THE full story of microphones. Well, I did warn you...!

Receivers

RF amps and my memory

The simple transistor RF amplifier shown in Hot Iron #103 has some shortcomings: Tim Walford nudged my grey cells and remarked on the choice of a resistor as collector load as not able to give an adequate output swing. When I wrote the piece I had a picture in my mind of a test rig I used to measure the ft of RF power transistors: this was the circuit given in Hot Iron #103, but with a subtle difference - which I was reminded about whilst chatting with a colleague from those halcyon days.

Those of you who have had the (somewhat dubious) luxury of running 807 tetrodes at full whack will recall the anode cap often had a low value resistor with a few turns of wire wound over it to suppress parasitic oscillations - 807’s were particularly prone to “taking off”. The resistor / inductor put a VHF lossy element right on the anode connection, to kill any VHF oscillation - and the same technique was used to stop power transistors in a test rig from “hooting”. Only this was done by using a *wire wound resistor* rather than a winding over a resistor body, the wire wound resistor features inbuilt inductance and resistance: so I got two components for the price of one.

This was the resistor I remembered - it was in fact the collector choke load and parasitic stopper for the common base RF amplifier. The moral of this tale is that the common base RF amplifier shown in Hot Iron #103 must have an inductive collector load, be it a choke or a transformer!

CW trainer for the blind

The reliable and low cost pin drive printers of a year or two ago prompted me to think of Braille patterns: surely the pin drive mechanism could be used to present Braille characters to the blind amateur radio operator? The reasoning is this: that some amateurs become progressively deaf to a certain extent in their later years; and a pin drive Braille mechanism would mean more years of amateur radio for those blind operators who’s hearing is failing, to whom amateur radio is a lifeline.

Of course, this all points at that favourite hobby-horse of mine: the accurate decoding of hand sent Morse. I'm not of the generation who happily talk of modern microcontroller technology and the like; I find the manufacturer's programming suites so convoluted, inaccessible and assuming the user has full understanding of the terms and features of the software to be unusable by the amateur radio enthusiast. Some of the real experts (hiya, Terry...) find the programming software so far "over the top" as to be a real pain in the arris; combine that with the design of "AI" (artificial intelligence) to decode hand Morse in real time, well, it just isn't my field of interest or expertise.

Samuel Morse didn't design his telegraphy system to be a hand driven system, he had electro-mechanical designs to create the code's dits, dahs, and spaces; at the receiving end, to decode them and print the decrypted letters on paper tape. But, humans being what they are, Morse's operators soon learned the sound that represented particular letters - and the rest is history. Admitted the problem of decoding in real time sounds simple enough until you actually start considering how to differentiate between slower sending, atmospheric / ionospheric distortions, but it *must* be possible somehow?

More exciting perhaps...

I heard on a BBC Radio 4 programme about speech synthesis directly from brain neuron signals in the cortex, from a research team in California (where else?). This really is an amazing breakthrough: with simple skin electrodes picking up the appropriate signals from the brain - already an established technology in medicine - they can reproduce in words what is being thought about! I assume you must "think" the words (I dread to think what it would make of some of my thoughts...!) and it uses successive approximation to "learn" the pattern of your individual brain waves. The programme illustrated the unit working: it's first translation sounded muddled: like a drunk with a heavy cold trying to order an Italian meal. The second iteration was far clearer: it just sounded a bit muffled. The third iteration was spot on, perfectly readable. Between each iteration, the researchers tweaked the settings, but the comment was that once the pattern had been learned for one individual, it got it right 90% of the time.

What an achievement! And how useful for people paralysed from the neck down, trapped in a body they can't use? Those without full speech capabilities (for whatever reason) being able to communicate clearly and reliably? The mind literally boggles: this is a wonderful advance for humanity. Until the Government gets hold of it and uses it in Police cells, that is... shades of Huxley's "Brave New World" and Orwellian "Thought-Crime" perhaps?

But what a superb auto Morse keyer - just think the words and there they go! I wonder if it can be engineered in reverse? The dits, dahs and spaces translated into electrical impulses and fed into the brain to make letters sound inside your head? Wow!! You heard it in Hot Iron #104 first!

SSB and all that... the DDS VFO strikes again

Reproduced from an article in QST, November, 1952 - and how the IF carrier insertion oscillator is considered NOT the best way to do the job! The article concludes that SSB and full carrier AM can be used in "round table" on-air discussions with little, if any, problems.

More to the point perhaps, is the ready availability and use of DDS / microcontroller VFO's - which could very easily provide signal frequency carrier re-insertion at the receiver. One neatly packaged (die cast box is a good idea) VFO would cover the needs of dozens of receivers in an amateur context, thus relieving the need for individual carrier reinsertion oscillators in every receiver, and give a good indication of the stability or the receiver's local oscillator, too.

Here is the article as presented on the archive web page, and many thanks to QST for this:

"Practical Pointers on Two Methods of Operation

By Paul N. Wright, W9 OHM

Reinserting the Carrier:

In a superheterodyne receiver, the carrier may be replaced by injecting the carrier from a local oscillator at the i.f. frequency into the. i.f. section of the receiver, or by injecting the carrier from an oscillator at the signal frequency at the antenna terminals of the receiver.

If carrier injection from the b.f.o. in the receiver is used, the receiver should be adjusted as follows: First, with the receiver set up in the regular a.m. position, tune the bandspread dial for maximum deflection of the S-meter from the s.s.b. signal. Do not touch the bandspread dial after this. Next, reduce the r.f. gain to zero and increase the audio gain to maximum. Bring up the r.f. gain until the signal is heard at a comfortable level; then turn on the b.f.o. and carefully adjust the frequency of the b.f.o. until the voice sounds natural. If this procedure is followed closely, little difficulty should be experienced tuning the signal, regardless of which sideband is being transmitted.

In using the b.f.o. method of carrier insertion, it should be pointed out that practical reception of s.s.b. signals depend upon the stability of the h.f. oscillator in the front end of the receiver, as well as the stability of the beat oscillator that supplies the carrier. Any frequency change in the h.f. oscillator produces the same effect as changing the frequency of the transmitter on the other end. The h.f. oscillator in most receivers is fairly stable on the lower frequencies. However, at frequencies above 5 Mc. the stability of many h.f. oscillators leaves much to be desired, when thinking in terms of the stability required from these oscillators when using i.f. carrier insertion.

In using carrier insertion at the signal frequency from an external oscillator, the procedure is as follows: With the receiver set up in regular a.m. position, first tune the bandspread dial for maximum indication of the S-meter from the signal. Then adjust the frequency of the external oscillator to the approximate frequency of the incoming signal, and increase the amplitude of carrier injection to a point that approximates the amplitude of the s.s.b. signal. When this point is reached, the S-meter will no longer swing with modulation. Carefully adjust the frequency of the external oscillator until the voice sounds natural. Rock the receiver bandspread dial back and forth across the carrier. You will easily be able to tell which sideband is being transmitted. As you leave the carrier, on one side the audio will drop off; as you swing on the other side, the audio will come up. The more selective the receiver, the more pronounced this effect.

An s.s.b. signal suffers a certain amount of nonlinear distortion when demodulated by a linear rectifier. The amount of distortion produced is relative to the modulation depth of the injected carrier by the s.s.b. signal. Increasing the carrier injection above the 100 per cent modulation point will reduce the nonlinear distortion in the detector to a negligible amount. Increased carrier also helps swamp out adjacent channel QRM and generally to improve the signal-to-noise figure.

The advantages of front-end carrier insertion are:

1) Stability of the received signal.

2) S-meter reports may be given on s.s.b.

3) It makes round tables including s.s.b. and a.m. stations practical, since the receiver remains in the a.m. position at all times.

4) Oscillators in the s.s.b. exciter may be used to furnish the stable carrier to the receiver, providing consistent "on frequency" operation of the transmitted signal.

Point 4 is very important from the standpoint of pleasurable operation and good operating practice of a s.s.b. station. Since the oscillators in the s.s.b. exciter furnish the carrier to the receiver, the transmitted signal is automatically on the same frequency as the received signal. This means that only one oscillator has to be adjusted to get both the receiver and the transmitter on the same frequency. Of course, any large frequency shift would require resetting of the receiver bandspread dial. This method, if universally adopted, would make practical operation of single sideband as simple as operating an a.m. transmitter, by eliminating the extra tuning procedure. With amateur s.s.b. operation still in its infancy, elimination of a tuning operation may not seem of much importance. However, as new s.s.b. stations come on the air and spread out on the bands, the elimination of a tuning operation becomes more important. If all s.s.b. stations involved in a voice-controlled round table were using their exciter VFO for carrier insertion to the receiver, they would remain on the same relative frequency. Using this system, any drift occurring in the local VFO, or drift occurring in a VFO on the other end, is compensated for while listening. It would not be necessary to halt the entire round table QSO every so often and realign on somebody's frequency. Proof of the need for the adoption of this operational method can be obtained by listening to any large s.s.b. round-table QSO on 75 meters. Note the confusion and the lost time caused by off-frequency operation. Then, too, it is rather difficult to impress anyone that single sideband has come of age and can step in the same ring with a.m. after they listen to that sort of operation.

There is another advantage to VFO carrier insertion. Those who have used it have found that when they are in QSO using voice-control break-in operation, they can control the QRM situation very nicely. If they hear QRM come in on the low side, they merely move the VFO higher until the QRM disappears. If the QRM comes in on the high side, they move the VFO down until the interference disappears. With the tuning ease afforded by this system, rapid QSY is practical, providing a most effective way to dodge QRM.”

A valve that has saved lives

The following article is presented with great thanks to Henk Zwier, Robert van der Zaal, and Tim Walford. It was translated from the original in QRP Newsbrief # 169 by Robert van der Zaal.

I also thank the Dutch Philips engineers, WW2 clandestine radio operators and all others involved in the Allied radio communications during WW2. Every time I have visited the Netherlands I have always been mightily impressed by the industry, ingenuity and determination of the Dutch nation, who make the absolute most of their compact country - and in technical engineering and artistic appreciation, are truly superb.

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“THE SECRET RADIO VALVE EF50
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“the valve that made the war got won”
By Henk PA3CLL

Each radio amateur that got active after the Second World War no doubt has come across famous transmitting valves like the 807 and 813. These, then, modern valves could be found in virtually all British and American built transmitters. Without these valves the Allies would never have been able to win the war. Less known but possibly even more important was the development of the EF50, also known as VR91, CV1091 or ARP35. Later versions are the EF54, EF55 and EF90.

Officially, Philips developed the EF50 as to be used in the 45MHz IF of television receivers. This was however a disguise as the valve was developed for use in English radar equipment, like the “ground mapping radar” H2S. In an earlier talk I mentioned the importance of the H2S radar, a system considered to be the first “airborne” radar. H2S was of crucial importance in combating the German “U- boats” and allowed the RAF and USAAF to “blind” bomb targets in poor visibility.

In the 1930’s, before WW II that is, most radio communication took place below 30MHz but due to a low amplification factor and a high noise level the then available valves were poor performers in the higher range of the spectrum. The two main reasons for these shortcomings were capacitance and auto induction caused by the construction of the valves. Another important reason turned out to be the speed of electrons which appeared to be lower on higher frequencies. On, say, 3MHz an electron moves between cathode and the grids in about 1 nanosecond. Around 100MHz this “leg time” becomes an important factor resulting in a lower impedance and amplification factor of the valve. If the impedance on, say, 10MHz is 4kΩ, on 40MHz it has dropped to 1kΩ and on 80MHz to only 250Ω.

Research in VHF valve techniques
In the 1930’s a lot of research was done by Philips Netherlands and her English branch Mullard aiming at improving the performance of valves on higher frequencies. Before WW II Philips also cooperated with Siemens and Telefunken when developing valves for VHF. This all resulted in valves of the EF series like the EF11, EF12 and EF15. Philips solved the problem of the internal capacitance by mounting the anode sideways, leading to shorter internal wires to their pins.

TV and the secret radar valve
In 1936 England was well on its way in developing “modern” television by using electronically scanned images. The sound carrier was at 41.5MHz, the picture carrier at 45MHz. The then available valves lacked in performance, especially in amplification, this leading to the need for valves with a higher amplification above 30MHz. This was obviously not just for TV as the development of RADAR had become of utmost importance.

In those years the English already had quite some experience with, what was then called, “Radio Direction Finding” (RDF) and later called “Radar”. Radar research took place at Bawdsey Manor in Essex, mainly in cooperation with Mullard (Philips!) Valve Company and the British government. Mullard approached the Philips HQ in Eindhoven asking whether there was a valve available with the required amplification in the VHF area. To disguise the actual application in Radar technology Mullard referred to the valve as to be used in TV equipment. A special valve, developed for that purpose in the late 1930’s, was introduced in 1939 and was: the EF50!

The EF50 was developed by Professor Jonkers of Philips Eindhoven and by PYE Electronics in England suggesting a full metal shielding around the glass. The EF50 was the first glass valve with all pins at the bottom, matching the socket. This way the use of a top connection for the anode was avoided. Teething problems occurred however in making the valve “gas tight”.

The secret RADAR receiver

In the end the EF50 was used in a number of systems. In 1939, the first "airborne" radars were equipped with an IF strip of EMI. By sheer coincidence one of the project managers involved in the Radar project discovered the 45MHz TV receiver strip of PYE. This strip showed a much better sensitivity with a much lower noise figure. With six EF50's in a row the strip could serve as an off-the-shelf fixed IF receiver for Radar. Other advantages were the lower price and lower weight. Next to the poorer performance, amplification and noise wise, the low production capacity of EMI did not allow the production of sufficient IF strips. PYE (Philips) had a sufficient production capacity but….

Philips helps PYE and the English:

Early 1940 the British authorities were worried about the availability of the EF50, after all, that valve was crucial in the development of Radar systems. But Mullard in England had difficulties producing the valve. As although the print on the valves read "Mullard", the EF50's were produced in Eindhoven, soon to be occupied by Germany. The English leader of the Radar project (Watson Watt) realised that when the occupation was there, the production in Eindhoven would fall in German hands. Early 1940 he arranged a meeting with Theo Tromp, head development of Philips, urgently asking Tromp to produce as many EF50's and send them to England as soon as possible.

Philips Eindhoven started to work day and night producing loads of EF50's. Just before the German invasion on the 10th of May, on the 9th of May a lorry with production machines, 25,000 EF50's and 250,000 basic EF50 parts was driven from Eindhoven to Flushing and shipped to England on an English ship leaving Flushing on the 10th of May, at 05:00AM, a few hours before the German invasion started. Although the ship was shot at during the crossing of the Channel, its cargo including the EF50's safely made it to London. Later, Sylvania, USA produced loads of EF 50's.

Amazingly, the EF50 made the victory of the Allies in WW II have a touch of Dutch!"

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Transmitters

Pink Brazilian

I decided to build a valve project because of the simplicity that "hollow state" design gives, and rugged robust performance under extreme SWR that valves tolerate. Sure, the job could be done with solid state devices, but for sheer elegance, ease of use, and bombproof survival ability of a valve in the event of short / open circuit antennas made a valve the component of choice.

Valves are like steam locomotives: they engender respect and appreciation, and besides that, look great, and are warm, living things that glow a healthy red. And... they keep your tea warm on top of the cabinet!

Mind you, I do have a soft spot for valves; I earned my living for many years working with high power RF generators using Siemens RS3150CJ triodes (and others of similar capabilities - the 3150CJ is certainly NOT an amateur valve!), so I have much respect for these beasties. They deliver reliably under the most extreme circumstances, and give ample warning of failure: something solid state devices - the fastest three-legged fuses ever invented - never do, despite complex current and voltage limiting power supplies. Valves just take overload in their stride, then return to the fray
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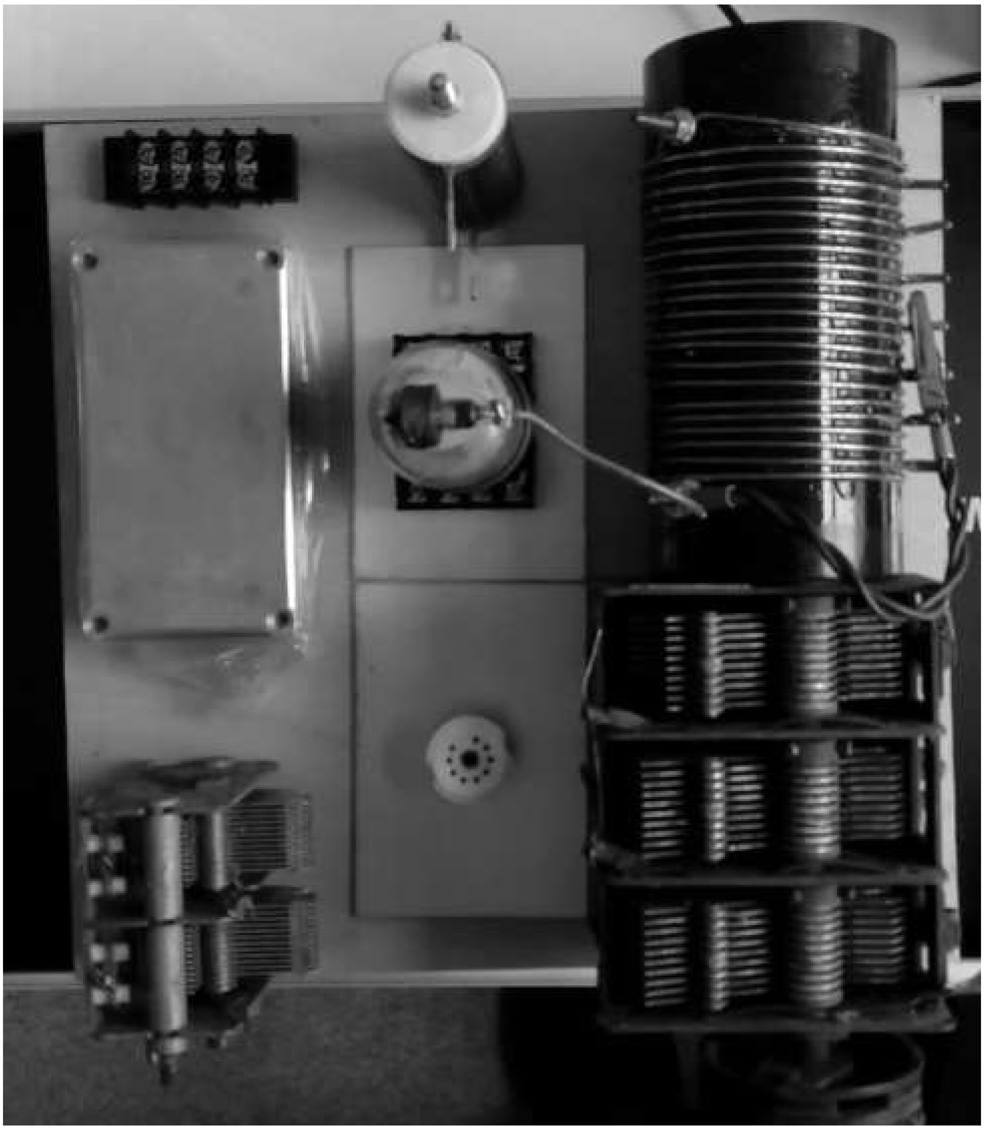
ne'er a watt lost, once the fault's been found and fettled. Let's see a power mosfet survive after a 10kV DC HT supply flashover!

Here's a picture of my proposed layout for the Pink Brazilian A.M. transmitter, on the plywood "breadboard" I'm using. Starting top left, you see the 4 way screw terminals for power input; centre top is the RF choke, made from a 50 watt power resistor. I stripped off the resistance wire by finding the ends - they were wrapped around the lugs you see sticking out, pointing "South". The vitreous covering green paint-on ceramic just flaked away, leaving me a perfect ceramic cylinder, with terminal lugs already fixed at each end and a mounting steel bolt (which secured the right angle bent tin legs on the resistor) now used as a vertical support and gives the extra bonus of a thin steel core to my RFC, increasing the inductance a tad.

Top right is my matching coil: the Pink Brazilian uses an "L" network to match the anode impedance to 50 ohms. You can see my tap selector mechanism, since amateur A.M. operation is on spot frequencies, I don't need a fully variable matching coil, simple taps will be fine. The coil is wound with 14 SWG enamelled copper wire on a 75mm / 3" diameter piece of PVC - I did the microwave oven test (bung it in the microwave with a glass of water, blast on full power for a minute and see if the PVC gets warm) to see if it would absorb any RF, it didn't, so it got used.

Left hand side centre is the diecast box for the cathode modulator. Good screening is an absolute "must" - it's a quality box, with deep flanges, and will have a heatsink bolted to the top so the power mosfet (mounted inside) can be cooled properly.



It's important to ensure the mosfet mounting bolt is earthed to the diecast box: otherwise this would be a path for stray RF to enter the modulator AF section. I had considered a suppressor grid modulator, but since the 6146 is a tetrode, it doesn't have a suppressor grid! The cathode modulator works just fine with any triode, tetrode or pentode, so it's a flexible and simple choice.

More or less dead centre is the 6146, in an Octal relay socket, mounted over a piece of FR4 copper-clad board which will have components mounted Manhattan style on super-glued pads. I've set the relay socket ½" / 13mm above the copper clad board, to allow wires, components and such to be easily fitted beneath. You'll notice the 6146 has a commercial VHF parasitic stopper on the anode cap. This came with the valves (salvaged from a 500W "fish-phone" trawler Tx), and it saves me making one. The 6146 is a powerful beast and can run a full 50 Watts output / 30W anode dissipation (and a fair bit more if you push it) at 175MHz. This is one serious bit of Hollow State technology! I'll be running on 80m / 60m / 40m A.M. slots, so the 6146 won't be suffering transit time effects (and have plenty of gain) running well under it's limit frequency.

To the right is the bottom of the anode tuning coil: the croc clip tap selector is perfectly adequate - and I want to check how the beast runs with shorted turns (as in the photo) as opposed to open circuit turns (if the blue twisted pair go straight to the anode connector). Tim Walford prefers open circuit turns, though I've seen many circuits running just fine with shorted turns. The difference is this: with open circuit turns, you've a potential Tesla Coil - those open turns induce some hefty voltages at the open end. With shorted turns, you put a damped element on the inductor, but the damping is very small - it depends on the coupling co-efficient of the coil turns. Above 200kHz or so it seems to make little difference, but on industrial eddy current RF heater units (used to fire "getters" inside vacuum devices) running at 10 - 80kHz, the Tesla Coil effect is terrific - if the shorted turns become open ended, i.e. if the wire breaks with vibration from the cooling fans or pumps - then you get some fearsome blue flashes from a few inches to a foot long!

Lower left is the VXCO frequency adjust capacitor. It's way too big for the job! I'm going to change it for a 10 - 70pF variable I have. The crystals I have are all 30pF parallel calibrated; so with circuit strays I guess I'll only need less than half what I've available in the 10 - 70pF variable. A.M. operation is very simple in being on specific spot frequencies: saves the need for precision wide range VFO's / DDS / VXCO's.

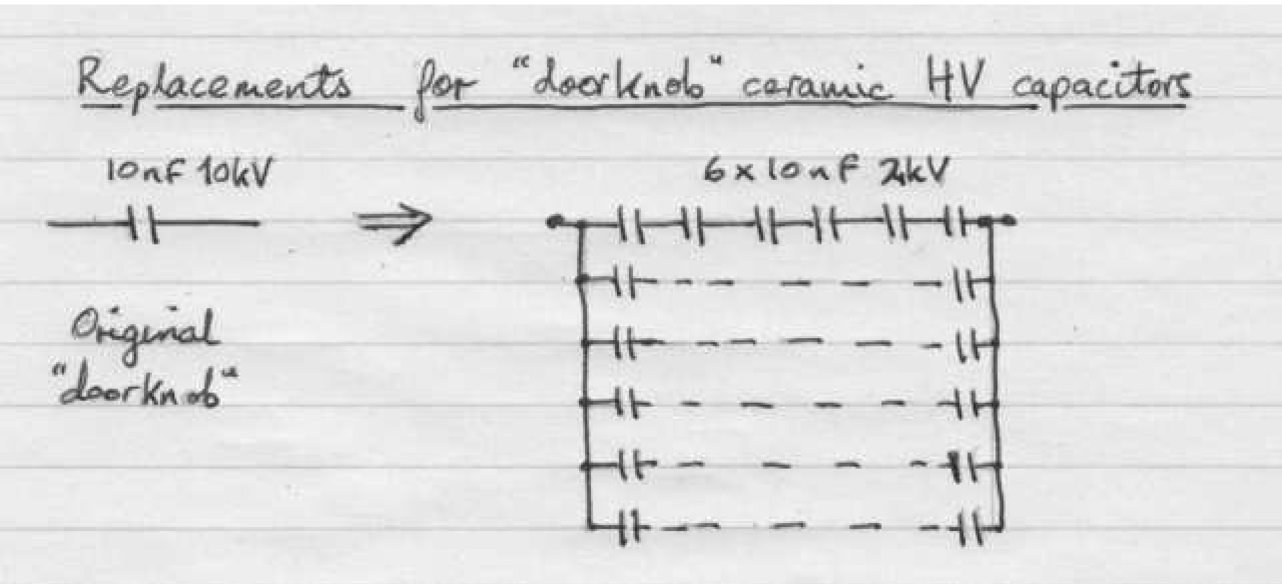
In the lower centre is the FR4 copper clad board for the VXCO. It will be "stitched" to the 6146 FR4 board with a zig-zag 18SWG wire, bent like a concertina, laid across the butt joint, then soldered to each side right across. Simple and easy, that makes a substantial earth plane; I'll probably fit an M5 brass bolt somewhere on one of the FR4 boards as the "star" earth point, but I haven't decided just where yet. I like to get stuck into building each module up and then see where the shortest run to a star point is - and that's where the bolt goes. The VXCO will be a twin triode Butler VXCO, running on the fundamental. The reasoning for this is modern crystals are but babes in arms compared to the paving slabs inside the old FT style crystals, and do not like more than the lightest sniff of RF up 'em! The Butler puts the crystal under very low voltage and current stress as it's a two stage amplifier oscillator, so doesn't wallop the crystal as a Pierce or Colpitts would. The noval valve holder will be mounted with some 25mm long 3mm diameter screws and spacers, to elevate the valve holder allowing components and wires (if necessary) to run beneath, as per the 6146.

Bottom right is a whacking big three section variable capacitor, that needs a full refurbish and clean. I don't know how old this is, or what total capacitance; but I do know that it withstood a 4kV flash test for 1 hour after a quick blow clean with compressed air at a "local friendly electronics manufacturing company" (ahemm). This old girl will be fine in the role, as I'll be fitting a double section anode coupling capacitor which gives "double indemnity" in stopping of anode DC supply reaching the tuning capacitor or the antenna.

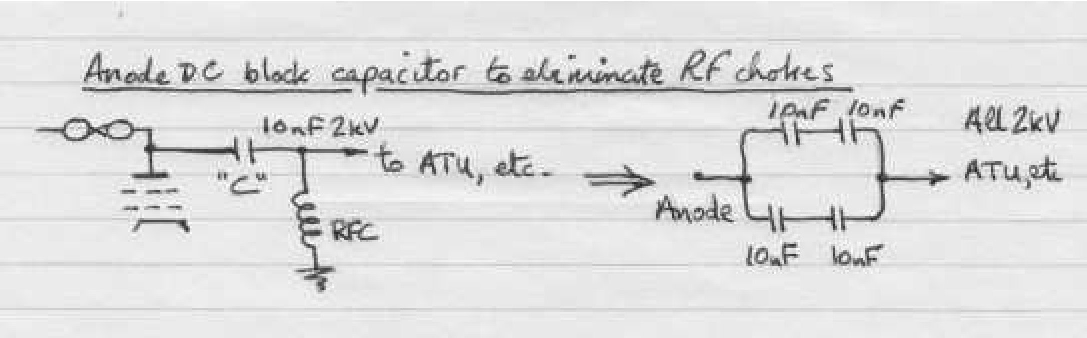
I'll be using an in-line 50 ohm 5 pole Butterworth low pass filter in the antenna co-ax line to clean up the output further; I might alter the output matching to a "Pi" network if the harmonic suppression isn't adequate as I suspect my antenna, being very short on 80m, might need the extra capabilities a Pi network gives. We'll just have to see!

HV "door knob" output capacitor substitutes

The large ceramic high RF power "door knob" capacitors are not commonly found nowadays on the used market or from manufacturers at prices to suit amateur budgets; but a useful substitute can be made from 2kV rated 10nF ceramic disc capacitors, available for very reasonable prices and of very small size. But... that's the snag, the size indicates that these little beasties won't take the ooomph from a hefty transmitter for very long. The answer is to assemble an array of these capacitors, following the "series / parallel" method, which is two capacitors in series to get 4kV rating, but of only 5nF; add an identical pair in parallel and you're back to 10nF. This divides the RF power between four capacitors so each capacitor has a much less stressful life. It's a good idea to always add an extra margin... but to add more capacitors, you need more assemblies like this, again arranged capacitors in series with an identical series capacitors in parallel - this gets you good kV rating, at 10nF, and the RF power is divided equally between many capacitors. Now you're talking! Make sure air flow can get to each capacitor: space 'em out and mount 'em securely!



An added advantage of these series / parallel arrays is that if one capacitor weakens, sags at the knees and gives up the ghost, the remaining capacitors in the array keep running safely, feeding RF until you can repair the damage - which will be obvious! Note too that if used for DC blocking from an anode, to prevent the DC HT appearing on the antenna, series / parallel arrays more or less obviate the need for "safety" earthing chokes as the DC anode supply is safely blocked by the other capacitors: at least two capacitors must fail. Not unknown, but very, very, rare - and you'll certainly not be left in any doubt when a capacitor goes down, and can make repairs as and when safely.



Power Supplies

Safety & EMO systems

The safety of amateur constructed equipment is just as important as any other application: it's got to be safe, especially high voltage power supplies, or high current supplies. The HV aspect is (I hope!) obvious: it is a blatant danger, but the high current supply is a serious contender. Modern rechargeable batteries pack a lot of amps into a very small package - witness the small "booster boxes" now available to jump start cars, able to deliver 350 - 400 Amps for 60 seconds, certainly enough to throw a cold engine over sufficiently briskly to start it. Whilst this is only 12 volts, the "ampacity" is enough, if accidentally shorted by, for instance, a wedding ring on a finger, will burn through flesh and bone in no short order. I learned the danger of high current power supplies in an electroplating shop: the DC bus bars, accidentally shorted by a dropped spanner (no, not by me!), blew one end clean off the spanner, and the other end spun skyward in the magnetic force generated by the kilo-amps current.

In industry, special relays have to be used for "emergency OFF" circuits: a simple latching relay circuit - where a relay coil is energised by it's own normally open contacts, temporarily bridged by a "start" push button, is not accepted as safe. The reason is that if the "start" button is jammed in (for whatever reason or circumstance) then the power is applied. A momentary "start" must be a *pulse* so it cannot be applied more than a moment. The other problem with a latching relay circuit is "contact welding". The spring blade that carries the moving contact is designed to slightly "wipe" the moving contact over the static contact to break through any oxide or other contaminant on the contact faces: thus we have metal-to-metal with current flowing through it. Over time, electro-migration carries atoms of one contact onto the other, hence the pitting of one contact, and spiking of the other. These can easily lock the two contacts together, so releasing the coil volts doesn't open the circuit. A similar effect can be seen is the load current is very "spiky" - of low average value, but very high peak currents (when powering up a transformer feeding a large reservoir capacitor, for example). Or - the ultimate disaster - a short circuit load, inappropriately fused, so the full supply ampacity flows through the contacts. The contact resistance, combined with the high amps flowing, yields i^2R watts, enough to weld the contacts together.

The answer for the amateur "shack" is a clearly labelled and accessible AC mains power switch right next to the door / entrance / access, that mechanically forces open the main power contacts -

DON'T RELY ON SPRING OPERATED SWITCHES OR RELAYS. You should include appropriate fuses or circuit breakers to protect the supply cables as well as the load fed by the switch / fuses; if in doubt as to what rating, cable sizes, installation requirements, consult a qualified electrician for your local area. An auxiliary "Consumer Unit", with isolator switch with combined earth leakage trip module and individual circuit breakers for each load; you could have individual benches, or outlets, fed separately so you can be absolutely certain you can isolate mains power to that section. You *can* use latching relay "start / stop" circuits on AC supplies, with emergency OFF buttons (EMO's) placed around the shack that can be reached from any operating or test bench. These should be tested regularly, usually every time the shack power is turned on, to avoid the relay contacts spiking and pitting over a long period. Industrial equipments commonly use "Pilz" relays for safety circuits: these employ mechanically forced return contacts, pulse start and lock-out facilities. For amateur service these are overkill; they also cost a great deal of money, but they are worth studying to see how it's done to the latest safety requirements.

ALWAYS turn the shack power OFF when you leave or finish your radio session. For obvious reasons, the shack lighting should NOT be fed by the shack "power" switch - the last thing you want in an emergency OFF situation is the lights blacking out the moment you push an EMO!

Keep in mind too that AC power drops to zero at every half cycle; switches and relays can open far easier on AC than DC for this reason. DC power controls must be considerably heftier that AC types (as Mr. "DC" Edison found out in competition with Mr. "AC" Westinghouse many years ago). Don't hesitate to rate DC controls very conservatively: observe the manufacturer's rating for contacts, AC vs. DC ampacities, and then add plenty extra.

This doesn't address the accidental contact with high value, high voltage electrolytic capacitors. These beasts can deliver hundreds, nay, thousands of amps; and are commonly used in high current low voltage power supplies, now common for hefty solid state linear amplifiers. Keep in mind the basic safety rules: NO rings or metal jewellery, NO metal tools anywhere near whilst energised / charged; take special care with 'scope probes having an earthed collar close to the probe needle tip. I've seen the probe tip blown clean off by an accidental touch on a DC power bus, running 47,000µF x 10 at 450 volts (no, not me; but I saw the flash from some yards away). The major injuries were the flash temporarily blinding the operator, and reflex action to pull back with untold possibilities for injury. In this case it was a deep gash below the elbow from a metal cabinet corner that bled profusely.

The voltage levels to be considered as "safe to touch" in my day was 50v AC or 70.7v DC; you need to be aware of what your local electricity regulations dictate. As responsible amateurs, if you have any equipment that has open (or touchable by a small finger...?) it must be protected, covered by appropriate barriers, covers, insulation - and ALL unaware people kept strictly well away.

Whilst power RF won't enter the body on an accidental contact - it is a "skin effect" current - where the RF then flashes over to earth from the body, it will cause very deep and painful burns that go septic very readily. The "no touch" rule also applies to open wire feeders and the like, where high RF voltages, even from a 12v supply transmitter, can exist, so make sure they are set well out of reach or otherwise protected.

USA vs. European Mains transformers

This question has cropped up occasionaly for as long as I can remember: "can a USA manufactured 60Hz transformer be used on European 50Hz mains electricity"? Since the supply of HV valve style transformers in UK / Europe has dried up completely, it's a good question to ask if the more commonly available (but at what scandalous shipping costs!) USA transformers could be used.

If it's anything to do with transformers or power chokes, I ask the UK guru on such topics: Martin Boardman, of Boardman Transformers, Ulverston, Cumbria.

He gave me the following advice:

"There are a couple of issues that would concern me, both around the core magnetisation.

In my experience, American Transformer Companies tend to run their Transformers quite hard, both in terms of core magnetisation and current density in the conductor. You rightly point out that the UK voltage is likely to be somewhat higher than 220V, pushing the iron circuit harder. The second and probably more significant factor is the 50Hz here as opposed to 60Hz in the USA.

If it has been designed with only 60Hz in mind, then it won't be so happy running at 50Hz in the UK, particularly in view of my previous comment about companies pushing the core hard anyway.

Running a 50Hz Transformer on 60Hz is fine, but running a 60Hz Transformer on 50Hz is not so good, 20% higher in flux density. It may or may not push it into saturation but it will certainly run a lot hotter. Perhaps you could ask your USA radio man if it is marked 50/60Hz, or just 60Hz.

Best Regards,
Martin Boardman"

Test Equipment

Pock-Pock RF test oscillator*

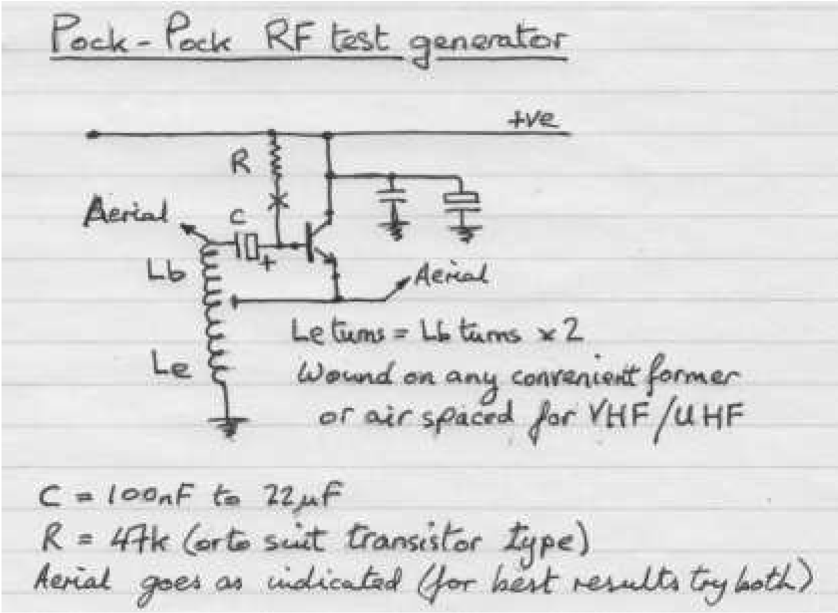
The Pock-Pock is a strange, unruly beast from the deep dark corners of the RF jungle: it has a remote cousin in the super-regen receiver, in that it is deliberately designed to be a "squegging" oscillator. But there the similarity ends: the Pock-Pock runs on many frequencies all at once, rather than being tuned with an LC resonator. "Why on Earth would anybody want such a beast?" is a fair question; but consider this: you've just set up your new microphone and want to see if it is adequately screened, earthed, and RF-proof: you can either chance it, or get the Pock-Pock out and hold it close to your mic and cable all the way to the Transmitter mic socket whilst listening on a local receiver for the very distinct "Pock-Pock" note in the transmitter's output. Any sign of "Pock-Pock" tone means the mic or mic cable is allowing RF to penetrate.

This broadband squegging oscillator is very useful for testing anywhere you want RF proof screening or similar: shielding, IF cans, audio amplifiers / pre-amplifiers, active headphones…. well, just about anything you don't want RF to sneak into. You can make the coil as small as you need to get into tight corners, but of course a 6 turn coil will run very different frequencies than a 60 turn coil!

Holding a Pock-Pock close to an Rx antenna input will show how your receiver copes with off-frequency signals of significant power; a good test for mixers too as the Pock-Pock creates many frequencies, which some mixers (single ended unbalanced, for instance) do **not** like it up ‘em!

You are invited to send in any Pock-Pock tests you find useful: you will get a special mention!

* *Because this is the noise it makes in a receiver!*

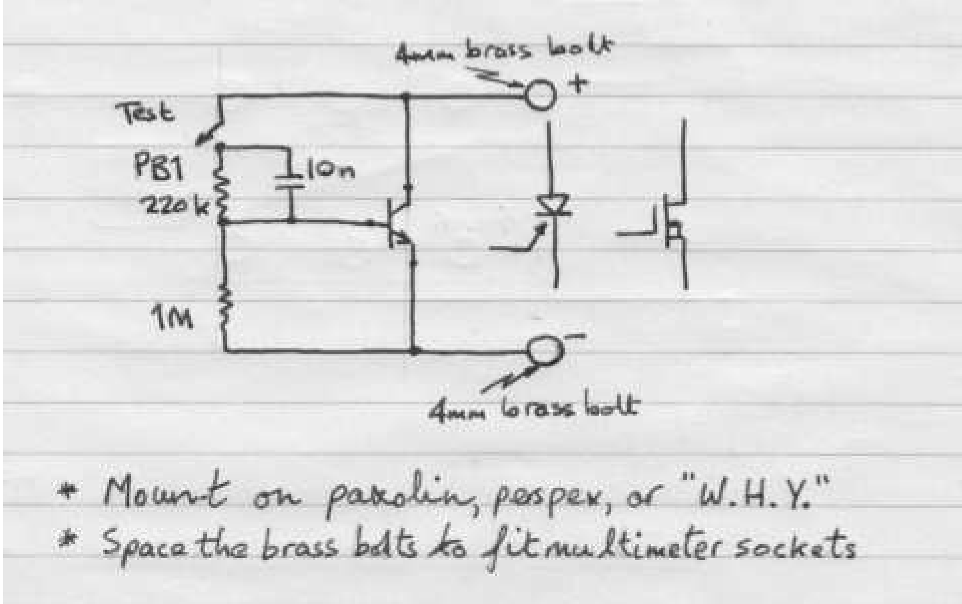


Transistor tester

Most (“cheap”) multimeters have an “ohms” test facility that can be switched between “diode” test and “ohms” - the difference being that “diode” uses a voltage sufficient to turn on a silicon junction, whereas the “ohms” range tests with less than (usually) 0.5 volts or so. Normally, “diode” test reads out the forward volt drop of the diode on test, whereas the ohms test computes the volt drop and applied current to give ohms readout. If your multimeter has a “diode” test setting that uses more than a volt or two, but no transistor test feature, then this might be just the job for you.

Fit into some insulating board (no copper FR4 material?) two 4mm brass bolts long enough to connect into your multimeter 4mm input jack sockets and add the components shown in the diagram; turning the multimeter to “diode” then applies a voltage to power the device. Fit a transistor, mosfet, scr, whatever, and note the meter reading: it should be “over-range”, “O/C” or something similar if the device on test doesn’t leak, collector to emitter / drain to source / anode to cathode. Push the test button: the reading should drop to the expected collector - emitter “on” voltage, typical for a bipolar transistor < 0.2v; for a mosfet, a very low reading; an SCR will show about 1.2 volts or so as it’s a four layer device (2 P-N junctions). Thus you now know several values: the off state leakage current; the on state volt drop and the device functionality.

Not bad for three components, a couple of brass bolts and a switch?



Finding SMT short circuit IC's

Got a pcb with a short circuit somewhere on it? Want to know which IC has gone down? Years ago using DTL / TTL logic, you'd soon find the dud package by looking for the cracked open IC package, or smoke coming from the plastic burning - but modern low current LSI chips just don't suck the amps (or the PSU limits and shuts down) that show the offending chip. How do you find the dud? Dead easy. Get some methylated spirits (or pcb cleaning solvent) and a paint brush - power up until the fault kicks in, and quickly "paint" all the IC's with methylated spirits.

The "bad" chip sucking the amps will evaporate the methylated spirit faster than the cooler "good" chips. You *could* use your finger tip... but leave a fair bit of skin behind and possibly blow static sensitive chips. Job done, and far cheaper than a "FLIR" heat camera! Oh, and observe strict "no smoking" whilst vapourising inflammable solvents!

"Volt Sticks" for Ham use

The volt sticks (non-contact voltage detectors) now commonly available are the LED version of an old and trusted friend, the neon bulb, and can be used in somewhat similar circumstances. Take note however, that they are only a relative indication: the lack of LED illumination might NOT mean a conductor is safe to touch as some volt sticks only illuminate on AC power; DC high voltages might not energise the volt stick's jfet. Generally speaking, the cheaper models from our favourite on-line auction house respond to almost anything, including rubbing the sensing tip on a shirt sleeve, generating some static charge - but don't rely on that if you're testing for for live cables or terminals, check it on a known voltage to establish the capability of the beast before attacking under battle conditions.

But, all said, a volt stick does make a dinky CW monitor, when set close to an RF hot spot - the flashing LED following every press of the key. If you have no easily accessible RF hot spot, run the volt stick tip along the antenna co-ax and (with luck) you will find a point on the cable or connector(s) where there is a sniff of RF, enough to energise the volt stick. Wrapping stiff copper wire round the tip to make an "antenna" can make some volt sticks far more sensitive to RF. Once the best place is located, a few cable ties, blu-tack, or adhesive PVC tape (of harmonious colour, please) and the visual CW / transmission monitor is complete.

Construction Notes

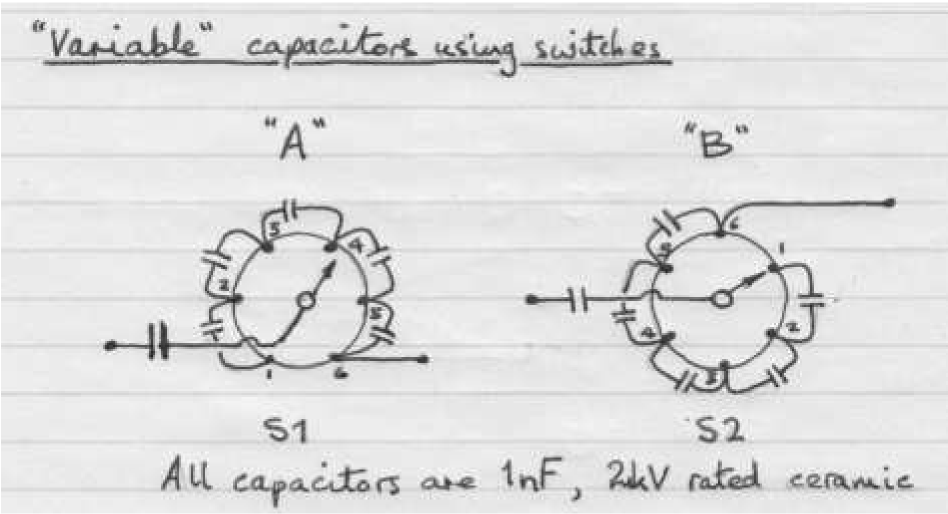
Elevated pcb bus rails

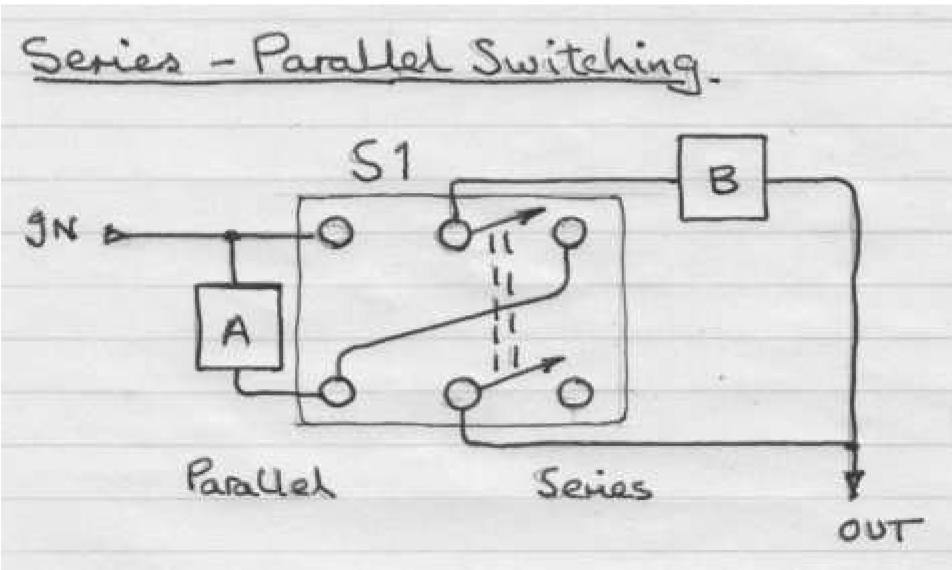
When using “Manhattan” or similar stick-down pad construction techniques, a simple trick that really helps keep construction neat and tidy, both mechanically and electrically, is elevating the power bus rail(s) above the earth plane copper to space the supply bus rail up about 6mm. Offcuts of perspex, FR4 etc. are ideal for this job. In the space below you can run wires, components, and the like, and solder 100nF disc ceramics / electrolytics at intervals along the bus; achieving more “distributed” decoupling. What’s not to like?

Antennas

Variable High Voltage Capacitors - using switches

It’s possible to use fixed capacitors as the “loading” element in a Pi Coupler ATU; the adjustment is nowhere near as critical as the input “Tune” capacitor. A useful replacement for the increasingly rare high voltage variable capacitor is a couple of rotary switches, and a change-over switch to effect a “series” or “parallel” connection - I saw this many years ago and have used it many times since in many different situations. Strongly recommended!





I have 12 way switches to hand (from our favourite on-line auction source), so the range of capacitances available augmented by series / parallel switching should cover just about every eventuality for me.

You'll notice a series capacitor feeds the wiper contact . This prevents a direct DC path through the system: no DC short circuits! For other jobs, you can rearrange the capacitors to be a direct through path, should you need a "zero" capacitance setting.

Getting feeder wires through a brick wall

The usual practice when running cable in and out of buildings is to use a long masonry bit to drill from the inside, of a diameter a mm or two bigger diameter than the protective pipe that you should always use (don't you?). Once the drill is through to outside, remove the power tool, and push the drill bit back into the room with the protective pipe. That stops any bits of broken brick or rubble falling and blocking the hole. So far, so good.... but what about modern, airtight houses, with super cavity insulation, and vertical DPC membranes in twin leaf brick walls?

A good idea is to use plastic conduit to line the hole, and smear silicone sealer around the outer diameter as you push the drill bit back inside. If you bore the hole in the masonry a good few mm's bigger than the conduit diameter, enough sealer is carried into the cavity to seal on the membrane and insulation. To avoid problems later, make sure the protective pipe is longer than the wall thickness. Then you can repeat the "sealer smearing" on the inside piece of pipe, and push it partially back out again, repeating the push operation inside and out until the sealer is well and truly spread right through the hole, thus making sure both leaves of the wall are sealed up tight. Push the protective pipe reasonably close up to the inside wall - you only have to trim off the outside excess length, thus not damaging the decorative finish on the inside of the house.

One note of caution: if you use a *metal* protective pipe, for instance copper water pipe - be aware that most Electricity Regulations insist that "all extraneous conductors be bonded to Earth", and you'll need to bond the metal pipe section to a solid mains earth point.

Notes from W9SCH, K7NS and VK5YE about "random" wire antennas

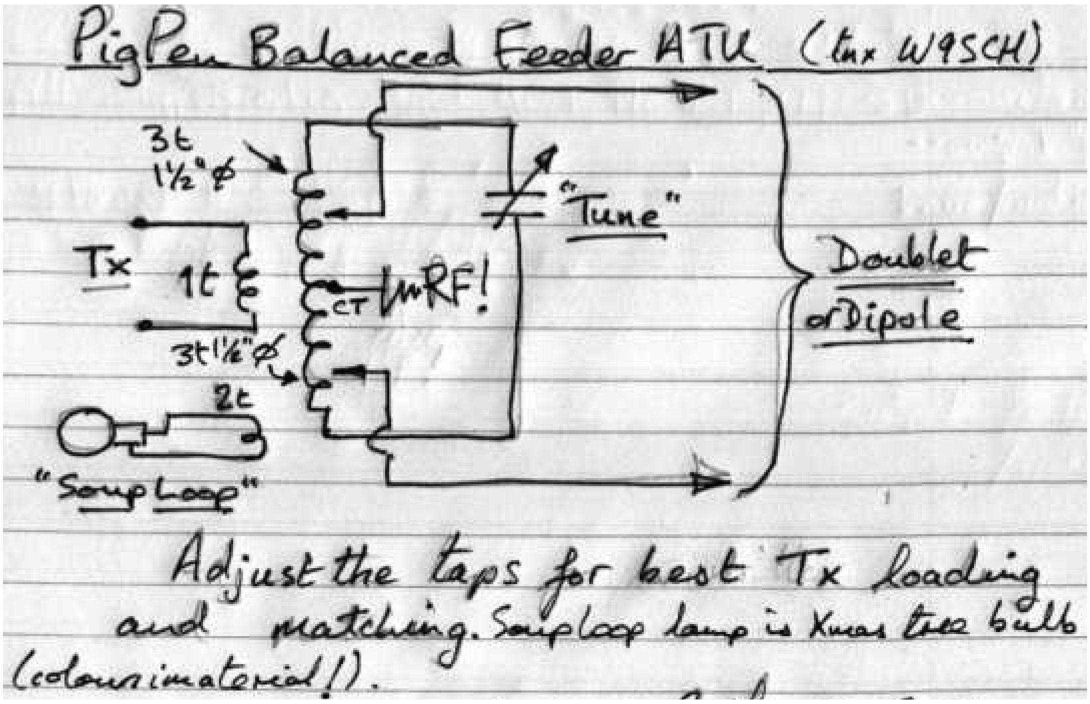
Chas. Rockey, W9SCH, Nyle Steiner, K7NS, and Peter Parker, VK3YE have all described on their web pages a simple fact that many amateurs forget, or just plain don't know: there is nothing, *nothing*, magical about a piece of wire a quarter of a wavelength long for a transmitting antenna - it just makes a direct connection to 50 ohm co-ax (sometimes!) possible. ANY length of wire, if matched to the transmitter output impedance, then brought to resonance, will radiate. In simplistic terms, if you can get the RF volts and amps in phase, in as large an amount you can, in the longest wire elevated in the open as best you can, you'll radiate a good strong signal.

It is a common misconception that a dipole is good Dx radiator. A dipole has significant upward radiation if it's less than ONE wavelength above ground: for Dx you want low angle radiation. Imagine a 30m band dipole in your yard: it's roughly 15 metres / 49'2½" long - and it needs to be HIGHER than that too! You're in for some serious tower engineering on bands 10MHz and down if you want the ultimate Dx dipole.

Why bother on the lower bands, you'll radiate a signal that's only a dB or two down from a full dipole from a length of wire you've got high, wide and handsome, with a vertical run down to your matching unit as an “inverted L” antenna - with as much of a counterpoise / ground as you can fit around your flower beds, fences, and yard walls? Feed the beast with a decent antenna tuner - and none finer than Chas. Rockey’s “Pig Pen” Tuner (below), and it will get good results.

The Pig Pen works quite simply by transformer feeding the transmitter signal into a parallel resonant circuit; the antenna wires having capacitance and inductance add to the ATU coil and capacitor and the whole shebang is brought into resonance. A coil for an “inverted L” on the low bands (10MHz and under) will need more turns - feel free to adapt the design, it’s based on a unit first used in 1914, so has proved itself over some considerable time! For a single wire radiator, you only need the top half of the coil shown: simply connect the coil and tuning capacitor in parallel, earth the frame of the capacitor and bottom of the coil - connect the “inverted L” to the coil “hot” end (or tap down), the counterpoise to the RF earth point, then tune to resonance as indicated by the “soup lamp”, held near the coil temporarily, glowing brightly whilst running a few watts of carrier. Move the lamp away for operation at full power. One valuable feature is the coupling loop that feeds the transmitter power into the tuning coil: this keeps RF off the outer of the co-ax from the transmitter to the ATU.

For a Doublet, fed by open wire feeders, use the centre tapped coil as shown, and MAKE SURE you have a long insulated control shaft on your variable capacitor, or use the “wafer switch capacitor” shown previously in this edition, which has fully insulated control shafts.



Conundrum Corner...

Transmission lines

Transmission lines are a conundrum: they are merely bits of wire, but oh boy, do they do some weird things! Take a look at https://www3.nd.edu/~wzech/CoaxialTransmissionLine.pdf and have a browse! Keep in mind, whilst reading, this is insulated copper wire, inside a screen: or a pair of wires spaced apart (open feeder). What could *possibly* be complicated about that? Hah!

You may recall that short lengths of co-ax can be used as high voltage capacitors for tuning antennas, etc., and so they can. They actually do the job, in the real World, with real amps and volts. Now recall the link above which showed shunt capacitors and series inductances modelling a co-ax line, exactly as you would expect - that's how they work as antenna tuning capacitors, surely?

Here's the crunch: whilst the model of shunt capacitors with series inductors is what we imagine is happening, and co-ax HV tuning "capacitors" *prove* this, surely? Don't they? I mean these things work in real life, don't they? Well, yes they do: but this is a classic example of Nature kicking sand in the engineer's eyes! Because, my dear Moriarty, those capacitors are not individual pieces; nor are the inductors, No, Sir. They are that mathematician's nightmare, an infinite series of components, all inside a few short cm's of wire!

How so? Let's consider the capacitance element. A capacitor is an electric field set up between two "plates", is it not? And a transmission line has zillions of these little capacitors every metre, yes? Each little capacitor forms a transmission line (recall that a metal conductor near another conductor = transmission line); and since a capacitor is a transmission line, each of these tiny capacitors is really a micro transmission line - that is made up of zillions of nano capacitors, all of which are a nano transmission line... and... and.... "little fleas have lesser fleas upon their backs to bite 'em"!

The whole thing becomes a Carollian White Rabbit disappearing down the rabbit hole: a never ending sequence of diminishing, but real and functional, capacitors, inductors (the logic runs true for the series elements too) and was studied by Oliver Heaviside in the 1880's. A useful reference is https://en.wikipedia.org/wiki/Telegrapher%27s_equations

Heaviside was a mathematical genius who derived the Laplace transform - the analysis of infinitely fast voltage steps, ramps, sine and other repetitive waveforms applied to complex circuits and in later years, control theory and partial differential equations. The Maxwell equations are distinctly similar; and Telegrapher's Equations (coupled linear partial differential equations) pop up in Quantum Field Theory and Relativity amongst many other of the apparently "simple" things observed in Nature.

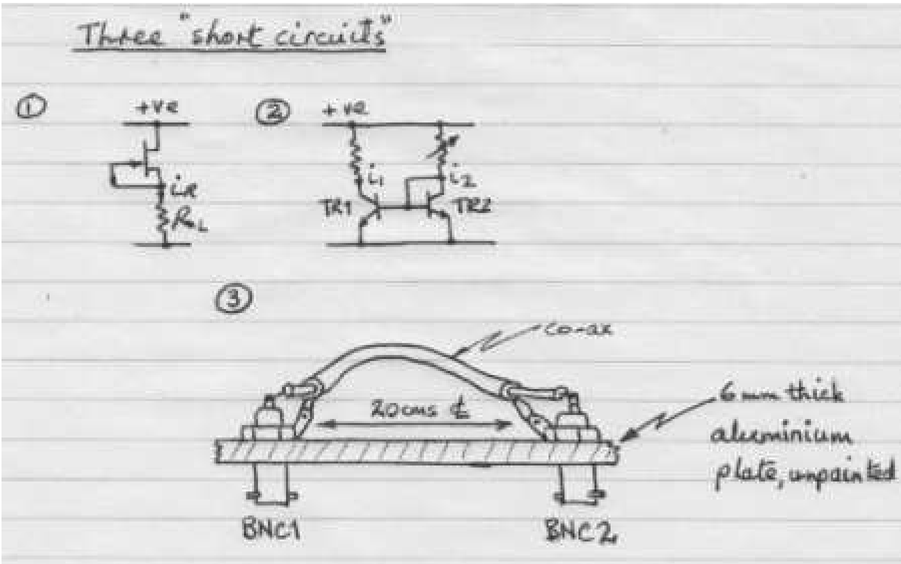
To handle "infinities" in maths as used by electrical engineers requires some fairly hefty sleight of hand maths: the idea being to cancel them out or otherwise "get rid" of them. Infinities caused profound trouble when Quantum Physicist Richard Feynman was forced to use similar maths tricks to shift infinities in his calculations using "normalising" procedures. Just to compound the frustration, just how many *different* infinities are there? Georg Cantor - see https://en.wikipedia.org/wiki/Georg_Cantor - discovered there are an *infinity* of infinities! All of them with different characteristics(?!).

Suffice to say: if it's good enough for Mr. Feynman, it will do very nicely for my home-made (twisted pair) feeder at G6NGR! All this from a bit of copper wire alongside / inside another bit of copper wire. That's because the copper wire doesn't carry the energy: it guides the energy through the insulating space between each conductor. Energy is a transverse electromagnetic field running between two waveguides - even at DC. And, as radio amateurs, we know the magic is delivered by electromagnetic fields every time we turn on our transmitters.

Or, I wonder, is the original model of shunt capacitors and series inductors as a transmission line is just plain wrong....? Is the model needing a thorough re-engineering to find a more rational and simpler electrical theory description?

Three short circuits

A challenge for our readers, with a special mention for the best responses (frivolous or otherwise) in Hot Iron # 105! Let's hear your answers! Just what are the "short circuits" in the following drawing for? How do they work, and why?



Data and Information

This information is for guidance only – you MUST comply with your local Safety Regulations. I have included information about AC power systems and conventions, as equipment can often be sourced from overseas nowadays and it's important that we know exactly how to connect it to our "home" supplies - but suffice to say, if there's any doubt - - - GET PROFESSIONAL, COMPETENT HELP BEFORE YOU CONNECT TO ANY ELECTRICAL SUPPLY!

Wire Information...

AWG Table

1 AWG is 289.3 thousandths of an inch
2 AWG is 257.6 thousandths of an inch
5 AWG is 181.9 thousandths of an inch
10 AWG is 101.9 thousandths of an inch
20 AWG is 32.0 thousandths of an inch
30 AWG is 10.0 thousandths of an inch
40 AWG is 3.1 thousandths of an inch

The table in ARRL handbook warns that the figures are approximate and may vary dependent on the manufacturing tolerances. If you don't have a chart handy, you don't really need a formula.
There's several handy tricks:
Solid wire diameters increases/decreases by a factor of 2 every 6 gauges,
" " " " " 3 every 10 gauges,
" " " " " 4 every 12 gauges,
" " " " " 5 every 14 gauges,
" " " " " 10 every 20 gauges,
" " " " " 100 every 40 gauges,

With these, you can get around a lot of different AWGs and they cross check against one another. Start with solid 50 AWG having a 1 mil diameter.
So, 30 AWG should have a diameter of ~ 10 mils.

36 AWG should have a diameter of ~ 5 mils.	Dead on.
24 AWG should have a diameter of ~ 20 mils.	Actually ~ 20.1
16 AWG should have a diameter of ~ 50 mils.	Actually ~ 50.8
10 AWG should have a diameter of ~ 100 mils.	Actually ~ 101.9

If you are more interested in current carrying ability than physical size, then also remember that a change of 3 AWG numbers equals a doubling or halving of the circular mills (the cross sectional area). Thus, if 10 AWG is safe for 30 amps, then 13 AWG (hard to find) is ok for 15 amps and 16 AWG is good for 7.5 amps.
The wire gauge is a logarithmic scale base on the cross sectional area of the wire. Each 3-gauge step in size corresponds to a doubling or halving of the cross sectional area. For example, going from 20 gauge to 17 gauge doubles the cross sectional area (which, by the way, halves the DC resistance).
So, one simple result of this is that if you take two strands the same gauge, it's the equivalent of a single wire that's 3 gauges lower. So two 20 gauge strands is equivalent to 1 17 gauge.

Wire Gauge Resistance per foot

4	.000292
6	.000465
8	.000739
10	.00118
12	.00187
14	.00297
16	.00473
18	.00751
20	.0119
22	.0190
24	.0302
26	.0480
28	.0764

Current ratings

Most current ratings for wires (except magnet wires) are based on permissible voltage drop, not temperature rise. For example, 0.5 mm^2 wire is rated at 3A in some applications but will carry over 8 A in free air without overheating. You will find tables of permitted maximum current in national electrical codes, but these are based on voltage drop. Here is a current and AWG table.

AWG	dia mils	circ mils	open air Amp	cable Amp	ft/lb bare	ohms/1000’
10	101.9	10380	55	33	31.82	1.018
12	80.8	6530	41	23	50.59	1.619
14	64.1	4107	32	17	80.44	2.575

Mils are .001". "open air A" is a continuous rating for a single conductor with insulation in open air. "cable amp" is for in multiple conductor cables. Disregard the amperage ratings for household use.
To calculate voltage drop, plug in the values:
V = DIR/1000

Where I is the amperage, R is from the ohms/1000' column above, and D is the total distance the current travels (don't forget to add the length of the neutral and live together - i.e.: usually double the cable length). Design rules call for a maximum voltage drop of 6% (7V on 120V circuit).

Note: it's 5% max, volt drop in UK / Europe.

Resistivities at room temp:

Element	Electrical resistivity (micro-ohm-cm)
Aluminium	2.655
Copper	1.678
Gold	2.24
Silver	1.586
Platinum	10.5

This clearly puts silver as the number one conductor and gold has higher resistance than silver or copper. It's desirable in connectors because it does not oxidise so remains clean at the surface. It also has the capability to adhere to itself (touch pure gold to pure gold and it sticks) which makes for very reliable connections.

Thermal conductivity at room temperature

	$W/cm^2/°C$
silver	4.08
copper	3.94
gold	2.96
platinum	0.69
diamond	0.24
bismuth	0.084
iodine	43.5E-4

This explains why diamonds are being used for high power substrates now. That's man-made diamonds. Natural diamonds contain sufficient flaws in the lattice that the phonons (heat conductors) get scattered and substantially reduce the ability to transport the heat.

Copper wire resistance table

AWG	Feet/Ohm	Ohms/100ft	Ampacity	mm^2	Meters/Ohm	Ohms/100M
10	490.2	.204	30	2.588	149.5	.669
12	308.7	.324	20	2.053	94.1	1.06
14	193.8	.516	15	1.628	59.1	1.69
16	122.3	.818	10	1.291	37.3	2.68
18	76.8	1.30	5	1.024	23.4	4.27
20	48.1	2.08	3.3	0.812	14.7	6.82
22	30.3	3.30	2.1	0.644	9.24	10.8
24	19.1	5.24	1.3	0.511	5.82	17.2
26	12.0	8.32	0.8	0.405	3.66	27.3
28	7.55	13.2	0.5	0.321	2.30	43.4

These Ohms / Distance figures are for a round trip circuit. Specifications are for copper wire at 77 degrees Fahrenheit or 25 degrees Celsius.

Wire current handling capacity values

mm2	R/m-ohm/m	I/A
6	3.0	55
10	1.8	76
16	1.1	105
25	0.73	140
35	0.52	173
50	0.38	205
70	0.27	265

Mains wiring current ratings

In mains wiring there are two considerations, voltage drop and heat build up. The smaller the wire is, the higher the resistance is. When the resistance is higher, the wire heats up more, and there is more voltage drop in the wiring. The former is why you need higher-temperature insulation and/or bigger wires for use in conduit; the latter is why you should use larger wire for long runs. Neither effect is very significant over very short distances. There are some very specific exceptions, where use of smaller wire is allowed. The obvious one is the line cord on most lamps. Don't try this unless you're certain that your use fits one of those exceptions; you can never go wrong by using larger wire. This is a table apparently from BS6500, reproduced in the IEE Wiring Regs which describes the maximum fuse sizes for different conductor sizes:

Cross-section	Overload current
CSA / area	rating
0.5mm²	3A
0.75mm²	6A
1mm²	10A
1.25mm²	13A
1.5mm²	16A

Typical current ratings for mains wiring

Inside wall

mm^2	Amps
1.5	10
2.5	16

Equipment wires

mm^2	A
0.5	3
0.75	6
1.0	10
1.5	16
2.5	25

Wire sizes used in USA inside wall

For a 20 amp circuit, use 12 gauge wire. For a 15 amp circuit, you can use 14 gauge wire (in most locales). For a long run, though, you should use the next larger size wire, to avoid voltage drops. Here's a quick table for normal situations. Go up a size for more than 100 foot runs, when the cable is in conduit, or ganged with other wires in a place where they can't dissipate heat easily:

Gauge	Amps
14	15
12	20
10	30
8	40
6	65

PCB track widths

For a 10 degree C temp rise, minimum track widths are:

Current	width in inches
0.5A	0.008"
0.75A	0.012"
1.25A	0.020"
2.5A	0.050"
4.0A	0.100"
7.0A	0.200"
10.0A	0.325"

Equipment wires in Europe

3 core equipment mains cable

Current	3A	6A	10A	13A	16A
Conductor size (mm)	16*0.2	24*0.2	32*0.2	40*0.2	48*0.2
Copper area (mm^2)	0.5	0.75	1.0	1.25	1.5

Cable ratings for 3A, 6A and 13A are based on BS6500 1995 specifications and are for stranded thick PVC insulated cables.

Insulated hook-up wire in circuits (DEF61-12)

Max. current	1.4A	3A	6A
Max. working voltage (V)	1000	1000	1000
PVC sheat thickness (mm)	0.3	0.3	0.45
Conductor size (mm)	7*0.2	16*0.2	24*0.2
Conductor area (mm^2)	0.22	0.5	0.75
Overall diameter (mm)	1.2	1.6	2.05

Common Cable colour Codes

American electrical contractors and electricians are required to follow the National Electrical Code ("NEC") with regard to wiring colours. NEC imposes the following electrical wiring colour standards:

- **Ground wires:** green, green with a yellow stripe, or bare copper

- **Neutral wires:** white or grey

In theory, wiring conducting live current in the U.S. is permitted to be any other colour, although in practice, electrical contractors and electricians follow these local conventions:

- **Single phase live wires:** black (or red for a second “hot” wire)
- **3-phase live wires:** black, red and blue for 208 VAC; brown, yellow, purple for 480 VAC

Most countries in Europe, including the U.K., now follow the colour conventions established by the International Electrotechnical Commission (“IEC”). These colour conventions are as follows:

- **Earth wires** (called ground wires in the U.S. and Canada): green with a yellow stripe
- **Neutral wires:** blue
- **Single phase live wires:** brown
- **3-phase live wires:** brown, black and grey

Electrical wiring in Canada is governed by the Canadian Electric Code (“CEC”). The following wiring colour requirements apply in Canada:

- **Ground wires:** green, or green with a yellow stripe
- **Neutral wires:** white
- **Single phase live wires:** black (or red for a second live wire)
- **3-phase live wires:** red, black and blue

It’s important to remember that the above colour information applies only to AC circuits. You are strongly advised to stick to convention as regards DC power wiring:
RED = POSITIVE; BLACK = NEGATIVES

A.M. Frequency slots in Amateur HF Bands

All Frequencies in MHz

160 Metres: 1.885, 1.900, 1.945, 1.985 (USA)

1.850 (W. Europe)

1.933, 1.963 (UK)

1.843 (Australia)

80 Metres: 3.530, 3650 (South America)

3615, 3625 (in the UK)

3705 (W. Europe)

3.690 (AM Calling Frequency, Australia)

75 Metres: 3.825, 3.870 (West Coast), 3.880, 3.885 (USA)

60 Metres : 5.317

40 Metres: 7.070 (Southern Europe)

7.120, 7.300 (South America)

7.175, 7.290, 7.295 (USA)

7.143, 7.159 (UK)

7.146 (AM Calling, Australia)

20 Metres: 14.286

17 Metres: 18.150

15 Metres: 21.285, 21.425

10 Metres: 29.000-29.200

6 Metres: 50.4 (generally), 50.250 Northern CO

2 Metres: 144.4 (Northwest)

144.425 (Massachusetts)

144.28 (NYC-Long Island)

144.45 (California)

144.265 (Los Angeles, CA)

Other AM Activity Frequencies

AM activity is increasingly found on a number of other bands, in particular: 5317KHz, 7143KHz, 14286KHz, 21425KHz and 29000 - 29150KHz.
There are several local AM nets in the UK on top band.

FM Frequencies

For mobiles working into VMARS events, 2m calling in on 145.500MHz (S20) is usual, before moving to a working frequency. At event locations where military equipment is in use, suggested FM "Centres of Activity" on VHF are 51.700Mhz, 70.425MHz (70.450MHz calling).

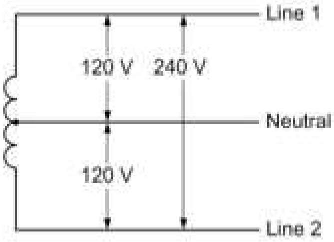
VMARS RECOMMENDED FREQUENCIES

3615 Khz	Saturday AM net 08:30 – 10:30
3615 Khz	Wednesday USB net for military equipment 20:00 – 21:00
3615 Khz	Friday LSB net 19:30 – 20:30
3615 Khz	Regular informal net from around 07:30 - 08:30
3577 Khz	Regular Sunday CW net 09:00
5317 Khz	Regular AM QSO’s, usually late afternoon
7073 Khz	Wednesday LSB 13:30; Collins 618T special interest group
7143 Khz	VMARS AM operating frequency
51.700 MHz	VMARS FM operating frequency, also rallies and events
70.425 MHz	VMARS FM operating frequency, also rallies and events

Electrical Supplies - Courtesy LEGRAND equipment

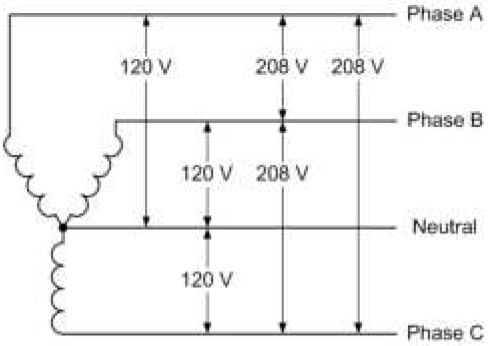
In the following drawings, the coil symbols represent the secondary winding of a utility service transformer or other step down transformer. Electrical code regulations in most jurisdictions require that the neutral conductor be bonded (connected) to the earth safety ground at the electrical service entrance. Note: regional variations may exist: if in ANY doubt, consult your Electrical Supply Authority.

Single Phase Three Wire



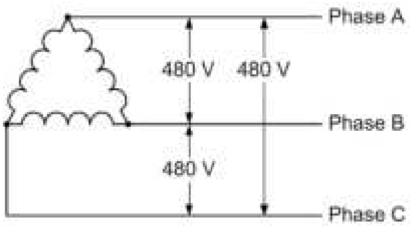
Also known as an Edison system, split-phase or centre-tapped neutral. This is the most common residential service in North America. Line 1 to neutral and Line 2 to neutral are used to power 120 volt lighting and plug loads. Line 1 to Line 2 is used to power 240 volt single phase loads such as a water heater, electric range, or air conditioner.

Three Phase Four Wire Wye



The most common commercial building electric service in North America is 120/208 volt wye, which is used to power 120 volt plug loads, lighting, and smaller HVAC systems. In larger facilities the voltage is 277/480 volt and used to power single phase 277 volt lighting and larger HVAC loads. In western Canada 347/600V is common.

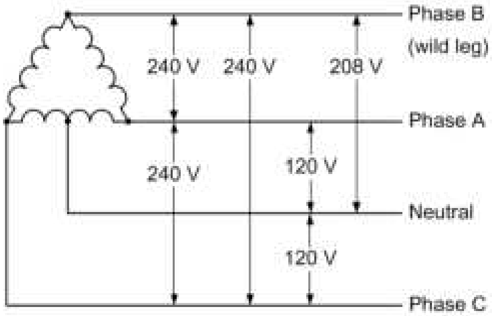
Three Phase Three Wire Delta



Used primarily in industrial facilities to provide power for three-phase motor loads, and in utility power distribution applications. Nominal service voltages of 240, 400, 480, 600, and higher are typical.

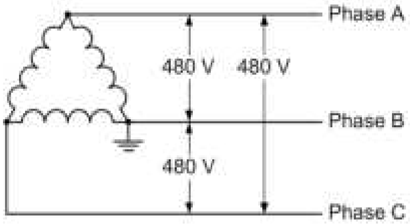
Uncommon Electrical Services

Three Phase Four Wire Delta



Also known as a high-leg or wild-leg delta system. Used in older manufacturing facilities with mostly three-phase motor loads and some 120 volt single-phase lighting and plug loads. Similar to the Three Phase Three Wire Delta discussed above but with a centre-tap on one of the transformer winding to create neutral for 120 volt single-phase loads. Motors are connected to phase A, B, and C, while single-phase loads are connected to either phase A or C and to neutral. Phase B, the high or wild leg, is not used as the voltage to neutral is 208 volt.

Three Phase Two Wire Corner-Grounded Delta



Used to reduce wiring costs by using a service cable with only two insulated conductors rather then the three insulated conductors used in a convention three phase service entrance.

International Electrical Distribution Systems

Description	L–N Vac	L–L Vac	Countries
1-Phase, 2-Wire 120 V with neutral	120	–	US
1-Phase, 2-Wire 230 V with neutral	230	–	EU, UK, Scandinavia
1-Phase, 2-Wire 208 V (No neutral)	–	208	US
1-Phase, 2-Wire 240 V (No neutral)	–	240	US
1-Phase, 3-Wire 120/240 V	120	240	US
3-Phase, 3-Wire 208 V Delta (No neutral)	–	208	US
3-Phase, 3-Wire 230 V Delta (No neutral)	–	230	Norway
3-Phase, 3-Wire 400 V Delta (No neutral)	–	400	EU, UK, Scandinavia
3-Phase, 3-Wire 480 V Delta (No neutral)	–	480	US
3-Phase, 3-Wire 600 V Delta (No neutral)	–	600	US, Canada
3-Phase, 4-Wire 208Y/120 V	120	208	US
3-Phase, 4-Wire 400Y/230 V	230	400	EU, UK, Scandinavia
3-Phase, 4-Wire 415Y/240 V	240	415	Australia
3-Phase, 4-Wire 480Y/277 V	277	480	US
3-Phase, 4-Wire 600Y/347 V	347	600	US, Canada
3-Phase 4-Wire Delta 120/208/240 Wild Phase	120, 208	240	US
3-Phase 4-Wire Delta 240/415/480 Wild Phase	240, 415	480	US
3-Phase Corner-Grounded Delta 208/240	–	240	US
3-Phase Corner-Grounded Delta 415/480	–	480	US

Hot Iron 105

August/ September 2019

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CQ-CQ-CQ

First of all, I'd like to offer a "thank you" to all those readers who have emailed me, on many topics, all of which I found very interesting and relevant. Please keep sending your emails, be they questions, requests, information, or whatever you find an interesting topic that is amateur radio related. All is fair grist to the mill, and very much appreciated. Hot Iron is yours!

Hot Iron 105 has a distinctly 'digital' flavour. This is because of the emails I've received asking or commenting about matters digital, but also because Moore's Law relating to the ever expanding complexity of microelectronics has some rather disturbing and unwarranted results - not always inside the ever smaller IC packages - that have a hefty bearing in an amateur shack and it's operations.

As an example, I can quote a few purely 'digital' problems I'm sure you'll have come across that are the equivalent of running into a brick wall, blocking further progress of a project, or, worse, doing damage to a vital piece of shack equipment.

For instance, I've been setting up some software defined radio projects, using the superb (and cheap!) RTL u.s.b. dongle. The dongle is an excellent piece of electronics, combining mixer, IF amplifier and many other functions in a bit of kit that costs (relatively) peanuts that plugs directly into a computer u.s.b. port; the computer then supplies all the other necessary functions such as filtering, bandwidth adjustments and audio processing, with a 'waterfall' display showing a slice of RF spectrum. By clicking the cursor onto the centre frequency of a signal in the frequency domain, it is demodulated, the mode selected being one of dozens of different modes as desired.

All well and good: but the receiver dongle has to marry up to the computer software that accepts the u.s.b. signals from the dongle and manipulates them via software to give the display, and that's the first major hurdle. Software isn't reliable. It is, just as it says on the tin, "soft". It's not "hard". More to the point, you can't find a dud bit of software with a meter. You can't remove a dud bit, byte or kilobyte and put a new bit in - not without losing all the "upgrades" in the rest of the system, leading to several days waiting whilst the whole software suite is reloaded and updated. That's why I run a Linux Ubuntu operating system on my shack computer, having had experience 'certain' (fenestration-like) operating systems for the past umpteen years driving me nuts (don't ask - but plenty of times in the "depths of a night shift", after 12+ hours of struggling to eliminate all the physical faults in a machine, find the software in the control computer has decided to do something barmy - everything else physically having been eliminated. As Sherlock Holmes said, "whatever is left after everything else has been eliminated is the culprit (then add "or Beelzebub has cast his spawn into the software").

When you issue, in a terminal programme, a very basic fundamental command like "change directory" and a string of errors comes back with no rational explanation as to why, it might be a simple matter of knowing the foibles of an unwieldy operating system, or the programme memory chip(s) - laughingly called "firmware" - are corrupted. Or the machine the computer is issuing contradictory commands to the power supply that cause rail-to-rail kilovolts output or swinging hundreds of amps, causing violent glitching and flashovers. Or the HV power supply's safety earth shunts are shorting the HV stack to ground because the control computer's lost it's bl**dy marbles, or switching the HV output polarity from "+ve" to "-ve" without an appropriate discharging of the system smoothing capacitance. Not usually a major problem in an amateur shack, but this was an Ion Implanter 160kV DC accelerator supply and analyser magnet drive. Not funny!

Then, to add insult to injury, the Day Shift Production Manager is baying for blood, you try telling him (and all the day shift operatives) that the production line's stopped because nothing's actually broken, but a machine has gone gaa-gaa - it's at that moment you realise the digital dream isn't quite what it was cracked up to be, and you know exactly where you'd like to shove your logic probe (with the hook tip fitted, of course) if only you could get at the software designer who foisted this unstable string of algorithms, untested in real World conditions, on you and your fellow engineering brethren.

Of course, the machine manufacturer gave you on a disc or (even worse, on-line) back up files to reload the software; the moment you try a software reload the software in the host machine recognises that an older version of software is being loaded - and promptly spits it's dummy out, refusing to accept the reload to revert to an older version. Or... if the control computer is firmly jammed in a never ending spiral of sub-routines and refuses to do any coherent activity, because a high voltage glitch has corrupted a few bits in the software, how do I connect to the manufacturer's on-line back up file system? I can't use any other computer as in his infinite wisdom the software designer has trapped out any attempt to download his software on anything but the original host computer, for "security" reasons" - which usually means "because the manufacturer wants to charge you an arm and leg for a set of new software discs".

What brought this about was that I recently loaded into my shack Linux computer an SDR / RTL waterfall display / demodulating software suite to run the aforementioned RTL dongle. It didn't work - well, not properly anyway - so I decided to purge it all out of memory, and load an alternative. It took me a week to get my computer back to rights. The dud software blocked a huge chunk of the operating system memory and wouldn't allow removal - it stopped all attempts to remove it, even some powerful "super user" Linux terminal techniques. I eventually had to do a full reload of the operating system, do all the updates, and restore all my files from the back-up hard disc drive, which, thank Gaia, Linux does extremely well, and quickly too.

Software issues have bitten me for many industrial years; I can't be the only one who has run into grief doing what should be a very simple job because some "disruptive technology" twerp in California has added so many bells and whistles to a software programme that it's rendered nigh on useless, or has become a major 'technology' in it's own right - needing an "IT" degree (now there's an oxymoron if ever there was one) to use to it's fullest extent. I don't know if they put mind altering substances in the software writer's drinking water, but whoever dreamt up the programming software for PIC's, and other popular micro-controllers, was away with the fairies in my opinion. Or am I taking E.F. Schumacher's "Small is Beautiful" philosophy too liberally? - but I know from bitter practical experience (as does any engineer who's tried to get a plant running under extreme duress, whilst dog tired, without the spare parts warehouse every machine manufacturer assumes his customers hold) that "simple is as simple does" and it's alter ego: if it's simple then it's reliable. Maybe it's not quite as reliable as a purely electronic software combination; but for those mere mortals of us who have to live in the real World of a time and budget constrained environment, simple systems (i.e. non-software) are eminently fixable, adaptable, and substitution friendly beasts.

A 400kW / 200kHz RF generator I worked on often came in two variants: one was significantly cheaper than the other, and the cheaper proved version very much more reliable in the face of 3 phase supply glitches, lost phases and brown-outs. It wasn't a few percent more reliable: it was orders of magnitude more reliable, and the RF generator of choice for developing countries where 3 phase power was not as reliable as we are accustomed to here in Europe / North America. The more expensive version had data logging, statistical process control displays of any variable you can name and was intra-net capable so control from a central office was possible. This all-singing, all dancing version was useless outside Europe / North America; the cheaper version, with it's box of contactors and power transistors in the SCR power control box, ran year in, year out with basic routine servicing and general maintenance - and you could squeeze a few more kW's out the thing by carefully manually tuning the system (the more expensive version had "auto tuning", or as we very quickly found out, "auto mis-tuning", after changing the power grid tube a few times) - the auto tuning couldn't cope with connections in the RF circuit over a few μohms, a common problem in copper bus bars with thousands of RF amps flowing through them causing premature failure.

It has to be said that electronic software systems running "CANbus" control are reliable, as witness the far fewer car breakdowns seen nowadays, CANbus being the acronym for "Computer Automotive Network bus". That said, I went to a classic car exhibition last weekend: a Ford Model "T", with original "buzz-box" ignition system was chuffing around; an "Austin 7", running a 750cc side valve engine, with coil / distributor ignition - all original parts - was happily clocking up 250,000 miles on the original crankshaft bearings; a Velocette MSS 500cc single cylinder motorcycle, running on the original Miller magneto, never having had a new contact breaker fitted, the original being perfectly serviceable and repairable with a new contact breaker points made from 4mm brass bolts fitted every 20,000 miles. Fixable; reliable, and economical, not a sniff of software or LSI integrated circuits anywhere - but more than that, they did what they said on the tin, with without fuss, gadgets, bells, whistles or useless idiotic features only one in a thousand customers would find useful.

The moral is this, in my opinion: if you want functionality in adverse conditions (surely THE most common operating demand made on amateur radio gear) then simple is (usually) best. If you have budget and time to waste, then by all means, spend your mega $'s / £'s on the latest technical wizardry, but I'll bet a Penny to a Pound you'll learn a lot more building basic bits of kit, fixing them after pushing them a bit too hard, modifying them to get the features you want, not what some marketing psychologist tells me you *need.*

I make only few exceptions to the above, which I've mentioned in Hot Iron before: DDS and PLL digitally controlled VFO's. I've chatted with quite a few designers of these wondrous VFO's, about using digi-switches and the like to set up the command words, but really, they cry out for simple micro-controllers as they use serial "words" to input the frequency control command. I also have vast regard for the designers who give us modern versions of "classic" CMOS and TTL logic gates - the 74HC families and the like. These wondrous beasties breeze along at 50MHz and more, driving healthy output currents - ideal for switching power mosfets via simple gate driver circuits. Combine a digital VFO with an HC NOR gate for easy on / off keying, a common base fast gate driver feeding an HV power mosfet with a class "E" output network and you've a very potent AM* / CW transmitter with very few components, superb frequency control, and very high power efficiency. Just the job!

* *AM being produced by pulse width modulation (class D or E operation) of the HV supply to the class E power stage - very low loss, very efficient audio modulation but great care needed to eliminate any birdies from the PWM switching frequencies.*

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A rant by Jenny List (and a busted TV)

Here's a rant by Jenny List - which I (partly) agree with - that I saw recently, that certainly highlighted many a headache I've suffered both in professional RF engineering and amateur times too. The one thing Jenny doesn't comment on is how an amateur can design with the modern "system on a chip", or, in fact, do an amateur repair of a pcb containing one of these beasts. A good example of that is a flat screen TV I recently "inherited" - the fault being a "dead set". "Aha!" thinks I, "that's a power supply problem if ever I saw one!"

I opened the thing up: it has two pcb's, each the size of a playing card or small postcard (if you can remember them...). One was the entire power supply, mains in, low volts out; the other was the "AV" board, RF, HDMI, SCART, Audio, Video, USB ports x 2 and a few other I/O's, with a 15 way ribbon cable connected the two pcb's and a 24 way flat cable to the display - which had decoder / driver electronics built into the edges. The AV board did ALL the signal processing: it had one massive chip in the middle, taking RF from a tiny tuner module, as well as the audio amplifier driving stereo speakers, and the remote control functions too.

I searched on the web for information: I found a page which - without going too deep - said of a dead set - "check the power supply output; if the +12v and +5v are present, the AV board's faulty. If the voltages are missing, or wrong, the PSU board's faulty. Replace as required". In other words, TV repair is now board level: no diagrams, circuits or test points. Just "check and replace". I should add the display, a 21" LED job, works perfectly; and was probably more than 80% of the cost of the whole thing. Replacement pcb's searched for on favourite on-line auction supplier - "Obsolete". Stock next due in? "None Available for foreseen future".

The TV was just over 5 years old, and destined for the bin, discarding the most valuable part - the display - which is surely the most wasteful and useless policy I've come across to date. If this is the
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standard of modern electronics recycling useful materials, then the future is getting a bit gloomy for amateur repairers and constructors, who want to work to component level, not bung in another pcb.

"Zombie Components - those that never die"

"As a fresh-faced electronic engineering student while the first Gulf War was raging in a far-off desert, I learned my way through the different families of 74 logic at a university in the North of England. 74LS was the one to use, the story went, because it's quick and doesn't use much power. At the time, there was an upstart on the scene: 74HC. Now that's *really* quick. New. *Exotic*, even.

Thus an association was formed, when you want a quick logic function then 74HC is the modern one to go for. It could have been a lifelong love affair, but over twenty years, after many factors of speed increases and some RF tricks with gates we wouldn't have dreamed of back then, it's over. There is a whole world of newer logic families to choose from, and while HC is still good at what it does, it's well past time to admit that it may just have been superseded.

A tendency to cling to the past with logic families is pretty harmless. Like "TIP" power transistors they're pretty cheap, still very much in production, and still do most jobs demanded of them excellently. But what prompted this piece was a far more egregious example of an old component still being specified: the RCA 40673 dual-gate MOSFET. Launched in the mists of time when dinosaurs probably still roamed the earth, this static-sensitive four-pin TO72 found a home in a huge variety of RF amplifiers, oscillators, and mixers. It worked well, but as you might expect better devices came along, and the 40673 was withdrawn some time in the 1980s. Unfortunately, nobody seems to have told a section of the amateur radio community about the 40673's demise. Or perhaps nobody's told them that many scrap analogue TV tuners of a certain age will yield a perfectly good newer replacement for free. Because even today, thirty years after the 40673 shuffled off this mortal coil, you can still find people specifying it. If you have a stash of them in your junk box, they're worth a small fortune, and yours could be the bench with the throng of people at the next ham radio convention.

A different but equally annoying manifestation of the phenomenon comes when the device everyone likes to specify is not very old and very much still in production, but the designer hasn't taken the time required to check for a cheaper alternative. Nobody ever got fired for buying IBM, they say, but perhaps they should be fired for specifying an AD8307 logarithmic amplifier in an amateur radio power meter. Don't take this the wrong way, it's a beautiful chip and probably a lot of work at Analog Devices has gone into laser-trimming resistors to make it perform to an extremely demanding specification. But *eleven dollars* for a chip? When a cursory search will turn up Maxim's MAX9933 which does a perfectly good job in this application at well under two dollars? Someone isn't doing their homework.

Sometimes there are components for which there are no perfect replacements. Germanium point-contact diodes, for example. 1N34As and OA91s are becoming like hen's teeth these days, and though Schottky diodes can replace them in many applications, there are still a few places if you're a radio person you'll hanker for the original. There are suppliers on Alibaba who claim to manufacture 1N34s, but the pictures always look suspiciously like 1N4148s, and anyway who can find a home for (a minimum order of) one hundred thousand diodes?

OK, maybe germanium diodes are an edge case and the examples above have a radio flavour, but you get the picture. What the full-blown rant in the previous paragraphs has been building up to is this: a plea for designers to do their homework. Please try to design every project for the next two decades, and as though any extras in the component price come from your company's bottom line. (We'll make exceptions for building something for which the whole point is a retro circuit. An Apple I replica like the Mimeo 1 [*click the link*] needs old logic chips for artistic purposes.)
Is there a vital electronic engineering skill that's being lost here perhaps? Back when the Internet was the sole preserve of boffins and Tim Berners-Lee hadn't yet plugged his hypertext ideas into it, we relied on catalogues. Big paper-bound books the size of telephone directories were our only window into the exciting world of electronic components. If you're an American yours was probably from Radio Shack, but for most UK-based hackers and makers who couldn't get their hands on a commercial account from RS or Farnell that meant the Maplin catalogue. Before they moved in a consumer-electronics direction, they were a component specialist whose catalogue with its distinctive spaceships on the cover could be bought at large news stands.
It's difficult to describe the impact of electronics catalogues in the '70s and '80s to someone who has known only the abundance of information from the web. These publications were our only window into the world of electronic components. They contained significant excerpts from semiconductor data sheets, and we read their wealth of information from cover to cover. We knew by heart what each device was capable of, and we eagerly devoured each new morsel of information as it arrived.

In short, when we specified a component, we did so with a pretty good knowledge of all the components that were available to us.

By comparison, nowadays we can quickly buy almost any device or component in production from a multitude of suppliers. There are millions more devices available, and if RS or Farnell don't have the part then Mouser or Digi-Key are sure to provide. The web allows us to find what we need in short order, and the miracle of global distribution means that we can have it delivered within 48 hours almost wherever we live.

Which means that all the new devices are available to us, but we've lost the ability to keep on top of them. We've become information rich, but knowledge poor. Printed catalogs still exist, but the sheer volume of information they contain forces brevity upon their entries and expands the size of the publication to the point at which it becomes an unwieldy work of reference. We therefore tend to stick with the devices and components we know, regardless of their cost or of whether they have been superseded, and our work is poorer for it.

We need to relearn the skill of inquisitiveness when it comes to the parts we use, and to rediscover the joy of just browsing, even if the medium is now a huge suppliers' web site rather than a paper catalogue. Otherwise we'll still be looking at circuit diagrams containing 74LS logic and 40673 MOSFETs in the 2030s, and that can't be a good thing!

There is of course also a slightly macabre alternative scenario. The highest online price we found for 40673s was over $30 each, so if a producer can make that kind of silly money then there's a danger that RCA's successors will see a business model in exhuming the corpse and re-animating it, thus ensuring that we'll **never** be free of the undead. We need to make sure that doesn't happen!"

[*My grateful thanks go to Jenny List for this excellent article. For those of us with a penchant for thermionics, though, it's a wise move to keep a weather eye open on solid state developments - before returning to sanity and simple, effective circuits that don't go up in a puff of smoke at the merest hint of overload or lightning strike a hundred miles away. I look forward with keen anticipation to the introduction of a solid state device of equal capability and price as a 4CX250! Mind you, at $30 for a 40673 it's very tempting to have a quiet word with some of my old pals in a wafer fab. Or... experiment with cascode connected BS170 / 2N7000 mosfets as a 40673 substitute? P. Th.*]

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Rx

A Franklin Receiver

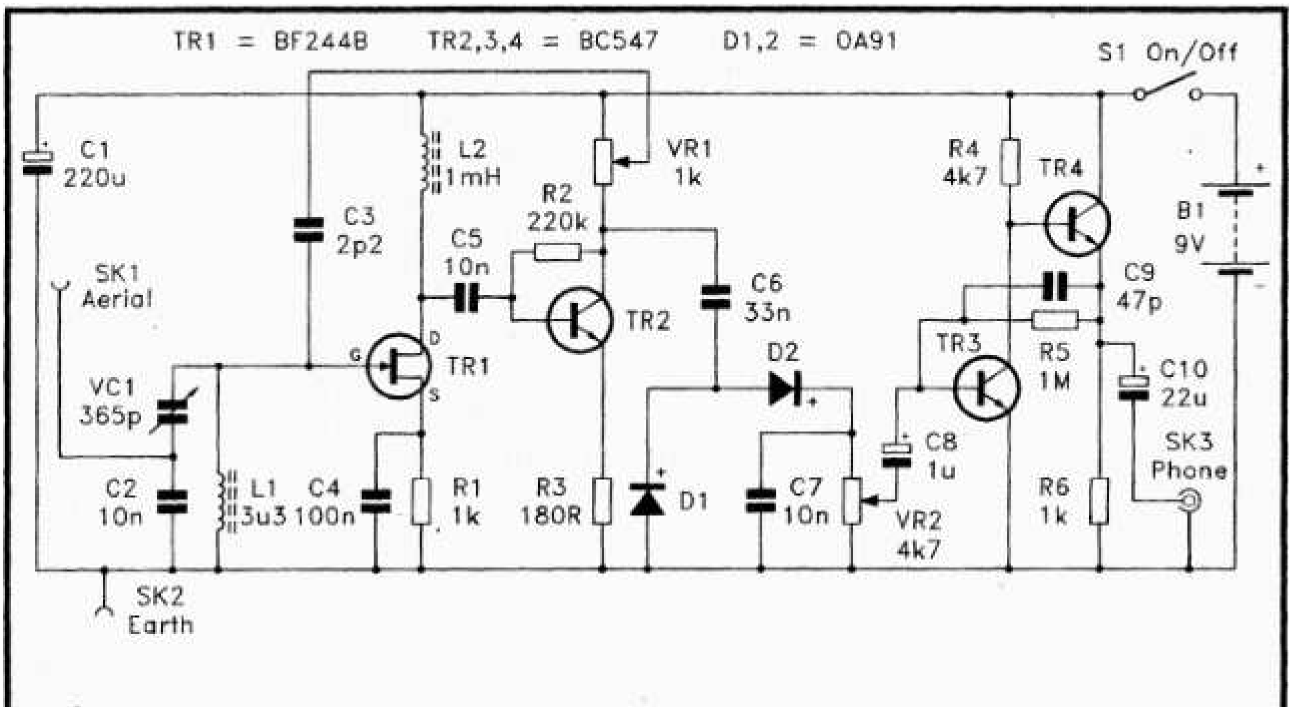
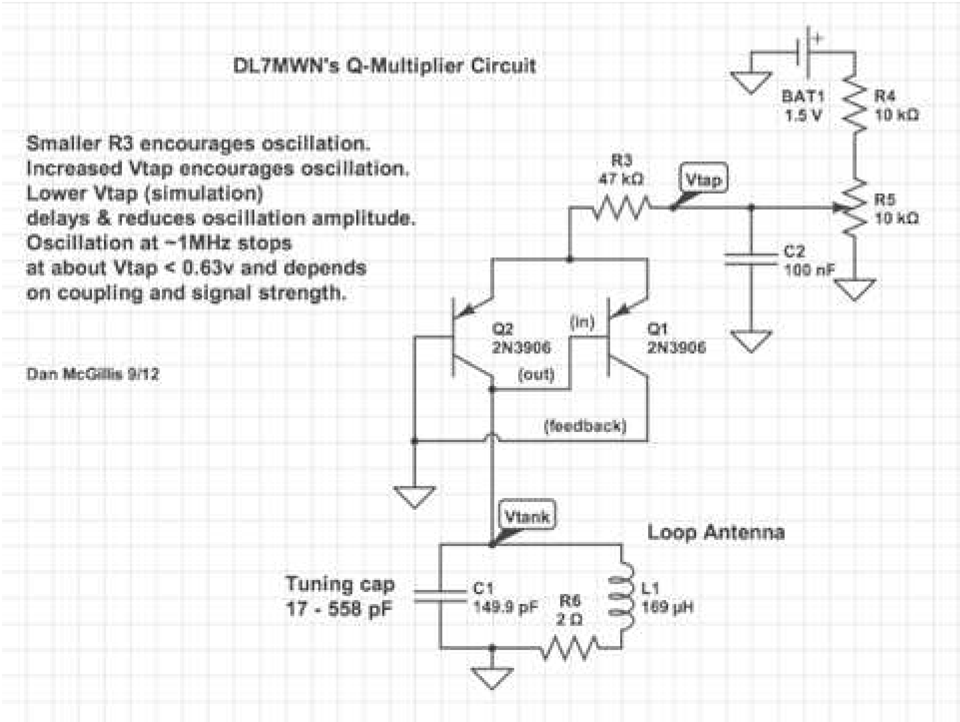


Fig.3.8 The circuit diagram for the s.w. t.r.f. receiver

The Franklin oscillator was a well known beast in the 1930's: using valves it was a very stable LC oscillator as the LC circuit is earthed at one end, and can be remote from the heat producing valves. The circuit was a derivative of the Eccles-Jordan flip flop; it's a multivibrator in disguise! Take a look at TR1 and TR2 in the above diagram (from the one and only R.A. Penfold; many similar found on the Internet).

A multivibrator is a pair of amplifier stages, the output of each stage feeding the input of the other - see below - and so you'll see in "the circuit diagram for the S.W. T.R.F. receiver" above: C5 feeds the base of TR2, C3 feeds the output of TR2 into the gate of TR1 - whose drain is connected to C5. Thus the loop is closed; the overall phase shift is a guaranteed 360° at all frequencies (within the parameters of the device's frequency responses, that is). VR1 picks off the signal at TR2 collector and controls the feedback to TR1 gate, via C3 which can be made very small - the loading on the LC circuit is minimal, so the circuit can be set just at the point of regeneration and the LC circuit Q factor kept as high as possible. The use of a jfet for TR1 is important: it reduces the loading on the LC tuning tank to almost negligible levels, allowing a very high Q and thus selectivity. A bipolar device in this position would significantly load the tuning tank as (without bootstrapping) the input impedance would be far lower.

The gain available in two devices as opposed to the usual one used in a regen detector receiver is far greater; and the phase shift around the amplifier loop is 360°, guaranteed by double inversion stages and not reliant on phase changes across inductors or capacitors. The nett result is that "two is better than one"; and if you look at some of the "Russian" two transistor oscillators and receivers by Viktor Polyakov you'll see they can be extremely simple and superbly effective- especially as add-on Q multipliers, needing only a 1.5v dry cell to power them, plus minimal power consumption.



Q1, Q2 form a multivibrator - note how the collector of each transistor feeds the base of the other - with an LC element frequency selective network (in this case, a loop antenna, but could be any LC network, or indeed, a quartz crystal) in the feedback path to force one frequency of oscillation; used here by Dan McGillis, and in many "Polyakov" designs. A low value resistor (say 27R?) in each emitter lead might "calm the beast", giving a more controllable oscillation onset: without a little degeneration, as Vtap reaches the Vbe of one transistor, the circuit suddenly comes alive; the added resistors give a little negative feedback to 'soften' the switching point.

In the Franklin the detection of A.M. is done by a voltage doubler circuit to feed the audio amplifier section, a standard two transistor design. I'd be tempted to fit modern very low noise audio transistors for TR3 / 4, I've seen references to ZTX851 transistors being ultra-low noise as the Rbb value (it's a power device) is around 2 -3 ohms, and the lower Rbb, the better for low noise. The ZTX851 has the added advantage of being a through hole E-Line device, so easily employed in amateur construction - and being a "ZTX" device, is as tough as old boots and very robust.

Of course, CW and SSB can be handled by allowing the Franklin to *just* oscillate; by adjusting the value of C3 by constructing it with a trimmer or even better, a few inches of hook up wire twisted together as a "gimmick" capacitor, that can be un-twisted little by little until the regeneration is silky smooth and only just capable of oscillation. Or of course, use an external carrier oscillator to introduce a sniff of carrier at signal frequency - a doddle for DDS / PIC VFO's.

You'll have noticed an anomaly in the Franklin diagram: the 10nF capacitor to ground below the tuning capacitor VC1 effectively shunts the antenna signal to ground. In my opinion, the antenna should be connected via a tiny capacitor to the gate side of VC1 - another “gimmick” capacitor is a great idea, or even a short wire close to C3. Adding a very low gain RF amplifier for isolation is a very good idea, capacitively feeding the gate circuit as suggested above.

For an interesting 160m / 80m receiver, the LC circuit can be constructed as a frame antenna, to give excellent directionality to null the thund’rous noise found nowadays on bands under 20m.

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RTL SDR receivers

I had an email recently asking about Software Derived Receivers and having had a ‘gross encounter of the worst kind’ with said SDR software, I dug out my notes and had another look. The very low cost ‘RTL’ USB computer dongle TV receiver has had much work centred around it, and probably represents the cheapest piece of powerful RF hardware you’ll find today in terms of bandwidth and capability. Whilst not the absolute ultimate in performance, it does a splendid job for very few £’s / $’s, **provided** you can get the driver software set up and stable on your computer.

There are several other important ‘features’ of the RTL - SDR; and this being the Journal of the Constructor’s Club, those features and how to employ them will be my focus: the innards of the RTL dongle’s chips are well documented on-line, and since you can’t get inside the chips with a soldering iron and wire cutters, are not of much import at G6NGR. The drivers and software gimmicks that derive the performance are, however: but you’ve probably noted my distinct warnings about software earlier in this issue and I’m not including software as a ‘construction’ feature unless it’s got a direct relevance to the job in hand.

So to business. The RTL dongle is a radio receiver that covers (approximately) 24MHz to 1600MHz (depending on version, manufacturer and type) and outputs two quadrature signals to the USB port, as per the Direct Conversion principle of sideband selection / elimination, the “I” and “Q” signals. The software inside the host computer does the rest: the amplification, demodulation, filtering, buffering and audio. Using some software ‘tricks’ the Nyquist limit is (apparently) overcome resulting in full coverage without aliases and other sampling errors and foibles.

The RTL USB dongle has an antenna socket input, and being designed for TV reception, is of 75 ohm input impedance. You get a mini antenna with the dongle, a short length of micro-coax leading to a crimped plug that fits the dongle’s antenna socket. Obviously the mini antenna can be removed, and connected to a superior antenna, and of course you can fit an RF amp / filter section if desired, but it’s probably not required unless you have severe noise / interference issues at 24MHz and up.

By now you’ll have noticed the first snag: ‘24MHz and up’. Yes, the RTL doesn’t go below 24 MHz. Some sneaky software tricks can help, as can physically opening the dongle and altering the mini pcb inside; but help is at hand for the discerning user - an *up-converter*.

Simply stated, assuming you want to receive signals below 24MHz, you feed the incoming antenna signal into a mixer, and transform the signal upwards in frequency to somewhere more fitted to the RTL’s specification: 50MHz or 100MHz are common up-shifts. Thus an HF signal at 10MHz becomes 60MHz or 110MHz; and you can adjust the antenna signal’s RF gain and filtering
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externally to better suit your environment. There a many up-converters described on-line, using every variety of mixer you care to name; but for my money it's a pre-packaged diode ring mixer for wide bandwidth and strong signal capability. Note the local oscillator driving the mixer should be set exactly as the manufacturer states; the drive level has to be set properly if aliases and noise are to be eliminated (as far as is possible, that is) and an appropriate termination used for the mixer output. It's an interesting discussion point to compare diode ring mixer drive signal wave shapes: the diodes need switching well and truly on / off, so logic level drive is often advocated, but this then includes all the harmonics! Sine drive is effective too, but you need to be sure you have the milli-Watts of grunt to really switch the diodes properly.

The next caveat is the positioning of the RTL dongle. It's tempting to plug it into your computer and off you go: and there, for all to see, are the spikes of noise the zillions of transistors in your computer are spewing out. Computers are (in RF receiver terms) noisy beasts to say the least! It's like listening to a faint signal in a roaring gale, with somebody running an old petrol lawn mower right next to you. The partial answer is a USB extension cable: but again, a caveat strikes: it's got to be USB 2.0 (at least) capable, the fastest data rate possible. Which limits the cable length to 5m or so before the speed degrades! The way round this limit is a powered USB buffer hub, to then allow adding another 5m USB cable to be connected, to locate the RTL dongle far enough away from the computer to avoid the racket your computer kicks out.

By now, the SDR as an easy option 'plug-n-play' radio receiver is fast disappearing! The problems can be overcome; the issues can be resolved - but be prepared for the problems, it's not as easy as you might think.

There exists, however, what must be the cheapest way to listen on-air to amateur signals: no mixers, no software loading your computer, no antenna, no mucking about - use an internet connected "web SDR" radio receiver that you tune, control and set up - all online - and observe the waterfall display just as if it was your own computer, in your own shack. Take a look at these for starters:

1. websdr.org (just type this in the address bar of your web browser)
2. https://www.globaltuners.com/receiver/
3. https://www.dxzone.com/catalog/Internet_and_Radio/Online_Receivers/

These are just a few of many web SDR (and conventional Rx with remote control) receivers you can access in many parts of the World, just by signing up to an account. Now that's digital technology I like!

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Oscillators

A Sweeping Oscillator

Terry Mowles, VK5TM, has been up to his wonderful tricks again, and produced a design for a sweep frequency oscillator for alignment and other useful purposes (anybody for frequency agile communications on an amateur band?) The link to Terry's design is below:

https://www.vk5tm.com/homebrew/simple_sweep/simple_sweep.php

Terry's web pages are always an interesting read, and you can get pcb's from him, should you require them for his projects. Terry maintains a good outlook on his projects, they do exactly what it says on the tin, no more, no less: what more can you ask? And he dislikes software over-engineering and features added for little purpose, which makes him very much on my wavelength. If you're programming PIC's and the like, try to download and use older versions of the software for the job - the archived versions before the 'bells & whistles' brigade had been at them and added more useless (by the majority of users) "eye candy" features.

Andrew Woodfield's (ZL2PD) PLL VFO's

Andrew very kindly wrote to me commenting on my recent notes in Hot Iron #104 about DDS VFO's, and recommended I look at his design for a PLL VFO that fits in **half a matchbox (!!!)** including a mini OLED display - and added a few thoughts too. I strongly suggest you look up his web page www.zl2pd.com and his note to me is reproduced below:

"*Thanks for the copy of Hot Iron, Peter. The remarks in this issue about DDS oscillators spurred me to write.*

DDS is good, but fractional-N PLLs are arguably more compact and cheaper, such as the now famous si5351a chip. I have built a number of these now. They are super cheap, and it can provide three vfo outputs from 3.4kHz to 295MHz or so, with steps from 1hz to 10MHz or whatever you choose to program. See some examples on my website at www.zl2pd.com *(That's ZL2PD not the number 12 in that URL). Must remember to upload some more examples next week. And these vfo consume less than 30mA at 3.3V usually while being capable of driving diode DBMs directly.*

With SMD, I can build a great drift-free vfo for HF and VHF in half a matchbox. With a tiny 128x32 oled display on the outside. I don't bother trying that any more with analog(ue) or DDS. Well, maybe occasionally.

For completeness, you could also mention the very recent design by VU3XVR which uses an ATtiny13 with a potentiometer, but no display(!!), relying on the variable resistor for tuning, and presumably it's knob scale for frequency readout. Importantly, although not stated there, it would also presumably require a very stable voltage rail for the pot. The Tiny13 would shift with changes *in voltage using this very simple approach. (See http://www.siars.org.in/) However, it appears to be a very cheap replacement for a ceramic VXO tuned with the same pot. With si5351a chips down as low as 79p in the UK, this looks an interesting approach, with care.*

For more features, maybe filling the rest of the matchbox, aside from all my designs of course, there are also the compact ATmega-based VFO/si5351a designs from Peter, DK7IH. See the VFO section of his Micro24, for example, on https://radiotransmitter.)

Cheers
Andrew ZL2PD"

I can only say that "you pays your money, and makes your choice"! But... and here comes the caveat - you need some of that "spawn of Beelzebub" software to set up the control micro-controller. Don't say I didn't warn you!

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Tx

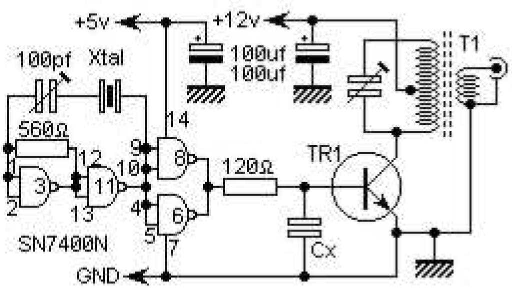
Frequency detecting PIC / rig control?

From VK5TM, Terry Mowles, comes yet another development using PIC's: a frequency switch that can be adapted for rig control too, sequentially switching bias supplies and the like. I won't waffle on about this as you can read the entire thing on Terry's web pages - click the link below:

https://www.vk5tm.com/homebrew/freq_switch/freq_switch.php

Terry is making some remarkable inroads to PIC applications; the next article is a project that would probably suit modern PIC technology very nicely. I must admit (and it's just my personal preference) fault finding with a meter and logic probe is a damn sight easier than trying to find an errant comma or other furtive software glitch!

SM0VPO's logic gate Tx



Whilst this must be one of the simplest and most effective transmitters ever devised, Harry's design lends itself to adding a few extras. Crystal control isn't everybody's cup of tea (but for QRP operators, working on an internationally known frequency whilst whispering into the ionospheric galleries is a definite advantage - QRP'ers know where to listen out for you) so some means of shifting frequency yet keeping "rock" solid stability is, for some, a *good thing*.

Of course, the modern DDS/PLL devices, with attendant microcontroller control, are superb, no doubt 'bout that - but for the meter and screwdriver dinosaurs like me, the following is a cracking
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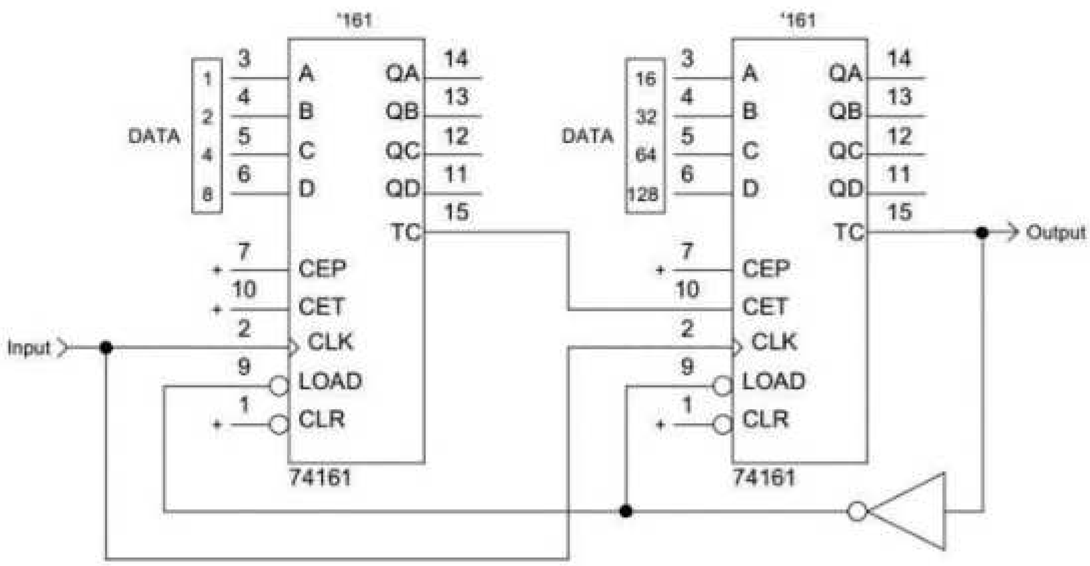
idea. I’ve always had vast respect for Chas. Wendel’s work: a true RF professional, he is a modest and helpful man - and if you stroll through the circuits he’s developed (many using only a couple of transistors!) you glimpse the humour in the man, and I await with bated breath his two transistor bread slicer! Below is a block diagram of my future investigations, once the Pink Brazilian transmitter has earned it’s stripes:

Divide by N Using the '161 Counter

Here is a simple circuit for obtaining divide-by-N from '161s. The technique will work for one, two, or more dividers to obtain the desired N value. One counter handles N values up to 16, two counters divide by N values up to 256, etc. The terminal count, TC, of the last divider is inverted and used to preset all of the counters. The other TC pins are connected to the following counter's CET input. The CET input of the first divider is connected to logic 1 (+VCC).



The data inputs are programmed for the desired division factor, N, using the equation:

DATA = 256 - N.

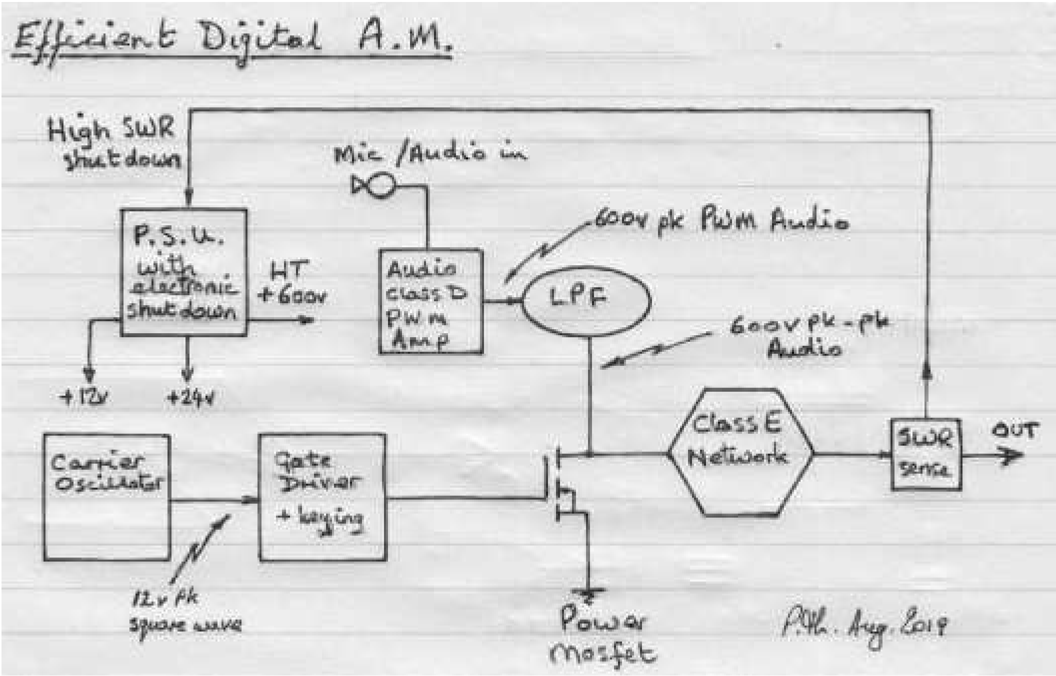
with the value of each bit as shown in the boxes. For example, to divide by 183:

DATA = 256 - 183 = 73

And the binary representation of 73 is 01001001 (the first digit being pin 6 of the second '161 and the last digit being pin 3 of the first '161).

www.techlib.com/electronics/74161Divider.htm 1/1

The IC's are of course the 74HC161 type; and my thanks go to Chas. Wendel for his superb work. Now consider: if we drive this circuit with a crystal oscillator, you can create almost any frequency you want, by selecting the division ratio, assuming you have a high enough frequency to start with and the '161's can clock at that rate. Now if we add a LOCO clock multiplier chip, we can divide and multiply by the integers available - LOCO clock multipliers can run to several hundred MHz, and offer ratios of 2,3,4,5,6,7,8 and more - and you can cascade them for even more numbers. With a bit of jiggery pokery you'll get virtually any frequency you want, crystal controlled, with a few tuppeny IC's. What's not to like? Combine this easy "bench" technology with efficient A.M. and you've a very potent phone transmitter indeed, reasonably simple, **no software**, which is a winner in my book!



(Many thanks to the http://www.classeradio.com/modulate.htm)

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Construction

Soldering technology

"Anybody can learn to make a perfect soldered joint; the trick is to make millions of perfect soldered joints, day in, day out". This was said to me at a World class soldering machine manufacturer's factory on a technical visit - and it sums up the job perfectly. There are many methods of automating soldering, including - but not exclusively - wave, reflow, vapour phase, inert atmosphere, vacuum, laser and many derivatives of these technologies. All rely on getting the joint hot enough to melt solder (note I say "joint", NOT "soldering iron") and removing surface oxides sufficiently to allow tin to dissolve copper to some extent. That's how soft solder works: tin dissolves a few atoms deep into the copper; copper dissolves a few atoms deep in the tin to make a
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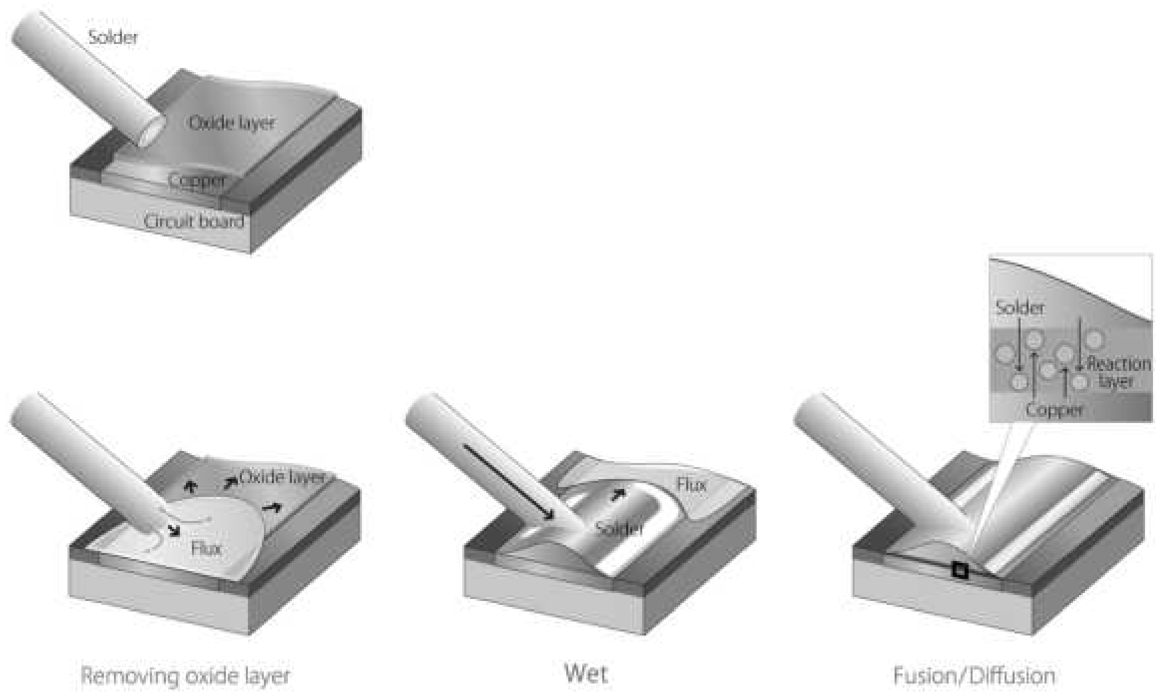
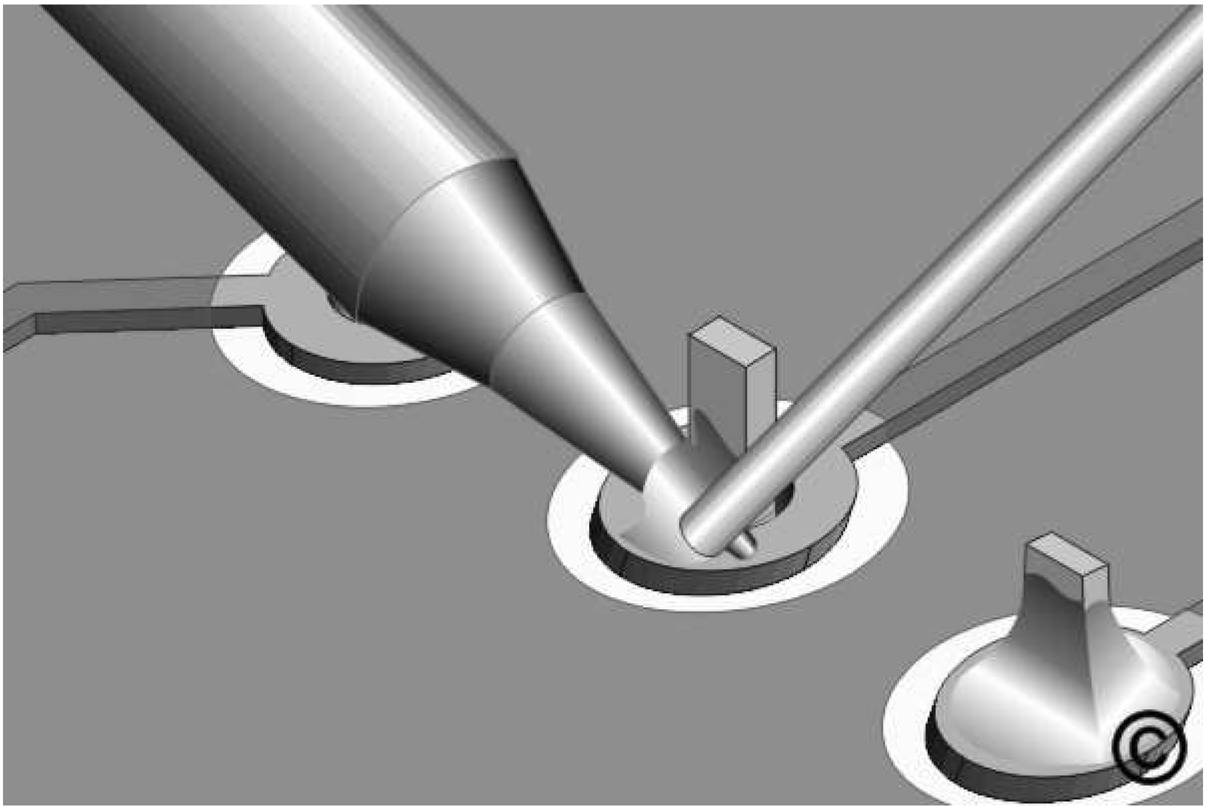
solute metal interstitial layer. After using such big words, a picture is perhaps a good idea. This series of images is from japanunix.com, and illustrates the creation of a soldered joint:



You’ll have to imagine the copper track has been heated by hot soldering iron contact.; the actual stages (you can actually see these stages down a microscope when hand soldering) are illustrated perfectly in the diagram. The stages are:

1. Flux cored solder wire is touched to the copper track
2. Flux melts from inside the cored solder onto the oxide layer, and strips the oxide layer away, exposing pure copper
3. The solder melts as heat is conducted from the copper track into the solder wire, and the flux is pushed along the copper track,much like a glacial moraine
4. The heat and time of contact (a fraction of a second) between the molten solder and unoxidised copper track allows the tin and copper to dissolve a few atoms deep - this is the mechanical and electrical connection.

The following illustration, from circuitrework.com, to whom I give my grateful thanks, shows a component lead being soldered - and illustrates vitally important features of a quality soldered joint:



Note how the soldering iron touches both the copper pad, and the component lead: the area of contact to each part of the joint determines how much heat is introduced to each part of the joint. The solder is applied to the pad, as this gets the flux to run directly onto the copper - if the solder wire was put onto the soldering iron bit, the flux would have cleaned (mostly) the bit, not the pad and lead! Note too the shape of the soldered joint to the right of the joint being soldered: it is truly concave, and uses a minimum amount of solder to cover the pad and most of the lead. Too much solder *does not improve the joint in any way*, and doing so may overheat the component. The soldering heat can only be tolerated by a component for so long before degradation of the semiconductor die inside occurs!

This last is a very important point in machine soldering: the time any component is withstanding the full heat of molten solder is a very important constraint. below is a diagram of a wave soldering machine, the most effective and cheapest mass soldering technology, where a bath of molten solder is pumped up to form an overflowing wave that contacts the underside of a printed circuit board. Flux applied prior to the solder bath is ‘activated’ i.e. removes the oxide from the pcb’s copper and component leads when the full heat of the solder is applied, thus the time of contact with the hot solder wave is critical for good joints every time.

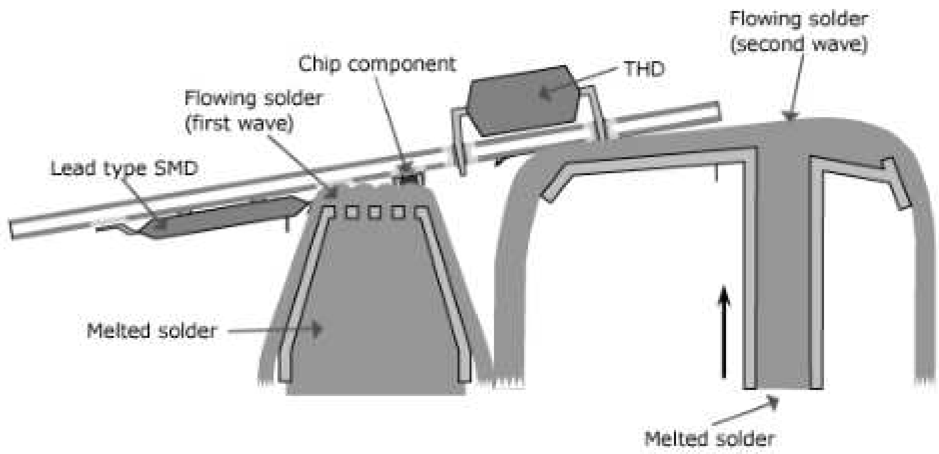


Figure 1.12 Flow (Wave Soldering) Method (Example)

This diagram is from edgar-blajec.squarespace.com, for which many thanks. The process is as follows; the circuit board and components are moving from left to right, along an inclined conveyor, the angle of which is critical:

1. The printed circuit boards, on entering the machine, are sprayed with flux which is then baked to remove the solvent and leave active flux evenly coated on the pcb.
2. The pcb is moved through the first 'wave', which is usually turbulent - you can see the multiple nozzles forming a 'ripple' wave which solders the intricate and shielded joints.
3. The pcb, now very hot, moves into the second, 'flow' wave, which solders the larger and more heat sinking components; you can see the actual region of contact of solder on the pcb is defined by the wave height (i.e. how fast the pumps push molten solder upwards to create the wave).
4. The pcb now leaves the flow wave, the solder peels off the underside cleanly, leaving soldered joint with a minimum of solder applied.
5. In some instances, a 'hot air knife' can be used to remove excess solder, immediately after the wave: this works by blowing an accurately defined stream of hot air (or nitrogen in some cases) to remove excess solder and drop it back into the solder bath below.

The temperatures, angle of conveyor, solder pump speeds, flux spray settings, pre-heat control are all specific to a particular pcb: it's not often that two different pcb's run the same machine settings unless they are remarkably similar. The 'process recipes' are usually held in the control computer, set up by running many trials until the optimum is found; as the production run continues, the solder in the baths becomes oxidised by being continually exposed to air. This produces 'dross', oxides of tin and dissolved copper, mixed with burnt excess flux and other contaminants that have to be removed. This is a continuous process; in some machines a nitrogen cover gas is applied to keep oxygen away from solder waves and pcb's - this is known as 'nitrogen inerting' and is a very costly (in terms of nitrogen gas used) process, involving airlocks to get pcb's in and out. Servicing is very difficult too, as all air has to be displaced by nitrogen before the process can be run after routine maintenance. I'm working on designing a much more efficient nitrogen inerting system, but that's beyond the scope of Hot Iron: unless you're planning on producing several million of your current radio project's pcb's that is!

Soldering is very much taken for granted when knocking a few boards together in the amateur workshop - but look around at the electronics in your home and workplace and give a thought for all the people and technology involved in bringing you modern electronics at such low prices.

Soldering Flux

From bitter experience, you MUST keep adequate ventilation and fume extraction at all times when soldering. IT IS DANGEROUS TO INHALE FLUX FUMES OF ANY SORT. You won't feel ill right away; but in time it can be - you may have permanent lung damage, including COPD / asthma.

I shudder to recall - in years gone by we smoked cigarettes whilst using resin cored solder at the bench, used Baker's Fluid (a barbarous mixture of metallic zinc chippings and hydrochloric acid), a proprietary brand of rosin flux(ite), and stainless steel flux containing phosphoric acid. That doesn't include silver soldering and brazing, both done with raw borax powder as flux and oxy-acetylene torches. We thought nothing of it at the time...

From article by Jeff Johnson, https://www.pcbtoolexpert.com/best-flux-for-soldering-electronics

"*The Best Flux for soldering Electronics*

If you work with electronics, you know that soldering is an essential part of your job. However, improper soldering can lead to bad joints or even no joints at all. To help increase the likelihood of a good solder, professionals recommend the use of a flux.

What is Flux?

When solder is melted down to form a joint between two opposing metal surfaces, it crease what is referred to as a metallurgical bond. In other words, the solder chemically reacts with other metal surfaces to create a joint. For a solid bond, there are two main things you need. The first is a solder that is compatible, in a metallurgical sense, with the types of metals you are bonding. Secondly, the metal surfaces that are to be jointed should be free of oxides, dust, and other such particles that can damage the integrity of the solder joint. While cleaning metal surfaces can easily remove the dust and grime, oxides are a different story.

Oxides

When a metal surface comes into contact with oxygen, it creates a chemical reaction. This reaction creates metal oxides on the surface of your material and can impact conductivity, current flow, and your solder. Rust on iron, for example, is a visible iron oxide created by this process. Tin, aluminum, copper and almost all other metal surfaces are susceptible to oxidation. When you metals are coated in oxides, soldering can become difficult, if not impossible. We live in a world supported by oxygen, so you will never be able to have a metal surface completely devoid of all oxides. When you solder, you apply high heat to the area. Oxidation occurs much faster when this type of heat is applied. By using flux, however, on the metal surface, you can prevent the growth of additional oxides while applying heat to your solder joint.

What Flux Does

The flux you choose is a chemical component that is vital to a successful solder. Flux should provide three key things. First, it should chemically clean your metal surfaces, help with the flow-ability of your filler materials over the base metals, and provide a protective barrier between the metal and your soldering heat. Second, flux should assist with the heat transfer between the metal surface and your soldering heat source. Third, your flux should help to reduce and remove any surface metal oxides currently sitting on your metal surfaces.

Types of Flux for Soldering

In certain cases, the flux that is typically included within the core of a solder wire is good enough. However, there are certain situations where the use of an additional flux is beneficial. This includes things like surface mount soldering as well as de-soldering. Regardless of the reason you are using a flux, the most ideal product is the one that is the least acidic but still works on any oxidation on the surface of your component. With that, it is important to point out that there are different types of flux to choose from.

Rosin Flux

One of the oldest types of flux is based off of rosin. (Rosin is a refined and purified pine sap.) While rosin flux still exists today, it contains a blend of fluxes instead of just pure pine sap. This helps to optimize the flux and increase its performance and characteristics. One of the great features of a rosin flux is that it potent and acidic only when in its liquid (hot) state. When it cools, however, it becomes solid and inert. Because it becomes inert when cold, rosin flux can be left in place when your soldering is complete. (That is unless the printed circuit board (PCB) or other surface heats to the point of melting the resin flax while in use. Should this occur, the resin can actually begin to eat away at the connection.) While a resin flux does become inert, it is always recommended that you remove it once your solder is done anyway. Rosin flux can be easily removed with alcohol.

Organic Acid Flux

Organic acid (OA) flux is extremely popular. OA flux is actually a water soluble flux. OA fluxes use common, but weak, acids. This includes things like citric, lactic, or stearic acids. These weak acids are then combined with other solvents, such as isopropyl alcohol or water. The phrase "weak acids" may make these fluxes seem weaker than other types. However, OA fluxes are stronger than resin versions. The acids in an OA flux work to clean oxides from metal surfaces much more quickly. Because these fluxes are water soluble, they are easier to clean up and remove. In fact, they can be removed with just water. Unlike resin fluxes, which become inert and could potentially be left on the surface of your PCB, OA products must be removed. (OA flux is electronically conductive and can affect the performance of a PCB if left behind.)

Inorganic Acid Flux

If an OA flux uses "weak acids", an inorganic flux uses much stronger ones. Typically, inorganic fluxes will use a blend that includes an acid like hydrochloric acid, zinc chloride, or ammonium chloride. Inorganic must be removed from your metal surfaces after use. Because of the stronger acids, inorganic flux can be extremely corrosive if left behind after use. This can destroy your solder joint. (Inorganic flux should never be used for electronic assemblies or electrical work due to its highly corrosive nature!)

A Note on Solder Fumes

Fluxes contain many chemical compounds. When soldering, the smoke and fumes that are emitted are dangerous. In fact, inhaling soldering fumes has been linked to asthma. Make sure you solder only in a well ventilated area. Additionally, it is important to take proper safety measures to ensure you remove any fumes or chemicals from your skin. This includes wearing a mask, thoroughly washing your hands and face, and avoiding eating or drinking in an area where soldering is performed.
In addition to this, some soldering fluxes will include the phrase "RoHS compliant." RoHS is short for "Restriction of Hazardous Substances." RoHS, which came from the European Union's Directive 2002/95/EC, restrict the use of certain materials that have been deemed hazardous when used in and for electrical and electronic products."

Diecast Box lid screws

[With obligatory 'Elf - N - Safety' note...]

Yes, those tri-lobe self tappers beloved of the diecast box manufacturers - those little beggars can be done up tight - tighter than a crab's b*m, and that's water tight. Help is to hand however: more oft than not, a kettle of boiling water poured over the box corner (or in the oven, get it really hot), then attack the screws with the appropriate screwdriver - new, not at all worn - and a good sharp twist usually shifts 'em. For this job you ideally need one of those screwdrivers with exchangeable bits, get the best you can from a good quality tool stockist.

And... it's vital to get the right screwdriver bit. Look for #2 Posidrive in Europe, #2 Philips in the USA / Canada (usually).

Any lid screws refusing to co-operate after this treatment - give 'em another kettle full of boiling first oxide of hydrogen, set them on a solid bench or block, put a new screwdriver bit in the head socket and, whilst holding the bit with long nose pliers, clout the bit short and sharp with a light hammer. The bit will stick tight in the head recess; then promptly fit the screwdriver handle without moving the bit. Keep all dead plumb vertical, give her a solid twist and out the offending screw comes.

<u>Compulsory Health and Safety warning:</u> *boiling water is hot, and can cause severe scalds as well as making good tea or coffee. Use a suitable insulating medium to grip the box once it's hot. Ensure the hot water flowing off the box does not run into / onto your hands, boots, pockets, sleeves, or the cat (or any other domestic / agricultural animal, reptile or other sentient being). Do not miss the box with the boiling water from the kettle. Do not hold any part of the kettle other than that which the manufacturer has designated specifically for that purpose. Always unplug the kettle if you are unsure of it's purpose, use and storage, and call for a competent person to assist. If in doubt, don't do it. Whatever 'it' is.*

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Power Supplies

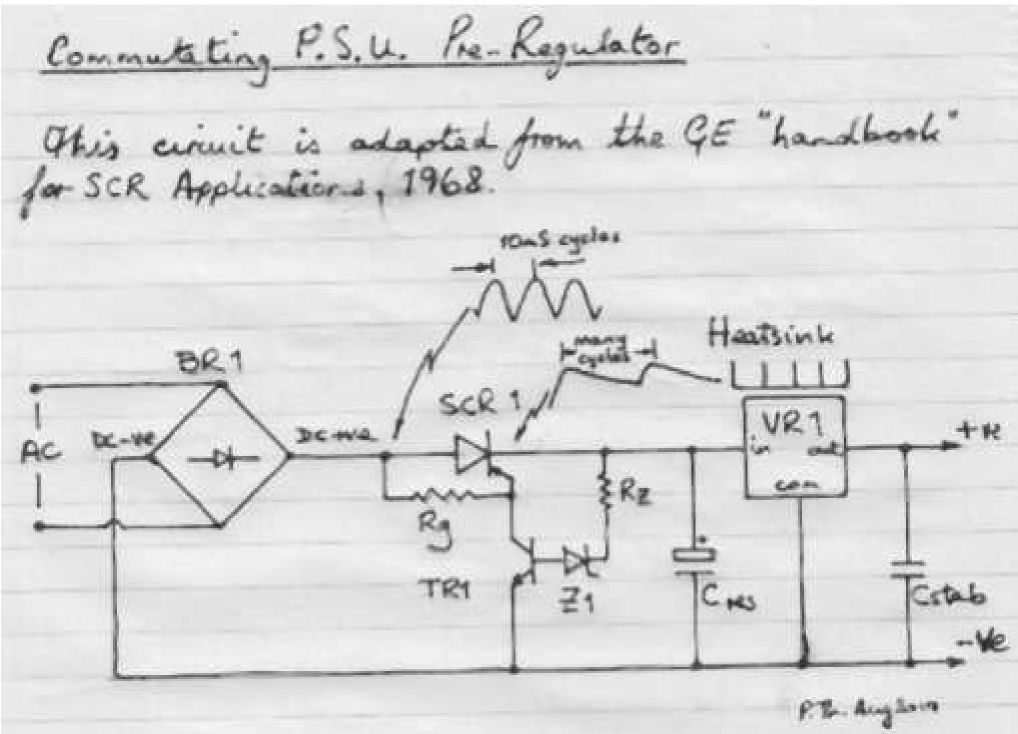
Commutating Pre-Regulators (2)

I had an email (thanks, Mike) about that perennial problem, generating 5 volts DC at some hefty amps from a 13.8v DC bench power supply.

The easy (but inefficient) answer is a linear regulator; but, as Mike points out, his regulator is cooking - it's dissipating (at 5 amps load current) over 35 watts. Using a decent sized power resistor as a dropper feeding the DC into the 5v regulator reduces the watts the linear regulator has to dissipate - but this arrangement merely moves the dissipated watts to the power resistor, and in these energy conscious days, is strictly verboten.

The circuit below has been built hundreds of times and has proved simple, robust and extremely reliable - it does what it says on the tin, and saves power using ultimate simplicity.

It's a good bet that if you can get into the bench power supply you can get to the mains transformer, and find the secondary (low volts) output terminals. A couple of extra wires are attached to the secondary, and brought out to a separate circuit comprising bridge rectifier, SCR and reservoir electrolytic capacitor to form a commutating pre-regulator, the SCR being controlled by a small auxiliary circuit board containing a resistor, zener and transistor, circuit schematic below:



The SCR fires via the gate feed resistor Rg if - and only if - the reservoir capacitor is discharged below a voltage equal to the zener plus one base - emitter volt drop. Make the zener equal to the drop-out voltage of the linear regulator, plus a volt or two for a comfortable operating point, and the SCR will fire only when the voltage on the reservoir capacitor approaches the drop-out voltage for the regulator. One or two half cycles from the transformer via the bridge completely recharge the electrolytic capacitor to the bridge output peak voltage, less the forward drop of the SCR (usually

1.2v or so) - leaving the linear regulator to discharge the reservoir electrolytic as the load current is supplied, and taking no power from the transformer. Result: far lower losses in the linear regulator and less power wasted.

Good, but not perfect, though, as the peak volts from the bridge exceeds the 5v regulator's drop out voltage - but far less power wasted than if the 5v regulator had to do all the dissipation. The commutating supply does not cause any RF noise; the switching is close to zero volts (actually about + 0.55 volts, the gate voltage required to turn on the SCR) and only repeats as and when the reservoir capacitor voltage drops to the zener plus base-emitter volts of the control transistor - certainly not every half cycle if the reservoir is of sufficient capacity. I've seen many other 'SCR' regulated PSU's on the web - almost all use some (complicated!) form of phase angle firing for regulation; this isn't at all satisfactory in the amateur shack. The noise created by non-zero cross switching is horrendous and exactly what you don't want within a mile of your super doozy Rx.

A simple approximation of Cres capacitance required can be made from considering the charge in Coulombs held in the reservoir: CV = Coulombs = iT, where C is capacitance in Farads, V is volts DC across the capacitor, I is the load current drawn from the capacitor and T is the time to discharge the capacitor in seconds. Assume the peak output volts of the secondary after rectification = 20 volts or so, and the drop out voltage of the external regulator is (say) 7.5 volts, then the capacitor feeding 5 amps load, on 50Hz mains, this works out to C = iT/V = 5 x 10mSecs / (20v - 7.5v) which is 0.5/12.5 = 1/25 Farad = <u>4,000µF.</u> This is an approximation; we don't know how often the SCR fires, so the "T" value might not be anywhere near 10mS - it could be much longer. So the formula gives an absolute minimum "C" value, double that and add more µF's if required after testing.

This isn't too much to ask nowadays - but you'll need capacitors with good ripple current ratings and low ESR: 2 x 4700µF in parallel should do the job, as you want the SCR not to fire too often for low power loss. Be aware too the bridge and SCR will need to be hefty: they both have to carry the half cycle inrush current of the first half cycle, and that's going to be a large current! Assume a minimum of 25 amp continuous rating and the surge capacity will be at least 250 amps. The transformer secondary winding resistance will limit the current well below that, in most cases, it will take a couple of cycles to fill the reservoir capacitor - you'll certainly hear the start-up "whump" of the transformer core! This soon settles to a "ping" of half cycles as the system settles into full running conditions.

USA vs. Euro Transformers... another good point

From Ross Whenmouth, ZL2WRW. Readers may recall in Hot Iron # 104 I reproduced a note from Martin Boardman, of Boardman Transformers, regarding the use of USA transformers on 50 Hz, rather than 60Hz - and the difference in flux density in the cores. Ross comments:

"Hi Peter,

Re: USA vs. European Mains transformers

In response to Martin Boardman's article on page 23 of Hot Iron #104:

I understand that a common industrial voltage in North America is 480V 3-phase 60Hz with 277V line-neutral voltage. A transformer with a winding rated 277V 60Hz should be quite happy with 230V 50Hz energisation because both the voltage and frequency are reduced by ~ 20% - thus the core flux density will be same as when energised with 277V 60Hz. However, the output voltage will unavoidably be reduced by 20% (but maybe you can get lucky and source a 277V to [desired output + 20%] transformer ?)

73 ZL2WRW
Ross Whenmouth"

My grateful thanks got to Ross, I'm always happy to hear alternative views and helpful information.

The 50Hz / 60Hz issue has been kicking the dust up for as long as I can remember; my experience was with USA manufactured 25kV 2Amp HV transformers in Perkin-Elmer electron beam crucibles for tungsten / nickel back coating of silicon wafers, to prevent back face gold migrating into the active regions. When we really pushed the power to the maximum (nickel and tungsten are a b*gger to evaporate) the transformers cooked - the cores were sizzling hot. We dumped the transformers into tanks filled with transformer oil, and fitted fans on the convection pipes on the outside (yes, those are the pipes you see on substation transformers). 50kW electron beams evaporated tungsten, but the deposition rate was low, so we switched to metal sputtering using RF plasmas in magnetron sputter heads running 8kV, 15amps of RF. Think on that next time you pick up a tuppeny transistor!

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Antennas

Antenna advice - and very true

For casual use with a simple receiver you don't need to worry too much about antenna wire length. Too long a piece of wire will diminish the performance of your receiver as it will provide more energy than your receiver can comfortably handle. The symptoms of this are hearing stations outside of the band, such as nearby AM short wave broadcasters. Too short a wire will not provide enough signal - the receiver will appear "deaf". So you should experiment and find out what's right for you. Sometimes 20 meters is dead (you won't be able to hear many signals because the atmospheric conditions are poor) so try your experiments a few times, until you find a convenient and effective length.

Or... take some advice from the very early days of radio.... below.

The Loose Coupler

This device came from the very earliest days of "tunable" radio operations, and is just as useful nowadays as it was then - eliminating overload whilst improving receiver selectivity and reducing noise by closing the received bandwidth down *before* the mixer or RF amplifier, following the principles of rejecting what you don't want, enhancing what you do. A close relative is the popular
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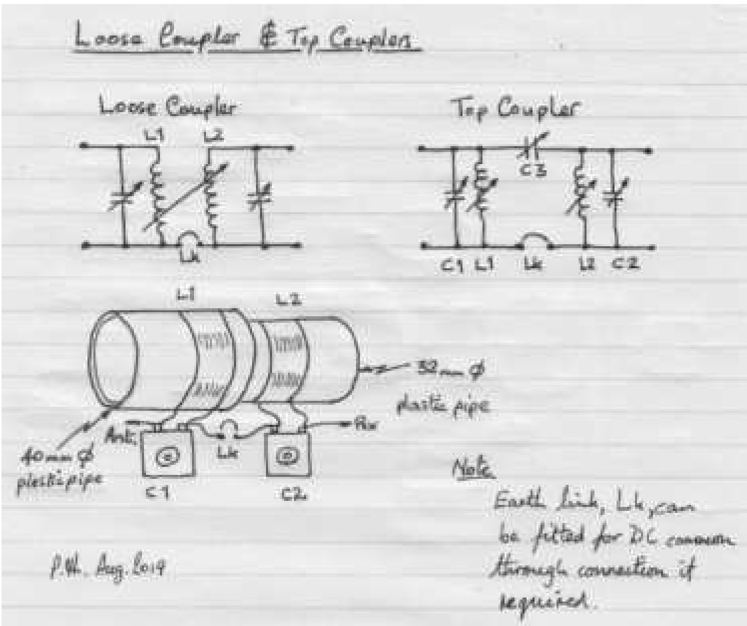
top coupled double tuned circuit - “top coupler” - which can, if constructed with commercial (TOKO style) coils, be effective if the top coupling capacitor is made variable, but that’s the rub. Making controllable, stable and easily adjustable pF capacitors *can* be done, but varying the coupling between the coils is far easier for the home constructor. Having said that, the loose coupler is probably the best bet for lower bands, under 20m perhaps, whereas the top coupler scores all the way to VHF, but is a bit more hassle to adjust (3 capacitors plus 2 coils).

Bearing in mind though the poor ionospheric conditions currently for the higher HF bands, the lower amateur bands are coming into their own: if - and it’s a big “if” - you can work in the crashing noise prevalent nowadays on the bands under 20m. The loose coupler can bring wanted signals out of noise, but the wideband nature of the interference (a deliberate design policy to avoid having to meet noise level tests conducted at spot frequencies - spread the noise far and wide, it becomes as Marmite - “spread exceeding thin” - but enough to overwhelm that tasty weak signal.

Regenerative receivers generally demand an attenuator (usually a potentiometer of some sort, as an “RF gain control”) at the antenna input, otherwise they easily overload with consequent drastic loss of selectivity; but the RF Gain controlled this way loses as much of the signal you want as well as the interference, but the loose coupler can control gain, *without losing any of the desired signal or selectivity*. A loose coupler enhances the signal you want, and can be used on several bands if designed with tapped coils and switched capacitors for tuning. You only need to fit a loose coupler prior to your receiver, peak it up on receive and adjust the RF input to the receiver by varying the coupling for best results.

The principle uses mutual inductance, in which two coupled coils become a transformer. If the coupling between the coils is made variable (i.e. varying the mutual coupling co-efficient, “k”), then the incoming signal can be readily controlled both in level and selectivity without sacrificing sensitivity.

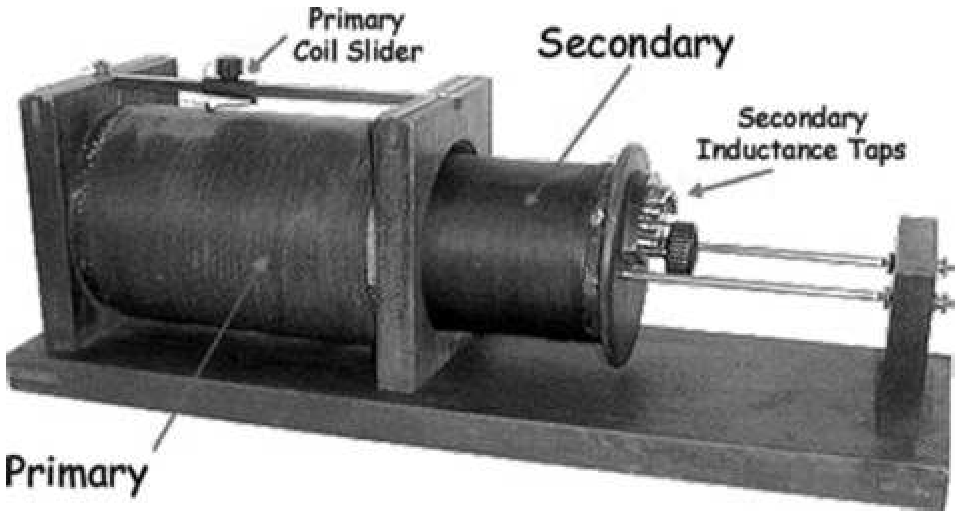
This is my loose coupler at G6NGR, using common UK waste pipe sizes:



The links shown as “Lk” are useful if

you have separate antenna and shack earths - or if earth lines are introducing noise into your shack. Fit as required.

A lovely “spark era” loose coupler (courtesy sparkmuseum.com) is below:



This was built for long waves, you don’t need anything like this number of turns for 160 / 80 / 60 / 40m! You’ll note that no variable capacitors are fitted: this is actually a variable transformer; the only resonances are from the coil inductance and capacitance. For amateur bands nowadays, make both primary and secondary tunable by shunting the coils with a suitable variable capacitor - a 365pF polyvaricon does nicely and they are readily available for very low cost.

A small antenna for 80m

Below is a link for a really effective transmitting antenna by Mike Dennis, G7FEK that covers a good few bands - and is of such a scale it should fit into small gardens.

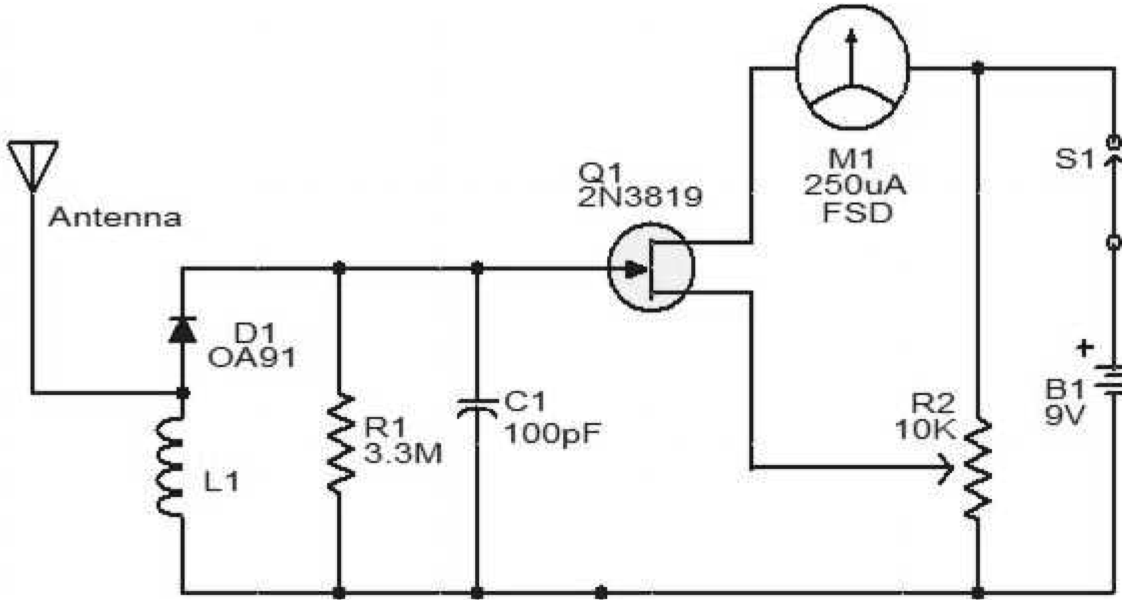
http://www.g7fek.co.uk/blogus/newsshow.php?page=80m_Antenna_for_small_gar_49493

Mike gives a comprehensive construction guide: a very thoroughly engineered job indeed in every aspect. Mike makes some excellent observations - that extra length isn’t always a good idea, for instance - as he’s worked out the resonant lengths just right. And he points out the oft forgotten component - the counterpoise(s)* play a significant part. I’ve found slightly elevated counterpoises work best - threaded around garden fences out of the way of mowers, footballs, washing line (the last being a critical point to observe in any antenna installation....). The point is clearly illustrated: a Marconi vertical radiator, with resonant top loading elements, counterpoise to match, give very good results in a very small space. Take my word for it: Mike’s antenna is a very good example of sound RF engineering.

*Mike comments that a separate and carefully arranged RF earths are the “make or break” for Marconi antennas. This is always a good principle to follow. A (series) tuned counterpoise network of multiple wires fanned out can help if you’re stuck for space; but be prepared for some “cut and try” with your earthing, especially on short antennas. The counterpoise(s) / RF earth is as important as the radiators!

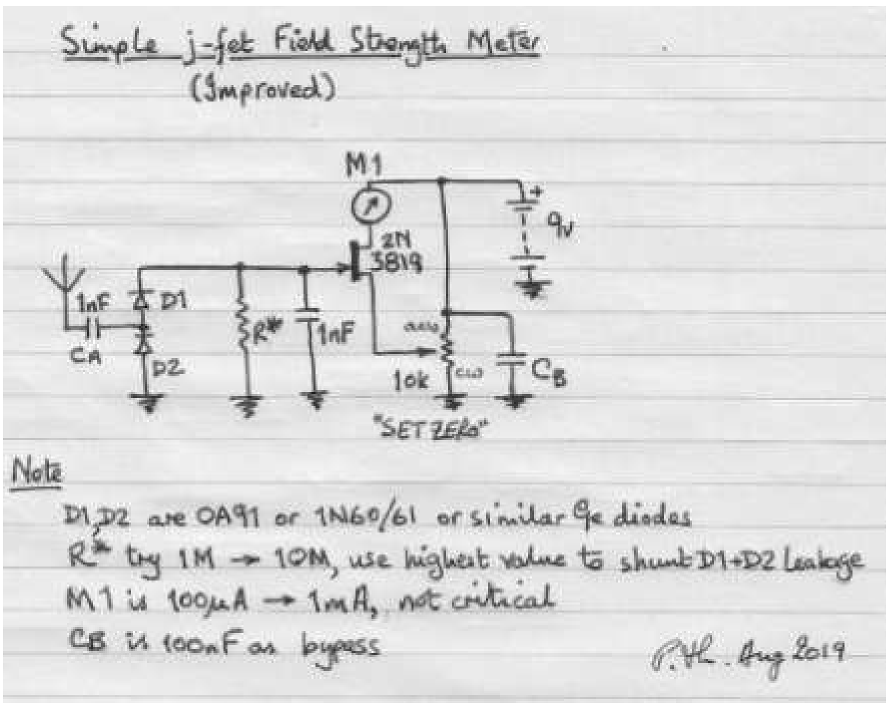
A simple very sensitive field strength meter

This schematic diagram has been floating around for years now; and is instantly recognisable by those who have ‘the knack’ - as one to avoid! The problem in this design is the inductor, L1. If you design it for, say, the 80m / 60m bands, at 20m and up L1 parasitic coil resonances cause weird readings. Similarly, if you size the inductor for, say, 15m/12m/10m, it’s nigh on useless anywhere



under 20m. But... the simple j-fet amplifier is a real boon for the QRP / QRPp operators, so below is a simple modification to get this little rascal back to sanity. Discard L1; add Ca and D2. This creates a voltage doubler rectifier, increasing sensitivity, as does a higher value gate resistor, R*. Fit 1M - 10M, whatever value works that gives reasonably stable meter deflection; R* also provides the DC reference for the j-fet gate. The 1nF capacitors Ca and the j-fet gate capacitor suit low band HF operation; increase to 10nF / 47nF for LF, and reduce to 220pF - 27pF for 6 /10 / 12/ 15m.

Note the pot wiring - make a habit of turning the pot fully anti-clock and unplug the battery when not in use, or fit a power switch.



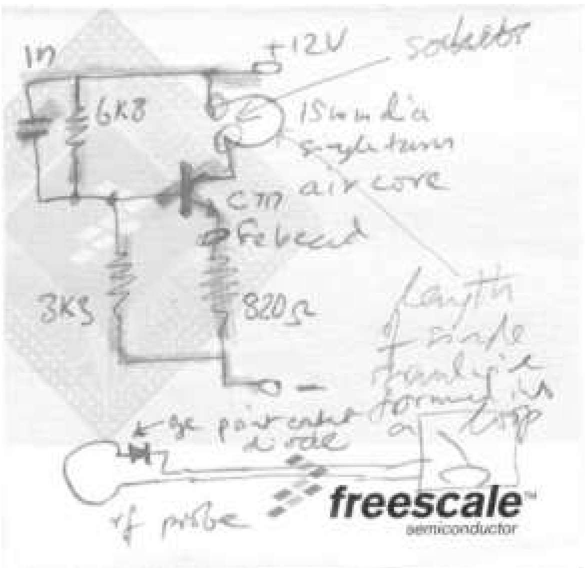
Conundrum Corner....

RF electricity does funny things! Inductance, capacitance mysteriously appear like mushrooms springing up to kibosh your latest design. It seems to have neither rhyme nor reason; touch an RF “hot” contact, and you don’t get electrocuted - just fried skin, as the RF stays in the very outer layers of the body, and makes notoriously difficult to heal deep burns. Make a transmitting antenna for LF, and the top glows blue with St. Elmo’s Fire (corona discharge) at night, even running just a few watts; at 160m or higher you’ll see nothing. Odd!

Sometimes seemingly simple devices can produce remarkable effects you can’t even detect: an RF transistor, energised, but with no drive, gets mysteriously hot. “Aha! parasitic oscillation!” is the thought; but any attempt to measure the frequency yields nothing; the moment you touch a probe to any terminal, the oscillatory heating stops. Adding extra capacitors doesn’t help, merely turns the continuous oscillation into “motor boating”!

Step in old hand who has seen all this before: “it’s inductance in the emitter lead / cathode wiring / source wires (delete as appropriate). The active device, with an Ft of maybe a few hundred MHz, is oscillating at GHz as the parasitic circuit elements surrounding the device have created a common base / grid / gate (delete as appropriate) oscillator, and once power’s applied, off she jolly well goes.

A circuit I came across years ago illustrates this nicely, it’s a UHF / μ-wave oscillator:



If you build this circuit with absolute minimal lead lengths, on a scrap of FR4 copper clad board you’ll see the oscillation way above the Ft value of the transistor. Transistors with Ft 0f 300MHz will easily achieve GHz frequencies - IF (and only IF) the construction is of absolutely minimal lead length and size. Ideally, surface mount components and chip capacitors if you can - and this thing will achieve Ft x 10 or more; the simple Ge diode and meter circuit detect the GHz's and display them as meter deflection. This little circuit is good fun to use with Lecher lines to find the frequency of oscillation. Incidentally, with OA91's (as pointed out earlier in this edition of Hot Iron) are as rare as hen's teeth nowadays - but a dig into any ancient volume of Towers International Transistor and Diode Selector book will find dozens of Ge diodes just as capable and often very cheaply available at out favourite on-line auction house. I'd suggest you find (and keep - never loan it out!) a copy of Towers - the useful parameters of millions of transistors are easily found as are substitutes, very useful in amateur (ahemm! and professional...) workshops.

Which leads very nicely to a conundrum! You may have heard of "mercury wetted" reed relays, a device first made in the early 1900's, I believe. These have a tiny, tiny drop of liquid mercury on the contacts - it really is a tiny drop, maybe thousandth of an inch high, such that as the contacts are closed, the circuit is made through the Palladium relay contacts as usual; but on opening, the drops of mercury on the contacts exhibit surface tension (as any liquid does), and the mercury between the contacts maintains the circuit closed until the mercury surface tension collapses the column of mercury and the circuit opens, very quickly - very quickly indeed. The mercury maintains the circuit until a single atom of mercury on each contact is the only link, then opens virtually instantaneously. I'm told it's the time it takes for electrons in the outer shell of the mercury atoms making the circuit to go into quantum exclusion, and open the circuit. The only thing that slows down the opening circuit electrical signal is the surrounding capacitance and inductance of the mercury columns, and, of course, the mounting wires and any oscilloscope probes (or whatever) connected to measure the moment of disconnection.

Here's a question: how fast does the mercury contact open, ignoring the external influences from leads, probes, etc.? It's been mooted (and up to now, as far as I know, nobody's disproved it) the speed of opening is - - - - less than 10^{-20} seconds! It's related to the outer shell electron orbit times of mercury; or, if you swing that way, to the frequency of the DeBroglie pilot wave the electrons dance round.

The practical application of this effect is used in very high speed pulse generators using charged transmission lines and sampling scopes to measure the propagation delay of gates and other devices. The mercury wetted relays are switched at about 10kHz so the sampling scopes can build a picture up within a few seconds.

Similar switching speeds are achieved in air gap triggertrons, used to pulse lasers, by switching 16kV charged capacitors into the flash tubes to pump the laser element. The triggertron uses two tungsten electrodes, spaced a few mm apart, with a third tungsten needle tip just to one side of the electrode space. A 100kV pulse is applied to the needle, the ensuing spark to both electrodes ionises the gap and *BANG* the capacitors discharge through the flash tube in very quick order. Below is a good description of a triggertron, from https://core.ac.uk/download/pdf/18320788.pdf

"Triggering of the output was accomplished by a triggertron high voltage spark gap switch. The triggertron is a three-port device and consists of a pair of rounded electrodes separated by a gap of about 1 cm. There is a hole in the center of one of the electrodes, which has the pin of a small spark plug peeking up through it. [Fig 3-5] When the two electrodes are at their charged potential there is

not enough voltage to cause a breakdown between the them. To trigger the device (to switch it on) a spark is created between the spark plug pin and the surrounding electrode by the triggering circuit. This spark releases ions into the space between the electrodes, triggering a breakdown between the two rounded electrodes activating the switch closure."

To conclude: if the mercury wetted contacts open in 10^{-20} seconds, what bandwidth must the connecting circuitry have to faithfully reproduce (i.e. not slow down) the switched edge? I'll give a clue: it might not be possible with current materials and technologies...! And it makes the fastest computer processors available today appear pedestrian. Don't forget that free space, with no wires, nor anything else, has capacitance and inductance, so that $1 / (\varepsilon_o \times \mu_o)^{-2} = C$, the speed of light, and the Zo of free space is 377 ohms.

You're well into the realms of experimental physics here: fast edges, of high voltage and current, are just as mysterious as the electromagnetic wave itself. Described by Maxwell's equations, we radio amateur disregard the many solutions of Maxwell's equations, choosing the one that seems to work for us (the "forward" solution) whilst ignoring the "retarded" solution - which describes how an equal but opposite wave to our transmitted wave comes racing backwards towards our antennas when we key.

There are other solutions too... but not for talking about now. The mathematics of fast edges are the very useful Laplace transforms, so useful for solving circuit and control theory differential equations; but maths allows infinities and zero time - the real World doesn't, and it's this difference that makes fast edge physics such an interesting research topic.

Data and Information

This information is for guidance only – you MUST comply with your local Regulations! I have included information about AC power systems and conventions, as equipment can often be bought from overseas nowadays and it's important that we know exactly how to connect it and control theory to our "home" supplies - but suffice to say, if there's any doubt - - - GET PROFESSIONAL, COMPETENT HELP BEFORE YOU CONNECT TO ANY ELECTRICAL SUPPLY!

Wire Information...

AWG Table

1 AWG is 289.3 thousandths of an inch
2 AWG is 257.6 thousandths of an inch
5 AWG is 181.9 thousandths of an inch
10 AWG is 101.9 thousandths of an inch
20 AWG is 32.0 thousandths of an inch
30 AWG is 10.0 thousandths of an inch
40 AWG is 3.1 thousandths of an inch

The table in ARRL handbook warns that the figures are approximate and may vary dependent on the manufacturing tolerances. If you don't have a chart handy, you don't really need a formula.
There's several handy tricks:
Solid wire diameters increases/decreases by a factor of 2 every 6 gauges,
" " " " " 3 every 10 gauges,
" " " " " 4 every 12 gauges,
" " " " " 5 every 14 gauges,
" " " " " 10 every 20 gauges,
" " " " " 100 every 40 gauges,

With these, you can get around a lot of different AWGs and they cross check against one another. Start with solid 50 AWG having a 1 mil diameter.
So, 30 AWG should have a diameter of ~ 10 mils.

36 AWG should have a diameter of ~ 5 mils.	Dead on.
24 AWG should have a diameter of ~ 20 mils.	Actually ~ 20.1
16 AWG should have a diameter of ~ 50 mils.	Actually ~ 50.8
10 AWG should have a diameter of ~ 100 mils.	Actually ~ 101.9

If you are more interested in current carrying ability than physical size, then also remember that a change of 3 AWG numbers equals a doubling or halving of the circular mills (the cross sectional area). Thus, if 10 AWG is safe for 30 amps, then 13 AWG (hard to find) is ok for 15 amps and 16 AWG is good for 7.5 amps.
The wire gauge is a logarithmic scale base on the cross sectional area of the wire. Each 3-gauge step in size corresponds to a doubling or halving of the cross sectional area. For example, going from 20 gauge to 17 gauge doubles the cross sectional area (which, by the way, halves the DC resistance).
So, one simple result of this is that if you take two strands the same gauge, it's the equivalent of a single wire that's 3 gauges lower. So two 20 gauge strands is equivalent to 1 17 gauge.

Wire Gauge Resistance per foot

4	.000292
6	.000465
8	.000739
10	.00118
12	.00187
14	.00297
16	.00473
18	.00751
20	.0119
22	.0190
24	.0302
26	.0480
28	.0764

Current ratings

Most current ratings for wires (except magnet wires) are based on permissible voltage drop, not temperature rise. For example, 0.5 mm^2 wire is rated at 3A in some applications but will carry over 8 A in free air without overheating. You will find tables of permitted maximum current in national electrical codes, but these are based on voltage drop. Here is a current and AWG table.

AWG	dia mils	circ mils	open air Amp	cable Amp	ft/lb bare	ohms/1000’
10	101.9	10380	55	33	31.82	1.018
12	80.8	6530	41	23	50.59	1.619
14	64.1	4107	32	17	80.44	2.575

Mils are .001". "open air A" is a continuous rating for a single conductor with insulation in open air. "cable amp" is for in multiple conductor cables. Disregard the amperage ratings for household use.
To calculate voltage drop, plug in the values:
V = DIR/1000
Where I is the amperage, R is from the ohms/1000' column above, and D is the total distance the current travels (don't forget to add the length of the neutral and live together - ie: usually double cable length). Design rules call for a maximum voltage drop of 6% (7V on 120V circuit).

Resistivities at room temp:

Element	Electrical resistivity (micro-ohm-cm)
Aluminium	2.655
Copper	1.678
Gold	2.24
Silver	1.586
Platinum	10.5

This clearly puts silver as the number one conductor and gold has higher resistance than silver or copper. It's desirable in connectors because it does not oxidise so remains clean at the surface. It also has the capability to adhere to itself (touch pure gold to pure gold and it sticks) which makes for very reliable connections.

Thermal conductivity at room temperature

	$W/cm^2/°C$
silver	4.08
copper	3.94
gold	2.96
platinum	0.69
diamond	0.24
bismuth	0.084
iodine	43.5E-4

This explains why diamonds are being used for high power substrates now. That's man-made diamonds. Natural diamonds contain enough flaws in the lattice that the phonons (heat conductors) get scattered and substantially reduce the ability to transport the heat.

Copper wire resistance table

AWG	Feet/Ohm	Ohms/100ft	Ampacity	$(mm^{2)}$	Meters/Ohm	Ohms/100M
10	490.2	.204	30	2.588	149.5	.669
12	308.7	.324	20	2.053	94.1	1.06
14	193.8	.516	15	1.628	59.1	1.69
16	122.3	.818	10	1.291	37.3	2.68

18	76.8	1.30	5	1.024	23.4	4.27
20	48.1	2.08	3.3	0.812	14.7	6.82
22	30.3	3.30	2.1	0.644	9.24	10.8
24	19.1	5.24	1.3	0.511	5.82	17.2
26	12.0	8.32	0.8	0.405	3.66	27.3
28	7.55	13.2	0.5	0.321	2.30	43.4

These Ohms / Distance figures are for a round trip circuit. Specifications are for copper wire at 77 degrees Fahrenheit or 25 degrees Celsius.

Wire current handling capacity values

mm2	R/m-ohm/m	I/A
6	3.0	55
10	1.8	76
16	1.1	105
25	0.73	140
35	0.52	173
50	0.38	205
70	0.27	265

Mains wiring current ratings

In mains wiring there are two considerations, voltage drop and heat build up. The smaller the wire is, the higher the resistance is. When the resistance is higher, the wire heats up more, and there is more voltage drop in the wiring. The former is why you need higher-temperature insulation and/or bigger wires for use in conduit; the latter is why you should use larger wire for long runs. Neither effect is very significant over very short distances. There are some very specific exceptions, where use of smaller wire is allowed. The obvious one is the line cord on most lamps. Don't try this unless you're certain that your use fits one of those exceptions; you can never go wrong by using larger wire. This is a table apparently from BS6500, reproduced in the IEE Wiring Regs which describes the maximum fuse sizes for different conductor sizes:

Cross-section CSA / area	Overload current rating
0.5mm²	3A
0.75mm²	6A
1mm²	10A
1.25mm²	13A
1.5mm²	16A

Typical current ratings for mains wiring

Inside wall

mm^2	Amps
1.5	10
2.5	16

Equipment wires

mm^2	A
0.5	3
0.75	6
1.0	10
1.5	16
2.5	25

Wire sizes used in USA inside wall

For a 20 amp circuit, use 12 gauge wire. For a 15 amp circuit, you can use 14 gauge wire (in most locales). For a long run, though, you should use the next larger size wire, to avoid voltage drops. Here's a quick table for normal situations. Go up a size for more than 100 foot runs, when the cable is in conduit, or ganged with other wires in a place where they can't dissipate heat easily:

Gauge	Amps
14	15
12	20
10	30
8	40
6	65

PCB track widths

For a 10 degree C temp rise, minimum track widths are:

Current	width in inches
0.5A	0.008"
0.75A	0.012"
1.25A	0.020"
2.5A	0.050"
4.0A	0.100"
7.0A	0.200"
10.0A	0.325"

Equipment wires in Europe

3 core equipment mains cable

Current	3A	6A	10A	13A	16A
Conductor size (mm)	16*0.2	24*0.2	32*0.2	40*0.2	48*0.2
Copper area (mm^2)	0.5	0.75	1.0	1.25	1.5

Cable ratings for 3A, 6A and 13A are based on BS6500 1995 specifications and are for stranded thick PVC insulated cables.

Insulated hook-up wire in circuits (DEF61-12)

Max. current	1.4A	3A	6A
Max. working voltage (V)	1000	1000	1000
PVC sheat thickness (mm)	0.3	0.3	0.45
Conductor size (mm)	7*0.2	16*0.2	24*0.2

Conductor area (mm^2)	0.22	0.5	0.75
Overall diameter (mm)	1.2	1.6	2.05

Common Cable colour Codes

American electrical contractors and electricians are required to follow the National Electrical Code ("NEC") with regard to wiring colours. NEC imposes the following electrical wiring colour standards:

- **Ground wires:** green, green with a yellow stripe, or bare copper
- **Neutral wires:** white or gray

In theory, wiring conducting live current in the U.S. is permitted to be any other colour, although in practice, electrical contractors and electricians follow these local conventions:

- **Single phase live wires:** black (or red for a second "hot" wire)
- **3-phase live wires:** black, red and blue for 208 VAC; brown, yellow, purple for 480 VAC

Most countries in Europe, including the U.K., now follow the colour conventions established by the International Electrotechnical Commission ("IEC"). These colour conventions are as follows:

- **Earth wires** (called ground wires in the U.S. and Canada): green with a yellow stripe
- **Neutral wires:** blue
- **Single phase live wires:** brown
- **3-phase live wires:** brown, black and gray

Electrical wiring in Canada is governed by the Canadian Electric Code ("CEC"). The following wiring colour requirements apply in Canada:

- **Ground wires:** green, or green with a yellow stripe
- **Neutral wires:** white
- **Single phase live wires:** black (or red for a second live wire)
- **3-phase live wires:** red, black and blue

It's important to remember that the above colour information applies only to AC circuits.

A.M. Frequency slots in Amateur HF Bands

All Frequencies in MHz

160 Metres: 1.885, 1.900, 1.945, 1.985 (USA)

1.850 (W. Europe)

1.933, 1.963 (UK)

1.843 (Australia)

80 Metres: 3.530, 3650 (South America)

3615, 3625 (in the UK)

3705 (W. Europe)

3.690 (AM Calling Frequency, Australia)

75 Metres: 3.825, 3.870 (West Coast), 3.880, 3.885 (USA)

60 Metres : 5.317

40 Metres: 7.070 (Southern Europe)

7.120, 7.300 (South America)

7.175, 7.290, 7.295 (USA)

7.143, 7.159 (UK)

7.146 (AM Calling, Australia)

20 Metres: 14.286

17 Metres: 18.150

15 Metres: 21.285, 21.425

10 Metres: 29.000-29.200

6 Metres: 50.4 (generally), 50.250 Northern CO

2 Metres: 144.4 (Northwest)

144.425 (Massachusetts)

144.28 (NYC-Long Island)

144.45 (California)

144.265 (Los Angeles, CA)

Other AM Activity Frequencies

AM activity is increasingly found on a number of other bands, in particular: 5317KHz, 7143KHz, 14286KHz, 21425KHz and 29000 - 29150KHz.
There are several local AM nets in the UK on top band.

FM Frequencies

For mobiles working into VMARS events, 2m calling in on 145.500MHz (S20) is usual, before QSY to a working frequency. At event locations where military equipment is in use, suggested FM "Centres of Activity" on VHF are 51.700Mhz, 70.425MHz (70.450MHz calling).

VMARS RECOMMENDED FREQUENCIES

3615 Khz	Saturday AM net 08:30 – 10:30
3615 Khz	Wednesday USB net for military equipment 20:00 – 21:00
3615 Khz	Friday LSB net 19:30 – 20:30
3615 Khz	Regular informal net from around 07:30 - 08:30
3577 Khz	Regular Sunday CW net 09:00

5317 Khz Regular AM QSO's, usually late afternoon

7073 Khz Wednesday LSB 13:30; Collins 618T special interest group

7143 Khz VMARS AM operating frequency

51.700 MHz VMARS FM operating frequency, also rallies and events

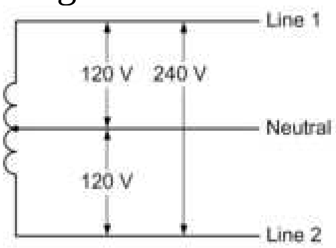
70.425 MHz VMARS FM operating frequency, also rallies and events

Electrical Supplies - Courtesy LEGRAND equipment

Common Electrical Services & Loads

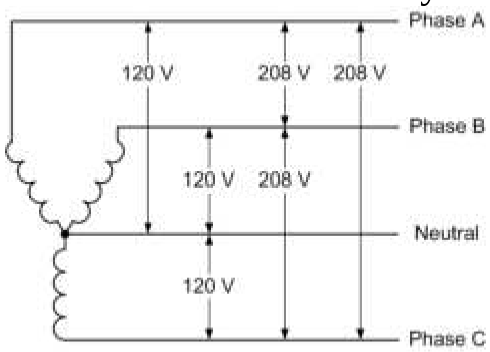
In the following drawings, the coil symbols represent the secondary winding of a utility service transformer or other step down transformer. Electrical code regulations in most jurisdictions require that the neutral conductor be bonded (connected) to the earth safety ground at the electrical service entrance.

Single Phase Three Wire



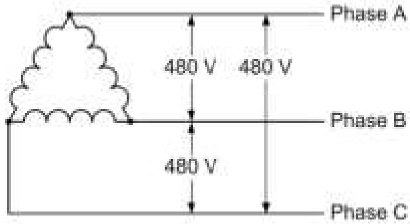
Also known as an Edison system, split-phase or centre-tapped neutral. This is the most common residential service in North America. Line 1 to neutral and Line 2 to neutral are used to power 120 volt lighting and plug loads. Line 1 to Line 2 is used to power 240 volt single phase loads such as a water heater, electric range, or air conditioner.

Three Phase Four Wire Wye



The most common commercial building electric service in North America is 120/208 volt wye, which is used to power 120 volt plug loads, lighting, and smaller HVAC systems. In larger facilities the voltage is 277/480 volt and used to power single phase 277 volt lighting and larger HVAC loads. In western Canada 347/600V is common.

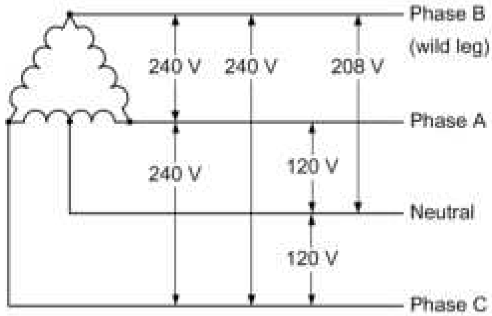
Three Phase Three Wire Delta



Used primarily in industrial facilities to provide power for three-phase motor loads, and in utility power distribution applications. Nominal service voltages of 240, 400, 480, 600, and higher are typical.

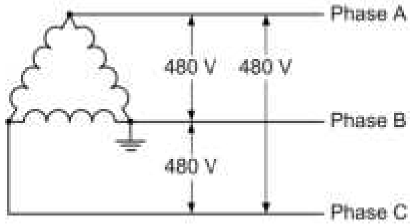
Uncommon Electrical Services

Three Phase Four Wire Delta



Also known as a high-leg or wild-leg delta system. Used in older manufacturing facilities with mostly three-phase motor loads and some 120 volt single-phase lighting and plug loads. Similar to the Three Phase Three Wire Delta discussed above but with a centre-tap on one of the transformer winding to create neutral for 120 volt single-phase loads. Motors are connected to phase A, B, and C, while single-phase loads are connected to either phase A or C and to neutral. Phase B, the high or wild leg, is not used as the voltage to neutral is 208 volt.

Three Phase Two Wire Corner-Grounded Delta



Used to reduce wiring costs by using a service cable with only two insulated conductors rather then the three insulated conductors used in a convention three phase service entrance.

International Electrical Distribution Systems

Description	L–N Vac	L–L Vac	Countries
1-Phase, 2-Wire 120 V with neutral	120	–	US
1-Phase, 2-Wire 230 V with neutral	230	–	EU, UK, Scandinavia
1-Phase, 2-Wire 208 V (No neutral)	–	208	US
1-Phase, 2-Wire 240 V (No neutral)	–	240	US
1-Phase, 3-Wire 120/240 V	120	240	US
3-Phase, 3-Wire 208 V Delta (No neutral)	–	208	US
3-Phase, 3-Wire 230 V Delta (No neutral)	–	230	Norway

3-Phase, 3-Wire 400 V Delta (No neutral)	–	400	EU, UK, Scandinavia
3-Phase, 3-Wire 480 V Delta (No neutral)	–	480	US
3-Phase, 3-Wire 600 V Delta (No neutral)	–	600	US, Canada
3-Phase, 4-Wire 208Y/120 V	120	208	US
3-Phase, 4-Wire 400Y/230 V	230	400	EU, UK, Scandinavia
3-Phase, 4-Wire 415Y/240 V	240	415	Australia
3-Phase, 4-Wire 480Y/277 V	277	480	US
3-Phase, 4-Wire 600Y/347 V	347	600	US, Canada
3-Phase 4-Wire Delta 120/208/240 Wild Phase	120, 208	240	US
3-Phase 4-Wire Delta 240/415/480 Wild Phase	240, 415	480	US
3-Phase Corner-Grounded Delta 208/240	–	240	US
3-Phase Corner-Grounded Delta 415/480	–	480	US

Note: regional variations may exist: if in ANY doubt, consult your Electrical Supply Authority.

Hot Iron # 106

Table of Contents

CQ-CQ-CQ

Thanks for the emails! I have had some interesting emails since Hot Iron #105, and would like to say a big “thank you” to all who offered advice, comments, asked questions and suggested ideas. They are much appreciated - Hot Iron is YOUR journal; it reflects not only my opinions but the reader’s thoughts sent to me at equieng@gmail.com, so if you have any thoughts, questions, want a specific semiconductor or other device for your project, I’ll gladly put a note in future Hot Iron editions. You’ll see the new “Wanted” section later in this edition.

One comment prompted me to review my thoughts about Hot Iron #106. I was asked to “keep it simple” as most constructors, if not building a kit, are working as a minority nowadays, without the comprehensive construction articles and drawings of years gone by. When you’re building your own gear, you have to be aware of many things not always too obvious: like keeping outputs well away from inputs, decoupling power supply rails, single point “star” earthing and the like.

Therefore I’m tilting the contents toward simplicity and practicality, to help constructors get some solder melted and wire croppings on the bench. In past issues of Hot Iron I’ve shown pictures of my simple tool kit, my “bench in a box”, and other bits of Test Gear I’ve built - as an apprentice I was told that Test Gear construction is a superb training ground for future more complex Radio projects, and for some, as addictive as Radio itself - and so it is with me!

In Hot Iron #107 I’ll put together some simple projects that amateurs can use, for actual RF measurements and Test, with basic construction notes. In the meantime I’ve included an article for an RF Impedance Bridge (from spark days!) in Hot Iron #106 which is just about the simplest and most practical design to do this job: and it makes a good and useful project for ANY amateur. Even if you only use it on resistors, capacitors and inductors, the actual construction and setting up are a cracking good start to building your own Test Gear - which inevitably leads to “real” Radio projects in the future.

The Bottom Line...

Amateur radio is a fascinating pastime, and means different things to different folk: some like Dx, others local A.M. nets; some are ex-military equipment enthusiasts, others run QRP operations; all come under the wide umbrella of “amateur radio”. The gist is, however, it’s whatever you enjoy doing, within your license bounds, that doesn’t interfere with anybody around you.

There is an impression amongst amateurs that those who achieve a contact furthest away are somehow “superior”; or those who run the “lowest power per mile” are somehow “better”. Not True! Even if you’re running a Michi. Mighty Mite and a two transistor regen, you’re just as “good”, “capable” or “proper” - enjoy it, have fun, keep within your license, the job’s a good ‘un!

Huge amounts of money are spent on buying ready made radio equipment; not only “Art of the State” but simple items too. I saw an advertisement for a “superior performance” 40m dipole antenna kit in the usual online auction house, for - wait for it - £39.99 ($50.00?). You got 2 flat plastic end insulators with holes for the wire, a flat plastic centre piece and several cable ties. This came with two coiled lengths of 7 x 0.2mm PVC equipment wire to make each half of the dipole. I checked the prices for that wire: less than £6.00 per 100m roll - you’d get at least FOUR 40m band dipoles out of that!

Which amateur will learn the most, enjoy amateur radio to a fuller extent and be prompted to make more radio equipment for his station? He who buys the ready made equipment or he who uses his imagination (and spares his wallet) by making his own dipole from bits of scrap plastic and a roll of bell wire?

All the parts you need for amateur radio projects are easily found with a little imagination and keen observation whilst out and about. My recent project, the 6146B “Pink Brazilian” A.M. transmitter, has a beautiful stainless steel chassis[1]; this comes with two free equipment handles for the cabinet which will be plywood from my local timber yard[2]. The antenna will (probably) be an inverted “L”, with Petlowany counterpoise[3], with home made insulators[4] and rigged to a mast[5] in my garden.

The “bottom line” describes the end result in cash terms which I believe emphasises the amateur who makes his own equipment wins - in his pocket and in the wonderful world of experimenting with radio equipment.

Notes...

1 Stainless steel oven tray 6” x 9” x 1½”, with (removable) handles from “Swedish” home & furniture store, £2.99

2 Timber yard offcuts box 1200mm x 350mm x 9mm birch faced ply, £1.50p

3 Odd roll of equipment wire 7 x 0.2mm x 100m (estimate) £5.00

4 Polycarbonate / perspex offcut 12” x 10” x ⅛” from DIY store offcuts box £0.50p

5 Mast: TV mast(s) from local demolition site, £5.00 (includes a bag of "U" bolts)

Complete Trasmitter & Antenna mechanical bits = £15.09

Amateur Radio for the Deaf

Amateur Radio for the deaf is a major topic. After all, radio communication - of any kind apart from digital modes and Baudot teletype systems - relies on hearing and audibility, topics I've commented on previously. How to make amateur radio a usable and practical feature in a deaf person's life is a question well worth answering; it would open a whole new World of direct communication for those trapped inside a silent sphere of deafness.

Samuel Morse never intended his code system to be encoded or decoded by humans: he designed electro-mechanical means for encoding the letters at the transmitting end and of presenting the dits and dahs on paper strips for secure (and private!) decoding at the receiving end, but the operators soon mentally attached letters to the clattering of the armatures of the equipment and thus the text transmitted and received. Samuel Morse's original principle is a good guide to creating practical amateur radio communications for the deaf - as you can *see* the dits and dahs, no need to hear them. Indeed, a picture of the dits and dahs would enable quick learning of the code for all amateurs: just as it did in Samuel Morse's telegraph stations.

A simple lamp *can* indicate CW; it's long or short illumination denoting the code. Let us step forward in today's technology and see how we can make things simpler and easier for the deaf operator by using the memory and display capability found in modern micro-controllers.

My proposition is this: assume the received CW signal can be digitised into logic "1" = signal present, logic "0" = signal absent. Feed these highs and lows (1's and 0's) into a linear memory - a shift register, perhaps, or (preferably) Mbits of RAM, with a variable clock rate. The 1's and 0's thus stored are displayed on a line of 128 LED's at a clock speed set by the reader, to display (for example) one LED lit for a dit, three or more (however long the transmitting "fist" times his dahs to his dits). Make the illuminated dits and dahs shift right, and the Morse in the memory will be graphically displayed as groups of short and long illuminated LEDs, with dark spaces between. A flick of a switch reverses the display (the RAM clock changes to count down) for instant replay of a letter or group of letters; thus the code in the RAM can be "rewound" and replayed forwards at any speed for the reader. Memory is so cheap and accessible with micro-controllers nowadays millions of letters could be stored and played back at an appropriate speed.

Letters thus rendered would be easily recognisable; letters, words and phrases would take on a shape; words and phrase "shapes" having long been accepted as how a human brain decodes fast Morse. If the display had two lines of LED's, one above the other, dits could be displayed on the top line, dahs on the lower line: the "heavier" dahs sitting below the "lighter" dits in a stepped pattern - imaging how "CQ" would look, or "AR"!

Thus we have translated a zero dimensional flickering lamp into a two dimensional shape, pattern and form: far easier to learn and recognise accurately. The ability to "rewind" a message to check a confusing character is another advantage, and learning odd characters not often seen - the control commands, for instance, or Q codes.

I’m no whizz kid with software; I hope some wonderful soul will step up and take these thoughts - and no doubt many other ideas related that could be applied - and turn them into reality for the deaf (and any other for that matter) amateur radio operator.

I’m probably re-inventing the Teletype, but my principle aim is for simplicity and effectiveness for deaf operators, and a great aid for anyone learning Morse.

Why I use Valves

For many years of my working life valves have been the only available devices that could run RF at hundreds of kilowatts, day in, day out, with efficiencies approaching 100% - admitted, a bit of a fiddle, this - as the anode cooling water was used to preheat the water feed to the factory’s heating boiler, so ne’er any watt was wasted. To this day, if you need several hundred kW’s of RF for industrial purposes, valves are the “go to” technology - MOSFETs are coming of age, but, in all sincerity, they can’t hold a candle to a valve above a few 10’s of kHz at big kW outputs.

I have seen some solid state RF generators running: the inevitable low frequencies cause levitation problems in the load coil / susceptor assemblies (think Prof. Eric Laithwaite’s hover trains), the noise from them is intensely irritating (both power devices and cables acting as magnetic loudspeaker elements, vibrating and buzzing) and they are liable to catastrophic failure which inevitably takes out the devices close by - they run in banks of paralleled devices to get the power.

For the amateur, this last is the best reason for considering valves. They don’t blow up destructively; they simply get red hot, fade on major overloads (or faults). Let them cool off, sort out the short or blown component, and off you go again, no fuss, no bother, 99 times out of 100. Valves can take it - unlike semiconductors, which, as Corporal Jones expounds, “don’t like it up ‘em!” Fastest three legged fuses known to man, for sure.

For the owners of “black box” radio equipment, the protection circuits that shut down the output in the event of a mismatch or fault save the day: but what do you do to fix the problem? An antenna feeder problem, fine - it’s findable and fixable. How about a blown driver though? A multi-lead Integrated Circuit, or (horror of horrors) a pin grid array, IC’s with no leads, bonded down in by hundreds of microdots of solder beneath the package, utterly and completely un-solderable without very special industrial equipment? Or micro size surface mount component, on a multi-layer PCB, inside an assembly that’s definitely not designed for serviceability? Let’s see you repair that in an evening! Better by far - in my opinion - a valve, which is going to carry on regardless once the problem’s identified and fixed - which generally can be done easily and simply as you can get at the circuit components, they are of a size you can do something with, using human hands.

The day that designers took to multi-layer PCB’s and micro surface mount devices and components, was the end for **amateur** repairs, I reckon. A valve’s higher impedance circuits make matching a doddle; the designs are vastly simpler, and the price of common valves are still very attractive providing you avoid the audiophool’s favourites (more on this later in this edition). Don’t be frightened by the high voltages involved: it’s all part of growing up, your transition into adulthood. Adopt simple safety when handling or testing, keep one hand behind your back when prodding about and you’re safe enough. I’m still knocking about after many years fault finding on HV power systems of 200kV DC / AC, RF powers of 500kW that could melt brass water fittings in a twinkling of an eye; I survived, so can you!

Tim's Topics

An 'Extra' CW filter – Tim G3PCJ

A good friend and customer David Perry G4YVM, a very keen CW operator and FISTS Activities Manager, recently regretted the lack of a CW filter in his Argonaut's receiver, and asked if one could be added easily. The answer is YES and this note describes a general purpose circuit that can be added to most transistorised receivers that run on a positive supply voltage between 8 and 30 volts! The essential point is that most people like to receive CW with a beat note of about 500 to 800 Hz – this means that anything above that range can safely be discarded: the removal of the excess audio band from about 1 to over 3 KHz (which is the typical upper audio band edge for most RXs) is far more important than the section below 500 Hz because there will be many more unwanted signals in that upper section. The circuit needs to have high input impedance, and a low output impedance and pass all signals near 700 Hz – ie a peaky response centred on 700 Hz. Often the easiest place to connect such a circuit is just before the rig's AF gain control where there is usually convenient and unmistakeable front panel wiring which makes it easy to also add a switch to include the filter or to bypass the extra filter for phone! (In an ideal world, this filter and switch would be installed before any audio derived AGC pick off point but that might not be easy to locate so connecting it prior to the AFG pot is the easiest thing and it will generally be fine!)

The easiest way to limit the high frequency response is with an active filter using a low noise operational amplifier (op-amp). Just in case the AF gain pot is working on low level signals it is best to use a low noise type such as the TL07X family which can take a supply voltage up to 30 volts! The twin op-amp version (TL072) makes it easy to use one op-amp for an input buffer providing the high input impedance that prevents any alteration of the characteristics of the existing circuits when the filter is switched out, and to then follow this with a humped low pass filter removing signals over about 1 KHz. With this scheme is it easy to have a third order low pass (three CR filtering time constants) because the humped second and third CR stages can operate at a high impedance to prevent loading on the first low pass CR section. The second stage capacitors and resistors are chosen to be very slightly oscillatory, to create the desired humped response with a rapid cut-off above the desired band, using the 'equal resistor Sallen and Key' filter circuit. The parts suggested in Fig 1 provide a peak with a Q of near 4 (for the second and third CR pair only) because anything higher might ring on genuine CW signals which could be annoying! The first low pass section (immediately following the buffer stage) works at low impedance and has a much lower 3 dB cut off frequency intentionally to reduce the excess of unwanted gain at the 700 Hz peak and to also increase the slope of the fall off above 1 KHz. The circuit is shown in Fig 1 and its measured response in Fig 2 (but beware the graph's frequency axis is neither linear nor logarithmic because I could not draw it properly!). The associated photo is of the unit built in 'dead-bug' form on a piece of plain single sided copper laminate.

The circuit has 15 nF and 330 pF capacitors for the second and third CR which give the humped response with a Q of near 4 but if you wish to try a sharper filter of Q = 5 giving a more pronounced peak you can try the alternative values of 22 nF and 220 pF shown in brackets. The last aspect is some tailoring of the less important low frequency response from about 500 Hz down. The filter input coupling components (100K and 4n7) provide the high 100K input impedance and a high pass filter with nominal 3 dB point of 340 Hz; a second high pass filter can be arranged provided you know the value of the AFG pot! The Argonaut has a 25 K AFG pot so a 22 nF output capacitor gives a 3 dB point of 290 Hz; the combined effect of these two high pass sections hardly detracts from the overall filter peak at 700 Hz. (The output capacitor can be adjusted for other AFG values – typically a 4K7 pot would need 100 nF instead of the 22 nF – if its value is unknown, fit 100 nF!) The circuit (and actual unit) also has four components added purely for mechanical reasons to hold the chip in place (2 x 10 nF discs on supply line), and 2 x 1 M on in/out leads for better rigidity – they are not needed for electrical reasons and, owing to their impedances, have no effect on circuit performance. I will not be offering this circuit as a kit of parts because it is so simple anybody ought to be able to acquire these common parts and make it yourself!

Tim Walford G3PCJ

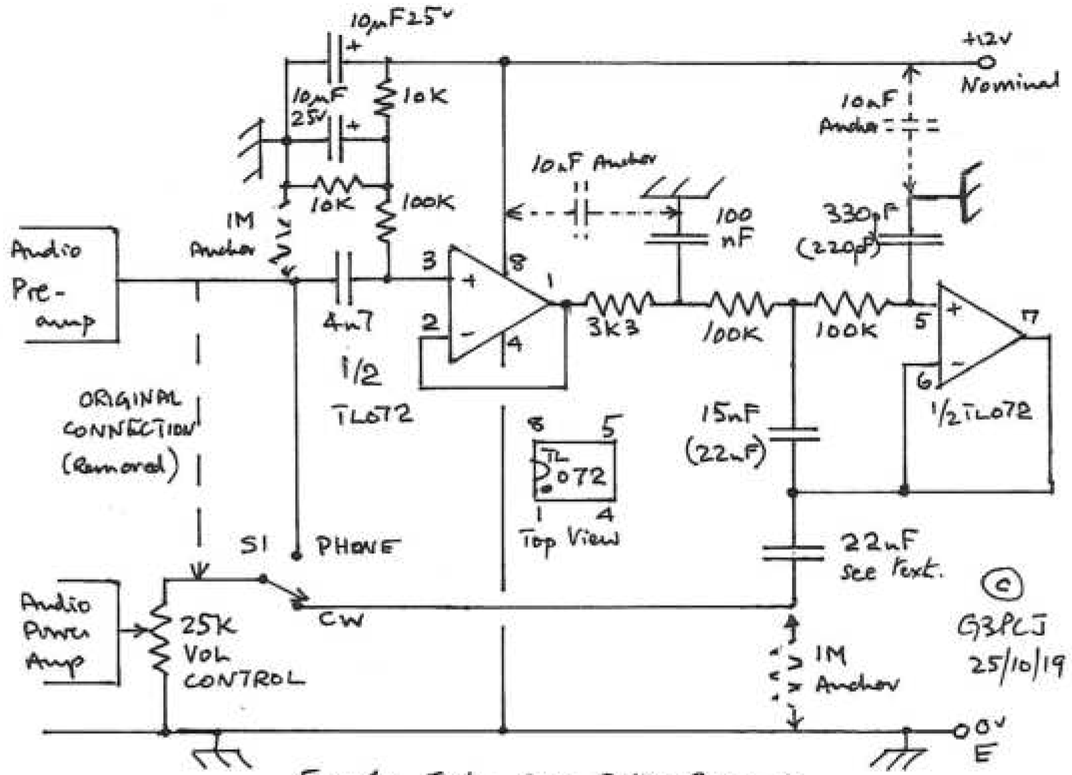


FIG 1: Extra CW Filter Circuit

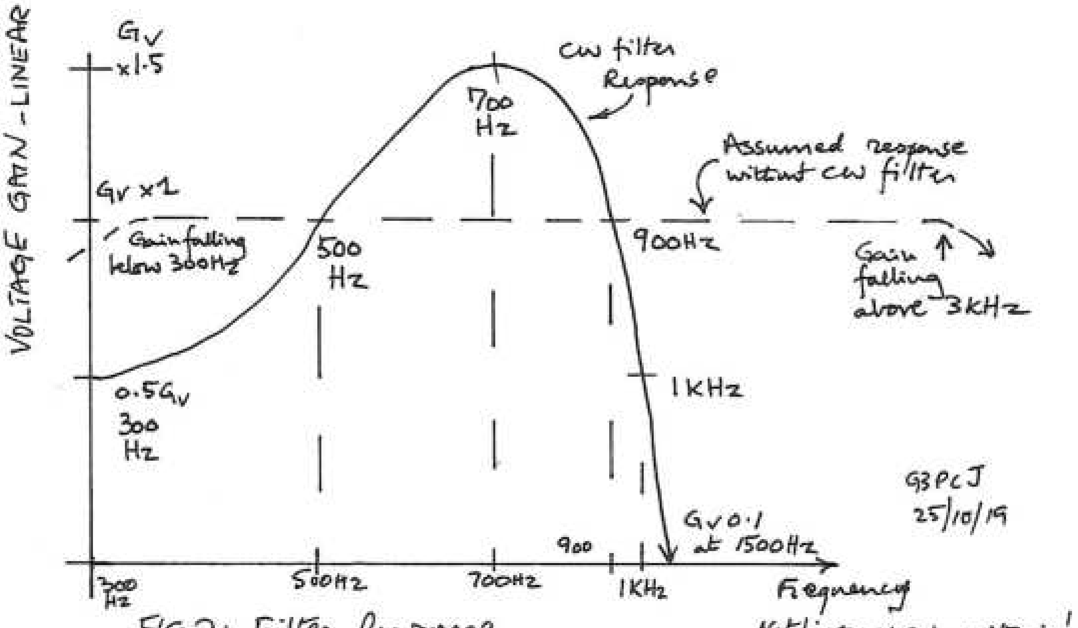
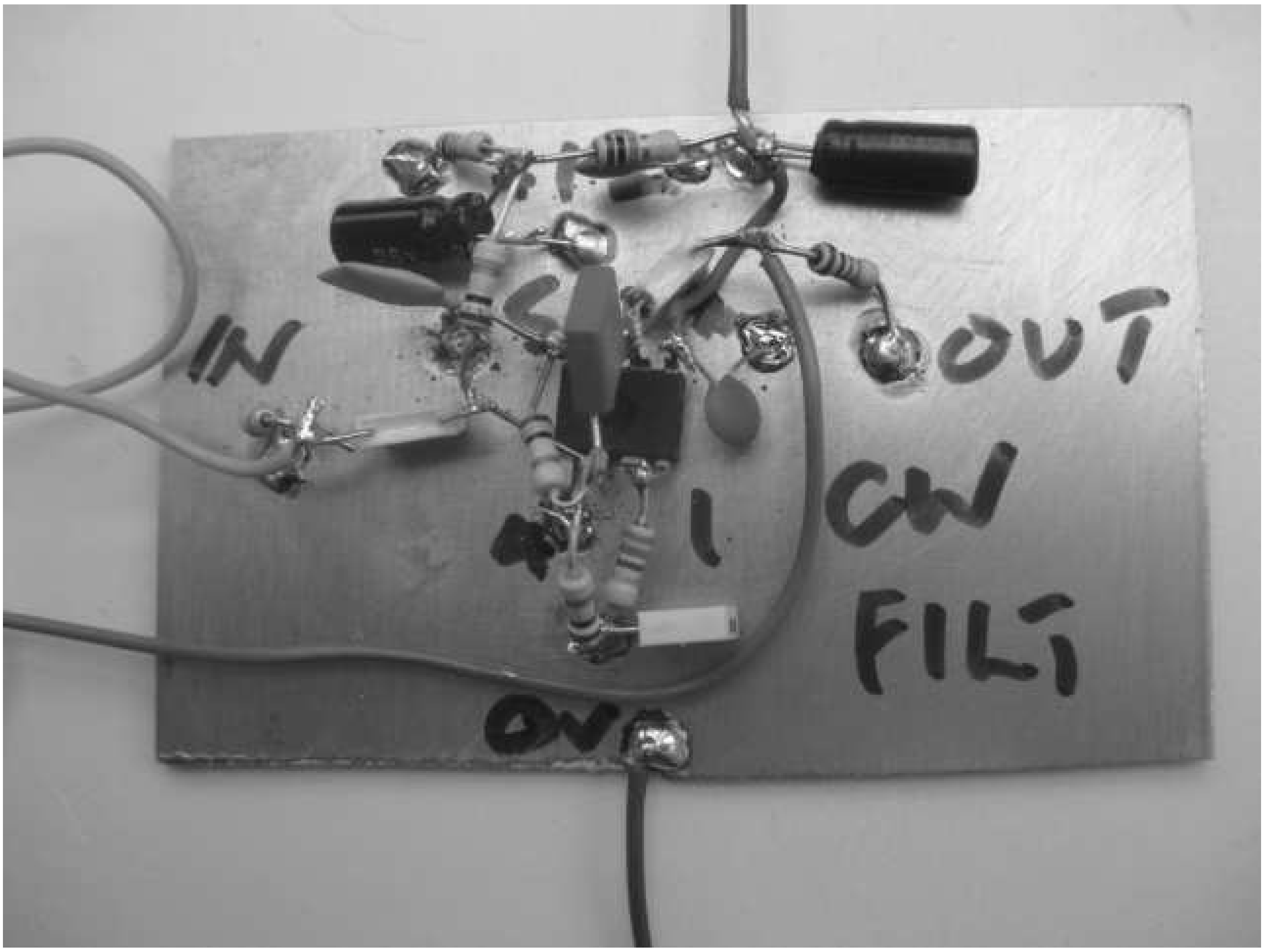


FIG 2: Filter Response



Rx

From Harry Lythall's wonderful radio web pages, another of Harry's superbly simple yet devastatingly effective designs... my notes in *italics*.

---------------- x ----------------

The easiest HF receiver ever

QUICK RECEIVER

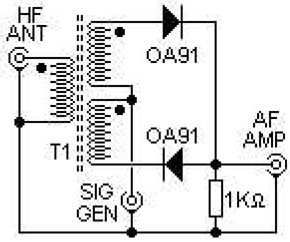
by Harry Lythall - SM0VPO

How many of you have got loads of test equipment in the shack that is not really doing anything most of the time. I have got a couple of RF signal generators and a stereo amplifier (for music) amongst other things. That's all I needed to receive SSB and CW on the HF bands.

A Direct Conversion receiver is nothing more than a mixer, an AF amplifier and a stable oscillator. I took one of my standard building blocks; a two diode mixer and connected it to my stereo amplifier

PHONO input then fed the signal generator into the mixer. Connect an antenna to the third port of the mixer and you can receive HF SSB and CW signals.

The mixer I use is a standard "building-block" for nearly all my projects that require a simple mixer and is given below.

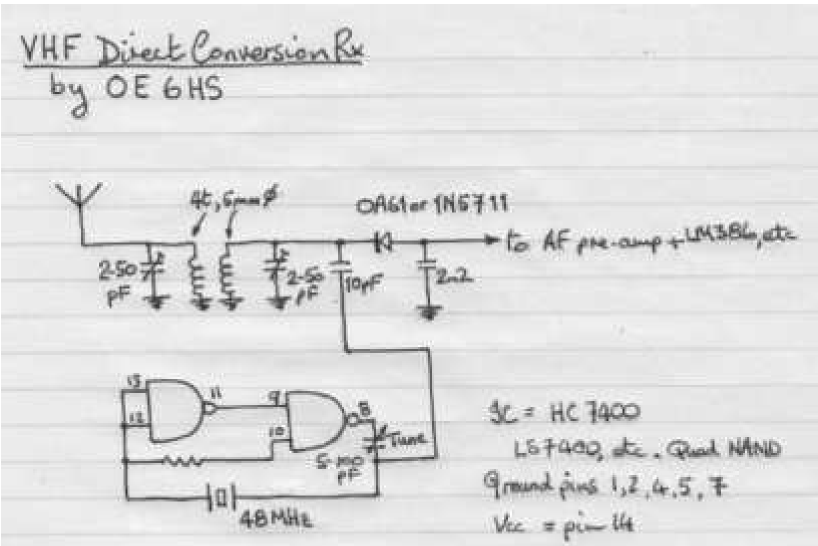


T1 is a Triflar wound component on a 1/2" ferrite ring (*a scrap one from a PC ATX power supply or similar would probably work...*). Twist together 3 lengths of thin enamelled wire and wind 17 turns on the ferrite ring. One winding is for the antenna and the other two are for the mixer. The black blobs by the T1 windings indicate the polarity of the transformer. All of the black blobs are the same end (*i.e. the "start" of each piece of wire*).

The mixer works best with a high level of RF input from the Sig-gen, but a "Marconi 995" works well if you take out the impedance matching box and screw the RF LEVEL right up. My Hewlett Packard Sig-gen gives out +7 dBm which is more than adequate. If you do not have a Sig-gen then you can do the job with a GDO. Wind 20-30 turns of wire on the end of a pencil and stuff it in the end of the HF coil.

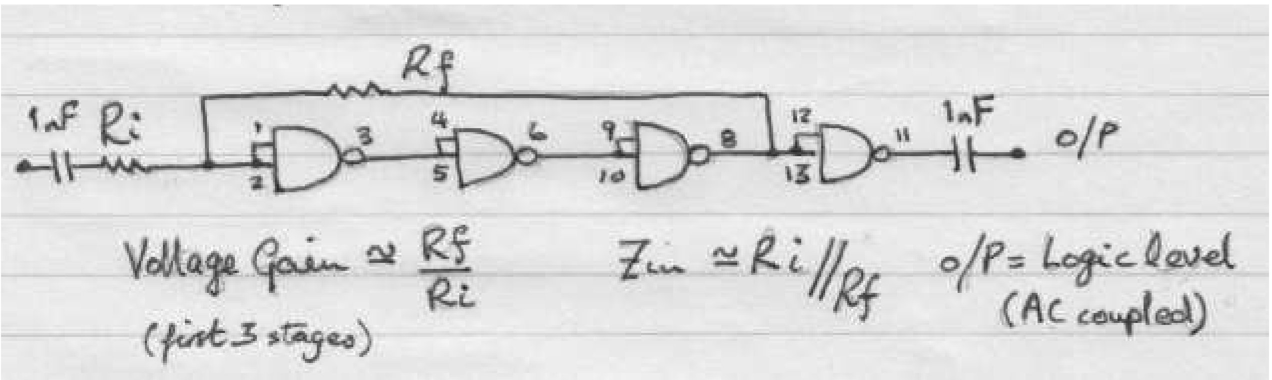
The final receiver is as stable as the RF Sig-gen and as sensitive as the AF Amplifier. A typical stereo amplifier will give out its full audio if there is one millivolt at the PHONO input. You can hear signals that are less than 1% of this (10uV).

The easiest VHF receiver ever



This circuit, from OE6HS, appeared in SPRAT (via John Beech, G8SEQ with many thanks) some years ago and it's a cracker. It illustrates how, with a bit of lateral thinking, a simple diode mixer and a logic gate pulse generator can make a useful harmonic generator for VHF. Use a decent antenna for best results!

A simple frequency counter buffer / adapter for oscillator readouts



A few notes are in order for this circuit; I first saw it in a high speed centrifuge speed controller module, which used some ancient TTL compatible CMOS gates from RCA - now unobtainium. Check the pin-outs if you substitute CD4011B's, they are different from those above!

The first three gates are forced into linear mode by the DC feedback via Rf, and the individual gain of each gate multiplied together in this fashion creates a near virtual earth at pins 1 & 2. Thus the first three gates with Rf and Ri connected create an inverting op-amp, gate 4 a squaring and logic level output driver.

The ratio of Rf divided by Ri is the approximate voltage gain; for High HF and VHF operation, Ri needs to be low, but not so low as to load the GDO or local oscillator. You need enough gain to reliably clock gate 4's input; and you'll need to capacitive couple gate 3's output to avoid jamming gate 4's internal biasing.

You can of course use discrete device(s); but you get a lot of "bangs for your buck" with CMOS logic gates: biased linear, they become potent RF amplifiers if Ri and Rf are kept to low values - especially if the chip supply is 12v, they are capable of good HF performance but watch you don't overdrive the load - it might be a PIC on 3.3v rails.

Using a DDS / PLL oscillator modules for DSB synchronous detection?

DDS / PLL modules and controllers are becoming readily available at low prices: their stability and low phase noise makes them very desirable indeed for almost every receiver VFO job you can imagine. Here's a thought that might open Dx communications: using double sideband suppressed carrier gives a 6dB improvement in readability over SSB. The price is of course extra bandwidth - but the signal will get through, as 6dB is a major improvement in power.

The cost however is usually very different: you need a demodulator to recover the audio from both sidebands to gain the advantage and this usually calls for phase locking technology - the Costas Loop being one very effective method. But is true phase locking really required, if the receiver local oscillator can be held dead steady to re-introduce the transmitter's suppressed carrier?

Enter the DDS / PLL VFO! The stability and accuracy are without doubt capable of DSB demodulation, but for *effective* DSB demodulation, to reap the full 6dB benefits, the *phase* must exactly match the transmitter too: not an easy task when the carrier is suppressed many thousands of miles away. This isn't a show stopper though if the WW2 concept from TRD sets is used; a *clarifier* control to tweak the phase of the DDS / PLL would solve this problem, just as the BFO control produces clear speech from SSB signals.

I asked Terry Mowles, VK3TM, about this, he being the "go to" man on these topics. Terry commented that all DDS / PLL VFO systems have a fine adjust, calibration or similar input; and the software controlling the DDS / PLL control word can be modified "on the fly" to increment the phase - the inherent stability of the DDS / PLL ensures that such tweaks (*by a "clarifier" control or the software control word being incremented slightly*) won't be needed (hopefully) too often, as the phase shift is from the distortion by the ionosphere in skip propagation.

Or... a sub audio tone, at (say) 15Hz could be added to the audio transmitted to provide a phase reference - this filtered out and used for the phase adjustment (*via the control word*) at the receiver. No need for a Costas Loop; and stability ensured without any tweaking control.

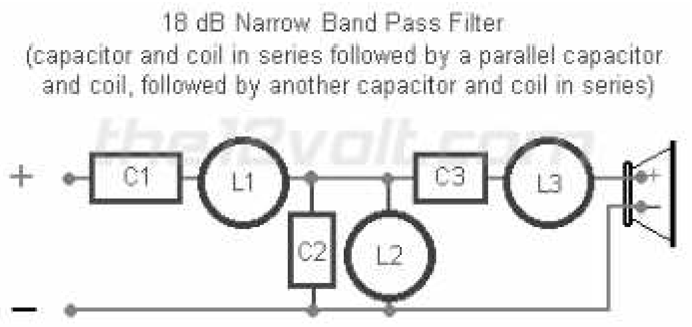
SSB converted to CW transmitter

One trick for a quick CW transmitter (if your SSB transceiver doesn't have a CW mode) is to key an LF audio oscillator, and feed the audio into the mic. socket of your SSB transceiver, thus you get a CW transmitter. The only drawback to the scheme is the wider bandwidth of the SSB transceiver's IF filters when you're trying to receive CW: but a simple tight bandwidth filter (as per Tim's design in Tim's Topics, in this edition) sorts this problem very effectively.

Tim's excellent design prompted my memory: for those who don't want to dive into a transceiver (for whatever reason) a filter between the Rx audio output and your headphones limits the audio bandwidth you hear: in fact the headphones can be used for exactly this purpose by connecting a suitable capacitor to resonate the coils inside them, to form a tuned circuit. You'll need a fair bit of cut and try but you should be able to improve CW readability with this simple method, first described (I believe) in the 1920's. I should add that this technique was designed to work with the high impedance headphones (~2k ohm) of the day; modern 8 ohm / 16 ohm / 64 ohm ear buds or headphones won't have anywhere near the selectivity that Tim's circuit delivers.

Another approach is a band pass filter fitted in the headphone lead, using L & C's as here:
https://www.the12volt.com/caraudio/narrow-band-pass-calculator.asp

This yielded results for a 3rd. order bandpass filter, 750Hz to 850Hz passband, 8 ohms in / out - ideal for placing in the headphone lead - but it's not going to be small!



The values for this filter are:

L1 & C1 = 18.95mH & 2.1µF

L2 & C2 = 0.15mH & 270μF

L3 & C3 = 6.37mH & 6.25μF

For these capacitors, you'll probably need electrolytics - but for audio / AC? Yes: connect two electrolytics in series, positives together to cover each half cycle. Snag is, though, capacitors in series = half the value of each, so you'll need plenty of electrolytics!

Inductors: use ferrite pot cores from a reputable supplier and the manufacturer's design guide or an online calculator. You're going to need a fair amount of fine gauge enamelled copper wire, too!

Well, I did say it wouldn't be small... and you'll lose a fair amount of audio output power too. But it will work!

Oscillators

CMOS gate oscillators

I came across a simple and straightforward Application Note from ON Semiconductors regarding CMOS gate crystal oscillators, and thought it worth sharing - especially about using standard logic gates, now available for pennies, that will run to 50MHz and more especially if you carefully tweak the Vcc +ve supply up to the maximum ratings.

This circuit uses appropriate parallel capacitance to run the crystal loaded as the maker intended; and the series 10k limits the crystal current - always a good thing for stability.

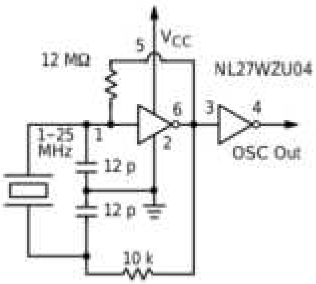


Figure 2. Complete Crystal Oscillator Circuit

The above circuit will serve as a good starting point for a design. The capacitor values may need to be altered to suit the crystal. This same design could be done using standard 14 pin devices, e.g. MC74HCU04 – just remember to tie off unused inputs.

PUBLICATION ORDERING INFORMATION

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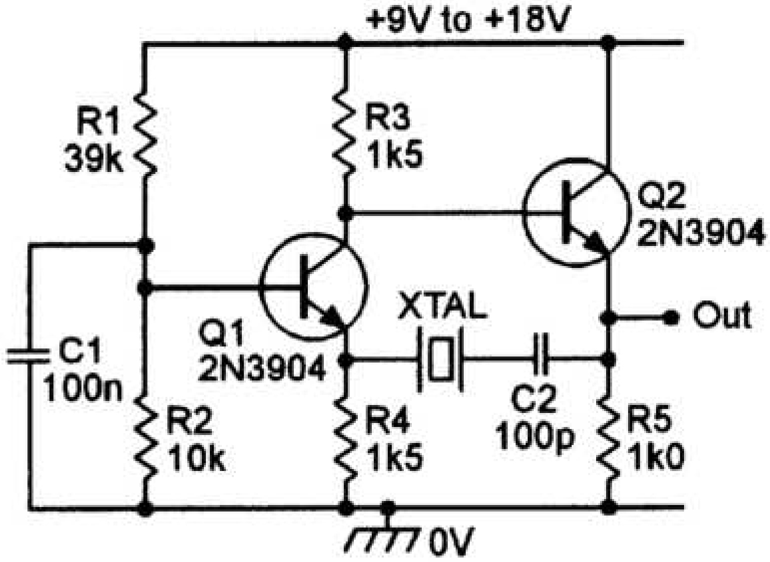
For additional information, please contact your local Sales Representative.

The Peltz, Zachary, Franklin and Butler Oscillators

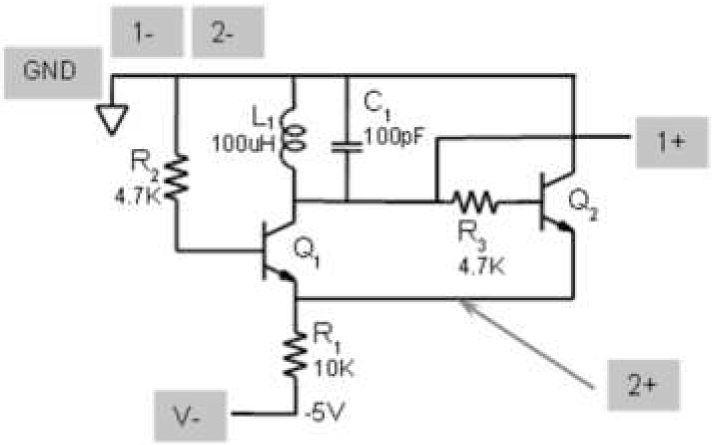
In looking for oscillators for test gear projects, I found some very useful oscillator circuits not in general circulation which have many advantages compared to the "standard" circuits usually specified. I didn't need the complexity of a DDS / PLL set-up, but a reasonably stable oscillator that could offer kHz to MHz performance. Such beasties do exist; and the universal feature is the use of TWO active devices to “make the bird sing”. The diagrams are below, and of course you’ll need to adapt L/ C values to get the frequencies you want but if you stick to the X_L and X_C in the same ratios you’ll not go far wrong.

Peltz Oscillator:



Or the L / C version:

(I’d decouple Q1 base to Ground with a 100nF capacitor to ensure Q1 runs in common base. You can of course use a PNP RF device, and invert the circuit for negative ground.) This diagram is from an Analog Devices training exercise:



This circuit could probably resonate a chunk of window glass, it’s got enough gain and the topography is ideal for driving tuned circuits and crystals - of any frequency (if the transistors have suitable HF gain characteristics). Q1 is running in common base connection, Q2 is an emitter follower so you have plenty of voltage gain followed by ample current gain; Q1’s load (Q2) is an emitter follower featuring high input impedance, so Q1’s collector is loaded very lightly.

I would suggest a 100nF capacitor to ground in the L / C version above for true common base operation.

Zachary Oscillator:

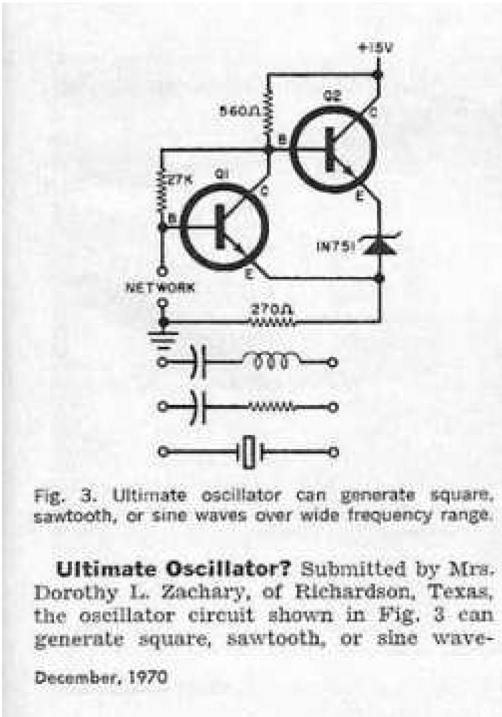


Fig. 3. Ultimate oscillator can generate square, sawtooth, or sine waves over wide frequency range.

Ultimate Oscillator? Submitted by Mrs. Dorothy L. Zachary, of Richardson, Texas, the oscillator circuit shown in Fig. 3 can generate square, sawtooth, or sine wave-

December, 1970

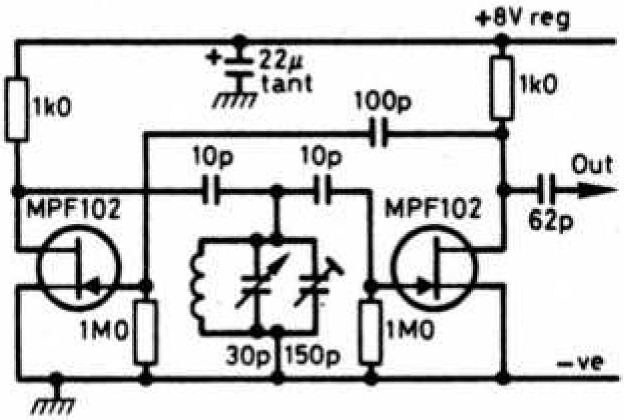
A close relative of the Peltz; but simpler: and illustrates the useful different outputs available with alternative resonator networks. I don’t know where the original image of December 1970 is from; but give my thanks to Mrs. Zachary and her erstwhile publisher!

From his excellent page: https://www.robkalmeijer.nl/techniek/electronica/radiotechniek/hambladen/radcom/1990/02/page32/index.html, we find...

Franklyn:

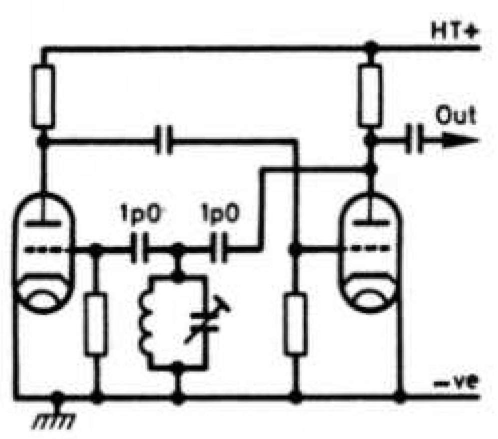
A close relative of the Eccles-Jordan astable multivibrator - note the tiny value (10pF) coupling capacitors - after a short warm-up period, this oscillator can stay zero beat with a crystal oscillator for hours. Makes a superb VFO (in non DDS / PLL terms) using decent components in the tank circuit, and kept well away from heat in the thermionic version.

jfet devices:



Twin triode version:

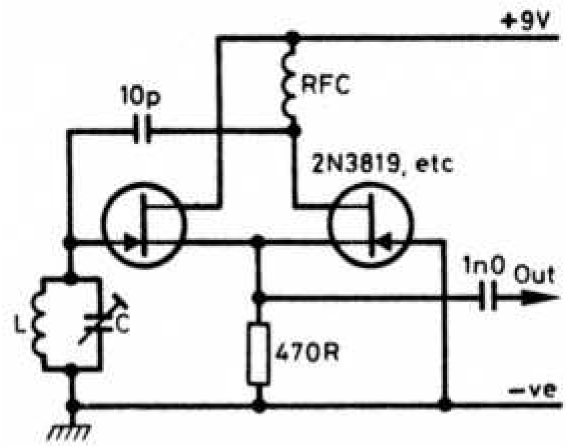
No mistaking the ultra-low coupling capacitors in this design!



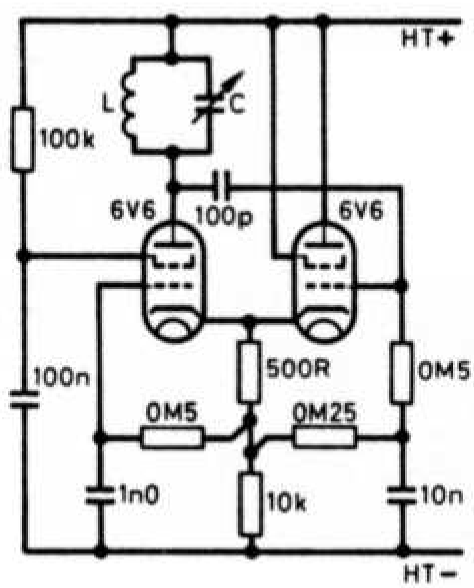
I'm tempted to try a double triode Franklyn with the L/C's isolated in a small die cast box, mounted underside the chassis to avoid the valve heat, to test the warm-up time and long term stability.

Butler:

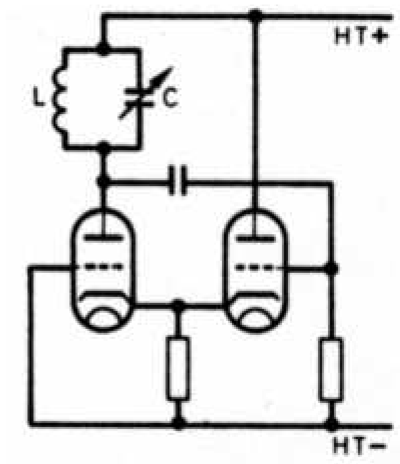
jfet devices:



Valves:



This is the generic circuit, use twin triodes:



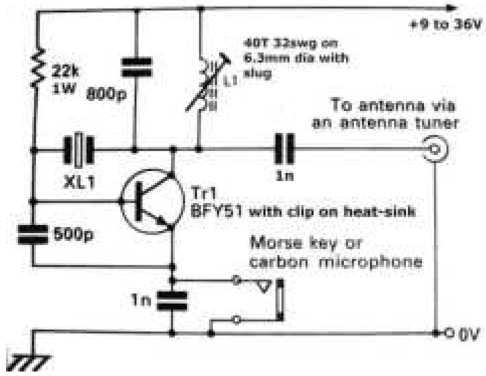
The differential “long tailed pair” topography is very obvious in the Butler design; and as an added advantage, yields superb overtone oscillators for VHF / UHF jobs - replace the anode to grid coupling capacitor with a crystal and set the tuned circuit to the overtone required.

9^{th}. overtones are possible with particularly lively crystals, but can be prone to mode skipping and spurious oscillation unrelated to the original crystal cut.

Tx

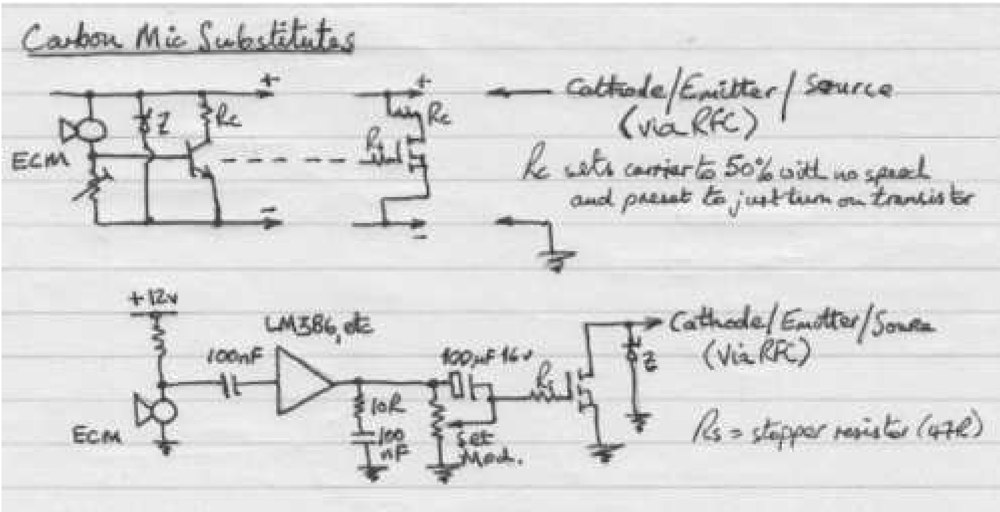
I’ve always had a fascination for single valve or transistor transmitters: add a simple low pass filter and you’ve a neat low power (and not-so-low-power) CW transmitter. With me being an A.M. enthusiast, I look for designs that I can easily modulate: the Michigan Mighty Mite is a champion little transmitter that takes very kindly to being emitter modulated - in the style of the old cathode modulation - using an LM 386 via an electrolytic DC stopper to modulate the voltage across the usual 27R emitter resistor. In my wanderings around the dusty radio archives, I find many interesting circuits for simple transmitters and modulation schemes. Many use the now “rare as hen’s teeth” carbon microphones, which disappeared from telephone handsets in the 1960’s as the modulating element. So I dug out some interesting circuits that eliminated the carbon microphone, thus re-enabling a host of the simple one transistor transmitters to send some full carrier A.M. into the ionosphere once again.

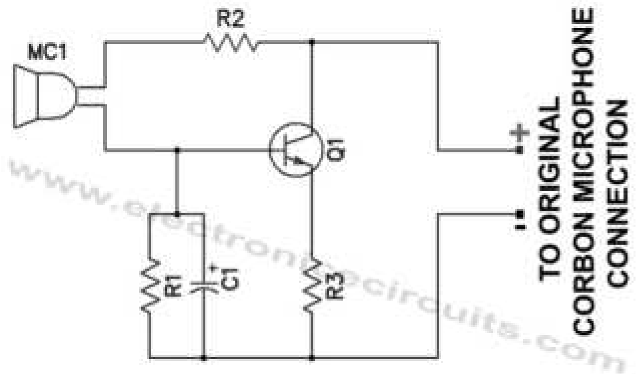
First, a single transistor transmitter that can certainly do the business: feel free to substitute other transistors or jig up a bias scheme for a power mosfet version.



Note the power supply voltages: this cheeky little chappie, with suitable rated power devices, could well run a much higher voltage supply rail, with bias tweaked accordingly. I'd tap the coil Michigan Mighty Mite ("MMM") style - indeed the MMM coil details could well be used "as is" in this circuit. All that remains for "A.M. on the cheap" is a carbon microphone in the key socket!

For your delectation, below are some electronic substitutes for a carbon microphone, and a link for a complex design that's subject to stringent copyright, of which I'm not going to fall foul. http://www.vmarsmanuals.co.uk/newsletter_articles/Electret_Mic_Replacement.pdf





This is from http://www.electronicecircuits.com/electronic-circuits/carbon-mic-replacement-to-magnetic-mike-converter-circuit...and illustrates how simple this job can be; but note no over voltage protection is fitted. There is a flaw in this circuit as shown: Q1 base is AC short to ground via C1; I think C1 should be in parallel with R3. R1 with R3 sets the quiescent current in Q1; this sets the carrier level with no speech to 50%, for full carrier A.M.

Keep in mind an Electret Mic has an internal jfet buffer, that effectively forms an (approx.) 0.5mA constant current source modulated by the speech into the Mic. Thus you can design a circuit to create the same effect as a carbon mic, remembering the carrier in a full carrier A.M. transmitter is 50% of maximum with no speech (if carrier control isn't used). Simply unplug the modulator, and the carrier should be 100% on keying. Plug in the modulator, and check the carrier reduces 50%. Tune your receiver to the transmitter frequency, and adjust the Mic. gain control for good speech.

A Morse Key for pennies

(and eliminates a problem)

A hacksaw blade, broken in the centre and cut into two 5” / 120mm long sections, the “hole ends” bolted together with a 4mm / 8-32 or 8-36 brass dome / cheese head bolt make a very serviceable “spring arm” Morse key. The brass screw’s threaded end points upwards through the two blades to hold the (INSULATING!) operating knob. The teeth are ground off easily with a small disc grinder, or some minutes with a file, the blade sections clamped teeth up in a vice. Once assembled, the blade “spring arm” can be coated with varnish, insulating tape or heat shrink (use thin wall shrink, or it will be too stiff) for electrical insulation.

The blades are supported at the cut end by being clamped in hardwood / plywood blocks using wood screws into a hardwood / plywood baseboard,of size to suit your desk and normal operating position. The clamp blocks also make the back connection and insulating support, a flexible piece of FR4 / plain copper foil / thin solder tag being clamped tight between the two blade sections after scouring the connection area clean and bright.

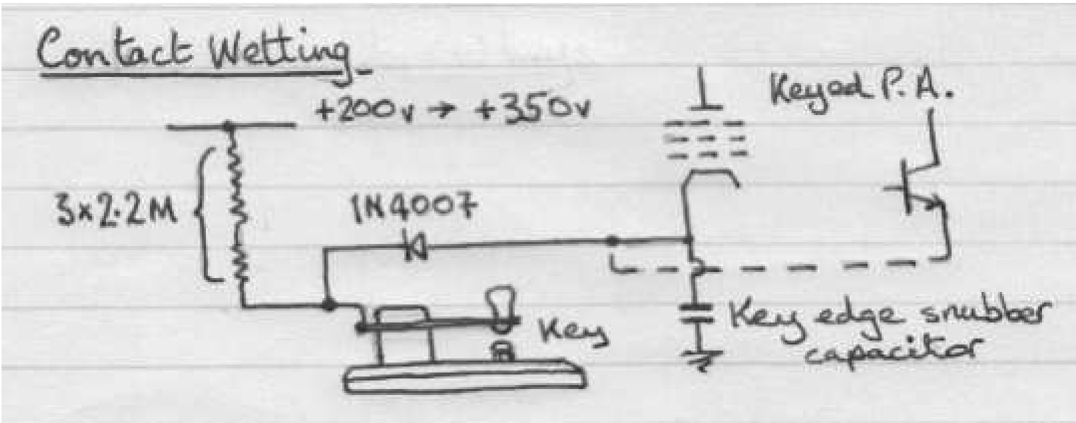
One nifty trick I learned as an apprentice is that decent ½” or ¾” (13mm / 20mm) hardwood ply can be tapped to take a thread - and thus the bottom “fixed” contact is a brass dome or cheese head bolt, screwed into a tapped hole in the plywood base; fitted with a (gap adjusting) nut and washer, a solder tag beneath, for a sound “fixed” contact connection.

The problem with **any** switch is keeping the contacts scrupulously clean. If you look inside a relay at the contacts, the supporting springs are designed to flex on closing, which “wipes” the contacts after initial contact is made. A straight up-and-down motion as in this (and most other keys, to be fair) doesn’t have the wiping action - so an electronic means must be used to keep the contacts clean and in excellent condition, no matter how light, heavy (or “ham fisted” in my case!) the operator.

For a Morse key, oxidised contacts spell disaster: poor keying, splatter, fudged characters, crackles, bangs and worse unless you slug the key contacts with umpteen nF’s which slows things right down (who said Morse transmitters were ‘simple’?). A Morse key, with its ‘up & down’ motion doesn’t clean the contacts, allowing oxidation of the contacts and eventually intermittent, high resistance connection that needs a heavy “fist” to key reliably.

Unless... you add a contact “wetting” circuit to keep those contacts sparkling (NOT “sparking”, please!). Use a series diode to connect your key to the transmitter - ensuring the transmitter is happy with being grounded via a diode forward volts drop - and connect your Morse key moving contact to +200v DC or more via 3 x 2.2M resistors in series, which ensures any current in your body, should you touch the bare metal of the key, is way below what you can feel or will hurt you, even if one resistor fails short (*very unlikely*). The high voltage can be derived from a multiple section Cockroft - Walton multiplier fed from a 12v A.C. transformer, if you don’t have a valve power supply to hand.

The Cockroft-Walton circuit: http://home.earthlink.net/~jimlux/hv/cw1.htm is a very useful resource and has design illustrations (many thanks to EarthLink). Select a load current of < 200µA to be safe when choosing the parameters - and it saves on the capacitors. The diode blocks the high voltage back feeding into your transmitter; make the diode PIV equal to double the “wetting” voltage.



A keying monitor for free

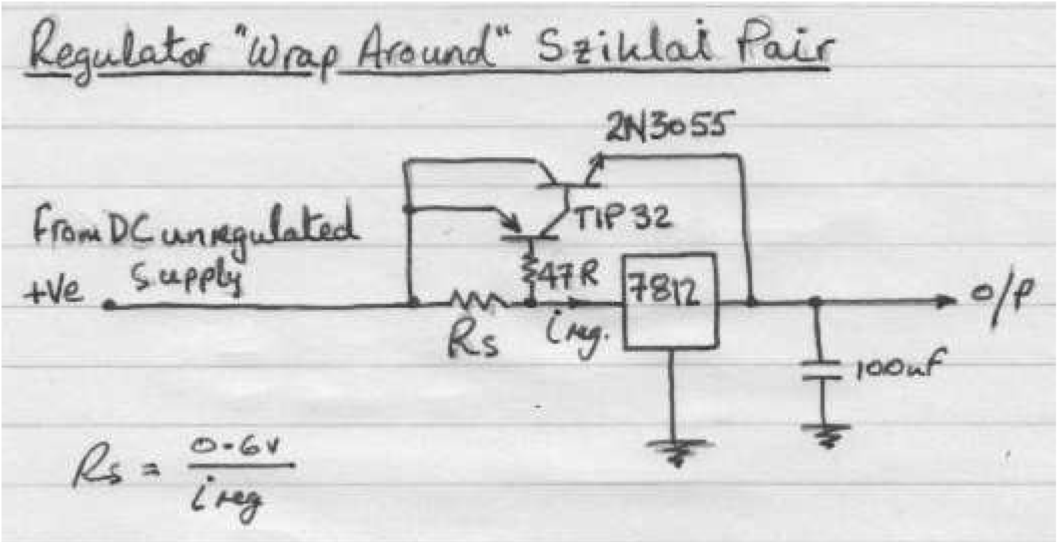
I maintained silicon epitaxy reactors for a living a few years ago, which used high power (500kW) RF to heat a process chamber to 1270°C - with a hydrogen atmosphere inside. It was an “interesting” few minutes after servicing the process chamber when the RF was applied - any air leaks and the whole thing was a very capable bomb. It really helped to know when the RF was “on” - the machine being inside a clean room, in which I had to wear special clean room overalls, gloves, boots and hood - and the RF generator in the service area outside. A round plastic “speak through” was alongside the machine, through which I could see the steel covers of the oscillator section of the 500kW generator; so I cut a 6” / 150mm hole in the oscillator box steel panel, bolted some perforated mesh over the hole to stop RF leakage, which allowed me to see my magic “RF ON” indicator - a 6” fluorescent lamp fastened above the grid current meter with cable ties, and wired to....   NOTHING.

It took a mere sniff of RF to light the fluorescent lamp, the RF inside the cabinet more than enough without ANY electrical supply to the lamp whatsoever - shades of Nikola Tesla! Thus, peering through the “speak through” I could see the lamp inside the oscillator box; an added bonus, if I was adjusting the RF generator, I had a clear view of the grid current meter (0 to 5 AMPS!). Job done!

Which brings me to an interesting proposition - perhaps more suited to valve / tube transmitters, but, hey, you don’t know till you try - a small fluorescent tube, near the matching network coil, Pi-net or whatever you use - would make an easy and effective keying monitor for free. A novel feature for your next transmitter perhaps? Wind a turn or two of insulated wire as a pick up coil near the aforesaid matching network, a diode and capacitor or two, and run a small DC piezo loud-squeaker from the RF picked up, giving an absolute and unambiguous keying monitor.

Power Supplies

Linear wrap around using a Sziklai pair



Select Rs by deciding the regulator current you want in the regulator before the wrap-around starts taking the load - assume you have a 78L12 100mA regulator, and don't want more than 50mA through it. Thus Rs = 0.6v / 50mA = 12 ohms.

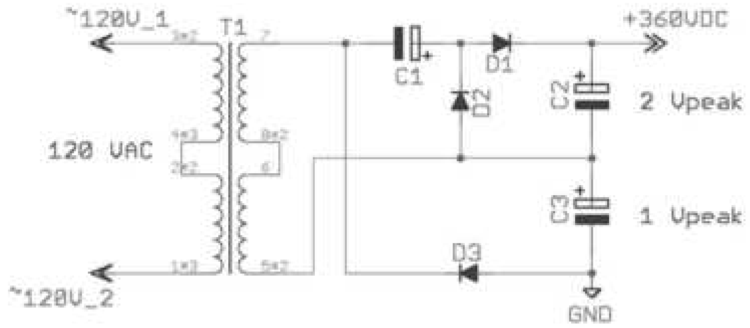
This circuit, whilst similar to the conventional PNP power "wrap-around" regulator booster, allows far more common NPN power devices to do the job. The Sziklai pair is named after the Czech engineer who first described it, and offers the advantage of having an overall volt drop in saturation of one Vbe, rather than two as in a conventional Darlington Pair. Lower volt drop = less power dissipated = smaller heatsink! The 47 ohm in the TIP 32 base is an emergency current limit in the event of an output fault; it saves the TIP32 base - emitter junction from destruction.

Safe and easy high voltage for Transmitters

There are a few power mosfets of the IRF 510 ilk that run very happily (and far better) on a +50v drain supply in linear amplifier and other power applications. The higher voltage means less amps for a given power: this is an effective increase in impedance and makes matching far easier - as in valve / tube circuits. The question is, though, how to achieve this kind of voltage from the usual 12v power supplies?

In previous Hot Iron issues I've mentioned the full wave doubler circuits, typically the 8 x 8 HV power supplies; full wave doublers with modern miniature electrolytic capacitors are a ready answer for "HV" transistor circuits. Take, for instance, an 18v RMS transformer, to be used for a power supply: 18v RMS applied to a full wave doubler will deliver +48v nearly; on load dropping to +40v. A full wave tripler will get you to +50v on load easily, at a good few hundred mA's, if the electrolytics are big enough. For power circuits, always choose a full wave multiplier: half wave types cannot deliver the current efficiently without heavy ripple.

The circuit below assumes 120v secondary; adapt for your requirements.



The voltages shown above are easily altered to suit your application, rate your capacitors appropriately. (Diagram from http://www.augustica.com/full-wave-voltage-doubler-tripler-and-quadrupler-ezp-36, with many thanks).

Series connected electrolytics for high voltage ratings

Shunt diodes connected across series connected electrolytic capacitors are a good idea in high voltage power supplies: imagine one electrolytic in a series chain going high impedance. The electrolytics below in the chain force the errant electrolytic to be back biased, with consequent explosive results. A diode, cathode to capacitor positive, anode to capacitor negative will safely shunt current around the dud electrolytic preventing (messy!) disaster.

Test Equipment & Fault Finding

PIC frequency counters

Using PIC frequency counter / displays, if the input is over driven, do not like it up 'em! They blank or flood the display, and if the over drive isn't removed quickly, permanent damage will occur. The PIC inputs are protected to a limited extent by internal diodes, but a pair of fast 1 Amp Schottky clamp diodes will do the job; but be sure your power supply rails can absorb any over voltage; or a whole section of your electronics might suffer.

How a grid dip oscillator works

No excuses, no indecision: a Grid Dip Oscillator is as important as a soldering iron if you're a constructor - no doubt about it. I use my GDO to tune up antennas; a simple two or three turn loop of insulated wire connected directly to the antenna feedpoint tells me immediately whether or not the antenna is too long, too short or near enough to try a few watts into it with my home made SWR bridge in line. I do have another bit of test gear - an RF Impedance Bridge - that I use to be absolutely sure my latest "Wonder Wire" is a round-the-World design (still trying you'll note.... not done it yet!).

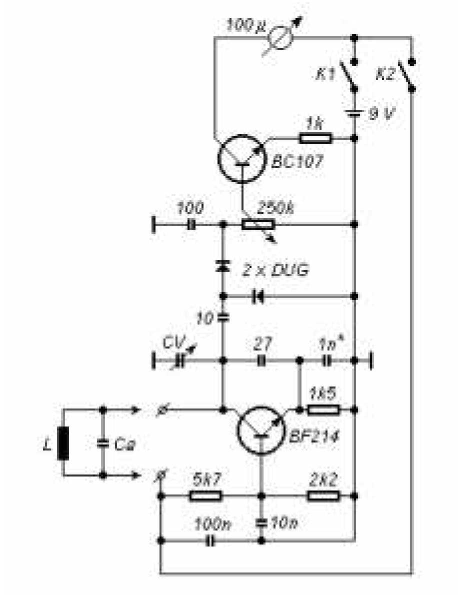
The basic principle of Grid Dip Oscillator is to induce RF into a resonant circuit, be this a tank L / C circuit, antenna, ½ λ or ¼ λ section of co-ax or anything else that might be reasonably suspected of having resonant properties, and noting the level of oscillation in the instrument. Using a valve / tube oscillator, the grid bias / current dips when the GDO's oscillator coil is delivering power into a resonant load - if the frequency of the GDO is altered, the resonant frequency of the item being tested is shown as a dip in the meter. Using a transistor GDO, the level of the oscillator's RF output can be monitored (or the supply current to the GDO, or any other operating parameter that shifts on coupling to a resonant load for that matter) and the dip shows the resonant point of the circuit under test.

Knowing the resonant point enables many other features to be derived: if you attach a known capacitor in parallel with a coil, and measure with a GDO the resonant frequency, you can estimate the coil inductance. Once again, the wonderful simplicity of operating A.M. on the few recognised frequencies favoured in the HF bands allows me to use a crystal oscillator as a GDO - so I can peak up my antenna bang on the operating frequency knowing my transmitter will be exactly on the same frequency.

Many designs exist for GDO's. An excellent device is Harry Lythall's design and article on his web page, http://sm0vpo.altervista.org/use/gdo.htm, an absolute classic of the ilk: and you get Harry's GDO write up too, always worth a read. Harry uses (as do most wide range GDO's) an oscillator which uses a dual section tuning capacitor. Such devices aren't the easiest things to procure nowadays, and a Hartley tapped inductor design isn't the best either, as plug-in coils will need a 3 pin plug and socket arrangement. Not really a bother for me: my home made GDO uses 5 way / 270° DIN audio plug mounted in 15mm plastic water pipe as the coil former, to a 5 way socket in the instrument.

Below are extracts from an article: https://www.qsl.net/yo4rlp/wshp/gdo.html, which shows several forms of GDO using bipolar transistors, jfets and mosfets, so you pays your money and takes your choice! Me being an NPN silicon devotee, I'd go for that design as it allows a grounded (untapped) coil and a single section tuning capacitor (below, "Using Bipolars").

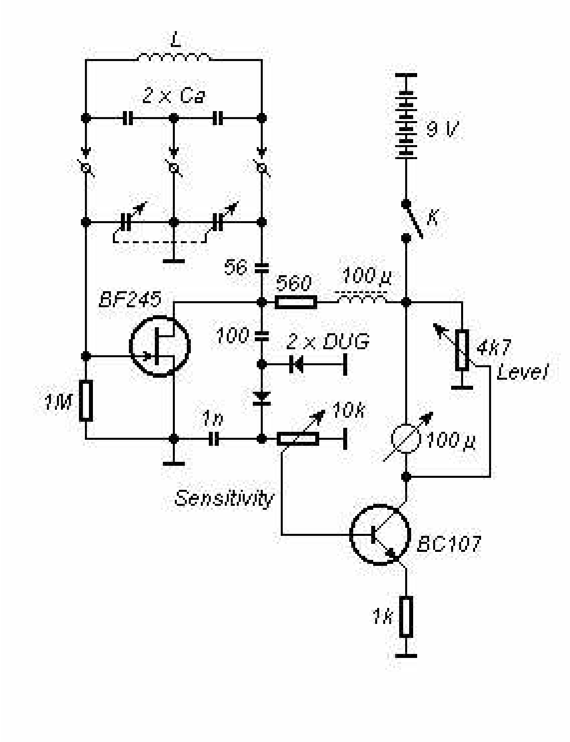
Using Bipolars:



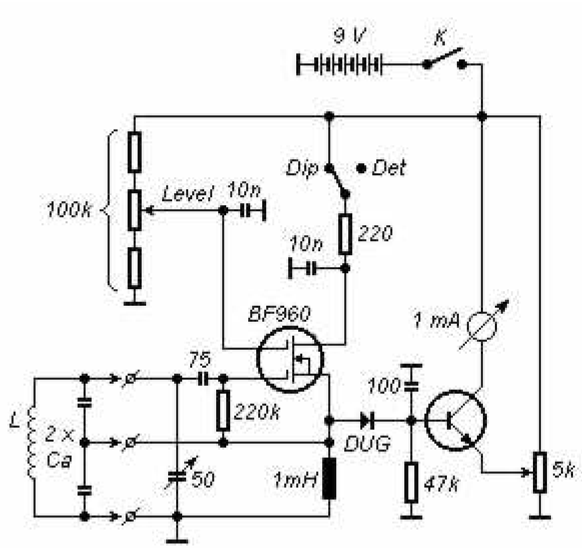
A BF199 should work well in this circuit.

Using jfet's:

A 2N3819 in this circuit will perform well.



Using MOSFET's:



A BS170 / 2N7000 or similar single gate mosfet would work admirably in this design - use the original second gate biasing network to bias the 2N7000 gate via a 220k resistor to set the oscillation level. You'll need about 2.5 volts on the gate for to kick her into oscillation.

The article by YO4RLP (where the above diagrams are from) has some good illustrations using a GDO: well worth reading.

I wouldn't be happy that I had given you the "full story" if I didn't include a "proper" version:

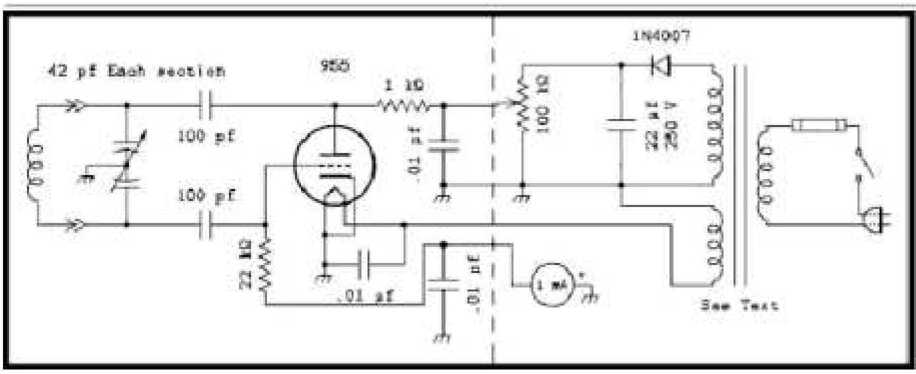


Diagram courtesy https://www.scribd.com/document/268728159/Tube-Grid-Dip-Meter

Yes, this is the real and original, and, for my money, the best! Any triode will do nicely, thank you!

Adding digital frequency readout

For a really useful improvement to GDO, add a frequency counter display, now very low cost on an online auction site - £3.99 / $5.00 for the one I bought - driven by a buffer amplifier, from the GDO oscillator. This eliminates the calibrated dial, and you can take into account the "pulling" of the simple GDO oscillator on load - very useful.

Finding a transistor substitute

From: https://www.electronics-notes.com/articles/electronic_components/transistor/choosing-replacements-transistors.php with grateful thanks.

"When working with electronics equipment, either to design, build or repair it is sometimes necessary to choose a replacement transistor. Either the type of transistor may not be to hand, or it may not be available. Fortunately it is normally possible to use a replacement transistor type as there is often a considerable degree of overlap between the specifications of different types of transistor, and by looking at the basic specifications it is normally possible to choose the correct transistor replacements.

This explanation is focussed on bipolar transistors, but it is possible to apply similar logic to field effect transistors to ensure that suitable replacements can be found.

When looking for suitable transistor replacements it is necessary to look at the main specifications for the transistor. Once the transistor specifications and parameters have been ascertained, it is possible to check for other replacement transistor types with similar parameters that will be able to operate within the circuit in question.

When considering any possible replacement transistors, it is necessary to look at a variety of parameters. These will include the basic parameters of the transistor operation performance. They will also include the environmentally related parameters, and the physical parameters. All these need to be taken into account when choosing a suitable replacement transistor.

Looking at the basic transistor parameters

When looking for a suitable transistor replacement some of the basic transistor parameters that need to be considered include the following:

1.***Semiconductor material:*** Most transistors will either be germanium or silicon. Other types are normally only used in very specialist applications. It is important to know what type the transistor is because there is a difference in the base emitter forward bias voltage drop. For germanium it is around 0.2 - 0.3 volts and for silicon it is around 0.6 volts. The circuit will be designed around a particular voltage drop.
2.***Polarity:*** It is absolutely imperative to find out whether the transistor is either NPN or PNP variety. Install the incorrect type and it experience the inverse of all the voltages it would expect and is likely to be destroyed.
3.***General application:*** Although it is not always necessary to exactly match the intended purpose for the transistor, a variety of areas of its performance will be tailored to its intended applications. Possible application types may include: switching, analogue, low power, RF amplifier, low noise, etc. Put in the correct type and it may not perform well. For example a low power general-purpose transistor is unlikely to work well in a switching application even if it has a high ft or frequency limit.
4.***Package and pin-out:*** Transistors have many packages. It is often necessary to match the replacement transistor package as closely as possible to enable the transistor to physically fit. Also the package may give an indication of other parameters.
5.***Voltage breakdown:*** It is necessary to make sure that the transistor is able to withstand the voltages it is likely to see. Transistor parameters such as Vceo, etc need to be checked.
6.***Current gain:*** , The current gain parameter of a transistor normally has a very wide spread. This is normally quoted as B or hfe. Although they are slightly different, for all circuit equivalences of this nature these transistor parameters are the same. Choosing a replacement transistor with approximately the same current gain is necessary. Normally it is not a problem to choose a replacement transistor with a higher gain. Often a lower current gain may be acceptable.
7.***Frequency limit:*** The upper frequency limit for a transistor is normally quoted as its "ft". It is normally important to ensure that the transistor can meet any frequency limits (but be aware the ft value is quoted for common emitter mode usually; if you run a device in common base you can get far higher frequency operation).
8.***Power dissipation:*** It is necessary to ensure that the replacement transistor can dissipate sufficient power. Often the package type is a good indication of this.

These are the main parameters that are of importance in most applications, but be on the look out for any other transistor parameters that may need to be included in the selection of the replacement transistor."

By this I'm assuming he means you should take into account the stored charges in the base region, or the gate / source, and switching speeds, and the like. Usually the common *mode d'emploi* of a device tells you what and where it fits comfortably: a 2N3055 won't be a happy chappy in a 2m linear amplifier!

Antenna Topics

Some Myths dispelled...

I have had emails about various antennas for both transmitting and receiving, and would like to add my two-pennyworth: here are a few simple truths about these oft misunderstood RF devices.

(1) **Any** length of wire, carrying RF amps along it, **in phase** with RF volts (to ground) upon it, will radiate RF. If you can get - by adding either inductance or capacitance - a resonant circuit, then the amps, in phase with the volts, will make the far-reaching electromagnetic radiation we care so much about.

(2) The higher and longer the wire carrying the in phase RF amps and volts the further the radiation will be transmitted; and a good radio "earth" (or counterpoise) is just as important as a good antenna.

(3) No antenna offers power "gain". A piece of wire **cannot** create power; nor can it magically boost a signal over and above any other bit of wire, UNLESS the wire is specially shaped or cut (as per Yagi array or ⅝ λ). "Gain" is a comparison with a ¼ λ antenna over a **perfect** ground. You can focus the direction of the radiation, but... what you gain in one direction, you lose in another.

(4) A RECEIVING antenna picks up electromagnetic radiation from any source: a mile long wire will pick up vast amounts of radiation - most of which will be atmospherics, interference, cosmic noise, man-made noise; the tiny bit you want will be buried in the cacophony. A short (i.e. << ¼ λ) antenna, carefully placed outdoors to avoid noise (from any source), will be effective for RECEIVING; as indeed will a short ACTIVE antenna with some selectivity (LW / MW broadcast rejection is a good idea) - providing it doesn't overload the receiver's RF amplifier / mixer.

Catenary wires and such

Supporting antenna wires so they don't break in malevolent weather is simple (even **very** thin wires) if you use a catenary support made of rot and UV proof 50lbs. breaking strain fishing line ("monofil") to support the antenna wire (in the past I've used lacing cord for this job successfully). Tape the radiating wire to the monofil every ½ metre or so, and suspend using only the monofil - tension it with a pulley to a weight (bricks with holes in are ideal, as are plastic buckets filled with rocks, with drain holes) noting you don't need insulators - the monofil does that job for you invisibly for free. Note that you'll need special knots to tie monofil loops - illustrations are on the web, see https://www.saltstrong.com/articles/best-loop-knot-for-fluorocarbon-leader/

Never fix antenna wires rigidly between two belays: using a weight and a pulley allows that bit of movement and the antenna will survive far longer.

You might try electric fence "wire" for a high impedance ½ λ antennas - it has stainless steel metal conductors woven into the nylon support cord - check your local farm supplier or the ubiquitous online Auction source. For ¼ λ low impedance antennas, copper conductors are mandatory at powers over a couple of watts.

Note too, for dipole lovers, ½"or ¾" plastic hose barbed TEE pieces (from fancy fish suppliers, garden centres, and the like), filled after assembly with silicone bath sealer, make perfect weatherproof dipole centre pieces. Silicone sealer is a wonderful adhesive - especially if a knot or two is tied in the dipole wires (and catenary) to “key” into the silicone that’s sealing the ends of the TEE piece. The feeder can’t be knotted, of course - so bung on a cable tie or two and silicone them in. The TEE pieces are remarkably strong, and can easily support a Balun if you like to use one.

Weatherproof, with low visibility thin wires on a catenary to take the strain, this antenna will deliver the goods for years with little or no attention.

Moxon...

My “go to” antenna reference is “HF Antennas for all locations” by Les Moxon, G6XN: yes, he of the “loop” fame and the calculators found on the web for Moxon “loops” (not quite loops... they are driven element and reflector) for any frequency. His book has antennas for - literally - ALL locations, described in his wonderfully simple logic, reasoning and construction notes.

I’ve seen antennas described in various texts, magazines, all of which perform wonderfully, amazingly, incredibly well - my emphasis on “incredibly”. By all means try one of these wonder antennas, but keep to mind that any antenna, even a simple dipole, if mounted less than ½ λ above ground, will have little relation to the “theoretical” radiation diagrams so often quoted. Consider an 80m band dipole, cut for (say) the CW section: it will be nigh on 40m long; and, to concur with the radiation diagrams, must be at least the same height! That’s a minimum, too - so don’t be too fussy about your dipole’s alignment. It’s more likely to affected by next door’s wet washing strung out than anything else.

The other thing to keep in mind is that no two locations are identical. That “Ion-o-Blaster” design might work fine for Fred in his back yard - but a Penny to a Pound your adjacent trees, bushes, neighbour’s clothes posts, metal guttering, wire fences and a million other influences will conspire to kick your clone of the “Ion-o-Blaster” in the can. Don’t be too discouraged; try re-arranging the elements, shift things around, try a fold or two: you might just get a “sweet spot”.

A final note: any antenna, advertised as a perfect 1 : 1 SWR, 160m to 6m, rated 1 kW, won’t radiate enough for anything but very local contacts: because it’s a non-inductive 1kW 50 ohm resistor, the only electrical component that can meet the above specification. No such thing as a free dinner!

An “All Band” Vertical

The concept of a vertical antenna is very simple: it’s a conducting “pole” sticking more or less vertically upwards, above a “ground plane”, made of many wires. So simple in fact it’s probably the most tempting for somebody with very little space; it can be constructed very cheaply and sturdily with readily available copper water pipes; the ground plane wires don’t have to be straight or neatly laid out, just lots of them, all around the antenna, to keep ground losses to a minimum; it needs a matching unit at the base to resonate the antenna and impedance transform to match the feeder and transmitter output.

That’s the theory! In practice, a lot of compromises have to be made. If you want to run every HF band, the antenna *can* be tuned to any and every frequency - providing you accept that on 160m, 80m and 60m, the bandwidth of the antenna will be tight - for a very short vertical the tuning might be just fractions of an inch on the antenna; which indicates a very tight bandwidth - maybe 10kHz or less. As the frequency rises, on the higher bands, the antenna might approach a self-resonant length, ¼ λ; if so you don't need any extra reactance to achieve resonance - IF the ground plane is effective at that frequency and self resonant.

There's the rub: the ground plane has to create an image of the antenna to create the Marconi dipole, and to do that the ground plane must be ¼ λ radials too, for every frequency you want to run: and formed in plenty of wires spread around the base of the vertical radiator. There are alternatives: but it all depends on the space you have and your preferences.

As the vertical antenna element approaches ¼ λ in (electrical) length, the top becomes a high voltage point - courtesy Nikola Tesla - and one way to stop corona discharges is to attach some capacitance to the top, a "corona ring". It's a form of capacitive "top loading" the antenna which is usually beneficial as it broadens the bandwidth and makes the antenna easier to bring into resonance.

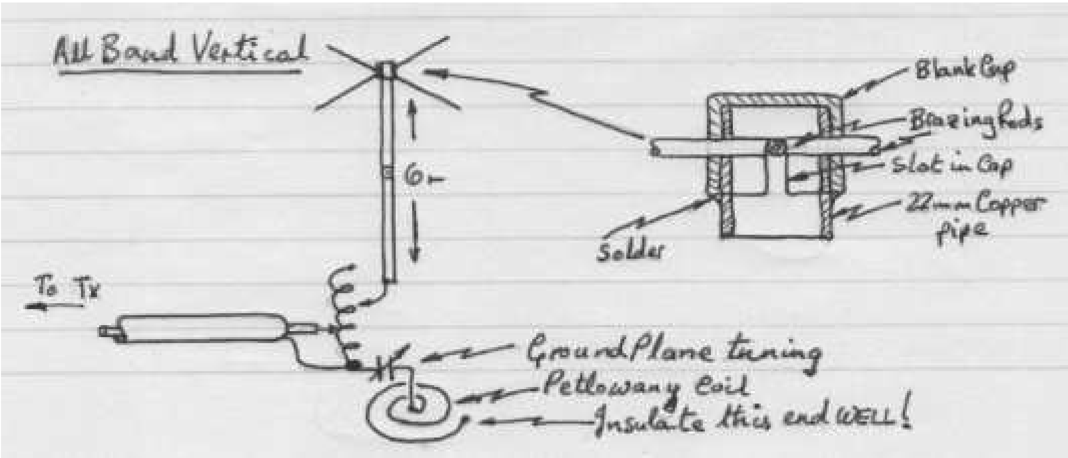
There are ways of helping the ground plane too: you can resonate the ground plane to simulate a ¼ λ set of wires for any frequency - you use series tuning to resonate the entire ground plane at the frequency you want to run, and then you don't have to bother cutting and trimming ground plane wires, laying them out neatly as "radials", burying them or suspending them slightly above ground. If you visit an LF or MW transmitter site, you'll not see the ground plane. It's usually buried copper mesh of large proportions (at LF) or roughly ¼ λ radials (at MW) - almost certainly using resonant ground planes to minimise losses with minimal cost of installation. It's far cheaper to replace a ground plane tuner than rip up acres of ground to repair a ground plane installation!

You may have heard of the "Pelowany" spiral coil antennas: a direct descendant from the Tesla "Magnifier" conical coils, the Petlowany has proved useful as a ground plane: see https://www.n0lx.com/petlowany_ground.html, Jake, N0LX's experiments with a helical vertical radiator above a miniscule Petlowany ground plane; and https://circuitsalad.com/2015/09/13/vertical-with-tuned-spiral-counterpoise-updates/, Ray's superb work.

Whilst Petlowany ground planes contain significant lengths of wire, they appear untuned: in Les Moxon's (G6XN), "HF Antennas for all locations" he expressly promotes tuned ground planes. But... as Les comments, you have to take a holistic view. The radiating element, be it a vertical pole or wound helix, is part of and connected to loading coils, capacitors, *and the ground plane*. They are all part of a complex network of inductance, capacitance and resistance and must be considered thus. I note the use of an auto-tuner in Jake's experiments - this will find a match by electrically resonating the whole network with a conjugate match - it has no "knowledge" of the separate items making up the antenna and ground plane. Therefore, even though he achieved good results, his results probably could be better by series tuning the Petlowany coil (which I personally would make larger, as per Ray's design) then resonating the antenna section, as Les Moxon recommends. This ensures the ground plane and the vertical radiator element are both optimally tuned; not the "compromise" match the autotuner found.

A "vertical" design: a 6m copper tube (2 x 3m lengths of 22mm diameter, with a solder coupling centre joint), forms the vertical radiator (from the design by Bill Orr, (W6SAI) & Stuart Cowan, W2LX "Vertical Antennas", pp 158) add a capacitance hat of 2 x 3mm diameter brazing rods in a “cross” through drilled holes at the top of the radiator, where I solder on a slotted blanking cap to secure the brazing rods in place; set this up above a Petlowany ground plane using a glass bottle as the base insulator and polypropylene cord guys, secured just above the centre joint with a rustless hose clip. Resonate the ground plane to the desired frequency, by adding a series capacitor and using a temporary shorting wire to the far end of the Petlowany coil - you have to make a loop to couple up the GDO! Now the ground plane is tuned, remove the temporary shorting wire.

Set up the antenna as the diagram below, and adjust the radiator tap to achieve lowest SWR on your transmitter (or inline SWR meter) whilst running a sniff of RF - just enough for reliable indication



of SWR. Adjust the feedpoint for lowest SWR; then re-adjust the radiator tap, as the tap points are somewhat interactive, so try a few tap placements either side to be sure you’re bang on the button.

A 6m long radiator will run as high as 15m band; try a 3m radiator if you want to go to 12m and 10m. Note too, that this scheme will easily adapt for other “random” length antennas - a short (i.e. less than ¼ λ) inverted “L”, for instance, will perform well set up like this.

A thought about Smith Charts

These charts are daunting to most amateurs; but professionals use them often - especially as the frequency rises, and long feeders of differing Zo (the *characteristic impedance* of the line) are in the system. But do amateurs really *need* them?

On this moot point I can only say this: the whole object of the amateur’s job is to get RF volts in phase with RF amps in the antenna, in as large a quantity as he / she can manage. At that point - resonance - the emitted electromagnetic waves are at a maximum. You can tell when maximum radiation occurs with a simple field strength meter (diode and meter being the simplest, as Nyle Steiner, K7NS, advocates in http://www.sparkbangbuzz.com/easy-ten/easy-ten.htm) placed anywhere convenient to view as you adjust the reactance you’re adding to achieve resonance.

The last three words of the last paragraph are the crux, the absolute truth: “to achieve resonance”. **Any** antenna (unless it’s a close multiple of ¼ λ) will present to the transmitter a reactance (capacitance **or** inductance) combined with series resistance representing the loss in the antenna. All you need to establish resonance is add “C” or “L”, and, most importantly, since amps and volts can’t read a Smith Chart, it’s up to you to adjust the reactance at the antenna to get the maximum reading on your field strength meter. This assumes the transmitter is connected directly to the antenna, a situation not normally possible in most environments. The transmitter’s power has to be conveyed to the antenna by a feeder of some kind; the most popular feeder is a coax cable of some sort, as it's convenient, has plugs and sockets designed specifically for it and is very efficient. But... and it's a big "but" - many other methods exist to do the feeder job, and whilst maybe not as convenient, are vastly cheaper and much, much, more efficient. Specific examples you probably use every day include the "ethernet" twisted pair cables run 100Mb/sec data without skew or corruption over hundreds of metres in Internet broadband telephone exchanges, or the heavy "parallel line" feeders at Royal Navy shore transmitters feeding the "T" antennas for worldwide LF communications. A simple twisted pair can be nearly as low-loss as coax, if you keep it well away from extraneous conductors as best you can - and it's dirt cheap and easy to make.

Once *antenna* resonance is achieved, the feeder connection can be made whilst keeping in mind the feeder must be *fed by* and *terminated by* it's characteristic impedance Zo for maximum power transfer. Thus when you connect the transmitter to the distant antenna with a coax feeder, because the feeder is terminated by a purely resistive resonant load that is equal to Zo of the feeder, what comes out the far end of the feeder is exactly what the transmitter pushed in. The transmitter has no idea anything but the antenna is connected to it's output terminals - the feeder is described as "flat" as it's Zo equals exactly the antenna's load and the transmitter's output resistance.

You might use a transformer (sometimes called a "balun", or "Guanella" or some such) at both ends of the feeder to achieve this state of RF Nirvana. Transformers shift impedances up and down very efficiently: they can be conventional transformers using separate primary and secondary windings, or "*autotransformers*" where a single winding is tapped at appropriate points to achieve this near miraculous state of affairs. Typical "balun" transformers rely on very tightly coupled windings (they are miniature "twisted pair" transmission lines in themselves, so we are led to believe) on toroid cores to achieve this; if you look up a typical collector / drain output transformer of a simple QRP transmitter you'll see that it's transforming a 12 ohm collector (drain) load into 48 ohms (2 : 1 turns ratio) - to achieve a very near match to 50 ohm feeder coax.

Now here's the crunch: in a typical amateur antenna installation in the UK, where we count ourselves very lucky if we live in a shoe box on a square yard of ground, the length of the antenna radiator element is way short of ¼ λ on any HF band so you're inescapably going to need to add inductance to achieve resonance. Ain't no way to beat that; that's the way it is, like it or not.

A simple impedance Bridge to measure antenna parameters

From: "Characterizing the Antenna", Max M. Carter

http://www.maxmcarter.com/spark/marconi.html

(With many thanks for Max's simple and clear descriptions; *my notes in italics*)

This method uses a (*Radio frequency, NOT Audio frequency*) signal generator, oscilloscope and impedance bridge. A spectrum analyser, frequency-selective voltmeter or S-meter equipped receiver could be used in place of the oscilloscope [*or the wonderfully simple zero offset diode RF detector of Chas. Wenzel's: cheap and portable, which can easily be built into the bridge enclosure or separate box as you wish. Note that the potentiometers mentioned should be carbon track types: wire wound or spiral types are inductive, and therefore useless in this role.]*

Max Carter's excellent page at http://www.maxmcarter.com/spark/ant_impedance.html *gives the calculations for the complex impedance of any antenna (or any other network, filter, what-have-you), but we as constructors need to know just two things: the reactance,* X_c *or* X_L*, to resonate an antenna and the antenna's resistive component - which should match the transmitter's output impedance and the transmission line that feeds it, typically 50 ohms.*

Measurement should be made right at the antenna connection; NOT at the end of the transmission line that feeds it; and any feeders should be disconnected or they will disrupt the measurement. Since your presence at the antenna will inevitably add some reactance you'll need to remove yourself (and thus the RF indicator instrument) to a remote point - some audio screened twin core cable connected to the "scope" socket can be used to get the detector well away from the antenna base or feedpoint. Bit of a bind, I know: but any antenna measurement will be disturbed by your presence, no matter what instrument you use: so skedaddle to check the detector indication!

"The battery and resistors generate a negative voltage near 100mV which is a good value for the 1N5711. Other diode types may need a different offset correction and the 82k value may be varied to give a correct reading when measuring a several volt RF signal. A 200k potentiometer may be substituted for the 82k resistor if an adjustable offset is desired - - - -"

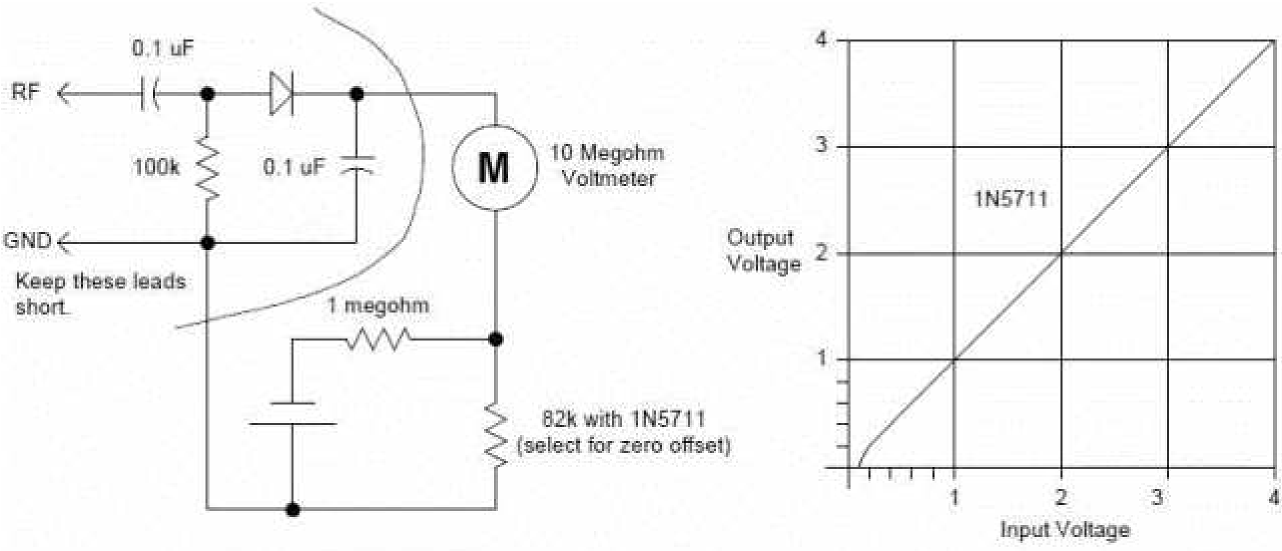


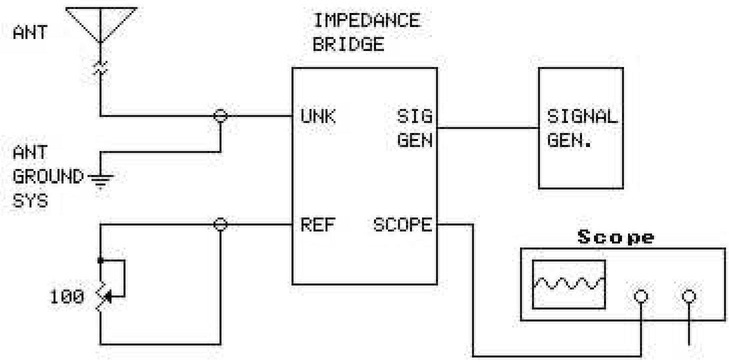
Figure 2: Series detector with offset correction. The 82k resistor may be varied for best results with different diode types.

Of course, if you want to make measurements and log details for design purposes, the Max Carter's article is nothing short of superb - see http://www.maxmcarter.com/spark/ant_impedance.html.

You need a source of RF to drive the measurement: your transmitter, feeding a 50 ohm attenuator is a good method to do this. A TEE or PI attenuator can be used: you'll only need a watt or so of RF - if that - but it's important your transmitter sees a purely resistive 50 ohm load so an attenuator is a useful piece of test gear to build. There are hundreds of online calculators for attenuators, I use [*https://www.everythingrf.com/rf-calculators/attenuator-calculator*](https://www.everythingrf.com/rf-calculators/attenuator-calculator) *as it's simple and accurate. A TEE attenuator for 20 dB is useful - set your transmitter to 5 watts out and you'll get 0.5 watts out with near-perfect match. The TEE attenuator can be made with two 39 ohm carbon composition* *resistors in series from input to output, and a 10 ohm carbon composition resistor to ground from the junction of the two 39 ohms. To be sure the 39 ohm resistors can handle the power dissipation you'll need 10 off 390 ohm (or the rarer 410 ohm will be just as good) 0.5 watt rated resistors in parallel for each series resistor and 10 off 100 ohm 0.5 watt rated resistors in parallel for the centre tap to ground resistor. This attenuator output drives the "Signal Gen." input of the bridge.*

First pass - find the resistive (real) component.

Connect the test equipment to the antenna as shown below. Connect the UNK test cable ground to the antenna grounding system (ground radials) or the counterpoise in the case of a balanced antenna (dipole). If the antenna includes a feedline, connect the test equipment to the feedline at the feedpoint (the near end) where the transmitter would normally be connected. (IMPORTANT: the signal generator, oscilloscope and REF are grounded through the test cable shields and case of the impedance bridge.)



•Adjust the signal generator [transmitter power output] to the operating frequency to 5 watts.
•Adjust the reference potentiometer for a dip. The dip will be sharp and narrow. You may have to vary the signal generator frequency to find it. (A nearby AM broadcast station can make this test difficult. See "Optional Bandstop Filter" below for a fix.) If a dip can't be found, replace the 100-ohm potentiometer with a 1000-ohm potentiometer and try again. Repeat as necessary to obtain the deepest dip. Do not disturb the potentiometer setting after the dip has been found.
•If you obtain *total* nulling, with no residual signal present (ie, flatline), then the antenna impedance is non-reactive - purely resistive - at that frequency. Measure the resistance of the potentiometer to obtain the impedance.

Z = R
where:

•Z is the antenna impedance
R is the measured resistance of the potentiometer in ohms.

•If you are not able to obtain a total null, leave the potentiometer undisturbed and proceed to the second pass.

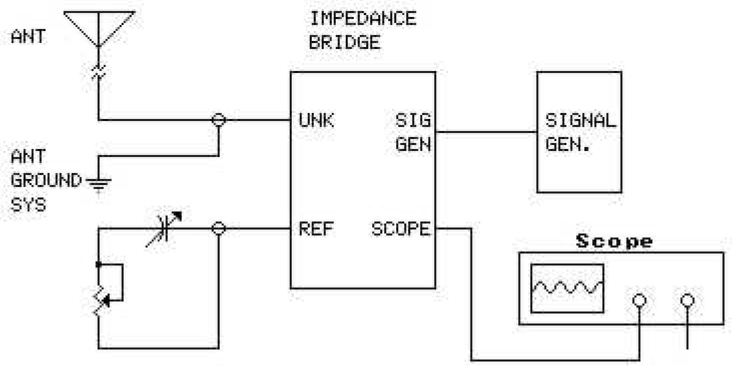
"Flatline" refers to a complete nulling of the test signal's *fundamental* frequency. Residual harmonic content from the signal generator may be evident in the scope trace after nulling, depending on how clean the generator signal is. Also, interfering signals from local transmitters may be present.

If the antenna is near resonance, i.e. physical length near some multiple of ¼ wavelength, it may not be worth your time to determine the antenna's residual reactance. In that case vary the signal generator [transmitter] frequency to find the actual resonant frequency (flatline on the scope). You can skip the second and third passes below.

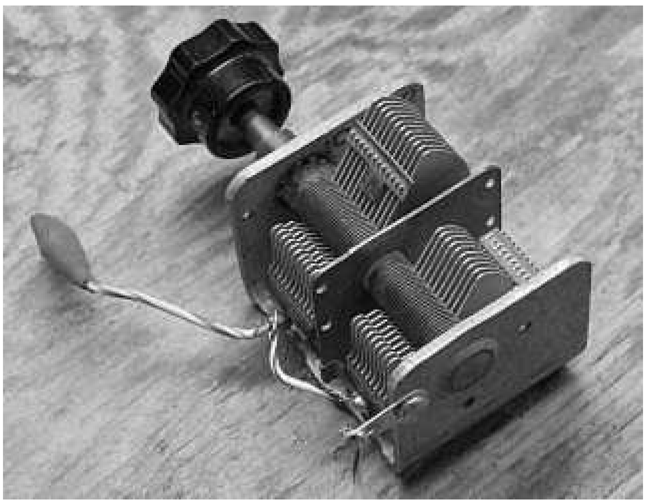
Second Pass - find the reactive component (capacitive)

Antennas **shorter** than ¼ wavelength have capacitive reactance, and need a loading coil to resonate.

Connect a variable capacitor (~500 pF)* in series with the potentiometer, as shown below (test lead grounds remain connected):



*Tuning capacitor from an old radio (sections wired in parallel) or a Polyvaricon.



•Adjust the variable capacitor to obtain the deepest possible null. You may have to slightly readjust the potentiometer.
•If you obtain a flatline/null, the antenna impedance includes a negative reactive component (capacitive). Measure the potentiometer to obtain the resistive component. Measure the test capacitor to obtain the capacitance; the reactive component is calculated as follows:
$X_L = 1/(2\pi FC)$ - [*this is the inductive reactance you need for resonance*]
where:

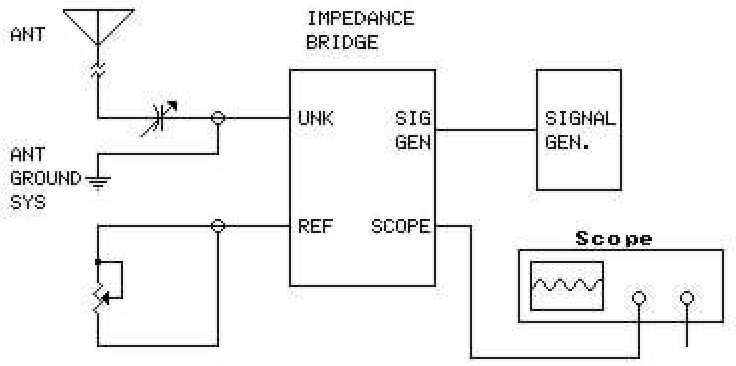
X_L is the inductive reactance in ohms, [$L= X_L / 2\pi F$ in Henries]
F is the operating frequency in Hz, and
C is the measured capacitance in farads.

If you are not able to obtain a total null, leave the potentiometer undisturbed and proceed to the third pass.

Third Pass - find the reactive component (inductive)

Antennas **longer** than ¼ wavelength are (usually) inductive.

Reconfigure the test setup with the test capacitor connected between the antenna and the UNK bridge port, as shown below (test lead grounds remain connected):



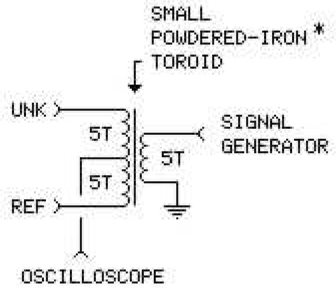
•Adjust the test capacitor to obtain the deepest null. You may have to slightly readjust the potentiometer.
•If you obtain a flatline, the antenna impedance is inductive. Measure the potentiometer to obtain the resistive component. Measure the test capacitor to obtain the capacitance [*this is the pF's you add to resonate the antenna*].

You will find this bridge useful for finding the resonant frequency and/or impedance of:

- Tuned circuits
- RF transformers
- LCR networks
- Input/output ports of "black boxes" (transmitters, receivers, filters, tuners, etc.)
- Transmission lines

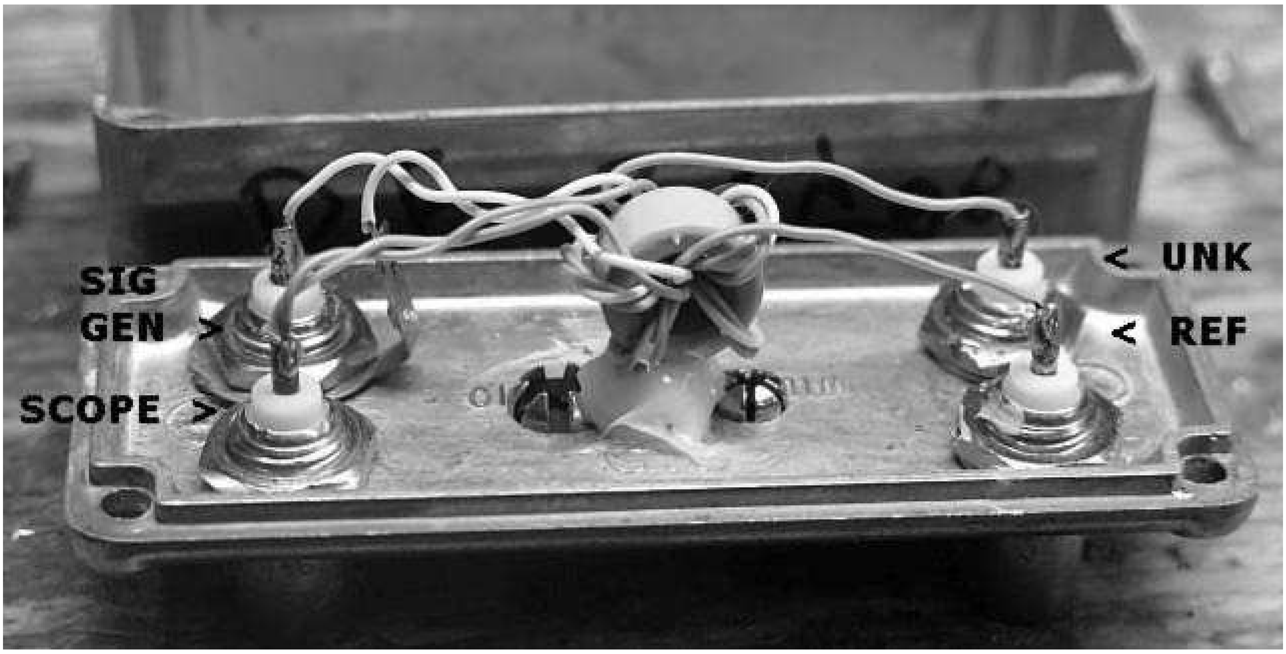
Building an Impedance Bridge

The Bridge Circuit



The ground connections for REF (reference), UNK (unknown) and oscilloscope are not shown. The circuit's aluminium enclosure forms a common connection point for all grounds.

Bridge Inside



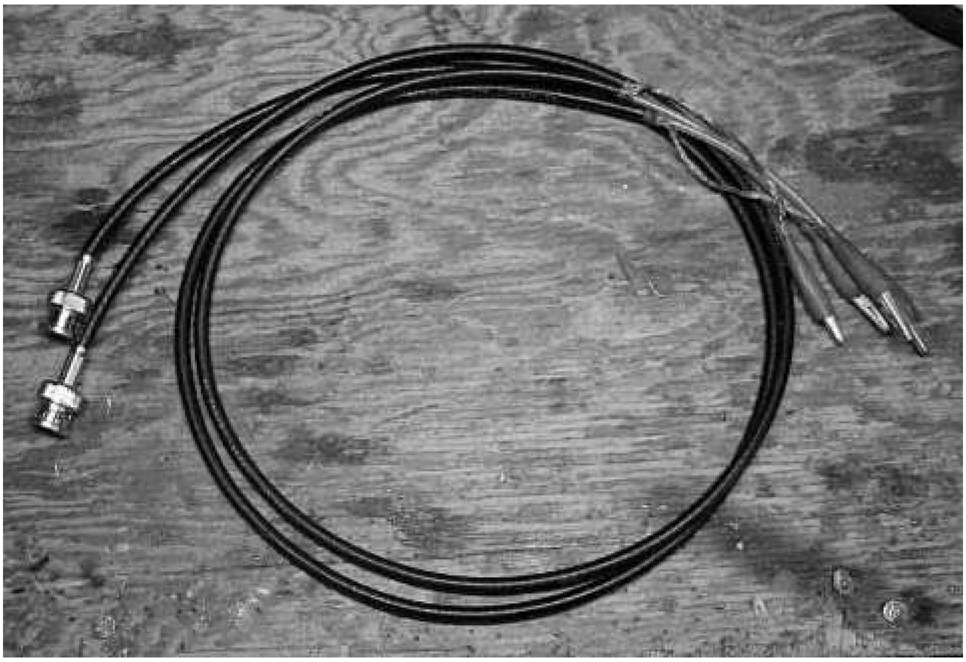
The windings are made by first twisting the three wires together into a cable, then winding 5 turns of the 3-wire cable on the core. White = GEN, brown = REF, green = UNK, brown/green (twisted) = SCOPE. [This method of winding is called "trifilar".]

*The core is green/blue, which is iron powder material 52. I don't think the particular core material makes much difference in this application, but it probably should be a powered iron mix rather than a ferrite. If I'm reading the specifications correctly, the 52 mix should be useful up to 100 MHz. I found this core in my junk, as I did the aluminium box, which had connectors pre-installed by someone. [Almost all components for this project came from the same source - junk.] *At G6NGR I used a 1" o/d, ½" I/d 'ring' out of an old AT PC power supply; works a treat to 50MHz.*

Bridge External

Equipment grounds are interconnected via the common case.

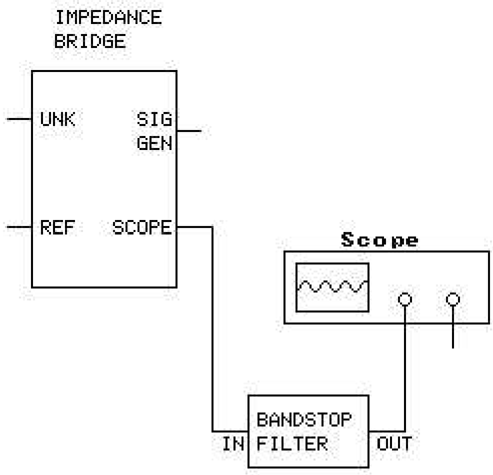
Test Leads



The test leads for REF and UNK, constructed with RG-58 coax, are made the *same length (IMPORTANT!)*. This cancels cable reactance. Leads for GEN and SCOPE, made with coax cable terminated at both ends with BNC connectors, can be any length.

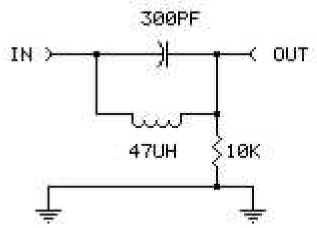
Optional Notch (Bandstop) Filter

If your antenna is within a couple of miles of an AM broadcast transmitter, signal pickup from the transmitter can obscure the test signal on the scope, making it difficult to see a null. Including a notch filter in the test setup, tuned to the broadcast transmitter's frequency, will make life easier.



1340 kHz Notch Filter Example

Circuit assumes 1 megohm scope input impedance (*or your RF detector circuit*).



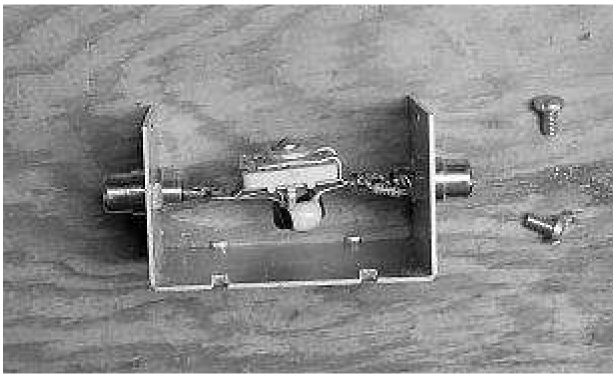
Design calculations:

$$L \cong 400/(2\pi F)$$
$$C \cong 1/(2\pi 400F)$$

- F is the desired notch frequency in Hz.
- For the lowest and deepest notch - ie, the highest circuit Q - use the lowest resistance inductor available.
- Use a variable capacitor or inductor to allow fine adjustment to a specific frequency.

As-built 1340 kHz Bandstop Filter

Inside **Outside**



The capacitor in this filter is adjustable.

Rotators and Stepper motors

Stepper motors are often used for positional rotators, they look like simple brushless motors driven by pulses applied to stator coils set around a toothed rotor. The commonest types are 360 or 720 steps per revolution - each step is therefore 1 or ½ a degree of angle. They can rotate through a full 360 degrees, no end stops; it's common to have an opto-coupler or some other "zero" or "home" flag system to set the step counter to zero - the control logic simply releases N steps, and the stepper motor rotates exactly that number of steps, so precision angular movement is possible.

This is why stepper motors are ideal for antenna rotators: they have no brushes or other serviceable parts, and if kept clean and dry (not easy at the top of a mast...) will run forever - if the drive electronics are intelligent enough to protect against over current. Another feature of a stepper is the "holding" ability: once the drive steps have been applied, a small holding current will effectively lock the rotor in the final position - no need for a brake mechanism. Some modern steppers don't need the holding current: very clever pole design and tiny cerium magnets embedded in the rotor ensure that once the step count has finished, the magnetics hold the rotor rock solid. That's why they are a good choice for an antenna rotator.

Stepper drives are available from tiny fractions of a milliwatt (for tiny clock or instrument movements) to 50kW or more for hefty industrial purposes: I met these powerful beasts in paper and plastics manufacturing, easily capable of turning 2000kg reels of paper or plastic webs, accelerating up to speed without slipping a step in seconds, more than equalling a DC drive or AC inverter drive.

To reverse a stepper drive, you merely invert the polarity of one of the drive phases (they commonly use 2 phase drive, at 90° phase) and the drive reverses. Or - simply rotate in one direction a full 360° less the angle required to position.

Drawbacks: not many, other than the usual mechanical issues with motors, i.e. bearings, damp, corrosion, overloading - if you don't consider price. They are expensive! Not just the motors, but the drive electronics too. No doubt modern micro-controllers will have stepper drive subroutines in the libraries available; and modern power mosfets are ideal for driving the highly inductive stator coils with sharp edged pulses (and creating lots of lovely RF interference as well!).

Troubles with stepper motors are few. In my experience, it's almost always the control gear that's the culprit, but one in a million the motor might suffer mechanical or magnet fracture. Check first the drive electronics power supply: this does all the grunt, and is usually where manufacturers skimp. Second, look for the "zero" position sensor - if the drive electronics can't establish zero count, it will get confused. Usually it's a quick clean of an opto-coupler or adjusting a reed or microswitch. Note too that not all stepper systems use a zero sense - if overloaded the motor slips steps, the step count doesn't turn the exact angle - or if extreme wind has forced the stepper off it's lock position. Otherwise, these little darlings run for years trouble free.

Wanted... Wanted... Wanted...

A section for any reader who wants any radio related items or information, swaps, exchanges, W.H.Y.? Please forward to me at equieng@gmail.com and I'll include your request in the next Hot Iron; replies will be forwarded to you if you provide your email address, please.

ZN424 Gated Op-Amp Apps Note / booklet

This was a Ferranti device, an op-amp that had a gating input that switched the output into tri-state high impedance, so you could connect them to a common analogue bus and switch them with logic.

I had a Ferranti Application Note - a small booklet - with many circuits using the ZN424. One was a superb servo amplifier that ran 50v-0-50v rails with 2N3055's as output drivers, delivering a genuine and reliable 150 watts. The ZN424 was merely an input conditioning amplifier; I built many of the power amplifiers for diverse functions over the years, and the design proved superb.

If any reader has scans, copies or PDF's of the ZN424 applications booklet page showing the 150 watt servo amplifier please forward me a copy: I can't find for love nor money my Apps Note - and my memory isn't as good as it used to be!

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Simple is as simple does

I'm looking to compile a booklet for e-publication of simple yet effective and efficient radio amateur circuits - the type of thing you've seen in this edition of Hot Iron - for first time constructors and more experienced radio amateurs wishing to regain the simplicity and fun of building and operating simple equipment. Receivers, transmitters, test gear, power supplies... if it's simple, easy to build, non-critical and, most of all, of low cost and easily available parts, then please send it to me at: equieng@gmail.com and I'll start compiling the pages. You will, of course, be credited in full for your input; and the booklet will be free of charge when completed, for all who appreciate amateur radio to see and enjoy.

Data and Information

This information is for guidance only – you MUST comply with your local Electrical Safety Regulations! I have included information about AC power
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systems and conventions, as equipment can be bought from overseas nowadays and it's important to know how to connect it safely to our "home" supplies. Suffice to say, if there's ANY doubt - - - GET PROFESSIONAL, COMPETENT HELP BEFORE YOU CONNECT TO ANY ELECTRICAL SUPPLY!

The Unobtanium & Obsoletite files...

A list of those solid state parts made from Unobtainium and Obsoletite - please let me know your alternatives! **Note:** when Unobtainium and Obsoletite parts are overheated, over-volted, or over-amped, the rare elements used inside the plastic / metal packaging react violently, emitting "magic smoke" which renders any solid state device instantly useless. In a Yocto-second, no less.

Useful cross-reference web pages:

https://english.electronica-pt.com/components-cross-reference?ref=

https://archive.org/details/TowersInternationalTransistorSelector

For Solid State fans...

These are more or less equal equivalents, use in both directions i.e. BFY90 = 2N5178. Any more that have been proven in actual circuits, please let me know: the supplies of Unobtanium and Obsoletite is getting harder and harder to find, any help is always welcome.

2N5179	BFY90	½ watt VHF NPN
2N3866	BFY90	½ watt VHF NPN
2N4427	BFR91	1 watt VHF / UHF NPN
ZTX300	BCY70	0.3 watt HF NPN
OA91	1N60/61	Ge signal diode, 50v, 50 mA

For Valve / Tube fans...

("Hooray for Hollow State" to the tune of "Hooray for Hollywood")

https://en.wikipedia.org/wiki/List_of_Mullard%E2%80%93Philips_vacuum_tubes

(Well, you *did* ask...)

http://www.angelfire.com/electronic/funwithtubes/tube_select_guide.html

(THE 'Magnum Opus' of bottle lists)

https://frank.pocnet.net/sheets5.html

(Is the broadest range of data sheets I've ever used, very helpful in finding usable alternatives)

Some not very obvious alternatives:

ECL 82 is an audio triode / pentode, much beloved in vintage radios, economy audio amps and the like. However... if you have 12v. ac heater volts available (or higher) then the bottles following can be useful with a dropper resistor to tweak the heater volts down (and get long heater life too). Don't forget that half wave rectified 12v. r.m.s. = 6v. r.m.s.; near enough for 6.3v. heaters; or strap two 6.3v. bottles in series if their heater currents are near equal, to run on 12v. AC - or a car battery.

ECL82 = LCL82 (10.7v heaters) = 11BM8 (10.7v heaters) or PCL82(16v) / UCL82(50v) / XCL 82(8.2v). There are dozens of equivalent or similar electrode structures but with different heaters. For instance: PCL82 = 16A8 = 30PL12 = 16TP12 = 16TP6 = 16Ф3П Different heater volts = 8B8 (8.3v ac)

Check the web page: https://www.radiomuseum.org/dsp_searchtubes.cfm where you can search for many different tubes, characteristics and equivalents. For instance, web searching for an ECL84 equivalent - typically LCL84 - yields dozens of hits. If you want an ECL84, which are as rare as hen's teeth nowadays because Audiophools buy them at nosebleed prices, try the different heater volts equivalents and alter the heater supply appropriately.

Keep to mind that 5v or 6.3 v AC heater supplies, if doubled or trebled, will yield higher heater volts if you don't want to modify an existing or historically important piece of kit - but take great care not over volt filaments / heaters! A true RMS multimeter is handy for this job.

HF & VHF Output Types:

Search as I might, I can't find a cheap alternative to a 4CX250B (or the bases)! My apologies... I'm still searching!

6146B = 8298A = S2001; or nearly so, YL1370 = 6146 = 6146A = 6146W

807 = VT-100 = QE06/50 = Г-807 = GL807 = RK-807 = A4051I = ZA3496 = CV124 = 5S1 = 4Y25N = VT199_GPO = 5B/250A = CNU-807; nearly so = 10E/11441 ; 4Y25 ; ATS25 ; ATS25A ; ATS25N ; CV1364 ; CV1374 ; FU-7 ; HY61 ; QV05-25 ; RK39 ; VT60 ; VT60A

Audio valves; useful for low band RF:

From an article by Robert H. Levi

"My Favorite Tubes"
by Robert H. Levi

Small Signal Tubes:

12AX7

Substitutes: ECC83, 12AX7A, 12AX7WA, 7025, 5761, 6057, 6681, 7494, 7729, 7025#, ECC83#, 6L13, 12DF7, 12DT7, 5751, 7025A, B339, B759, CV4004, E83CC, ECC803, M8137

The GE 5751 is a bargain basement musical giant! The Mullard CV4004 is still King of the Hill.

12AU7

Substitutes: 12AU7A, ECC82, 5814, 5814A, 5814WA, 6189, 6680, CV4003, E82CC, ECC186, ECC802, ECC802S, M8136, 7025#, ECC83#, B749, 6067, 6670, 7730, B329, 5963, 7316, 7489

I discovered the 5814A from RCA is a bargain and the best sounding 12AU7 made in the USA!

The Mullard CV4003 is still fairly cheap, plentiful, and magnificent.

12AT7

Substitutes: 6201,6679, ECC81, 12AT7WA, 12AT7WB, 6060, 6201, 6671, 6679, 7492, 7728, A2900, 8152, B309, B739, CV4024, E81CC, ECC801, ECC801S, M8162, QA2406, QB309

As good as the GE and RCA are, the Mullard CV4024 is not pricey and totally glorious.

6DJ8

Substitutes: ECC88, 6ES8#, 6ES8, ECC189, ECC189#, 6FW8, 6KN8, 6922, E88CC, CV2492

The bargain priced PCC88, the 7 volt version of this tube, works nicely in the vast majority of 6 volt applications. I use them in a cocktail with their 6 volt brethren all the time for top results. You can still actually afford the Telefunken, Dutch Amperex, and Siemens versions of the PCC88!"

Rectifier Tube:

5AR4

Substitutes: GZ34, 52KU, 53KU, 54KU,GZ30, GZ32, GZ33, GZ37, R52, U54, U77, 5R4GYS (from Philips) The Mullard GZ34 is King of the Hill. Buy it used, but checked, if necessary. The Philips 5R4GYS is a recent find by Upscale Audio in Upland. A killer tube, but huge and requires lots of space (bigger than a KT88.)

Other Dual Triode Tubes:

6SN7

Substitutions: 6SN7A, 6SN7GT, 6SN7GTA, 6SN7GTB, 6SN7W, 6SN7WGT, 65W7, 5692, B65, ECC33, 6SN7L, 13D2, B65, 6SN7GTY, 6SN7WGTA

The available brands of these tubes are highly variable musically and microphonically. The vintage GE and RCA are very fine if hand selected. The Electro Harmonix is very good, too.

6SL7

Substitutions: 5691, 6SL7W, 6SL7WGT, 6113, ECC35, 6SL7GT, 6SL7L

Same comment as 6SN7 type.

Output Tubes:

EL84

Substitutes: 6BQ5, 6P15, 6267, 7189, 7189A, 7320, E84L, EL84L, N709, Z729, 6BQ5WA, EL84M I have had little use for these. Am told the NOS Mullard prices are strong, but worth it.

EL34

Substitutes: 6CA7, 7D11, 12E13, KT77

Lots to choose from. Usually your manufacturer tuned the gear to a certain brand of these. Be mindful of that before you spend tons of money on vintage NOS versions that end up not sounding as good.

6550

Substitutes: 7D11, 12E13, 6550A, 7027A#, KT88, KT90 Type 2 or 3, KT99, KT100, KT120/KT150 (only if sufficient bias is present) Unless forbidden by your manufacturer, I would try some of the high powered goodies on the market to boost performance. The EH KT90 or the new KT120 may be astounding in your amp. At least try KT88s!

6L6

Substitutes: KT66, 5881, 6L6S, 6L6G, 6L6GA, 6L6GAY, 6L6WA, 6L6WGA, 6L6WGB, 6L6WGC, 6L6WGT, 6L6GB, 6L6GC, 6L6GT, 6L6GX, 6L6Y, 1622, 5932, 7581, 7581A, WT6, EL37

Same comment as EL34 type.

KT88

Substitutes: 6550, 6550A, KT90 Type 2 or 3, KT99, KT100, KT12O/KT150 (only if sufficient bias is present) Though your manufacturer may have settled on a certain brand of these, the hunt for cool NOS types may be sonically worthwhile, or try switching to EH KT90s or bigger for more impact. I would!

Wire Information...

As used in Test Gear Maintenance at a factory I worked at:
Green (or green & yellow stripe) - Earths, Chassis connection

Blue	A.C. power lines (N, single Φ, inside machinery)
Brown	A.C. power lines (L, single Φ, inside machinery)

Note: 3Φ supplies external to machinery or distribution systems may use some of these colours; **check, check and check again** what the wiring is!
NEVER, NEVER, assume a blue wire is a neutral; you may have an old 3Φ installation which ran colours as follows:

Red	Phase 1
Yellow	Phase 2
Blue	Phase 3
Black	Neutral

Valve Electrode wiring:

Gray	heaters or filaments
Red	DC power supply positives (numbered sleeves indicating voltage)
Black	returns, commons, NOT grounded
Orange	screen grids
Yellow	cathodes
Pink	control grids
White	anodes

Violet	AC / DC control signals (AGC, etc.)

From Kevin, VK3DAP / ZL2DAP seen on a web page recently, is another wiring code - last seen in a Savage 5kW audio amplifier driving a vibration table for semiconductor testing:

Valve Electrodes:

Anode	Blue
Cathode	Yellow
Control grid	Green
Screen Grid	Orange
Suppressor	Grey

DC Supplies:

Chassis / Ground	Black
Positive to Chassis	Red
Negative to Chassis	Violet

Miscellaneous Wiring (control signals & the like):
White or mauve

AC Supplies (modern UK &European):

Active or Phase	Brown
Neutral	Blue
Earth	Green/Yellow stripe

AWG Table

1 AWG is 289.3 thousandths of an inch
2 AWG is 257.6 thousandths of an inch
5 AWG is 181.9 thousandths of an inch
10 AWG is 101.9 thousandths of an inch
20 AWG is 32.0 thousandths of an inch
30 AWG is 10.0 thousandths of an inch
40 AWG is 3.1 thousandths of an inch

The table in ARRL handbook warns that the figures are approximate and may vary dependent on the manufacturing tolerances. If you don't have a chart handy, you don't really need a formula.
There's several handy tricks:
Solid wire diameters increases/decreases by a factor of 2 every 6 gauges,
" " " " " 3 every 10 gauges,
" " " " " 4 every 12 gauges,
" " " " " 5 every 14 gauges,
" " " " " 10 every 20 gauges,
" " " " " 100 every 40 gauges,

With these, you can get around a lot of different AWGs and they cross check against one another. Start with solid 50 AWG having a 1 mil diameter.
So, 30 AWG should have a diameter of ~ 10 mils.

36 AWG should have a diameter of ~ 5 mils.	Dead on.
24 AWG should have a diameter of ~ 20 mils.	Actually ~ 20.1

16 AWG should have a diameter of ~ 50 mils.	Actually ~ 50.8
10 AWG should have a diameter of ~ 100 mils.	Actually ~ 101.9

If you are more interested in current carrying ability than physical size, then also remember that a change of 3 AWG numbers equals a doubling or halving of the circular mills (the cross sectional area). Thus, if 10 AWG is safe for 30 amps, then 13 AWG (hard to find) is ok for 15 amps and 16 AWG is good for 7.5 amps.
The wire gauge is a logarithmic scale base on the cross sectional area of the wire. Each 3-gauge step in size corresponds to a doubling or halving of the cross sectional area. For example, going from 20 gauge to 17 gauge doubles the cross sectional area (which, by the way, halves the DC resistance).
So, one simple result of this is that if you take two strands the same gauge, it's the equivalent of a single wire that's 3 gauges lower. So two 20 gauge strands is equivalent to 1 17 gauge.

Wire Gauge Resistance per foot

4	.000292
6	.000465
8	.000739
10	.00118
12	.00187
14	.00297
16	.00473
18	.00751
20	.0119
22	.0190
24	.0302
26	.0480
28	.0764

Current ratings

Most current ratings for wires (except magnet wires) are based on permissible voltage drop, not temperature rise. For example, 0.5 mm^2 wire is rated at 3A in some applications but will carry over 8 A in free air without overheating. You will find tables of permitted maximum current in national electrical codes, but these are based on voltage drop. Here is a current and AWG table.

AWG	dia mils	circ mils	open air Amp	cable Amp	ft/lb bare	ohms/1000’
10	101.9	10380	55	33	31.82	1.018
12	80.8	6530	41	23	50.59	1.619
14	64.1	4107	32	17	80.44	2.575

Mils are .001". "open air A" is a continuous rating for a single conductor with insulation in open air. "cable amp" is for in multiple conductor cables. Disregard the amperage ratings for household use.
To calculate voltage drop, plug in the values:
V = DIR/1000
Where I is the amperage, R is from the ohms/1000' column above, and D is the total distance the current travels (don't forget to add the length of the neutral and live together - ie: usually double cable length).
Design rules call for a maximum voltage drop of 6% (7V on 120V circuit).

Resistivities at room temp:

Element	Electrical resistivity (micro-ohm-cm)
Aluminium	2.655
Copper	1.678
Gold	2.24
Silver	1.586
Platinum	10.5

This clearly puts silver as the number one conductor and gold has higher resistance than silver or copper. It's desirable in connectors because it does not oxidise so remains clean at the surface. It also has the capability to adhere to itself (touch pure gold to pure gold and it sticks) which makes for very reliable connections.

Thermal conductivity at room temperature

	W/cm²/°C
silver	4.08
copper	3.94
gold	2.96
platinum	0.69
diamond	0.24
bismuth	0.084
iodine	43.5E-4

This explains why diamonds are being used for high power solid state substrates now - that's man-made diamond. Natural diamonds contain flaws in the lattice that phonons (heat conductors) get scattered and substantially reduce the ability to transport the heat.

Copper wire resistance table

AWG	Feet/Ohm	Ohms/100ft	Ampacity	(mm^{2})	Meters/Ohm	Ohms/100M
10	490.2	.204	30	2.588	149.5	.669
12	308.7	.324	20	2.053	94.1	1.06
14	193.8	.516	15	1.628	59.1	1.69
16	122.3	.818	10	1.291	37.3	2.68
18	76.8	1.30	5	1.024	23.4	4.27
20	48.1	2.08	3.3	0.812	14.7	6.82
22	30.3	3.30	2.1	0.644	9.24	10.8
24	19.1	5.24	1.3	0.511	5.82	17.2
26	12.0	8.32	0.8	0.405	3.66	27.3
28	7.55	13.2	0.5	0.321	2.30	43.4

These Ohms / Distance figures are for a round trip circuit. Specifications are for copper wire at 77 degrees Fahrenheit or 25 degrees Celsius.

Wire current handling capacity values

mm2	R/m-ohm/m	I/A
6	3.0	55
10	1.8	76
16	1.1	105

25	0.73	140
35	0.52	173
50	0.38	205
70	0.27	265

Mains wiring current ratings

In mains wiring there are two considerations, voltage drop and heat build up. The smaller the wire is, the higher the resistance is. When the resistance is higher, the wire heats up more, and there is more voltage drop in the wiring. The former is why you need higher-temperature insulation and/or bigger wires for use in conduit; the latter is why you should use larger wire for long runs. Neither effect is very significant over very short distances. There are some very specific exceptions, where use of smaller wire is allowed. The obvious one is the line cord on most lamps. Don't try this unless you're certain that your use fits one of those exceptions; you can’t go wrong using larger wire. This is a table apparently from BS6500, reproduced in the IEE Wiring Regs which describes the maximum fuse sizes for different conductor sizes:

Cross-section	Overload current
CSA / area	rating
0.5mm²	3A
0.75mm²	6A
1mm²	10A
1.25mm²	13A
1.5mm²	16A

Typical current ratings for mains wiring

Inside wall

mm^2	Amps
1.5	10
2.5	16

Equipment wires

mm^2	A
0.5	3
0.75	6
1.0	10
1.5	16
2.5	25

Wire sizes used in USA inside wall

For a 20 amp circuit, use 12 gauge wire. For a 15 amp circuit, you can use 14 gauge wire (in most locales). For a long run, though, you should use the next larger size wire, to avoid voltage drops. Here's a quick table for normal situations. Go up a size for more than 100 foot runs, when the cable is in conduit, or ganged with other wires in a place where they can't dissipate heat easily:

Gauge	Amps
14	15
12	20

10	30
8	40
6	65

PCB track widths

For a 10 degree C temp rise, minimum track widths on 1 oz. copper are:

Current	width in inches
0.5A	0.008"
0.75A	0.012"
1.25A	0.020"
2.5A	0.050"
4.0A	0.100"
7.0A	0.200"
10.0A	0.325"

Equipment wires in Europe

3 core equipment mains cable

Current	3A	6A	10A	13A	16A
Conductor size (mm)	16*0.2	24*0.2	32*0.2	40*0.2	48*0.2
Copper area (mm^2)	0.5	0.75	1.0	1.25	1.5

Cable ratings for 3A, 6A and 13A are based on BS6500 1995 specifications and are for stranded thick PVC insulated cables.

Insulated hook-up wire in circuits (DEF61-12)

Max. current	1.4A	3A	6A
Max. working voltage (V)	1000	1000	1000
PVC sheath thickness (mm)	0.3	0.3	0.45
Conductor size (mm)	7*0.2	16*0.2	24*0.2
Conductor area (mm^2)	0.22	0.5	0.75
Overall diameter (mm)	1.2	1.6	2.05

U.S.A. Common Cable colour Codes

American electrical contractors and electricians are required to follow the National Electrical Code ("NEC") with regard to wiring colours. NEC imposes the following electrical wiring colour standards:

- **Ground wires:** green, green with a yellow stripe, or bare copper
- **Neutral wires:** white or grey

In theory, wiring conducting live current in the U.S. is permitted to be any other colour, although in practice, electrical contractors and electricians follow these local conventions:

- **Single phase live wires:** black (or red for a second "hot" wire)
- **3-phase live wires:** black, red and blue for 208 VAC; brown, yellow, purple for 480 VAC

Most countries in Europe, including the U.K., now follow the colour conventions established by the International Electrotechnical Commission ("IEC"). These colour conventions are as follows:

- **Earth wires** (called ground wires in the U.S. and Canada): green with a yellow stripe
- **Neutral wires:** blue
- **Single phase live wires:** brown
- **3-phase live wires:** brown, black and grey

Electrical wiring in Canada is governed by the Canadian Electric Code (“CEC”). The following wiring colour requirements apply in Canada:

- **Ground wires:** green, or green with a yellow stripe
- **Neutral wires:** white
- **Single phase live wires:** black (or red for a second live wire)
- **3-phase live wires:** red, black and blue

It’s important to remember that the above colour information applies only to AC circuits.

A.M. Frequency slots in Amateur HF Bands

All Frequencies in MHz

160 Metres: 1.885, 1.900, 1.945, 1.985 (USA)

1.850 (W. Europe)

1.933, 1.963 (UK)

1.825 (Australia)

80 Metres: 3.530, 3650 (South America)

3615, 3625 (in the UK)

3705 (W. Europe)

3.670 & 3.690 (popular AM frequencies, Australia)

75 Metres: 3.825, 3.870 (West Coast), 3.880, 3.885 (USA)

60 Metres : 5.317

40 Metres: 7.070 (Southern Europe)

7.120, 7.300 (South America)

7.175, 7.290, 7.295 (USA)

7.143, 7.159 (UK)

7.125 (Primary AM Calling, Australia)

7.146 (Secondary and WIA Sunday morning Broadcast, Australia)

20 Metres: 14.286

17 Metres: 18.150

15 Metres: 21.285, 21.425

10 Metres: 29.000-29.200

6 Metres: 50.4 (generally), 50.250 Northern CO

2 Metres: 144.4 (Northwest)

144.425 (Massachusetts)

144.28 (NYC-Long Island)

144.45 (California)

144.265 (Los Angeles, CA)

Other AM Activity Frequencies

AM activity is increasingly found on a number of other bands, in particular: 5317KHz, 7143KHz, 14286KHz, 21425KHz and 29000 - 29150KHz.
There are several local AM nets in the UK on top band.

FM Frequencies

For mobiles working into VMARS events, 2m calling in on 145.500MHz (S20) is usual, before QSY to a working frequency. At event locations where military equipment is in use, suggested FM "Centres of Activity" on VHF are 51.700Mhz, 70.425MHz (70.450MHz calling).

VMARS RECOMMENDED FREQUENCIES

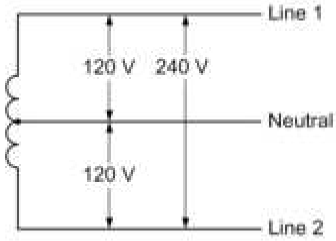
3615 Khz	Saturday AM net 08:30 – 10:30
3615 Khz	Wednesday USB net for military equipment 20:00 – 21:00
3615 Khz	Friday LSB net 19:30 – 20:30
3615 Khz	Regular informal net from around 07:30 - 08:30
3577 Khz	Regular Sunday CW net 09:00
5317 Khz	Regular AM QSO's, usually late afternoon
7073 Khz	Wednesday LSB 13:30; Collins 618T special interest group
7143 Khz	VMARS AM operating frequency
51.700 MHz	VMARS FM operating frequency, also rallies and events
70.425 MHz	VMARS FM operating frequency, also rallies and events

Electrical Supplies - Courtesy LEGRAND equipment

Common Electrical Services & Loads

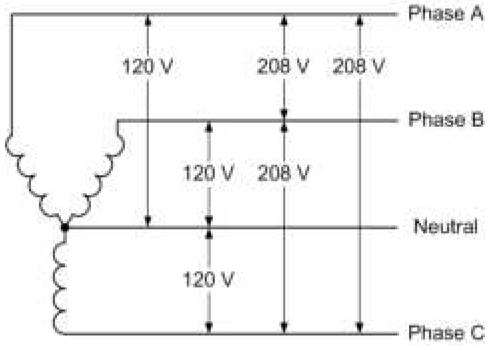
In the following drawings, the coil symbols represent the secondary winding of a utility service transformer or other step down transformer. Electrical code regulations in most jurisdictions require that the neutral conductor be bonded (connected) to the earth safety ground at the electrical service entrance.

Single Phase Three Wire



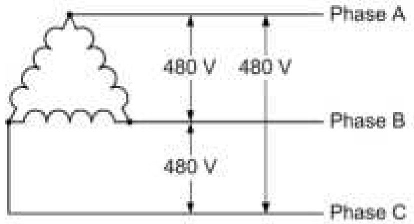
Also known as an Edison system, split-phase or centre-tapped neutral. This is the most common residential service in North America. Line 1 to neutral and Line 2 to neutral are used to power 120 volt lighting and plug loads. Line 1 to Line 2 is used to power 240 volt single phase loads such as a water heater, electric range, or air conditioner.

Three Phase Four Wire Wye



The most common commercial building electric service in North America is 120/208 volt wye, which is used to power 120 volt plug loads, lighting, and smaller HVAC systems. In larger facilities the voltage is 277/480 volt and used to power single phase 277 volt lighting and larger HVAC loads. In western Canada 347/600V is common.

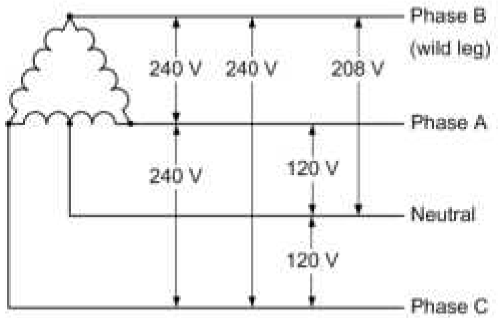
Three Phase Three Wire Delta



Used primarily in industrial facilities to provide power for three-phase motor loads, and in utility power distribution applications. Nominal service voltages of 240, 400, 480, 600, and higher are typical.

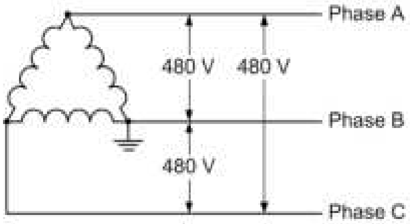
Uncommon Electrical Services

Three Phase Four Wire Delta



Also known as a high-leg or wild-leg delta system. Used in older manufacturing facilities with mostly three-phase motor loads and some 120 volt single-phase lighting and plug loads. Similar to the Three Phase Three Wire Delta discussed above but with a centre-tap on one of the transformer winding to create neutral for 120 volt single-phase loads. Motors are connected to phase A, B, and C, while single-phase loads are connected to either phase A or C and to neutral. Phase B, the high or wild leg, is not used as the voltage to neutral is 208 volt.

Three Phase Two Wire Corner-Grounded Delta



Used to reduce wiring costs by using a service cable with only two insulated conductors rather then the three insulated conductors used in a convention three phase service entrance.

International Electrical Distribution Systems

Description	L–N Vac	L–L Vac	Countries
1-Phase, 2-Wire 120 V with neutral	120	–	US
1-Phase, 2-Wire 230 V with neutral	230	–	EU, UK, Scandinavia
1-Phase, 2-Wire 208 V (No neutral)	–	208	US
1-Phase, 2-Wire 240 V (No neutral)	–	240	US
1-Phase, 3-Wire 120/240 V	120	240	US
3-Phase, 3-Wire 208 V Delta (No neutral)	–	208	US
3-Phase, 3-Wire 230 V Delta (No neutral)	–	230	Norway
3-Phase, 3-Wire 400 V Delta (No neutral)	–	400	EU, UK, Scandinavia
3-Phase, 3-Wire 480 V Delta (No neutral)	–	480	US
3-Phase, 3-Wire 600 V Delta (No neutral)	–	600	US, Canada
3-Phase, 4-Wire 208Y/120 V	120	208	US
3-Phase, 4-Wire 400Y/230 V	230	400	EU, UK, Scandinavia
3-Phase, 4-Wire 415Y/240 V	240	415	Australia
3-Phase, 4-Wire 480Y/277 V	277	480	US
3-Phase, 4-Wire 600Y/347 V	347	600	US, Canada
3-Phase 4-Wire Delta 120/208/240 Wild Phase	120, 208	240	US
3-Phase 4-Wire Delta 240/415/480 Wild Phase	240, 415	480	US
3-Phase Corner-Grounded Delta 208/240	–	240	US
3-Phase Corner-Grounded Delta 415/480	–	480	US

Note: regional variations may exist: if in ANY doubt, consult your Electrical Supply Authority.

HOT IRON

Issue 107 End Feb / Start March 2020

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CQ-CQ-CQ

More and more people are finding that buying a modern, all singing, all dancing gizmo (be it a camera, radio, or anything whatsoever) holds no long term satisfaction as compared with something you have to *learn a skill* for good results. That's why home-made regenerative receivers, simple transmitters and other miscellaneous radio gear are becoming more popular by the day. Of course, your home-made 1V2 regen Rx can't compete with a £1000+ transceiver - but **you** made it. **You** made it work. **You** created it on your kitchen table, or on your “radio” bench under the stairs, which **you** probably made yourself.

Creativity is one of mankind's basic satisfactions: be it art, photography, writing, studying Nature, whatever. The principle that gives lasting satisfaction is that **you** made it happen **your** way, in **your** time, to suit **your** desires. No Japanese mass-produced "black box" radio transceiver can come within a million miles of that; **you** are individual: each and every one of us are different.

When you are looking to finance buying the latest “wonder” Transceiver keep to mind that next year, after the marketing and advertising men get to work, your current “wonder” transceiver will be “obsolete” and worth a piddling fraction of what you paid for it when you part exchange it for the next “wonder +1” model you *simply* must have, if you believe the B/S the advertising and marketing swindlers peddle. Don’t be taken in; year after year the reviews, the performance testing, don’t tell you the simple truth that no matter how good a performer that wonder receiver is, or however potent at sending out a signal that transmitter is, it’s whoever’s operating it and the antenna it’s connected to that makes the difference between success and failure - whatever they are, in your context! No mass produced item fits all people; the marketing men want **you** to fit **their** device. Reverse the equation: make your radio equipment fit **you**.

Vive la home built - **always** better than shop bought.

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Seen recently a comment that the ONLY acceptable telephony mode for RESPONSIBLE users of HF bands phone is SSB, quoting that “DSB will disrupt adjacent traffic”. What about the distinct A.M. slots on the HF bands? The author of this wondrous missive has obviously not read her License; I can only comment on the UK / OFCOM License, but CW, A.M., FM and a few data modes are specifically allowed; the parts of the band where these modes are allowed aren’t mentioned - you could, without breaking any of your UK license conditions, use A.M. or any other mode allowed, anywhere within the bands - with due regard to the transmitted signal’s bandwidth near the band edges.

As a gesture of goodwill, we stick to the band plans put forward by the (purely voluntary, with NO official authority or sanction) RSGB. The UK license does not in any way insist on SSB for phone, and those misinformed individuals who think that SSB is the only “responsible” mode ought to read their UK licenses fully and not decry any licensed user who sticks to them.

Those suggesting that A.M or DSB is in some way irresponsible or unlawful are acting in a very irresponsible manner themselves. Whilst A.M. might not (quite reasonably) use the whole width of an HF band due to the bandwidth of the signal emitted, ALL band plans are voluntary in the UK. Indeed, the A.M. spot frequencies prove a most useful means of enjoying A.M. amateur radio operation, and are an excellent way to attract newcomers to amateur radio telephony as construction of A.M. transmitters and receivers is simple, being tuned to a single frequency, and affords a vastly cheaper entry to the bands where A.M. slots exist for those who can’t or don’t want to blow several £k’s to become Black Box operators and not have the ultimate pleasure of building their own station from scratch.

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RF Basics

A very useful description and source of information for all radio nuts:

https://www.ti.com/lit/ml/slap127/slap127.pdf

Well worth a look for all would be amateur radio operators and designers. No matter what your experience or skill level, it does no harm to review and look at the fundamentals of our hobby. It gives a good starting point if you're asked about Radio, or need "Elmer" skills.

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"Filling the Vacuum"

From Grayson Evans, TA2ZGE / K7UM:

My thanks to Grayson for his pointing me to this publication: and I'm very happy to let Hot Iron readers know about it. I'm sure we all wish the Museum well!

You can find more at: https://themuseums.org/international-vacuum-tube-museum/

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From Terry Mowles, VK5TM:

This was prompted by my suggesting that the stability and controllability of DDS / PLL oscillators would allow effective demodulation of Double Sideband Suppressed Carrier A.M.

Re. the DDS phase comments (pages 11 & 12 in Hot Iron #106), a lot of DDS chips can have their output phase controlled in software, although I'm wondering if in fact it might just be simpler to adjust the phase of the incoming signal, capacitors and inductors are good at that sort of thing. The atmosphere has already done a lot of phase shifting of the signal before it reaches you, so a bit more isn't going to make much difference, just a thought.

(I note that apparently I have moved to Victoria by the change in my call sign hihi! Funnily enough, even Google thinks that's where I am at the moment, must look outside and see what's changed).

On Page 16 (Hot Iron #106) and the Zachary Oscillator, the full article (well paragraph in another article), is in Poptronics, page 85 of the December 1970 issue, available on the American Radio History site.

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From John Kirk, VK4TJ (1):

Get The "H" Out of Here

My ancestors have been known to squeeze a quid so hard that it screams, so it's no wonder I can be found on certain far-eastern auction sites, picking up "bargains" on certain electronic components. "Bargains" in quotes, as some things are clearly not what they seem.

I was first alerted to a potential problem by one of my Foundation licence graduates – his uBITX was not behaving as it it should, and he thought his LM338KC regulator might be suspect. "C'mon, Mike", I thought, "It's only got 3 legs – how can you stuff that up?". This guy sand-casts his own heatsinks(!), so is no stranger to "sweat equity" in rigs.

As it happened, I had purchased a handful of the same chip from the same, or at least a very similar source. Sure enough – the chip behaves perfectly until the very final "brick on the key" test (You do perform those, don't you?). It is at this point that the internal pass transistor departs this earthly vale of tears with alacrity, fortunately in an open state, rather than the more often seen "Let's dump the entire job lot of unregulated DC into the gozouta" state I am familiar with.

We expanded our field of research to include additional suppliers, as well as similar 78H05 & 78H12 regulators. Not a one was found to be what it said on the tin!

Fortunately, they have not found it cost-beneficial to counterfeit 2N3055 & MJ2955 transistors (yet!), so make yourself a nice cup of tea and re-read Hot Iron 106, where Peter discusses "wraparounds". No, not the sunglasses, nor the skirts your YL used to favour back when granny glasses were de rigueur, but ways of extending the current capacity of the lowly 1-amp 3-legged regulators.

VK4TJ

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From Tim Walford, G3PJC (1)

A quick comment on that simple gate oscillator (Hot Iron #106) with 10K in the feedback path – I suspect that most modern gate family equivalents will not work with this circuit because the loop gain will be too low due to low 'gain' in the gate part of modern gate families. Somewhere in my deep memory I think most modern gate families have a voltage gain of about 10 when biased in their linear region – so 10K in the feedback path is too much for oscillation. Typical circuits now use about 1 to 3K in series.

(That also reminds me that the three gates in series biased in their linear region for linear amplification are quite often prone to oscillation unless they are very fast gates. You can of course put a CR network in the feedback path to shunt that route for AC signals!)

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From John Kirk VK4TJ (2):

I know you were half-joking about cheap equivalents to the 4CX250B, but I have been having great fun with Russian Gi-6B's as a "functional" equivalent @ 7USD. No socket really required - spring steel tool clips from the hardware store work just fine. Yes, they are a triode, not a tetrode, but, at that price, can we really afford to be so choosy? There is an ancient article on my blog on how to hose one up for HF:

https://vk4tj.blogspot.com/

You are welcome to it if it fits the general tone of "Hot Iron", but might need a bit of editorial dusting off & updating.

Many thanks John; your G1-6B blog article appears in the Transmitter section of this issue of Hot Iron.

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From Tim Walford, G3PCJ (2)

….after some thoughts I had discussed with Tim about rising edge speeds in transmission lines:

“Yes, absolutely: it becomes very easy to visualise if you think of the Catt description of a step moving down a line. The input energy is stored in the insulating medium between the line's conductors: the lines themselves merely guide the step to it's destination. The losses the step suffers are due to the current down each line, I^2R, plus the radiated energy of the step as it moves charges down the line. Try it with a twin wire line: one line right next to a MW A.M. receiver ferrite rod antenna, the other looped well away, feeding a 24 watt 12v bulb at the far end. You will hear a click every time you connect a 12 volt battery as the step passes on closing the circuit.”

I replied: There you go! Quantum Field Theory with a battery and bulb! This simple experiment illustrates the edge of the DC step function contains many high harmonics. The Laplace / Heaviside transform of a step with infinitely fast edges contains EVERY frequency: if it were possible to create this in a laboratory, you’d see a flash of light as this step passed your viewing station. The problem comes in the time it takes for the electric field to travel in an insulator - in this case, the cable’s insulation - but in outer space, in near perfect vacuum, it might be almost possible IF you have a gate that can switch an edge in the Planck Time, that is: 5.391×10^{-44} seconds, give or take a smidgeon, and drive the inductance and capacitance of a perfect vacuum. The Planck Time is the lower bound value for two connected events to occur; in this case the application of the voltage and the field occurring in the transmission line; i.e. a bit sharpish.

The quantum unit of time - the time it takes for light to travel the diameter of an electron - is the Chronon; this it seems, depending on circumstances, is the discrete step that time changes in. As *quantum theory dictates, time is not a smoothly flowing analogue function but moves in miniscule discrete jumps of one Chronon. This is part of Caldirola's work from 1980, more details at https://en.wikipedia.org/wiki/Chronon. A Chronon (again, depending upon circumstance) is approximately 6.27×10^{-24} seconds - for an electron, that is.*

There are attempts to study the quantum nature of time, using Infinite Dimensioned Hilbert Spaces, but that's about as abstruse a proposition as trying to cross London on the Underground in less than an hour! I suggest you look at https://www.britannica.com/technology/chronon for a comprehensive (and printable) discussion, be it a linear progression on an N-Dimensional plane or a convoluted N-Dimensional Manifold. I'll leave it there, as I haven't time, interest or the philosophical training to go into it any further. Suffice to say I'll stick to valves, at least they keep your mug of tea warm whilst you're tuning up!

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A Conundrum, following on from Chronons...

Many years in the future, in a lab somewhere, are a couple of Technicians setting up some Test Gear, to check the rise time of the output of a newly developed Quantum logic gate: it has been designed to have ZERO rise time, using the Quantum property of a charged particle (unknown to us ancient Earthlings in 2020) called a Yubba Ray, which has (like the Neutrino) zero mass, and is capable of being in two places simultaneously, as Feynman's "Sum of Many Paths" theory explains.

The question is: can ANY technology in this Universe ever generate zero rise time? To make it simpler to imagine, the lab is in deep space, there is no gravity, no gas molecules, indeed, a perfect vacuum, and no adjacent electrical or magnetic influences. Imagine the gate output is just a point that changes potential in ZERO time.

If any such gate output has ZERO Rise Time (i.e. a "ZRT" gate), could it ever be connected to another gate to make a logic function? In other words, what is the fan-out of the ZRT gate? What current would the ZRT output have to source / sink to create a true ZRT gate?

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A note about Copyright and similar matters

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Tim's Topics

Here's a lovely regen. receiver by Tim. It's simple, effective, and functional by separating the detector from the Q-Multiplying RF amplifier. Enjoy!
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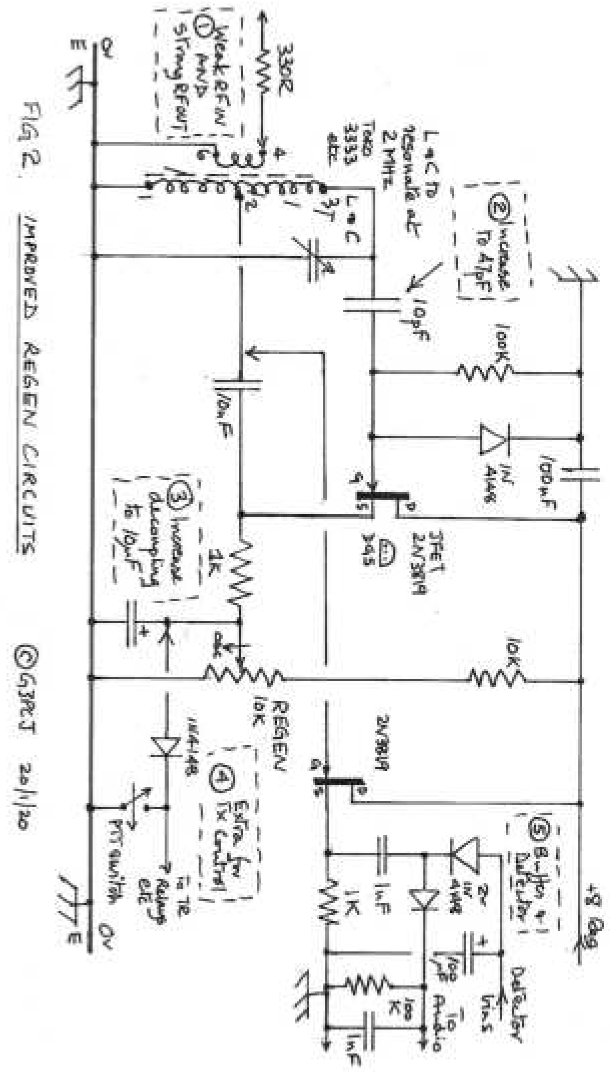

My apologies for the odd image rotation!

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Components and Circuits

40673 - a friend indeed

I had been prompted by a certain gentleman (“from the left coast” as he often says in his podcasts) that jfets would substitute for a 40673 dual gate mosfet; surely the most useful signal handling semiconductor ever made. As most know, RCA, the manufacturers of the original (and ubiquitous) 40673 ditched the production for pastures new some years ago, but so universally useful is the venerable 40673 that you’ll find it specified in designs seen even recently. The question, therefore, is: “how do I build a circuit with all the capabilities of a 40673, with modern easily available components?”. Certainly, dual gate devices are available; some run out at £10.00 or so each with
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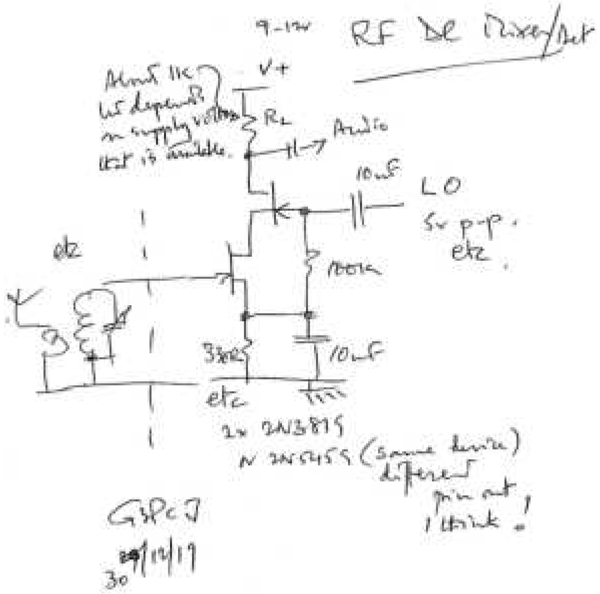
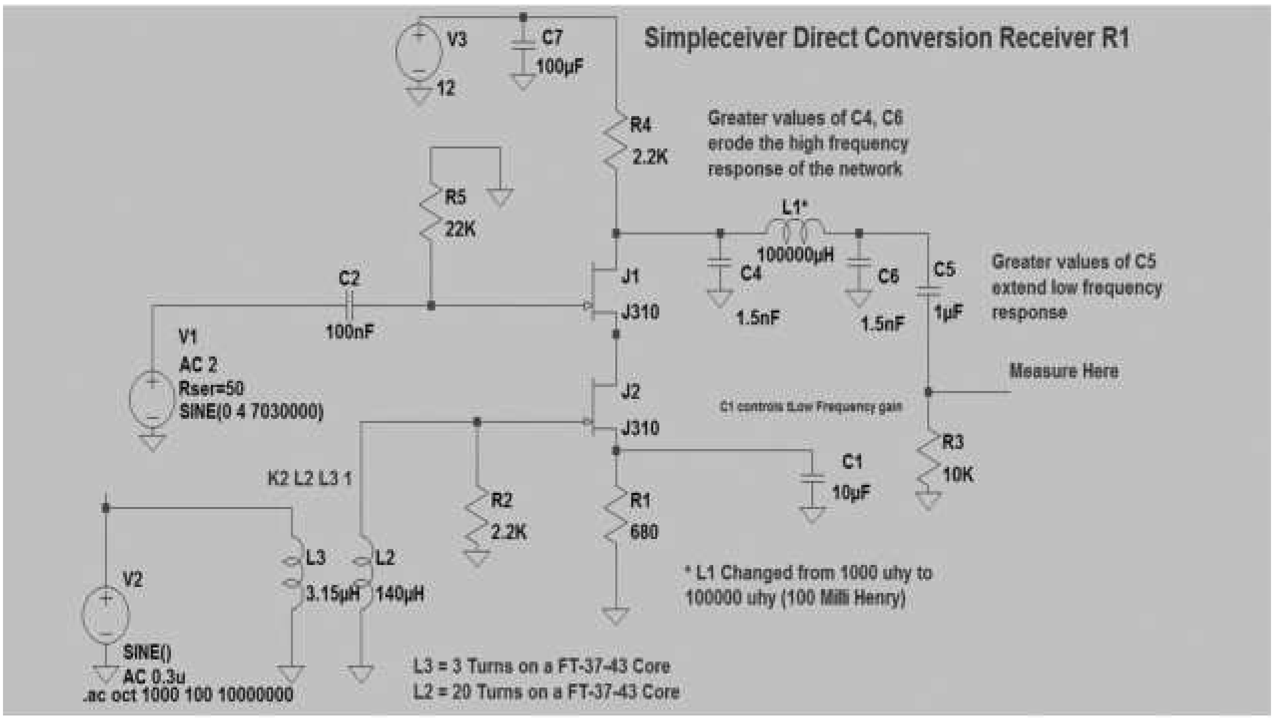
horrendous shipping charges, or others, as per http://www.digitroncorp.com/Products/Product-Line/Dual-Gate-Mosfets are available in TO72 packages (i.e. with legs on for through hole pcb mounting) but... you'll need to be ordering in quantity to secure.

Below is a mixer design Tim has run previously in his designs and had excellent results with; this is his quick sketch:



Pete Juliano (N6QW) reminded me.... below is his design using SPICE simulation which showed considerable promise, which he entitles the "Simpleceiver":



And here's an article from commercial radio manufacturers who have hit on a similar solution:

"*The cascode jfet was used commercially. In part that may have been because it became available maybe a couple of years before dual-gate mosfets, and even then, some makers waited a bit longer again (about another year I think) until protected-gate dual-gate mosfets became available before using them.*
FM tuner RF amplifiers was an early application for the cascode jfet. Scott was one of the first, with a jfet shunt cascode RF stage in its top-end FM front end towards the end of 1965. Heathkit used a jfet shunt cascode RF stage in its AR-15 of late 1966, and I think stayed with jfet-based FM front ends for about a decade, even though it had adopted dual-gate mosfets for AM in 1969.
B&O reworked the front end of its Beomaster 5000 tuner to use a jfet series cascode in place of the original germanium bipolar RF amplifier.
In general though, jfets gave way to dual-gate mosfets for FM front-end applications by the end of the 1960s. Economics may have been a contributing factor, in addition to relative performance. One dual-gate mosfet probably cost a bit less than two jfets.
There were also commercial applications. The GEC RC410R HF receiver (1967) had two tuned RF stages, each using a jfet series cascode with agc bias applied between the source and gate of the lower unit. Apparently the original RF amplifier design was bipolar, but with this the desired noise factor and intermodulation performance could not be achieved at higher frequencies, so a change to jfets was made.
The Marconi Hydrus point-to-point ISB receiver (1968) used series-cascode jfets in the RF amplifier, mixer and IF amplifier positions. In the RF (and I imagine the IF) case, agc bias was applied to the gate of the upper unit. For the mixers, the signal was applied to the lower unit gate and the oscillator input to the lower unit source. Thus both the signal and oscillator were looking into a cascode. Given that the first oscillator input could be as low as 41.5 MHz and the IF output was at 40 MHz, and wideband (± 0.6 MHz), my inference is that it was thought desirable that the oscillator input as well as the signal input be screened from the output in order to minimize regeneration opportunities.
The Eddystone EC964 marine spot-frequency SSB receiver used a triple jfet array for its 2nd mixer, said to be chosen for good signal handling in a position were low noise was not essential. This could be seen as a jfet series cascode with the upper unit replaced by a source-coupled pair. The oscillator went into the lower unit gate, the signal into the left-hand upper unit gate and the output was taken from the right-hand upper unit drain.
Thus were there various ways in which the jfet cascode was used. Whilst the signal input was (mostly) the lower unit gate, agc bias and oscillator injection points varied. With dual-gate mosfets, there seemed to be more uniformity, with signal nearly always on gate 1, for amplifiers, agc bias on gate 2 and for mixers, oscillator on gate 2. An exception to the latter was in VHF TV tuners."

From: https://www.vintage-radio.net/forum/showthread.php?t=154799

Below is an article I saw along similar lines...

Some notes about (jfet) Mixers, by Russell Kincaid

A mixer consists of a non-linear device which handles two signals of different frequency. The output has the original two signals plus the sum and difference frequencies. A filter is required at the output to select the desired frequency, usually the difference frequency. A diode makes a good mixer but the best you can do is -6 dB gain from RF input to IF output. An XOR logic gate can also be used as a mixer within its frequency range.

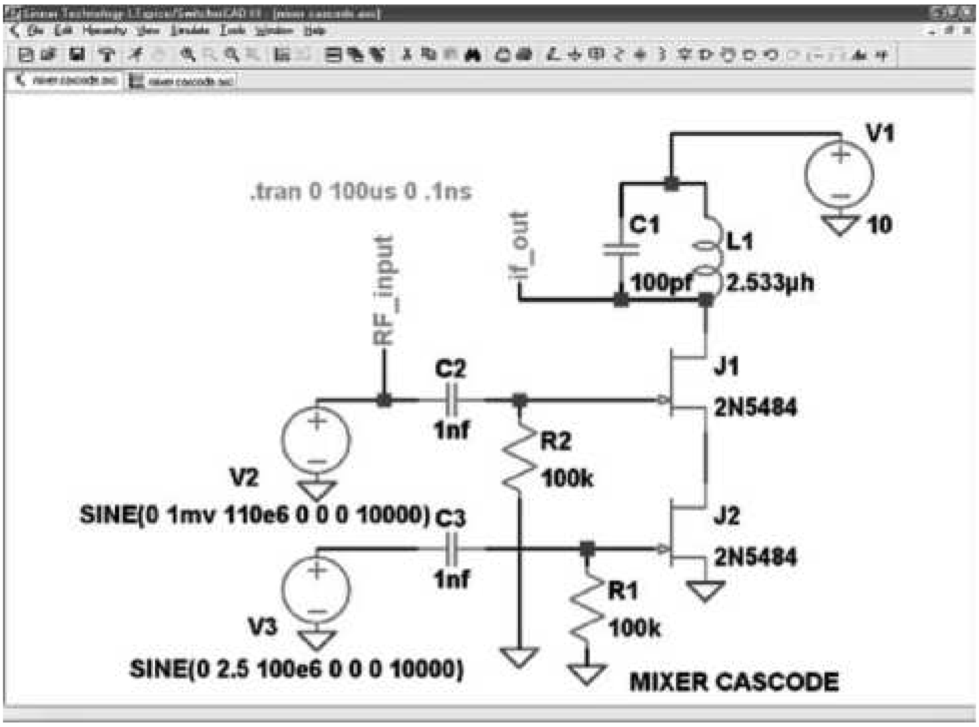


FIGURE 1.

Your request for a two transistor circuit brought a cascode circuit to mind, so I threw together the circuit of **Figure 1** in the LTspice simulator. The RF input to J1 is 2 mV peak-to-peak at 100 MHz; the local oscillator (LO) input to J2 is five volts p/p at 110 MHz. The output circuit is tuned to the difference frequency of 10 MHz. **Figure 2** is the output signal. The 10 MHz is about 70 mV p/p, a gain of over 30 dB. The LO output is significant, more filtering is needed.

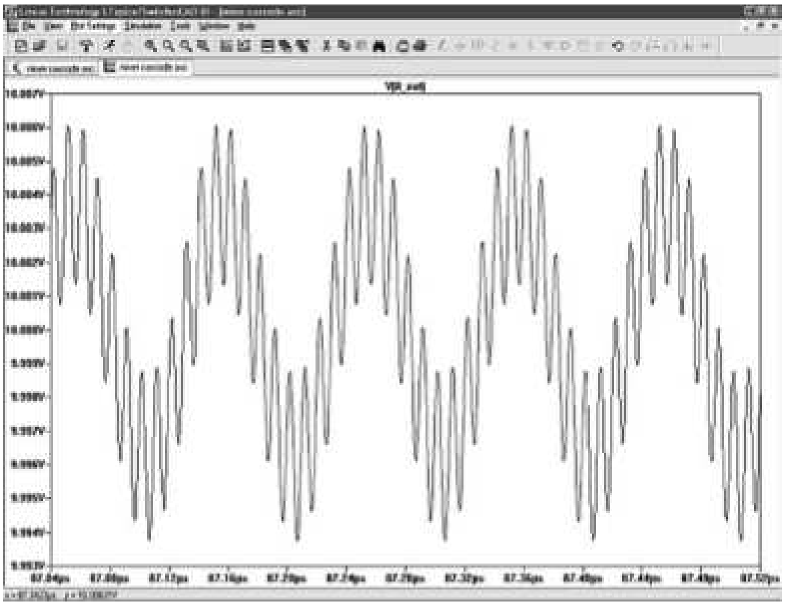


FIGURE 2.

A single transistor can be used as a mixer and oscillator at the same time, but the problem is that a strong RF signal can “pull” the LO off frequency, causing increased interference and reduced gain. This problem increases as the RF and LO signals get closer together.

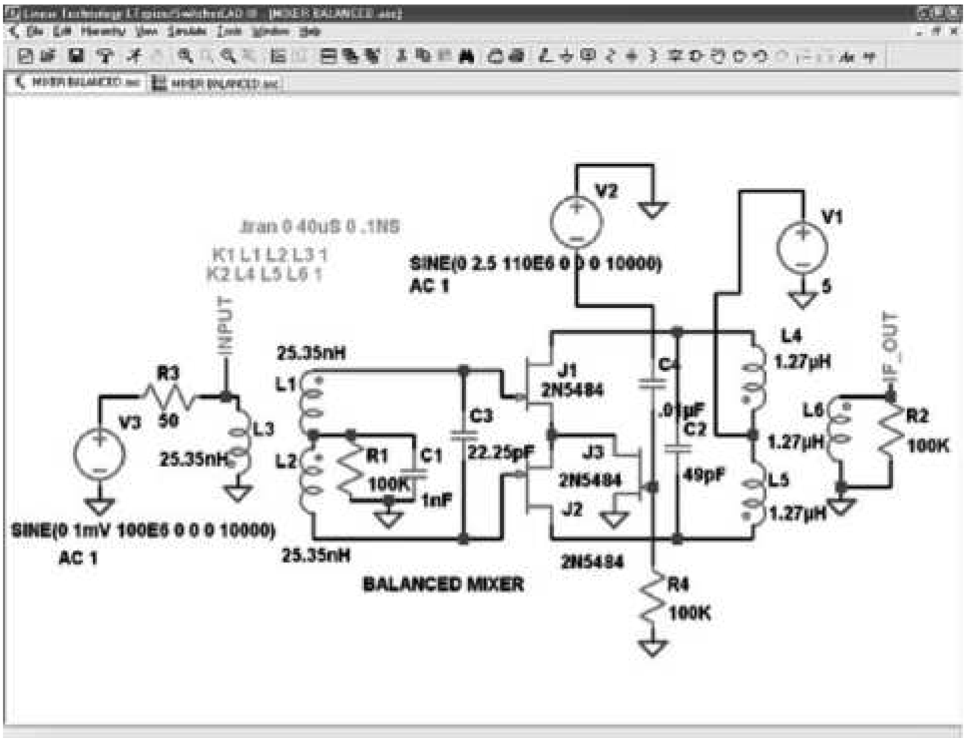


FIGURE 3.

There is a lot of interest nowadays in balanced mixers which will reject the LO signal, making the output filtering easier. A single balanced mixer rejects just the LO, a double balanced mixer rejects both the RF and the LO. **Figure 3** is a single balanced mixer. The input transformer is center-tapped to provide push-pull drive to the output transformer, through the JFETs. The local oscillator drive is common mode and does not couple to the output. The output transformer must be well balanced, such that when the same signal is applied to both sides, the result is cancellation. As you can see in **Figure 4**, there is no LO in the output waveform. The 10 MHz is 70 mV peak, a gain of over 36 dB.

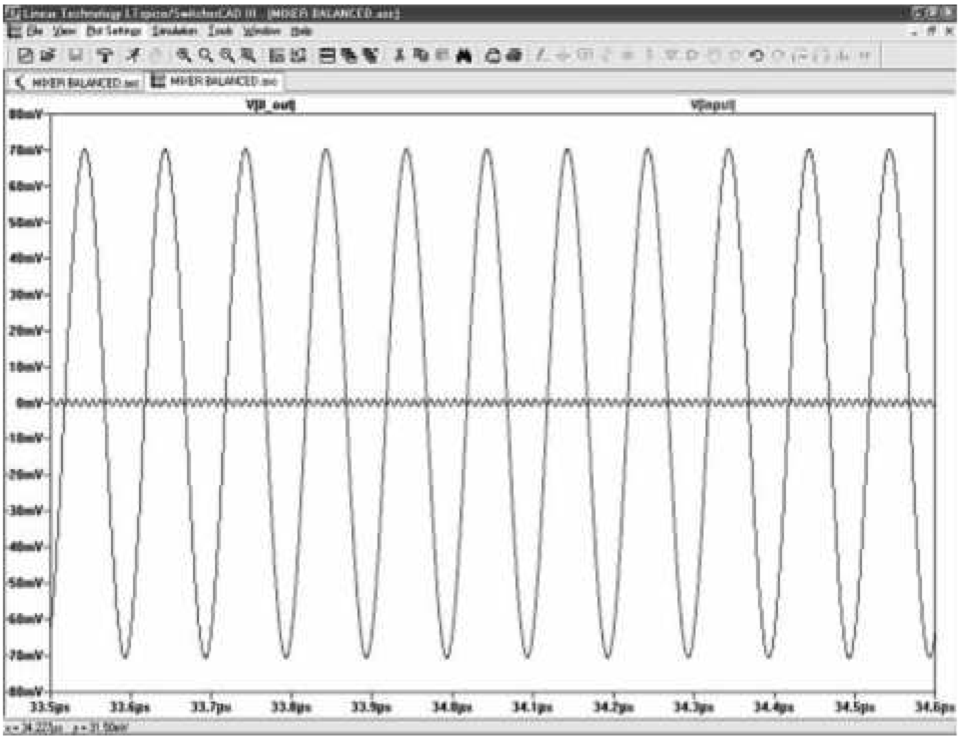


FIGURE 4.

I used the 2N5484 because it was in the library; it is similar to the MPF102, and costs 11 cents.

Pete Juliano and Tim Walford have long been advocates of using modular circuit blocks (as I have too) which can be “built” into both receivers and transmitters using relay switches to steer the signals in the appropriate direction.

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Bidirectional Amplifiers

From: https://www.everythingrf.com/community/what-are-bidirectional-amplifiers

A **Bi-directional amplifier** is a device that supports two-way communications and amplifies the signal in both transmit and receive mode. It consists of a power amplifier (PA) at the transmit end and a low noise amplifier (LNA) at the receive end. In receive mode, this device amplifies a weak input signal and feeds it to the radio. While in transmit mode, it amplifies the signal coming from the radio and transmits it further, extending the range of the signal.

Bi-directional amplifiers are most often used to extend the range of a cellular or radio systems. They are also used for transmitting and receiving radio signals in key applications such as unmanned aerial vehicles (UAV), unmanned ground vehicles, L and S-band radar, military radio,
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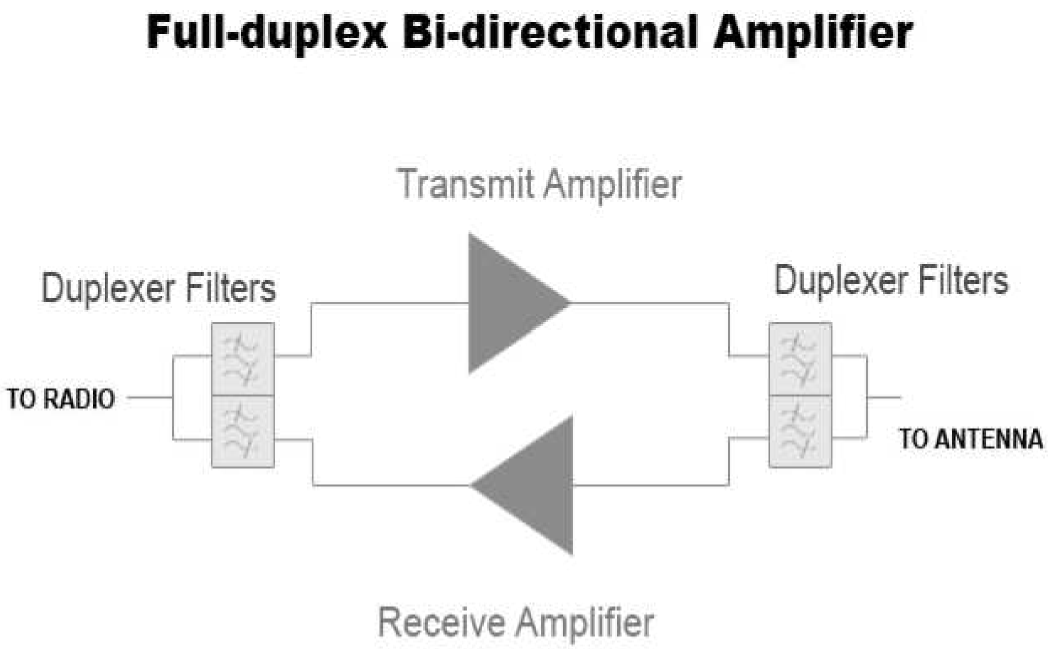
commercial air traffic control, weather and earth observation, satellites and high gain driver power amplifiers.

There are two types of Bi-Directional amplifiers:

Full-duplex Bidirectional Amplifier: A full-duplex bi-directional amplifier can simultaneously perform transmit and receive function. This simultaneous operation is possible by having a separate transmit and receive frequency or by frequency division multiplexing (FDM). This amplifier uses duplex filters to prevent the transmit signal from interfering with the receive channel.

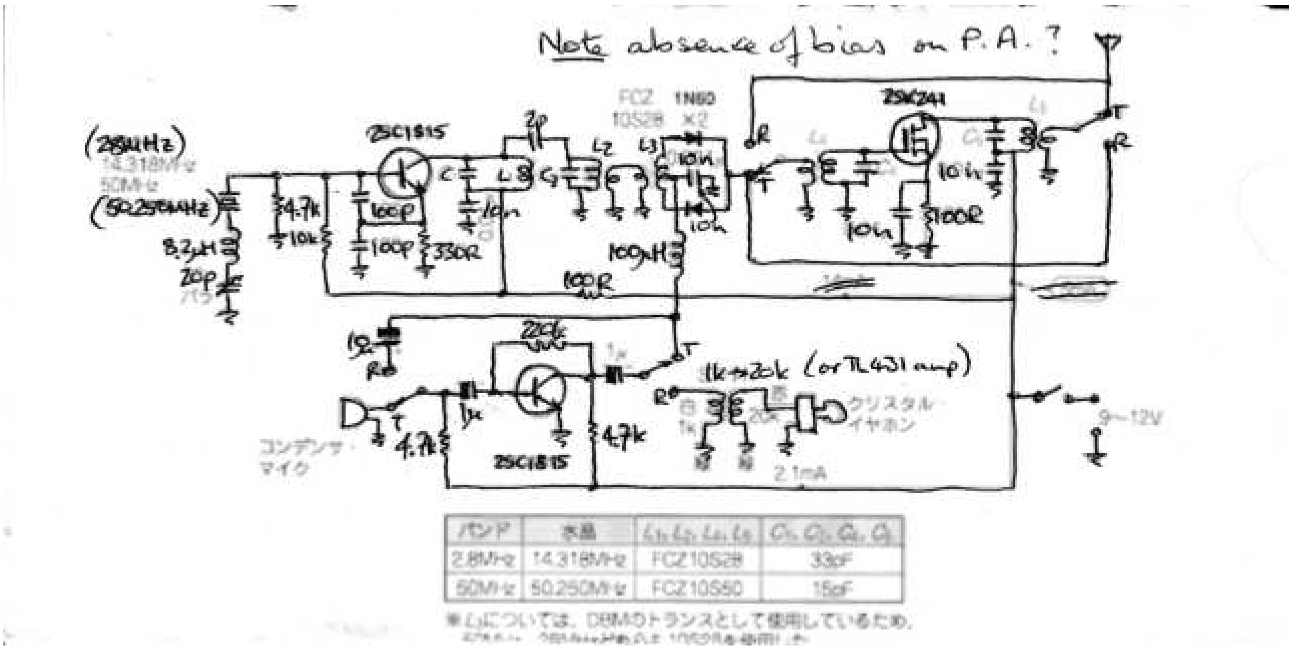


Half-duplex Bidirectional Amplifier: A half-duplex bi-directional amplifier performs either the transmit or receive function at one time. In this amplifier, transmit and the receive function are selected with the help of a switch at the input and output ports, or by the use of intelligent biasing.

Bidirectional Amp. example

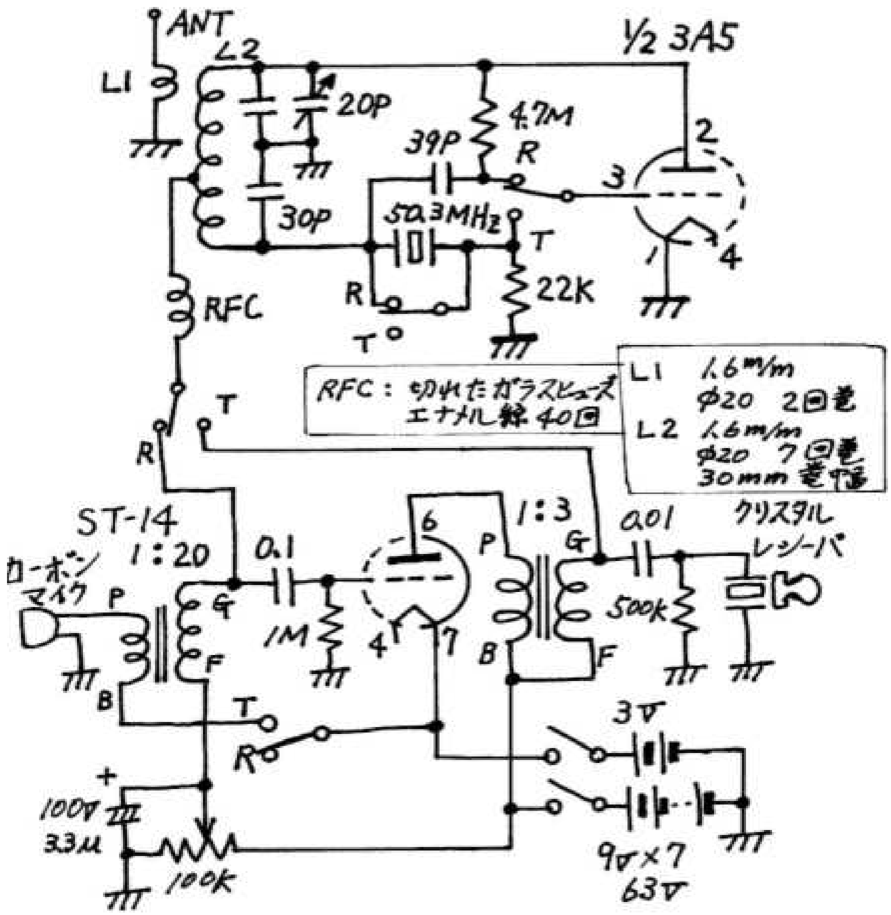
From: JF10ZL

This is a genuinely elegant little transceiver; it is simple, functional and a little beauty to operate. Sure you won't be flushing out rare Dx, but hey, let's appreciate local (and not-so-local) telephony. It's hard to beat!



Note the P.A. device is used as an RF amplifier on receive - truly bidirectional via relay switching. Please forgive my scribbling and notes!

Using a double triode:



Note how the oscillator / PA is switched to become a regen receiver; not truly bidirectional, but a clever use of the stage in two different "directions".

A Transceiver using bi-directional stages

From those magicians in silicon, Ben Kuo, KK6FUT and Pete Juliano, N6QW comes yet more simple and elegant design:

Let's Build Something: Part 1

Ben Kuo—KK6FUT
Pete Juliano—N6QW
kk6fut@verizon.net
radioguy90@hotmail.com

This article is the first of a series designed to introduce newcomers to the wonderful world of home brewing your own equipment. Absolutely no experience is required beyond an ability to read simple schematics and do some basic soldering. If these two skills are new to you, there are many excellent resources on YouTube and similar sites, or in the *ARRL Handbook*.

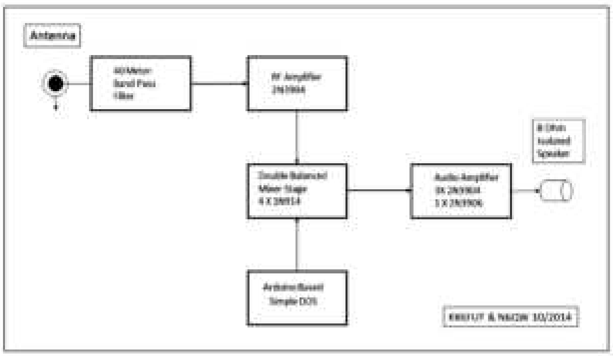


Figure 1—Direct conversion receiver block diagram.

The authors realize that building your first, home-brewed radio project can be very intimidating, especially if you don't have an Elmer in your neighborhood for ongoing guidance. We hope to provide the next best thing in the form of a series of supplemental YouTube videos which show the details of building many of the circuit blocks for this project. A listing of the URL's for the portion of these videos that relate to the first part of this project appears at the end of this article.

We have further simplified the overall project by using a very simple building technique that is as old as ham radio itself—breadboarding. Early radios were often constructed by fastening parts to a board meant for cutting bread. We will do something very similar. In our case, we will be constructing each stage on a small piece of PC board stock obtainable on the popular web auction sites and then mounting each stage on a board for interconnection. We will worry about packaging the total project later. "Al Fresco" construction greatly aids in understanding the circuit elements and most importantly for making changes or repairing modules. Later once everything is perking along you can think about optimized packaging and shrinking down the size. There is nothing wrong with a bread board radio—our ham forefathers operated exactly that way!

The stages will be built using an easy method of Manhattan construction. This involves gluing small pads of PC board stock to a larger blank board for use as junction points. For ease of construction, we will be using MePads and MeSquares available from W1REX at www.QRPme.com. These boards take Manhattan construction way beyond super gluing copper squares to a PCB and enable the homebrewer to focus on building hardware and not removing super glue from their hands! Our goal: make this a fun experience without having to have years of tribal knowledge before soldering the first connection.

Where is this project ultimately going? We will tell you if you promise not to panic. When you finish this deliberately simple set of projects, you will end up with a fully functional QRP SSB transceiver. But don't worry as we promise to take it slow and easy. In the meantime, you will be building all of the modules that will eventually comprise the transceiver. You will find that, as the project progresses, you will finish intermediate, useful pieces of equipment at the end of each article in the series. The various modules will be reused at each stage, so nothing (or at least not very much) becomes a dead end.

For this Part 1 article, we describe a very, very simple receiver project, which takes advantage of the wide availability of the Arduino microprocessor and direct digital synthesizer (DDS) modules and couples that with a simple, homebrew double balanced mixer (DBM), a one transistor RF amplifier, a band pass filter made from commercial IF transformers and a few simple transistors as an audio amplifier, which gives you the ability to listen to sideband (voice) [and CW] ham radio transmissions. It goes without saying that both of us were amazed at how good the receiver sounds and we you think you will be too!

Why Sideband?

Traditionally, the first ham radio homebrewing projects have been CW transmitters and receivers. However, with the removal of the code requirement to becoming a ham radio operator in recent years, there has been a dramatic falloff in the use and proficiency in code. That lack of code ability means that there is an entire generation (or two) of ham radio operators for whom code is non relevant. Putting aside the politics and arguments over the loss of code in the ham radio community, this poses a huge problem for attracting prospective homebrewers to the hobby. Many new hams simply want to talk, using radios they built and not resort to pounding brass. This project sidesteps the CW code issue by going directly to SSB.

Unfortunately, coupled with the lack of CW proficiency, there has been a big loss of available kits for new homebuilders—the traditional entree into homebrewing for radio. Kits like the single band SSB White Mountain—a traditional entree into building your own SSB transceiver—are now discontinued, and projects like the BITX and Minima—although excellent designs—are a huge jump for the new builder. This project attempts to help the new builder along the path to building more complex projects or, hopefully, tackling their own radio designs from scratch!

How Direct Conversion Receivers Work

The first part of our project will be a direct conversion receiver. You'll see later how the parts to this receiver will be used in the final project. In a receiver of this type, an oscillator (in our case, a DDS) operating at the exact frequency of the sideband signal is used as one input to a double balanced mixer. The desired sideband signal is the second input to the mixer and the difference frequency is the desired audio output. In this case, there is no intermediate frequency (IF) and the result is sometimes referred to as a zero IF receiver. Direct conversion involves, as its name implies, a direct conversion of off the air signals to an audio base band. A typical example would be a 40 Meter (7 MHz) SSB signal that is converted to audio directly via a mixing process. For this to happen, we need but a few circuit blocks, shown in Figure 1.

A double balanced mixer produces sum and difference frequencies of the signal coming from the antenna, and the local oscillator. For example, an incoming signal at 7.2 MHz would be mixed with either a 7.199 MHz local oscillator or a 7.201 MHz local oscillator—depending on what sideband (upper or lower) we want. In the first case, two frequencies would be produced: the sum which is 14.339 MHz and the difference is 1 kHz, which is the one we want. In the second case the sum is 14.401 MHz and the difference is 1 kHz, again this is the one. All mixers are capable of producing these sum and difference products. The term "double balanced" implies that the original signal and local oscillator frequencies are deliberately nulled out as part of the mixing process and do not appear at the output.

To clean things up a bit we do a bit of audio filtering following the DBM and top that off with an audio amplifier block.

As shown in Figure 1, there are five major blocks to this project: the local oscillator (Arduino with DDS); our homebrew double band mixer (DBM); the audio amplifier circuit, the input band pass filter and finally an RF amplifier block. All of these blocks will be used in the final SSB transceiver circuit.

We have found that building "backwards," that is building projects from the output to the input, is a key to success in these projects. We will use that method here. This allows you to carefully debug the circuits, ensuring each block or stage is fully working before moving on to the next part. Most kits and construction instructions today tend to emphasize a "stuff and smoke" approach—stuff all the components, plug it in, and see if it smokes.

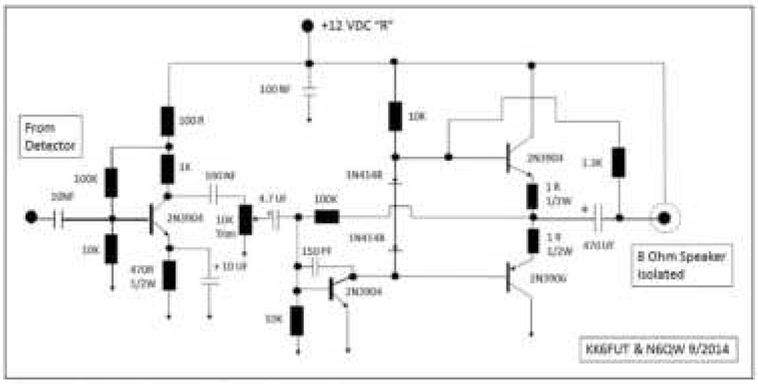


Figure 2—Audio amplifier schematic.

However, that approach means lots of smoked parts, and no understanding on what does or does not work in your circuit! We will start with the audio amplifier and work our way forward.

Before we begin, let's talk a bit about construction. After you have built each stage, you will be attaching the stage to a large board (2 ft. × 2 ft.) using a few wood screws. Then, you will need to supply power for operation. A suggestion is to bring the power into terminal strips (available at Radio Shack) and then power can be distributed to the various modules where power is required. You might also want to cut all of the blank PC boards used for the various stages at once. The sidebar to this article shows a plan for efficiently cutting these boards. If you are not familiar with how to cut the boards, there are quite a few methods exhibited on YouTube videos. However, most of these methods release fiberglass dust into the air. For this reason, you should always wear a mask and safety glasses during this activity.

First Major Piece: The Audio Amplifier

It would have been a simple matter to pop in a packaged amplifier such as an LM-386 or TDA7052 for this project. But, we think you will learn more by working with discrete components. Figure 2 is the schematic. The audio amplifier consists of a 2N3904 pre-amplifier, a second 2N3904 as a pre-driver and a complementary pair 2N3906/2N3904 for the output. Word of warning here—The audio output jack is "hot," so if you later install the amplifier in a metal box you will need to insulate any output connections from that box as you cannot directly ground the output connector to the chassis.

YouTube Hint: If you want to see how the amplifier is laid out, just watch the corresponding YouTube video. You will be able to see how the pads are placed on the blank PC board and how the various components connect.

Testing of the amplifier once completed follows the rigorous N6QW amplifier testing process. Step 1: After checking for shorts, solder bridges, wrong connections, wrong part values or the wrong polarity of the power being supplied AND finally using an isolated phone jack with 8 ohm speaker attached, apply power. If it doesn't smoke or your power supply trips proceed to Step #2 where you take a metal objects such as a tip of a screw driver and touch the input—if you hear a large hum in the speaker—the test is complete. If no hum, go back through step 1. How much more rigorous can you get?

Tribal Knowledge tip! A simple way to avoid hooking the wrong polarity to the circuit is to place a diode in series with the + lead to the board under test. The cathode connects to the circuit and the anode to the source supply. If you get the source leads reversed current will not flow. The arrow part (banded end) of the diode points the way!

Mixing It Up: The DBM

The Double Balanced Mixer (DBM) can be thought of simply as a frequency converter. In Part I we are converting signals in the 40 Meter ham band to an audio output. In applications such as a mixer stage which we will do in the final SSB

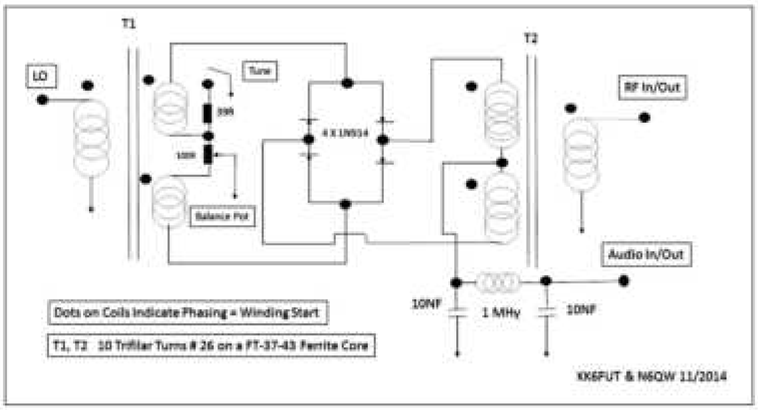


Figure 3—Double balanced mixer schematic.

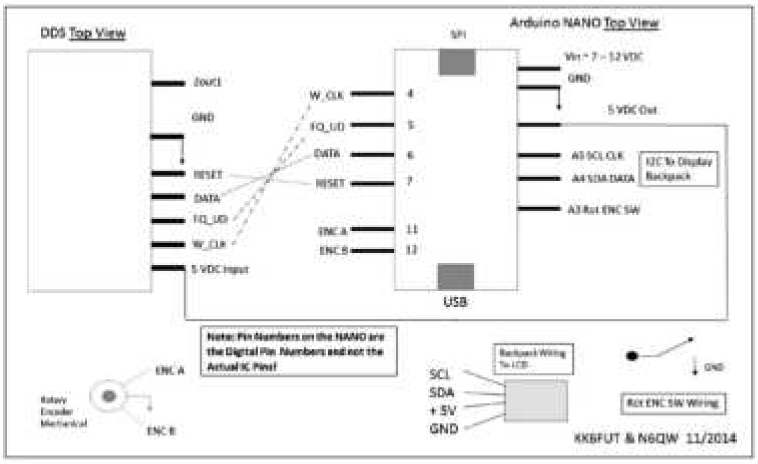


Figure 4—Arduino DDS schematic.

transceiver build, the DBM is employed as both a receiver and transmit mixer stage so that on the air signals are converted not to an audio based band but to an intermediate frequency (IF). Example: 40 Meter signals at 7.2 MHz are mixed in the DBM with an LO (VFO supplied by the DDS) of 12.1152 MHz and the difference frequency (which is what we want) is 4.9152 MHz. Our homebrew crystal filter will operate at this frequency where the signal will pass on to a second Double Balanced Mixer stage. Here, this DBM becomes a Product Detector on Receive and a Balanced Modulator on Transmit. The signal coming in at 4.9152 MHz is mixed with a BFO signal slightly above (or below depending on the sideband in use) 4.9152 MHz and the difference is audio. In the transmit mode, the first mixer stage now outputs the signals back to the 40 Meter band. We'll describe this more in the rest of the series.

This is where the mental light bulbs should light brightly. Our Part I direct conversion receiver is nothing more than a product detector connected to an antenna and in lieu of a fixed BFO frequency we are making it tunable. So what is being built in Part I is the back end of the SSB transceiver. Notice we said light bulbs as the second bulb is that the DBMs are bidirectional! If we hook up a microphone amplifier instead of the audio amplifier, that same product detector circuit becomes a balanced modulator. So what was the input to the product detector is now the output of the balanced modulator. This means that Part I will give us much of the circuitry needed for the low level transmit part of the SSB transceiver. The Double Balanced Mixer Schematic is shown in Figure 3.

YouTube Note: There are a series of three YouTube videos on the DBM that take you from the basics of the DBM through the final construction and these appear on the N6QW YouTube channel.

Tribal Knowledge Tip: The Importance of Heat Sinking any Diodes before soldering!

One of the keys to constructing a double balanced mixer (DBM) is proper construction technique. One of those techniques is making sure that sensitive components—in this case, your diodes—are properly heat sunk during the soldering process. The authors are a fan of using a hemostat, affixed between the point of soldering and the device itself, to make sure you do not overheat the diode. Soldering tips can reach an excess of 800 degrees, enough to render a diode (and other components) useless. Those hemostats are removed after the solder has cooled. We are now careful to mention this removal process for in an earlier article we failed to mention the removal of the hemostats. An email from a builder inquired how to fit that project into an enclosure with the hemostats dangling all over the circuit.

Modern Oscillator: The DDS

When we first started working on this project, we looked at a number of different options for an oscillator, including a VFO, varactor tuned oscillator, and a DDS. After building several versions of this oscillator, we decided that the easiest option—surprisingly—was to go directly to a DDS, due to the ease of soldering modules together, and the ability to directly use this DDS for our full fledged transceiver in the future.

There are three major parts to the DDS: the Arduino microprocessor to control the DDS, the DDS itself, and an LCD display and rotary encoder to allow us to change the frequency. Fortunately for us, there are only four lines we need to connect between the Arduino and the DDS, and only four lines between the Arduino and our LCD display. This actually makes using a DDS one of the simplest parts of this project.

The schematic for this oscillator is shown in Figure 4, which includes the hookup for the Arduino Nano and the AD9850 DDS Board. The Nano and the

AD9850 can be found on the major auction sites for very little cost. The Nano was chosen because of its small size. That said, the Uno R3 or even the Pro-mini can be used. The Uno is much larger physically and the Pro-Mini lacks the serial interface hardware. Moreover, no matter which Arduino device is used, just wire to the Digital and Analog pins for those respective boards. The other observance is that when loading the sketch you must select the device you are using and the appropriate COM Port. Most of the Arduinos like to see an input power to the Board in the range of 7 to 12 VDC. The easiest answer is a 9 VDC 1 amp regulator that is hung off of the main power supply rail (12 - 13.8 VDC).

We have NOT shown a booster amplifier on that schematic, which is optional for the receiver project, but may be required for full driving of the mixer stage when the transmit functions are added. The booster is a utility type amplifier stage employing a 2N3904 that is used in other parts of the radio—remember reusable blocks? Just build another RF amp as described later and insert it between the DDS and the mixer stage.

We've also included pre-built software (Simple DDS), which allows the use of the DDS on a single band, and handles input from the rotary encoder to change the frequency. You do not need to know how to write software on the Arduino to use this—we've already included everything you need, and all you need to do is load the software onto your Arduino using the Arduino IDE.

The software needed is on the N6QW Website under the Arduino Link. Use this link to find the software, http://www.jessystems.com/arduino_build.html. This link has the software in the section marked Sketches.

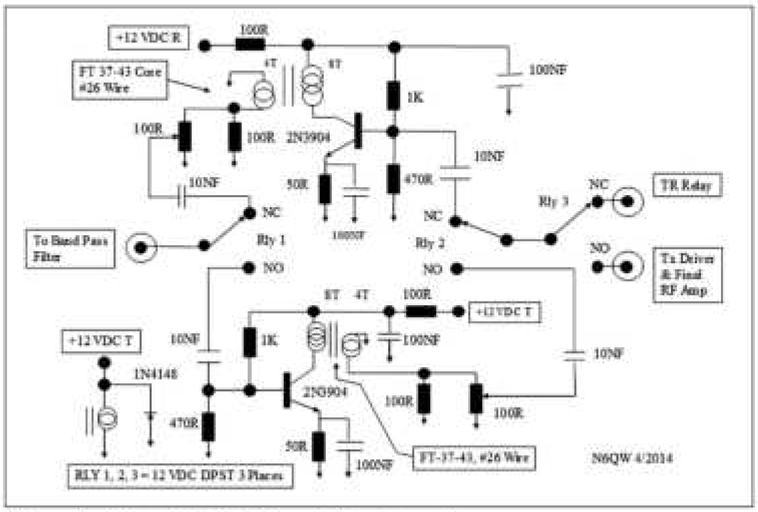


Figure 5—Bilateral Rx/Tx RF amplifier schematic.

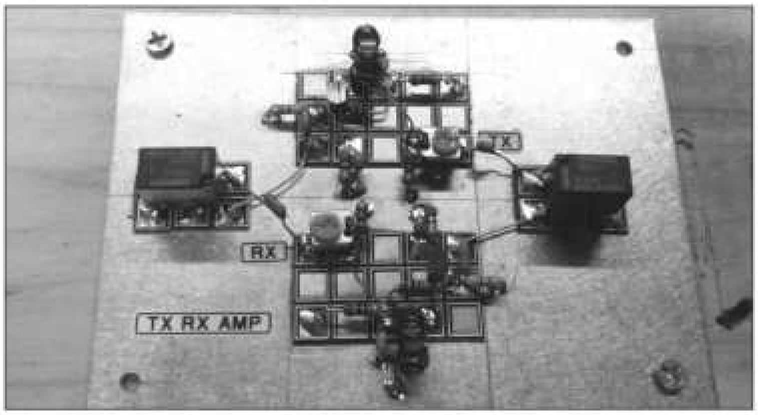


Figure 6—The completed Rx/Tx RF amplifier.

The RF Amplifier: So Much from a 2N3904

The signal levels coming from your antenna are pretty small, and running those through a DBM is not all without some penalties. For all of the good stuff about a DBM, such as rejection of the incoming and LO signal at the output and lower noise than active mixers, the offsetting penalty is that they are a gain loss device suffering up to 5 or 6 dB loss. (DBMs are what is known as passive mixers meaning they do not provide any gain.) That means that off-the-air signal levels are further reduced in the mixing process. There are many ways to handle this, including tacking on a post mixer amplifier, using a high gain audio stage and adding an RF preamplifier to boost the signals ahead of the DBM. We did two of the three by adding an RF pre-amplifier stage and a high gain audio stage.

This pre-amp is un-tuned and thus broad banded, so everything coming into the antenna is amplified. Because of that, we need to include a band pass filter, which limits those signals to only the ones within our desired, 40m ham band. The Rx pre-amp stage provides better than 10 dB of gain which helps make up for the gain loss in the DBM. The parts cost is low in comparison to the gain available. (Certain circuit configurations of a 2N3904 can result in 15 dB of gain—so quite a lot of uumphf for a transistor that when bought in bulk can be had for 3 or 4 cents.)

This circuit block will be used in the final SSB transceiver serving the same purpose. In addition, the very same circuit will be duplicated and will serve as the Tx pre-driver circuit in the SSB radio. So, building two at the same time is probably a good idea, even though only one amplifier is used in the direct conversion receiver. Figure 5 shows the schematic for a two amplifier configuration with relay switching. The completed amplifier is shown in

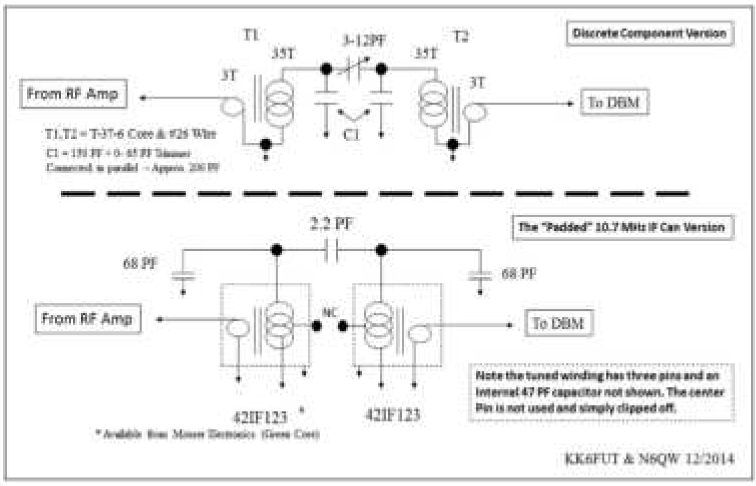


Figure 7—Bandpass filter schematic, with two options for building.

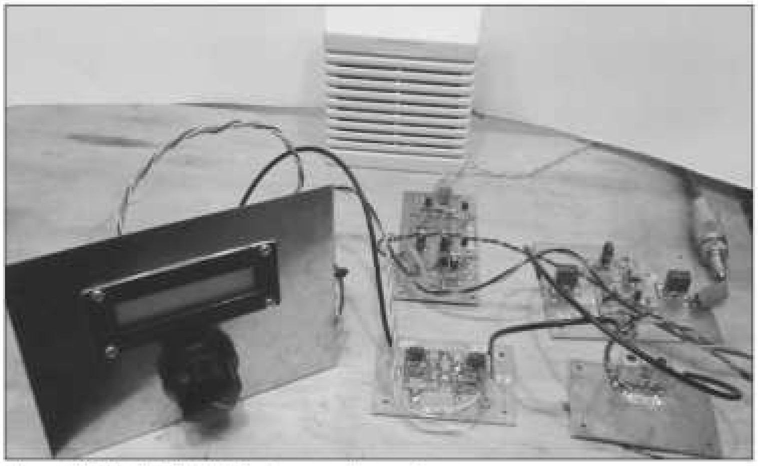


Figure 8—The finished direct conversion receiver.

Figure 6. Once again, when the circuit is completed follow Step 1 in N6QW's rigorous test process before applying any power!

The Band Pass Filter: Nothing to do with Rock Music

As mentioned earlier, the RF preamplifier being broad band will amplify anything coming through the antenna. As we tested this, we found you can faintly hear WWV and nearby shortwave stations coming through the speaker, which is a testimony to as "broad as a barn". The addition of a band pass filter helps keep most of the crud from being heard. The filter is a critical part that will be used in the SSB transceiver so that is another block that will be re-used.

There are two ways to build the band pass filter, both of which are shown in Figure 7: one involves a hand calculation using discrete components (harder but worth learning about) and the other uses packaged IF transformers (Mouser P/N 42IF123) along with three fixed capacitors. Since our goal in this article is to get you up and running, we suggest you build the IF transformer version as we will describe here. In a later part of this series of articles, we will suggest and describe a hand calculated band pass filter.

Building the filters requires adding some capacitance to the packaged IF transformers to lower the tuning range from 10.7 MHz to the 40M band. The 68 pF capacitors in parallel with the transformers accomplish this function. The external 68 pF adds directly to the 47 pF capacitor inside the transformer and resonates with the 4.7 μH coil at approximately 7 MHz. The tunability of the inductance accomplishes a resonance inside the 40M band. The third capacitor (2.2 pF) establishes the degree of coupling between the two transformers. Simply connect the parts as shown in Figure 7 and proceed to the tuning process described below.

Alignment of the homebrew filter following the Step #1 process involves N6QW's "Tune For Maximum Smoke" (TFMS) procedure. The circuit can be peaked for the loudest signal once installed in the radio. Or if a scope is available, feed the DDS signal operating at 7.2 MHz into the filter input and terminate the filter output with a 50 ohm non-inductive resistor. Next place the scope probes across the 50 Ohm resistor and observe the scope pattern. Adjust the pattern for a peak and note the value. Then tune at 7.1 MHz, and at every 25 kHz points, up to 7.3 MHz take similar readings. One can then plot a curve of the voltage reading versus frequency and thus characterize the filter. A flat response is what is desired and a bit of tweaking of the transformer tuning slugs will help improve that response. You will learn a lot about band pass filters using this method.

YouTube Hint: One of the "YouTube videos" that is referenced at the end of the article gives painful detail on how to do this.

Incidentally, these transformers can also be used as filters on other bands. For instance, N6QW has used these modified IF transformers in his multiband KWM-4 transceiver project. However, the transformers are not suitable for coverage across the entire 75M/80M band. In that instance, a filter using the hand calculation method is more suitable. For 30M and below, the procedure is very similar to what is described above. Just add a different capacitor to resonate with each transformer coil. Once you go past 30M up in frequency, one must "carefully" remove the 47 pF cap on the bottom side and use smaller values of capacitors across the tuned winding

Conclusion and Next Steps

Figure 8 shows what your receiver should look like at this point. It should be working successfully and you should be hearing signals.

We'll continue this series with our next article, which will allow you to proceed with the transformation of this simple direct conversion receiver into a SSB transceiver. Figure 9 shows how the modules built in Part I will be used in the SSB transceiver.

See the table below for YouTube video URLs and content descriptions. Hopefully, they will help you build this project successfully!

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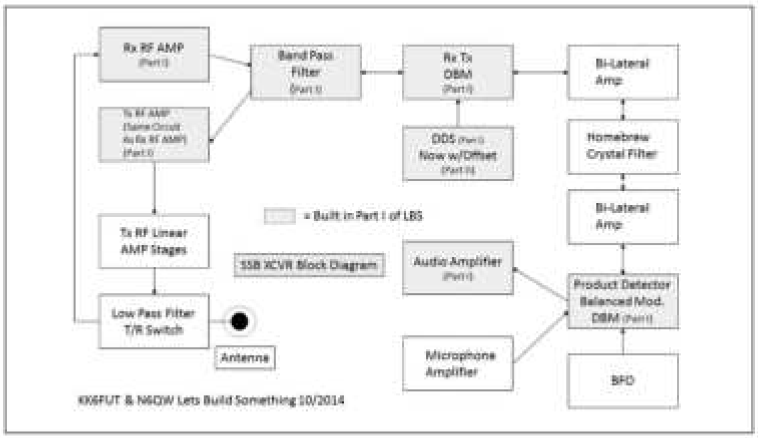

Figure 9—SSB transceiver block diagram.

YouTube URLs & Description

https://www.youtube.com/watch?v=GFZL8avwD3Y&list=UU4_ft4-oTdCMlWlL4XXHScg — Let's Build Something Demo of the Prototype

https://www.youtube.com/watch?v=kzcvNzpMv3U&list=UU4_ft4-oTdCMlWlL4XXHScg — Homebrew Double Balanced Mixer Part I of 3

https://www.youtube.com/watch?v=86n5gjlgmmI&list=UU4_ft4-oTdCMlWlL4XXHScg — Homebrew Double Balanced Mixer Part II of 3

https://www.youtube.com/watch?v=lShnfyXzCcs&list=UU4_ft4-oTdCMlWlL4XXHScg — Homebrew Double Balanced Mixer Part III of 3

https://www.youtube.com/watch?v=BjqvvzI1YLg&list=UU4_ft4-oTdCMlWlL4XXHScg — Building the 40M Band Pass Filter

https://www.youtube.com/watch?v=8p39-5Qcf3U&list=UU4_ft4-oTdCMlWlL4XXHScg — LBS Audio Amplifier Stage

https://www.youtube.com/watch?v=woFpYpSqzKA&list=UU4_ft4-oTdCMlWlL4XXHScg — Final Configuration

https://www.youtube.com/watch?v=b7BGB2oZNEo&list=UU4_ft4-oTdCMlWlL4XXHScg — Installing the Arduino/DDS in the Let's Build Something Direct Conversion Receiver

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Pullen Mixers

(since we're talking 40673's and such in this Hot Iron)

Just to throw a spanner in the works... the Pullen, or Cathode Coupled double triode mixer (see "A Like-New Mixer Circuit" by Staff 73 magazine, October 1961) can put up a hard-to-beat performance even nowadays (so long as you're not demanding ultimate low noise performance, which, on the current HF bands, isn't an issue what with all the man-made noise). For big signal handling you'll struggle to beat valves unless you're planning on a packaged diode double balanced mixer or a Horobin ("H-Mode") mixer - both of which demand premiums with either hefty local oscillator drive or complexity in the drive circuits to guarantee perfect switch phasing. For the H-Mode mixer, this factor can limit them to low HF bands unless you're willing to do some serious engineering. Digital drive to the H-Mode mixer can be used, yes, by all means; but I'll bet a penny to a pound you'll meet the wonderful world of "clock skew" on bands above 20m if you don't perfectly balance the clock parasitic time delays - nigh on impossible, as many a digital designer found to their cost! And... you'll have to keep the balance in control over a wide frequency range, too, somewhere along the line. Rather you than me! As ever, you pays your money and takes your choice!

The original article from 73 magazine is reproduced below. The description and biasing is important; it's how the mixer works. It would be a very interesting experiment to use 2N3819 jfet's in this circuit (with power rails and bias adapted of course).
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A Like-New

Mixer Circuit

By Staff
73 Magazine
October, 1961.

Would you like to improve the sensitivity and the stability of your receiver?

If you would, and don't mind delving underneath the chassis a bit, one of the quickest routes is to modify front-end circuitry. The technical article, "Up Front," in our March issue contained a rather complete collection of improved front-end circuits.

However, here's one which escaped attention when the article was prepared-and which has escaped almost everyone's attention since it was first developed. That's why we're calling it a "like-new" circuit; it's been around for a spell but it might as well be new since almost no one knows of its existence.

Before going into this circuit, it might be well to review the characteristics of a good mixer. The ideal mixer in a superhet receiver should:

(1) produce no spurious frequencies,
(2) provide ample gain for the signal,
(3) contribute no noise to the signal,
(4) provide complete isolation between oscillator and signal to prevent undesired radiation,
(5) present as light a load as possible to the oscillator to preserve frequency stability.

These characteristics, at least to a degree, are mutually incompatible with most conventional circuits. For instance, isolation of the oscillator from the signal circuit usually requires screening grids in the mixer tube, which in turn raise the mixer noise level and violate objective 3.

As pointed out in our aforementioned technical article, the best compromise to date has been the 6AC7 used as a pentode mixer, following the circuit described in Langford-Smith[1]. This circuit provided low noise, adequate gain, little in the way of spurious output, and adequate isolation for most purposes.

However, the particular version of the twin-triode cathode-coupled mixer which we're describing here outdoes the 6AC7 on all counts except gain, and runs it a close race there. On top of this, it can be installed in any set which uses an octal-base, a 9-pin, or a 7-pin mixer tube without changing the socket, since suitable twin triodes are available in all three basings.

The circuit is not original; it was found in K. A. Pullen's book "Conductance Design of Active Circuits," a volume[2] which incidentally should be in the library of every serious ham designer (plug unsolicited; Radio Bookshop please copy), and was field-tested in a vintage BC-779 in comparison with both a 6L7 and a 6AC7.

Results were judged on a purely subjective basis, due to lack of test instruments suitable for adequate and accurate measurements. numerical values mentioned here are calculated figures, but the field tests confirm them as closely as possible.

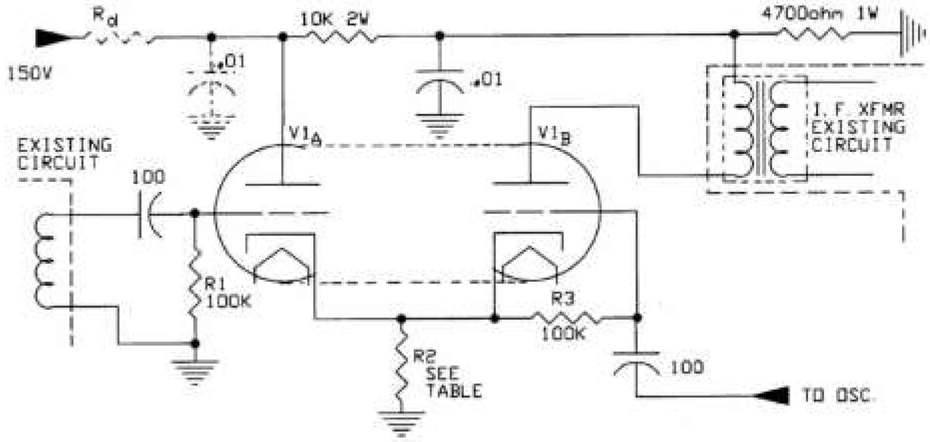


Fig. 1.

The full circuit is shown in the schematic, Fig. 1. Table I lists parts values and operating conditions which vary with different tube types or design objectives.

At first glance, you may be led to believe that this is approximately the same circuit as that recommended by Geisler[3] or Lee[4], or may be a version of the Crosby triple-triode product detector[5]. While the general configuration is similar, the circuit operation and its advantages are radically different.

The key point is the low value of plate voltage supplied to V1B. Pullen recommends only that V1B's plate supply be "considerably" lower than that for V1A. The best operation was found with 50- and 150-volt supplies, respectively, and component values shown are for use with these voltages.

By operating the two nominally-identical triode sections with a common cathode resistor but at two different plate-supply voltages, a relatively small change in current in one tube will cause a large change in the gain of the other. This is accomplished without sacrificing average gain in either tube.

In addition, the cathode-follower action of each stage completely isolates the oscillator from the signal circuit. Since the signal sees only a pair of triodes, noise is not increased.

This circuit is a true linear mixer rather than a detector; its output contains only the two original frequencies and the "product" of the original signals (numerically equal to the sum and difference frequencies but without their usual noise content). The chain of spurious frequencies usually found in detection-type mixer circuits is absent.

Those who have tried triode mixers before, even of the cathode-coupled variety, may wonder about gain. Calculations showed that the version first tested should have shown a conversion gain of about 20, as compared to the calculated pentagrid mixer gain of about 5 under the same conditions.

The test signal was a broadcast station with consistent strength. S-meter reading with the pentagrid mixer was recorded and the twin-triode circuit then substituted and mixer alignment readjusted. The S-meter showed just under 2 units improvement.

Considering the free-wheeling calibration of most S-meters, and this one was no exception, this is a remarkable correlation of theory and experiment. Frankly, we disbelieved it and substituted another tube which had a calculated gain of 13. After realignment, the S-meter dropped one unit.

Regardless of such gain figures, which are dependent on many variables not all of which are under control, this version of the twin-triode mixer shows more signal gain than many pentagrid mixers. Its noise figure is so low that mixer noise simply disappears, even with three *IF* stages following. The result is almost complete silence between stations, leading one to believe at first that the circuit is a dud. Then, though, a fading long-hop signal will come through, moving almost instantly out of the no-signal region into clear audibility, and the design is vindicated.

Every type of twin-triode tube tested to date works in this circuit, but some give better results than others. As noted in Table I, oscillator injection voltage requirements vary drastically from tube to tube. In a like manner, sensitivity varies.

Among octal-base tubes, the 6SN7 gives greatest gain but requires higher voltages to get there. The 6SL7 develops its gain (just half an S-unit less) with much weaker signals and much less oscillator injection. Therefore, the 6SL7 is recommended.

Table I.
Voltage Requirements for Various Tubes and Values of R2 With Typical Conversion Gain

Tube	6SN7 (also 12AX7)			6SL7 (also 12AU7)			12AT7			6J6	
Value of R2	100	500	1000	100	500	1000	100	500	1000	100	1000
Input--Voltage (Signal)	2.1	10.5	21	0.32	1.6	3.2	1.4	7.0	14.0	2.1	21
Input--Voltage (Osc.)	2.5	11.5	22.4	0.42	1.9	3.6	1.6	7.0	13.1	2.3	22
Conversion-Gain if IF Xfmr impedance Is 50K ohms (For Comparison)	18.5	18.3	18.0	13.9	13.7	13.6	100	150	160	80	130

Dozens of twin triodes are available on 9-pin bases; among the most popular are the 12AX7, the 12AU7, and the 12AT7.

The 12AX7 is directly comparable with the 6SL7, and the 'AU7 with the 'SN7. However, the 12AT7 is the hottest tube available for this circuit, with a gain of more than 100 and comparatively low injection- and signal-voltage requirements, so it's the only recommended type. If you're willing to change sockets, the 12AT7 is the best for any set regardless of original tube type.

In the 7-pin basing, there's only one choice – the 6J6. Aside from the fact that the 6J6 is the only 7-pin twin triode easily available, it is surpassed only by the 12AT7. Gain is in the neighborhood of 100 (see Table I).

The entire circuit is simplicity itself to install. Remove all old connections from the mixer-tube socket, being careful not to cut short either the grid lead from the tuning coil or the plate lead from the *IF* can. Then rewire according to the schematic.

If you don't have +150 vdc available in your receiver (many don't), install resistor Rd and its bypass capacitor (shown on the schematic in dotted lines). Value of Rd must be determined by trial and error. Start with 50K ohms, and work down until you find the resistor which gives 150 volts at point A after everything has warmed up.

With the new mixer installed, you'll have to realign the mixer tuned circuits. The cathode-follower inputs reduce input capacity so drastically as to completely detune the stage, so don't be surprised if nothing comes through at first.

The input capacity change has least effect at the low end of any band, so it's best to reverse normal alignment procedure and start by adjusting the *trimmer capacitors* in the tuning assembly at the *low end*. Simply adjust for maximum signal strength (or higher S-meter reading).

Next, tune to the high end of the band and rock the trimmer slightly to see if the adjustment is optimum. If not, adjust the trimmer again for the best high-end signal strength.

If the high end required adjustment, return to the low end but this time adjust the coil slug for maximum signal. Then return to the high end and readjust the trimmer. You may have to repeat this slug-at-low-end-and-trimmer-at-high-end procedure several times to restore tracking, since the change in input capacity usually amounts to about 10 mmfd, which upsets original tracking adjustments.

F_{sig}

an output of

$$K_{total} = K_1 \times K_{2av} \times F_{osc} \times F_{sig}$$

, and since AC signals are *vector* rather than *scalar* quantities, the indicated multiplication must be carried out by vector rather than by straight arithmetic methods. The result is that the output consists of the original two frequencies, the numerical sum of the original frequencies, the numerical differences, *and nothing more*.

Getting away from the exotic mathematics, the big difference between this process and detection-type mixing using non-linear devices such as diodes or overdriven tubes is that only four output frequencies are present. Harmonics and spurious outputs are not.

In addition, the cathode follower is far more tolerant of overload than is any other basic amplifier circuit, and as a result no clipping or distortion occurs in the mixer.

A common problem with many conventional mixers is cross-modulation, in which two carriers become "intertwined" and an unwanted signal rides in on the one you want.

Even under extreme conditions, such as local injection of a signal strong enough to almost block the *IF* strip, cross-modulation could not be induced in this mixer. Apparently this is another by-product of its unusual method of operation.

Although no tests have yet been made, Pullen's analysis of the circuit indicates that it should provide a good high-output product detector for converting SSB and CW to audible signals; simple substitution of an RC coupling network (or an audio transformer) for the *IF* transformer is the only circuit change, though you might want to increase the value of resistor R2.

In summary, this overlooked mixer circuit appears to offer extreme advantages over more conventional circuits in all of the five characteristics of the ideal mixer, with fewer parts than usually required. It works as well in the set as it does "on paper" in the design stage, and can easily be adapted to any receiver. Try it, and let us know how it works for you.

References:

1. Langford-Smith, F., "Radiotron Designer's Handbook", Fourth Edition, Radio Corporation of America, Harrison, N. J., 1968, pages 988 and 967.
2. Pullen, K. A., "Conductance Design of Active Circuits", John F. Rider Publisher, Inc., New York, 1969.
3. Geisler, Leonard, "Souping The Super-Pro," CQ Magazine, December, 1957, page 80.
4. Lee, Cmdr. Paul, "Save Your Super-Pro For SSB," CQ Magazine, September, 1958, page 52.
5. 73 Staff, "Beat Generation," 73 Magazine, February, 1961, page 28.

Uncited by number. 73 Staff, "Up Front," 73 Magazine, March, 1961, page 32.

(Editor's Note: In the original circuit, as published by Keats Pullen, a triode HFO's output is coupled through another cathode-follower to the input grid of the mixer, V1B. This substantially alleviates, if not totally eliminates, the pulling on the oscillator that was noticed in the follow-up 73 Magazine article of August 1966 entitled "Another Look at the *Like New* Circuit")

Receiver Topics

A simple “TV” tube receiver

From: http://www.electronixandmore.com/index.php with many thanks to Jon.

This wonderful design shows that, with good imagination (and a copy of Grayson Evan’s Book, “Hollow State Design”), you can make a thoroughly useful receiver using “unpopular” TV type valves readily (and cheaply) available in our favourite online auction pages; and the valve “equivalents” referred to in the Data section of Hot Iron will help you root out other possibilities.

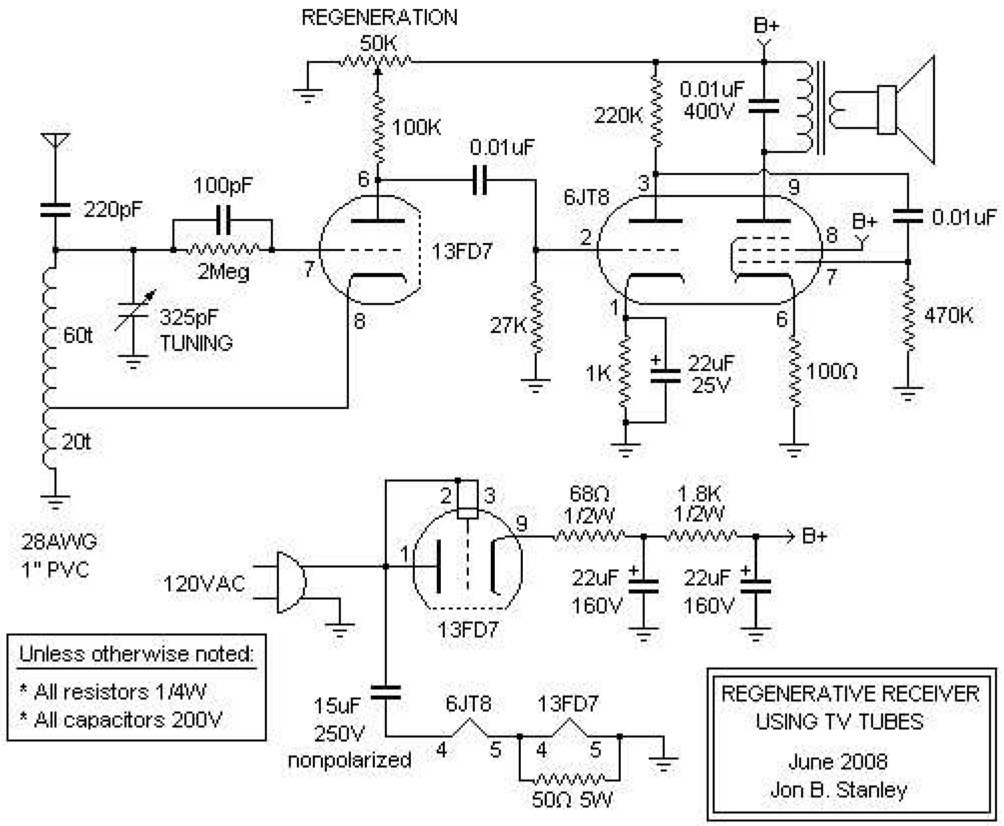
TV Tube Regenerative Receiver

Return to Home
Return to Projects

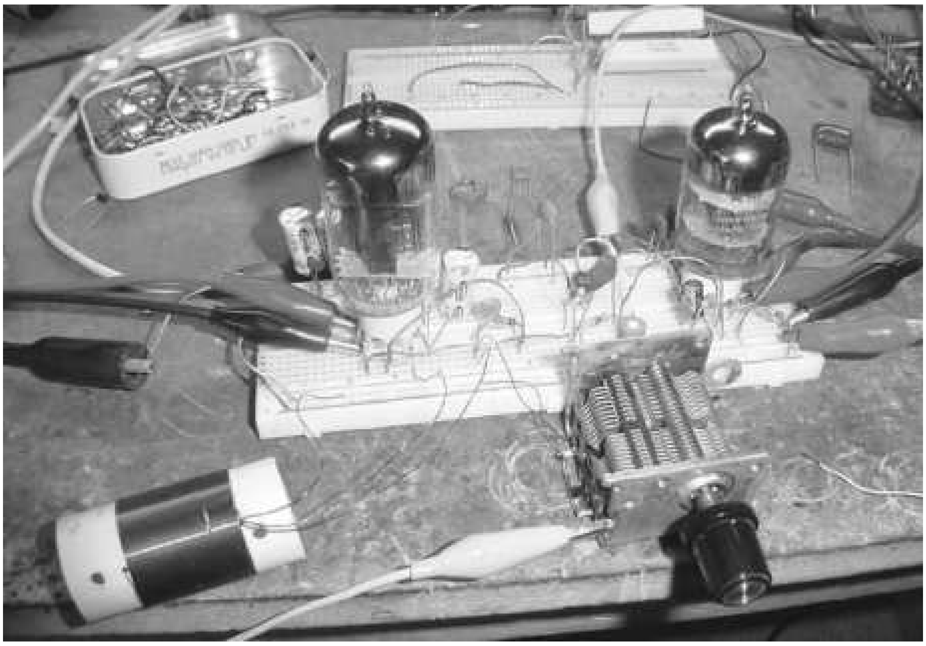
Over the years I have amassed many TV tubes and many of these tubes are interesting because they contain many tube sections in one package. I have built an audio amplifier using a 6LU8 here. Out of the tube pile, I picked a 6JT8 and pulled up the data sheet on the tube. The 6JT8 contains a high mu triode and sharp cut off pentode, which are often used as a sync separator and video amplifier respectively in a colour television. On the other hand, the tube is perfect for creating an audio amplifier. The high mu triode is used in the preamplifier and the pentode as the output for driving the speaker. A circuit based on the audio stages of an AA5 radio was wired for the 6JT8 tube. A loud hum resulted when I touched the input of the amplifier so the next thing was to make this amplifier a bit more useful.

In a dusty corner of my closet was a crystal radio someone built from around the fifties. The crystal radio came with a bunch of other stuff in a box I had bought from an auction. It needed high impediance earphones and I don't carry anything of this sort but a high gain amplifier is a nice subsitute. After dusting off the crystal radio that sat in its niche for several years, I hooked up the earphone terminals to the input of the 6JT8 amplifier and connected a measly 6 foot antenna to the radio. To my amazement, the crystal radio actually picked up at least three stations. I thought to myself, if that simple radio consisting of a mere coil, a variable capacitor, and a single 1N34 diode can pick up stations then I should be able to build a radio that is far simpler than the superheterodyne I built years ago. Before the superhet, I had built various crystal and regenerative receivers that never seemed to work, but in hindsight I realize that these radios may have *almost* worked but I lacked the experience and knowledge back then to get them running. It's quite a shame that none of these radios I built in the past exist anymore because I stripped the parts to use in other projects.

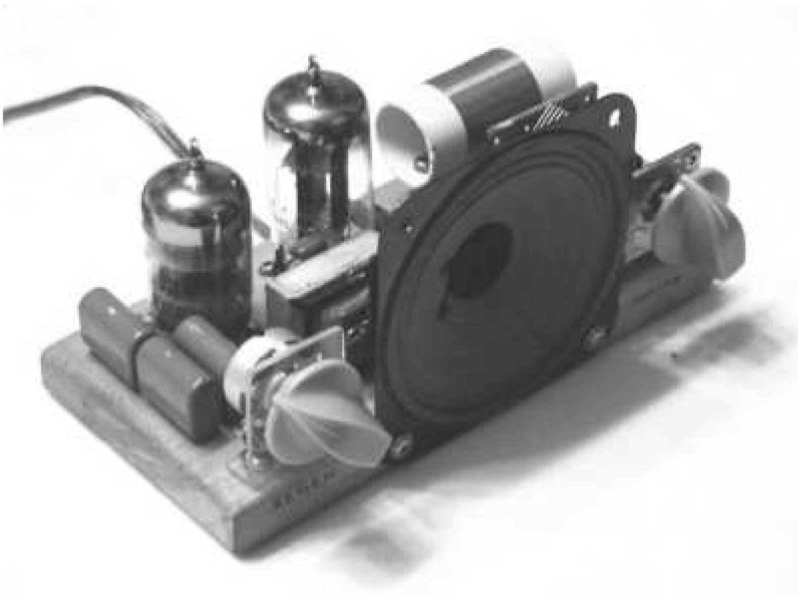
So, some eight years later I took a stab at building another regen receiver. After searching around online, I found a 12AT7 based regen that seemed simple enough to build. To my amazement, the radio worked on the first try so the next step was to find another TV tube that contains a rectifier and high gain triode in one package. During experiments when the 6JT8 was being used as the audio amplifier, the 170VDC B+ was provided by a semiconductor diode from 120V mains during the experiments. I was determined to replace the diode with a hollow-state equivalent to make a true all-tube regenerative receiver. After digging through various TV tubes and pulling up data sheets, I found a 33GY7 that contains a diode and pentode, which could be used as the rectifier and audio output respectively and the 12AT7 for the regen and preamplifier. It turned out that the pentode in the 33GY7 consumed a lot of power, which may be due to an internal short. I confess that I never tested the tube, but the 33GY7 clearly a poor choice for my goals. The next tube was even more promising, a 13FD7 that contains a low mu triode and a high mu triode intended for the vertical circuits in a TV. The 6JT8 could be brought back in the design as the audio amplifier, and the 13FD7 for the rectifier and regen. The low mu triode was capable of supplying sufficient current for the B+ so it was wired as a diode. The high mu triode section of the 13FD7 was used for the regenerative receiver. The circuit was rewired on the breadboard to adapt the 13FD7. The radio worked very well and was able to pick up at least five stations with a very short antenna. The next step was to move and permanently enclose all the components from the breadboard to a wooden board and voila, the TV tube regen radio was born. Below is the schematic of the final design.

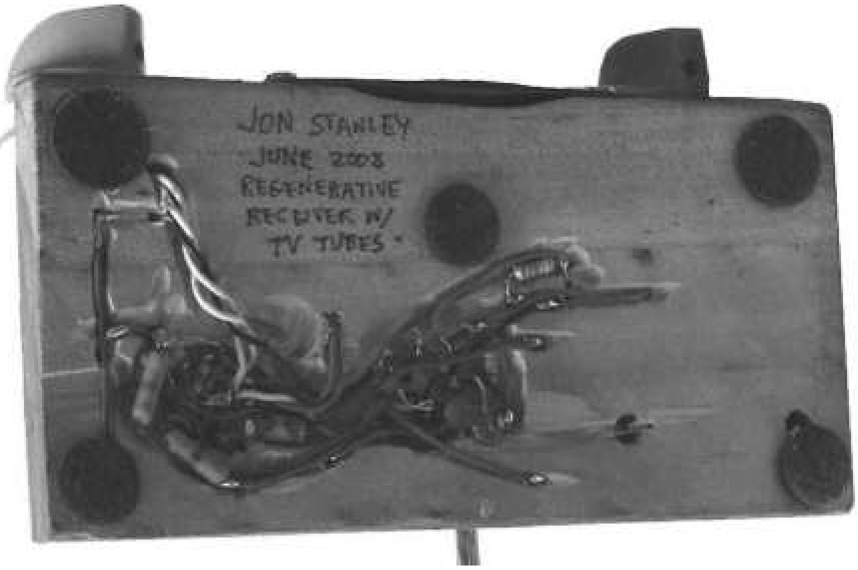


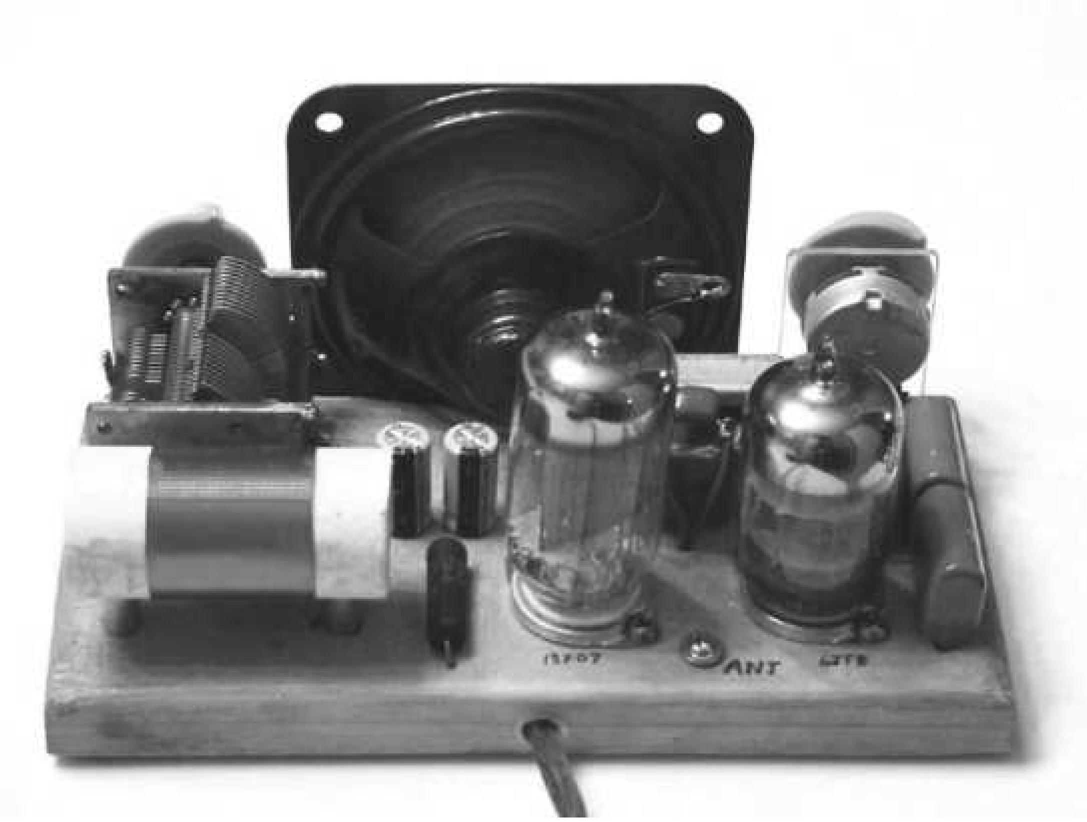
Note that the radio is transformer-less (*I **ALWAYS** ADVISE AN ISOLATING TRANSFORMER! G6NGR*) and the tube filaments derive their power from 120V mains while in series with a 15uF 250V non polarized capacitor. (*see the article later in this issue on mains connected capacitors! G6NGR*) The 15uF capacitor drops about 105 volts at 0.725A at a 60Hz line frequency. Most of the smaller parts such as the 1/4W resistors were stuffed under/inside the wood board. The radio picks up several stations with a short antenna.



The radio was first built on a generic breadboard for experimenting. I soldered longer leads to the tube sockets so they could plug into the breadboard easily. The filament power for the two tubes were supplied by two separate low voltage bench supplies.




JON STANLEY
JUNE 2008
REGENERATIVE
RECEIVER W/
TV TUBES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Audio Topics

Using a power transformer for valve audio amps

Valve audio output transformers are rare as dobby horse droppings nowadays, or nosebleed expensive - so try a mains transformer as a switch hitter until the genuine substitute is available. 230v to 6v are a good bet; a 2 or 5VA size will be adequate for a few watts of audio, but don't expect hifi!

Primary Volts rating	Sec'y Volts rating	Speaker Ohms	Anode Resistance
415	24	8	2.40k
380	24	8	2.05k
230	24	8	735R
230	15	8	1.88k
230	12	8	2.94k
230	6	4	5.87k
115	24	8	184R
115	15	8	470R
115	12	8	734R
115	6	4	1.47k

How to work out any impedance value:

(1) Calculate the Primary volts divided by secondary volts to get the turns ratio, "TR"

(2) Square the value you calculated for "TR"
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(3) Multiply this number by the loudspeaker resistance (commonly 8 ohms) to get the equivalent anode resistance.

For instance, consider a 115v to 5v rms transformer.

TR = 115/5 = 23. Square this number: TR^2 = 529. Multiply by the loudspeaker resistance you want to use, say 16 ohms: Anode resistance = 16 x 529 = 8.464k-ohms.

Wire the loudspeaker to the low voltage secondary; the high voltage primary is the anode load. HiFi it's not, but it will get you going until a proper replacement arrives. The iron in power transformers is designed for 50 / 60 Hz duty; you'll notice a degradation in the treble frequencies. Counteract this by using capacitors for treble boost (look up "tone control circuits", for example) on the primary side to lift the HF response; a bit of "cut and try" with whatever capacitors you have to hand will usually find a workable value. If you're a CW / Morse operator, you can peak up your preferred audio note (usually ~800Hz or so) with a resonance peak using parallel capacitors on the anode side, which will give you useful filtering and tighter receiver bandwidth gratis.

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Oscillator Topics

"Over and Under" frequency control

Many moons ago I had a job which required me to generate "over and under" frequency signals by comparing an incoming pulse stream with a precision reference square wave. With a handfull of NAND's, NOR's, and an inverter or two, I created the required signals. The problem was though, as the incoming pulse train closed in on the reference signals, the gates delivered narrower and narrower pulses: the gate speeds became an issue when I pushed the incoming frequencies up to 10MHz and beyond. I used low pass R/C filters to generate DC error signals from the "over and under" gates, very much as a PLL loop is stabilised by a LPF on the phase comparator output.

With modern 74HC gates, however, the speeds are well up to 50MHz; and using these simple digital comparison techniques would easily cope (in theory...!) with the HF bands. It would be possible to make oscillators that, given accurate timing references, could stay rock solid infrequency (in theory...!). The obvious flaws to this scheme are the phase noise characteristics, which weren't an issue in my low HF application, and the response to sudden shifts - anything with a LPF in the system can't react instantly! This also precludes any frequency agile requirements; not that amateurs are likely to be allowed "frequency hopping" and similar techniques!

The Huff-n-Puff system is a close cousin of these techniques: and again with modern 74HC gates, a simple oscillator can be stabilised to very effective limits. There are several existing logic gate Huff-n-Puffs which give superb results when implemented with 74HC gates; a web search will bring many ideas.

Timing reference pulses are the key in these techniques, or indeed any other "counting" or "comparison" circuits. A glance at:
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https://processors.wiki.ti.com/images/f/f1/TI_GPS_PPS_Timing_AppNote.pdf will give background for generating the timing pulses to high accuracy.

Transmitter Topics

An "Oddball" Tube A.M. Tx

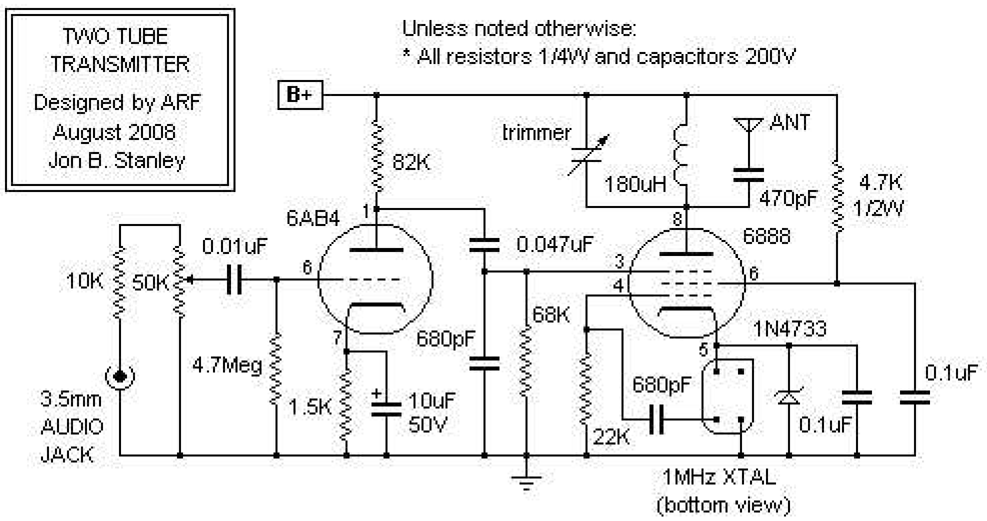
Following on from the receiver earlier in this edition, here's a lovely transmitter to go with it: it also uses an "Oddball" pentode very successfully and elegantly with suppressor grid modulation. Obviously a switch or two and a keying relay will produce a very nice QRP CW transmitter. "Where do I get such an oddball valve / tube?" you ask... look at:

https://www.ebay.co.uk/sch/i.html?_from=R40&_trksid=m570.l1313&_nkw=6888+pentode+tube&_sacat=0

Or check the valve / tube alternative references in the Data section of Hot Iron. For pentodes with an internal Suppressor grid to cathode connection, consider Screen grid modulation or Cathode modulation; each with added touch of Control grid modulation for better audio. You can use demodulated RF output as a feedback signal to "linearise" the audio response for these "unconventional" modulation methods.

Whilst this schematic is set up for 1MHz MW transmission, aspiring amateurs will very readily substitute a crystal oscillator more suitable - please note: a low pass filter is required for the antenna connection!

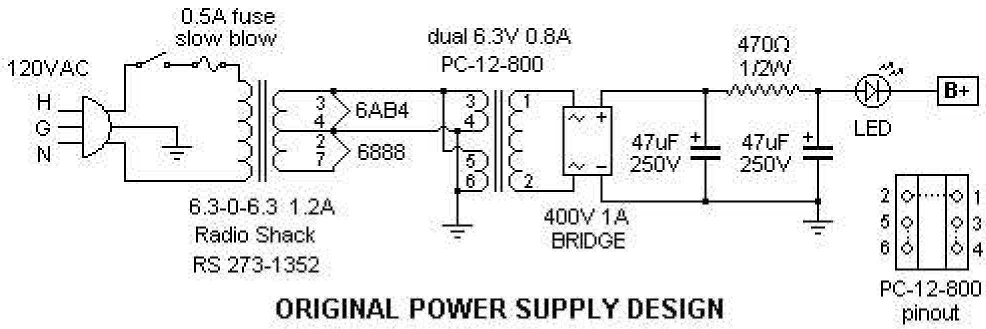
Some fellow ARF (Antique Radio Forum) members offered to send me some parts to get started on a quite successful 6888-based AM transmitter. The 6888 is an oddball octal tube that goes by the description of "dual control pentode" because its first grid and suppressor grid both are used as a control grid. In the kit design, a 6AB4 or 6C4 is used as an audio preamp and the 6888 as the transmitting tube. Below is a schematic of the transmitter as designed by members on ARF.



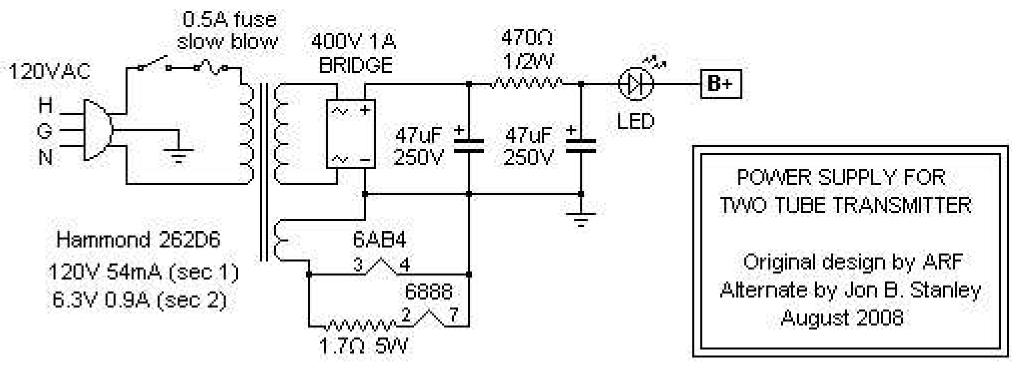
The circuit is fairly straight forward for a transmitter but there are some noteworthy features. The 1MHz crystal oscillator requires 5 volts and produces a nice square wave output at 1MHz. These oscillators are normally used in TTL or computer circuits because it is a self-contained oscillator rather than a mere crystal. The cathode current by the 6888 is sufficient to provide power to the crystal oscillator and a 1N4733 (5V 1W zener) is used to regulate the voltage. The oscillator output controls the first grid of the 6888 to create a clean 1MHz carrier on the plate. The inductor and trimmer capacitor above the plate of the 6888 serves as a tuned LC tank. The trimmer capacitor will adjust the output strength and thereby the range of the transmitter. The range is largest when the LC circuit resonates at 1MHz.

For use with stereo audio, another 10K is used from the second connector to the 50K pot to basically combine both channels into a mono channel before being transmitted. The 6AB4 serves as a very high gain preamplifier. The carrier is modulated by feeding the audio signal from the 6AB4 into the other "control" grid of the 6888.

The power supply is solid-state and uses a bridge rectifier to provide a very smooth B+ for clean audio quality in the transmitted signal. The original design used two back-to-back low voltage transformers to provide filament power and isolated mains voltage. The isolation allows this transmitter to be safe to use with just about any audio equipment without the hazard of shorts or shock. Although I was sent the odd PC-12-800 transformer, I did not feel like sending in a mail order for the Radio Shack transformer so I used a Hammond 262D6 transformer that I had left over from an experiment. Below are schematics of the original and alternate designs.



ORIGINAL POWER SUPPLY DESIGN



ALTERNATE POWER SUPPLY DESIGN

The PC-12-800 is a dual secondary transformer that is capable of producing 12V 0.8A with the secondaries in series, or 6V 1.6A in parallel. The Radio Shack transformer is 12VCT 1.2A and half gives sufficient power for the 6V 0.8A filament power requirements of the 6888 tube. The other half provides power to the 6AB4 and the two 6V windings of the PC-12-800 transformer to produce isolated 120V on the other side.

Another interesting thing to note is the use of an ordinary indicator LED in series from the B+ to the transmitter load. When the transmitter is first turned on, the LED remains off and slowly illuminates to full brightness when the tubes warm up completely. The LED is a good indicator of the load current and most LEDs are limited to 20mA of current so I figured the 120V 54mA winding of the Hammond transformer should have no problem. During construction I experienced some unforeseen short or miswiring in the circuit that caused the transformer to heat up quickly and give off the smell of fresh polyurethane. Not good. The bridge rectifier ended up ruined and caused a 500mA !!! load on the 120V 54mA secondary of the transformer. Now with the issues cleared up, the B+ runs at around 180V at 20 to 25mA as expected. Before determining the cause of the short on the 120V secondary, I assumed the overheating was due to the 50mA excess load on the 6V winding. The 6888 and 6AB4 filaments combined draw 0.95A at 6V while the transformer is only rated for 0.9A. However, inserting a 1.7 ohm 5W resistor reduces the 6888 filament current to a reasonable 0.75A to bring the overall current load to a tolerable 0.9A for the transformer, albeit a slight reduction in transmission strength due to a cooler 6888 tube.

The 50K pot in the circuit controls the amplification of the input audio signal and in effect controls the modulation strength of the output. For strong audio signals, too much amplification would result in over modulation and distortion. In short, the pot is used to adjust the output to achieve 100% modulation for best audio quality.

The transmitter components, including the Hammond transformer, were quite literally crammed in a roughly 2x5x2 inch Radio Shack project enclosure box. When in operation, the transmitter was able to reach many radios in the entire house with a short 3 foot telescoping antenna. With a portable CD player as the audio source, the audio quality of the transmitted signal through many AM radio receivers were very good.

Single Sideband FM...

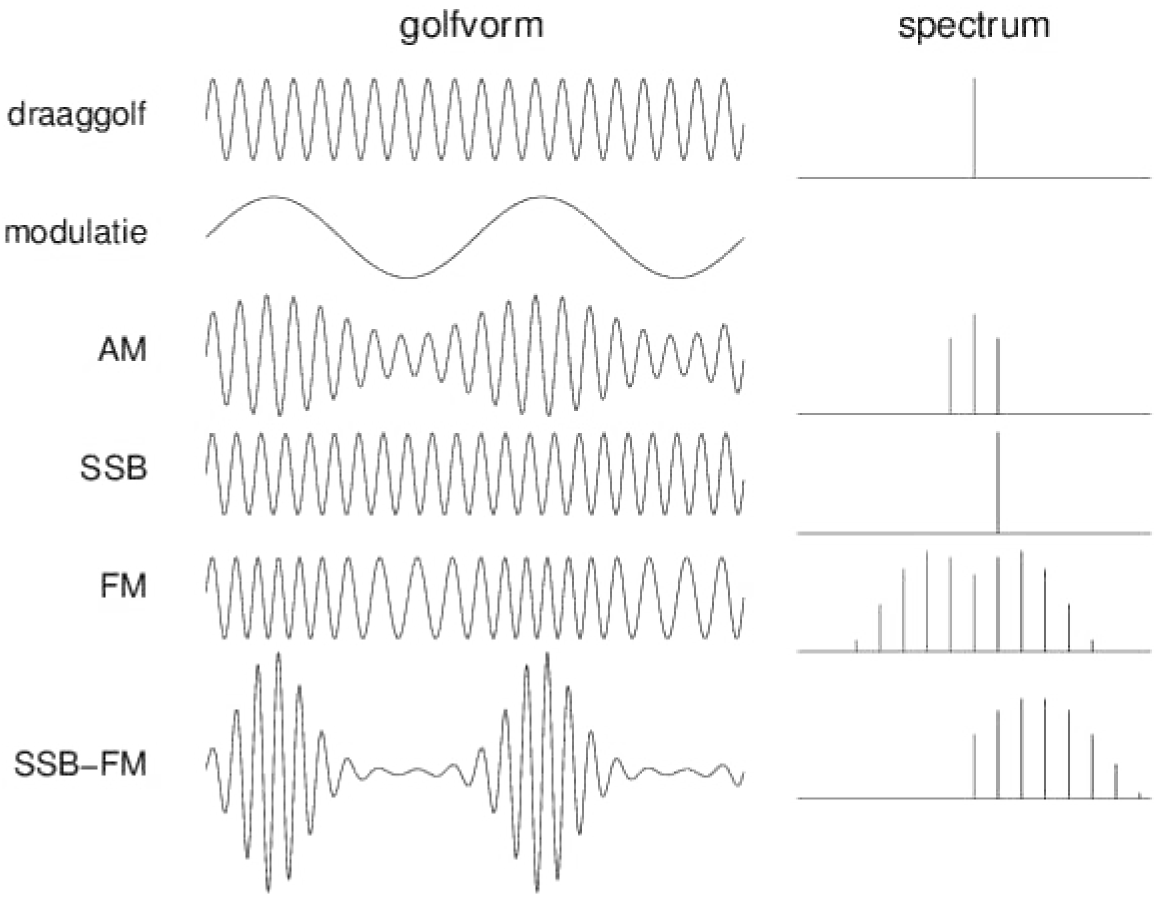
Pieter-Tjerk de Boer, PA3FWM pa3fwm@amsat.org
(This is an adapted version of an article that I wrote for the Dutch amateur radio magazine *Electron*, July 2012.)

This instalment is about SDRs, about inductors, capacitors and antennas, and starts with a strange modulation type.

Single-sideband FM

When studying for an amateur radio license, one learns about several modulation types, in particular amplitude modulation (AM), frequency modulation (FM) and single-sideband modulation (SSB). SSB saves bandwidth in comparison to AM by omitting one of the two sidebands, because they contain identical information anyway. With FM, there are also sidebands on either side of the carrier. Does that mean one could make a single-sideband version of FM?

Indeed, in the 1960s research has been done into "SSB FM". That was not done by taking a normal FM signal and filtering one sideband, but by *simultaneously* modulating the carrier's amplitude and frequency. This method was invented in (1) based on a mathematical analogy with "normal" SSB.



Let's compare the different forms of modulation. The top part of the figure shows an unmodulated carrier, both in the time domain (the sine wave) and in the frequency domain (the spectrum diagram at the right). Just below this, the modulating signal is shown, in this case a slower sinewave. Below this, AM and SSB are shown; the sidebands have only a single peak here because the modulation is a pure sinewave.

Next is FM: we see that the amplitude is now constant, but the frequency varies: in the peaks of the modulation, the frequency is highest, in the valleys it is lowest. The spectrum is more complicated: even with a pure sinewave as modulation, there are multiple components in each sideband.

At the bottom, single sideband FM is sketched. If one looks carefully, one sees that the frequency varies here exactly like with normal FM. Much more noticeable however is that the amplitude is also varying: in the modulation peaks the amplitude is high, but the signal disappears almost completely in the modulation valleys. This amplitude modulation is not linear, but is performed via an exponential function; that explains why the envelope is no longer a nice sinewave. In the spectrum we see that the lower sideband is completely gone, but the upper sideband extends even a bit further than with normal FM.

Can we intuitively understand what happens with SSB-FM? The effect of the amplitude modulation is clear: in the valleys of the modulation, the amplitude is reduced quickly; this is when the frequency would be below that of the carrier itself, i.e. in the range of the to-be-suppressed sideband. In the peaks of the modulation, the frequency is on the "good" side of the carrier, and the amplitude is increased. Intuitively, this already suggests that the upper sideband will be made stronger and the lower sideband weaker. By modulating frequency and amplitude simultaneously, *both* modulations contribute to both sidebands. Both of these contributions add, and then it can happen that the AM contribution precisely cancels the FM contribution. If one does this precisely right (mathematically proved), *all* lower sideband contributions cancel, leaving only the upper sideband, which however has become a bit stronger and wider.

Is this SSB-FM good for anything in practice? Well, not really (otherwise, it would surely have found more use). SSB-FM needs less bandwidth than normal FM, but still more than "real" SSB (i.e., derived from AM). An advantage of SSB-FM is that it can be demodulated by a normal FM demodulator. However, a disadvantage is that during the valleys of the modulation the transmit power is almost zero, especially at large modulation index (deviation). Practically, this means that the valleys of the modulation will have a rather bad signal to noise ratio.

In the 1970s, several Dutch amateurs (in particular PA0EPS) invented something related but different, namely "SSB-compatible FM", also called "phase-locked loop SSB" (2). This was made by sending a normal SSB signal through a PLL. The PLL then creates a signal with constant amplitude, whose frequency depends on the SSB signal. Thus, the signal only varies in frequency (so we can justly call it FM), but in a way which can still be listened to using an SSB receiver (hence "SSB-compatible"). The main purpose was to reduce interference to consumer electronics.

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A solid state 4CX250B? Nearly!

This is from John Kirk, VK4TJ, and describes my thoughts to a "tee"...

"I'm really a QRP'er. Honest! It's a lonely life, here at the edge of the planet, made that much more lonely by the insidious proliferation of switch mode power supplies, which seriously impair most of my QSO partners ability to dig deep for the weak ones. I had a rant about this in a recent "K9YA Telegraph" article. While it made me feel better, it didn't actually result in any more QSO's. If I cannot change your predilection for surrounding yourself with RF-noisy electronic gewgaws, I must give up the hobby or go QRO to tip the scales back in my favor. So QRO I go. Reluctantly. With much trepidation, for I have not worked with hollow-state devices or high voltages for some years. Subconsciously, I think I must have wanted this project to fail, because I imposed upon myself the ludicrously low budget of $25 – just 1 percent of the price of a new amplifier. The fact that you are reading this hints that, beyond all expectations, the project did in fact deliver the (white) goods.

Bill of Materials

Tube: No contest – cash in some of your cold war dividend and purchase a few GI-6B's from Vladi, UT5JDS. At just $7, these are the hands down clear winner in the watts per dollar sweepstakes. With 350-watt anode dissipation, you can expect 500 to 600 watts output from one tube. As you will read later, this dovetails nicely with the limitations imposed by our scrounged transformer. It's a bit frightening to contemplate the use of a self-described "microwave oscillator" tube in an HF amplifier, but in practice, they work out just fine. Being a triode, we neatly sidestep the beginner jitters around screen supplies and sequencing of power turn-on. Better still, the GI-6B really doesn't
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need a socket. Priced 4CX250 sockets lately? You'll understand why your new best comrade is in fact, a Red Army defector.

Plate Blocking Capacitor: While you are in negotiations with Vladi, price in a few 5 kV capacitors. At $3 ea or so, they won't break the bank either, and can be rather hard to find in the capitalist economy.

Socket: Wait a minute - I just finished telling you that the GI-6B doesn't need a socket! Pay attention, will ya! Seriously, it is convenient to be able to replace the tube without ripping the amp completely apart. I am deeply indebted to Frits, PA0FRI

http://www.xs4all.nl/~pa0fri/Lineairs/GLA1000/gla1000eng.htm

for pointing out the ordinary tool clips make good contact rings for the GI-7B/GI-6B.
Frits only used tool clips for **temporary** sockets, but in practice, I've found that they are a perfectly acceptable permanent solution.

Plate Transformer: Raid the kitchen garbage for a defunct microwave oven, preferably a 1 kW, or even 1.1 kW nuker. Dead it may be, but I've only ever seen one with a defunct transformer – generally, it is the magnetron that fails. Repair is not generally cost-effective, given that microwave ovens are currently on sale at my local "Junky John's" for $49 AUD. You are going to read all sorts of rubbish about microwave trannies – that they lack insulation at the earthy end, that it is somehow "too special" for our purposes, perhaps even that it eats it's own young, but your own investigations will reveal that they have just as many wraps of paper and varnish at the earthy end as they do at the hot end. Snip the grounded end at the rivet, build a front porch for the liberated connection out of etched PC board or some other suitably insulating material, and you are away. Don't forget to bung out the magnetic shunts – laminated rectangles of steel located betwixt the primary and secondary windings. It **is** true that the magnetizing current is rather high in a nuker tranny. If you suffer from cold feet in winter, it is recommended that you build the power supply in a floor-mounted separate enclosure so that you can warm your toes on it. Otherwise, find two roughly equivalent transformers, and wire them up series primary/series secondary. This dramatically reduces the standby current, and probably pulls the combo well back from the hairy edge of saturation as well. Sadly, microwaves are obviously spec'd out in "marketing watts", a unit of measure not bound by the physical constraints of our universe, so there is not much point in hosing up a second GI-6B in parallel to go for the full gallon. That's also why we're such fussy garbage-pickers, sending our meal back repeatedly to the kitchen if it isn't at least a 1 kW nuker.

You'll probably find that the secondary voltage is a tad high for our purposes – around 2200 VAC if yours are like mine. There is plenty of anecdotal evidence that the GI-6B will cheerfully withstand this, even full-wave rectified, but if you are lucky, you may find that turns can be removed from the secondary. No? Then consider **adding** turns to the primary (usually easier). Anything you are able to do on the primary side will, as an added bonus, also reduce the rather high magnetizing current.

Rectifiers: You guessed it – dead microwaves again. You'll need about four carcasses, so put the word out amongst your friends. Don't have any friends? Join your local "Freecycle" group (q.v.). You will be amazed how fast the dead can move (towards your junk box), and in what numbers!

Filter caps: There are two ways to go here – you can liberate lovely 1 uF oil-filled caps from microwave ovens that will probably provide you with years of trouble-free service, but you will need to find about 20 of them to parallel up. As an added bonus, each comes with an integral bleeder resistor - but – even 20 in parallel probably isn't enough bleeder for our purposes. Alternatively, if there are any PC CRT's left on the planet that haven't already been bulldozed, they generally contain at least one 220 uF, 450 volt electrolytic. Series up about 8 of these, and you've got a really nice filter bank. Of course, you then have to come up with equalizing resistors. Your call.

Blower: Yep, microwave again. Like most external anode tubes, the GI6B's **gulp** the air. In large doses. Conventional wisdom states that only an (expensive) squirrel cage blower can do the deed – that blade fans simply cannot handle obstruction. Sadly, conventional wisdom is nearly right. A cardboard mock-up, including a chimney around the fan blades and the anode cooler yielded – nothing! It was only when I mounted the tube axially, and cut a "wind tunnel" the same diameter as my blower blades into my enclosure, that I began to see any air movement across the anode cooler. Obviously, we must screen this opening with hardware cloth to keep prying fingers from finding our 2 kV supply, but mine was going into a 19 inch rack, so I'm pretty safe on that score. I also mounted the microwave blade fan as close as humanly possible to the cathode of the tube. The proof of the puddin' is obviously in the eatin': I see less than 2 degrees C temperature rise on the anode cooler after a 15 second "brick on the key" episode. I'm calling that a win! And, no, I'm not going to tell you how I made those temperature measurements – I'll reserve that for an episode of "Mythbusters". Or maybe a remake of "Dumb & Dumber".

Filament Choke: For a change of pace, we'll raid a dead CRT or television for this one. PY2WM put me on to the potential source of balun material in his brilliant treatise:
http://py2wm.qsl.br/balun/Balun_with_free_ferrite.pdf
It would appear that the flyback core, with its almost supernatural permeability, would serve us best. I glued the two halves of my victim end to end in order to keep the "gozinta" end well separated from the "gozouta". The swastika-like end result no doubt raises a few eyebrows, but performs well.

Filament transformer: I think mine came from a defunct AM/FM stereo receiver – I don't really know. The GI-6B wants a rather modest 12.8 volts or so at 2 amps, which shouldn't be too hard to come by. Don't ignore OEM or even PC power supplies. We're not slighting the sexual orientation of the filaments – they really are AC-DC! If you are really stuck, you could bung the secondary turns out of one of the baby 600-watt microwave transformers you accumulated along the journey, and replace them with a 12.8-volt low voltage secondary. There would be ample room for another "control electronics" winding for relays and suchlike.

Bias Board: My circuit was a blatant theft from: http://www.nd2x.net/oz1dpr/schalt.jpg
because the parts required were all in my junk box. No parts made of unobtainium here! I suspect my pass transistor was once a TV or CRT horizontal oscillator device, but I'm not really sure. Feel free to make substitutions – the circuit is quite tolerant of that.

Meters: Mine were QA rejects from my former employer. Since you are unlikely to be so lucky, I might suggest plant pot moisture meters. If it amuses you, you may leave the original calibration of "moist" to "wet" in place, or freehand some new scales. For a distinctly high-tech look, I am told that Asian Ebay sellers periodically put their DVM's on special for the princely sum of $1.99 each. You are unlikely to better this price, analog or digital! Of course, now you **really** need a "control electronics" DC supply – no way I'm reaching in there to change those 9 volt batteries!

Plate RF Choke: You guessed it – microwave again. I unravelled a blower motor winding for wire, and spooled it onto a ½-inch or so diameter dowel. I may have got a bit carried away, as my choke came in at over 400 microhenries, vastly more than we need, but no nasty resonances were noted, at least like where I like to operate, so I'm calling it a win.

Cheese Slicer "Tune" Capacitor: Sorry, you are on your own here. I prised mine from the fingers of an old geezer too long in the tooth to homebrew any longer, but if you are too proud to beg, you can always have a go at building your own:
http://www.eham.net/articles/5217

Plate Inductor: I happened to have a chunk of B & W Minidux in the junk box, so used that, but it's nothing you couldn't replicate with a bit of 2-inch PVC pipe and a bit of household wire. My amp is an untuned input, so a band change, while not trivial, is as simple as changing a tap – but not to be undertaken while half asleep! A roller inductor might be a better option, but would almost certainly blow out my modest project budget. A band switch capable of this kind of power is clearly out of the question! Interesting economics, eh? When playing with 7-dollar finals, it's actually less expensive to build 9 monoband amplifiers than to purchase a band switch!

Multi-gang "Output" Capacitor: I suspect that the aforementioned defunct stereo tuner might have donated this – I don't really know. It is about a 6-section variable capacitor, and, with all sections paralleled, yields about 1000 pF at maximum – not quite enough for 160 meters, but certainly more than adequate for 80 through 10 meters. As Bill Orr, W6SAI, amplifier guru extraordinaire, was quick to point out in the "West Coast Handbook" ("Radio Handbook", most editions), we're back to 50 ohms at this point in the circuit, so the plate spacing requirements are not onerous.

Relays: Ordinary control relays are quite adequate at HF – study any 70's vintage boat anchor, and you'll see what I mean. I'd like to say that I scavenged these from a dead microwave as well, but in reality, the beefy relays in a nuker always seem to be SPST. We want SPDT. I have no idea where mine came from, but suffice to say, they're a common item in the scroungers marketplace.

Chassis/Sheet Metal: You guessed it – microwave again. The presence of both an outer and an inner skin (cooking cavity) presents both some challenges and some opportunities. We can let components "dance on the ceiling" if we choose, knowing that their mounting bolts will not show, but some of the soldering is reminiscent of keyhole surgery, so special care must be taken to avoid cold solder joins. The sheet metal between the power supply compartment and the cooking cavity makes a very nice plate/grid shield, which we sadly violate, of course, when whittling our wind tunnel through the lot, but no signs of instability were noted. Although steel, the microwave oven carcass is of light enough gauge that there is no danger of burning out drill bits - an absolute pleasure to work with

Besides, how many other enclosures colour coordinate with your kitchen décor, and come with bragging rights: "Amp here is a Samsung, OM – strictly an appliance operator here".

Test Equipment & Fault Finding

Bird 43

Those of us who have done battle with power RF know Bird 43 instruments: simple, rugged, reliable and a true engineer's friend. Amateurs too can access a wealth of useful graphs, nomograms and data from the Bird user guide and notes, particularly the Loss vs. SWR charts and the like, for those who believe (incorrectly) that only a 1:1 SWR is acceptable. Take a look at:

https://birdrf.com/~/media/Bird/Files/PDF/Manuals/920-43.ashx

The information is applicable and useful to all amateurs.

Joe and his Multimeter...

Joe was a Technician who appeared one morning in the Autoprobe Test hall, where silicon wafers full of transistors were being probe tested for functionality - a basic 5 parameter go / no-go test. Duds were given a spot of ink, so the opto-electronics in the die bonders could ignore marked dies and move onto the next good device when the wafers went for die bonding onto the lead frames.

Joe had arrived without a toolkit - so a trip to stores got him a kit, plus a multimeter from the cupboard. Joe was not happy! Joe wanted a digital multimeter (not our favourite AVO MultiMinor analogue job) with a transistor test function, capacitance measurement, temperature sensing, just about every test function you could think of. So I got him a digital multimeter, garish yellow, from the local hobbyist electronics shop, and Joe was over the moon. For about a day! Problem was, he couldn't decide WHICH transistor to test, of the hundreds in the machine. Joe had the means to find almost any electrical value in the circuit; but it didn't help him diagnose faults. He could measure a mass of information; and soon realised that information is useless unless you know what to do with it!

The moral of this tale (apart from don't employ Joe in a fault finding job...): measuring every possible voltage, current and resistance IS NO USE WHATSOEVER. Fault diagnosing needs clear logical thinking, a multimeter - analogue or digital - that will show volts, amps and ohms, and a notebook and pencil to record what you've measured and where.

Applying this to amateur radio, you can have Mini network analysers, multi-function RF test gear, signal generators, RF voltmeters, Smith charts and a myriad other esoteric bits of kit; but believe me measuring or knowing every variable WON'T FIND FAULTS OR SOLVE PROBLEMS.

The rules of basic fault finding will find 99% of most problems. They are:

- Always check the power supplies!
- If point "A" is wired to point "B", don't assume it's electrically connected until you've tested continuity "A" to "B" then "B" to "A" and got the same (low ohms) reading both ways.
- Transistors have junctions; test them for continuity (on ohms or "diode" test) base-emitter, base-collector for conduction one way but not the other; and collector-emitter is open circuit.
- MOSFETs have no junctions; but continuity testing (watch polarity!) with the gate connected to source = open circuit; gate open and touched with a finger = short circuit drain to source (the AC mains pick-up on your finger turns the MOSFET on).

- Any transistor, IC or electrolytic capacitor that's boiling hot is suffering: be kind to your components, they do not like it up 'em! Either they are dud, or, more likely, something's low resistance in their vicinity, or they are in (unwanted) oscillation.
- Any electronic circuit has inputs and outputs: if you have output(s) with no input(s) then you've got either Divine Intervention (rare) or a circuit that's unstable or got shorts somewhere.
- It's almost impossible to see wiring mistakes on a strip board construction you've built yourself. Check every connection (and track break); pencil over the schematic diagram to show which connection you've just checked. Look too for tiny solder bridges between tracks, use a craft knife to cleat the gaps between the tracks.
- If you have the correct input(s) and no output(s) then that stage is dud, check from the input(s) forward toward the output(s), and look especially for open circuits.
- If that doesn't yield a result, check backwards from output|(s) back to input(s).
- To find dud coupling capacitors: try a capacitor on wire leads temporarily jumped in parallel with the suspect o/c coupling capacitor. If the stage comes to life with the shunt capacitor connected, you've an o/c coupler.
- Always replace resistors with identical parts; wirewounds are inductive, and if used in the emitter (or source) of an RF device, will most likely create a potent VHF oscillator.
- If adding an extra capacitor in an attempt to stop oscillation makes matters worse, odds on the stage is "squegging". Reduce the original capacitor a bit, and try again.
- If the antenna isn't resonant - or near resonance - then you'll need to add either inductance or capacitance **at the antenna** to get resonance.
- Don't waste time and effort trying to measure an antenna's reactance; out with your grid dip oscillator, and note the resonant frequency. If it's below your desired frequency, put some capacitance in series with the feed. If the resonant frequency is too high, add series inductance in the feed. It doesn't matter a Tinker's damn what the value of capacitance or inductance is, just try adding the capacitance or inductance until you have SWR of 1.5 or less. To work across a wide band of frequencies, you'll need to make the capacitance and / or inductance variable in some way.
- NEVER try to add reactance at the transmitter end of a co-ax feeder. Put it right at the antenna feedpoint.
- If the antenna impedance doesn't equal the co-ax transmission line characteristic impedance, you'll never get a good match; you need a transformer to get the impedances equal. This can be a tapped coil, "balun" or conventional primary / secondary transformer. The tapped coil is most useful for adjusting but make the taps secure and tight.
- Check the SWR is low enough across the range of frequencies you want to work.

- If the SWR is constantly low at ANY frequency, you've not got a perfect antenna; you've got a "dummy load"! Be aware that gross earth losses under a Marconi antenna can give the illusion of wideband low SWR, but yield very poor radiation as your RF is warming worms.

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Noise Source for Impedance Bridges etc.

In spite of the above "KISS" methods, a Noise Bridge is useful. Zeners will generate noise, but far better is detailed below.

(With grateful thanks to Gary Breed, K9AY and Terry Mowles, VK5TM)

A Logic Chip Comb Generator

A comb generator makes thousands of energy spikes across a very wide spectrum, making an ideal alternative to zener noise sources, with a better output over many decades. Examining the circuit (below) you'll see it relies on the propagation delay of NAND gates. I would suspect using Schottky LS TTL NANDs you'd get more in the higher frequencies; LS TTL gates are quick little beggars, but using CMOS in no way detracts from this ingenious circuit.

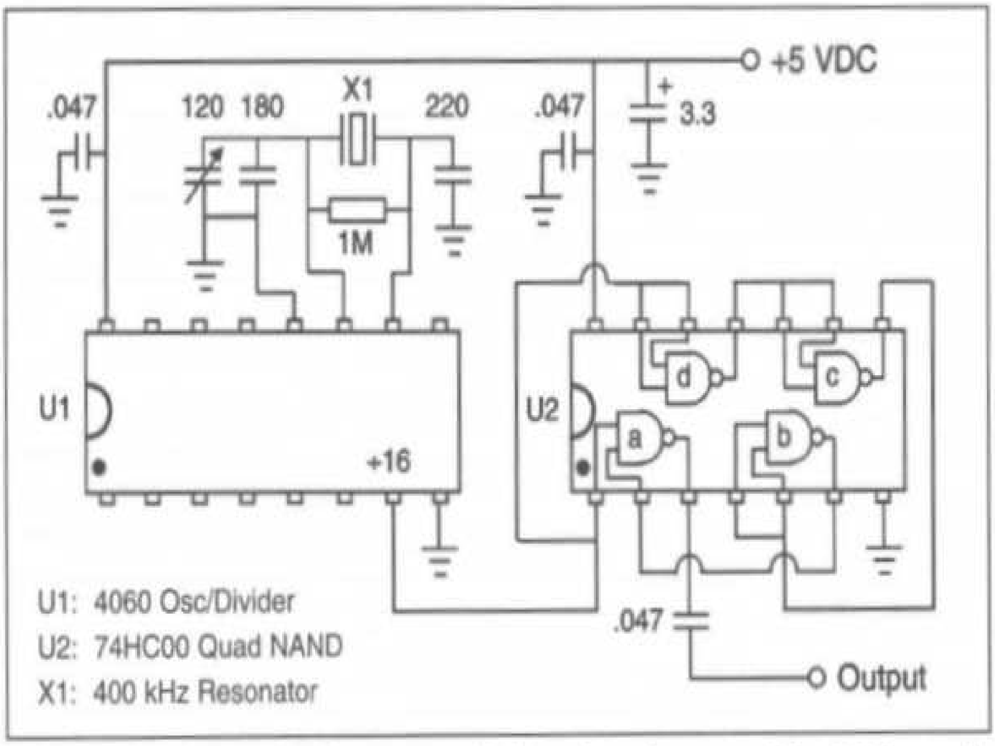

Figure 2—Circuit diagram of the simple two-chip HF comb generator.

On power up my oscilloscope showed it was all working...
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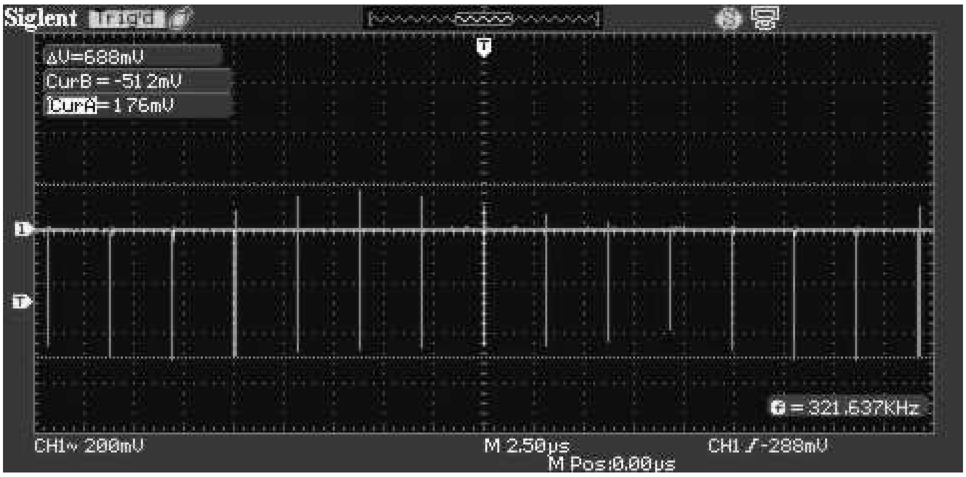
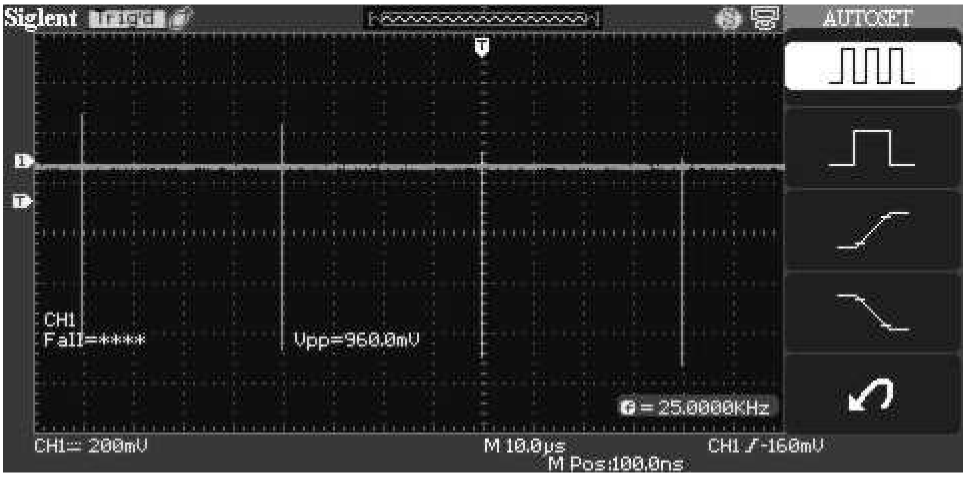


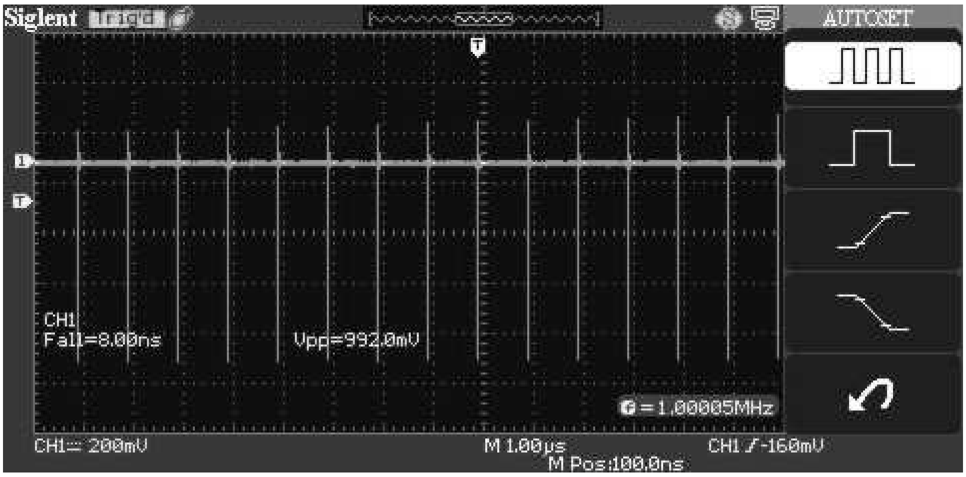
... except that it wasn't properly. The output was 321 kHz - not the 25 kHz it was supposed to be. Changing the ceramic resonator didn't help so I started googling for further knowledge - and found this document. Specifically, the clue was on page 14. Apparently ceramic resonators are known for going off at harmonic frequencies. The author suggested that capacitance around the ceramic resonator should be increased. So I added 100pF to the capacitor connected to pin 10 of the 4060 oscillator chip.

That was enough to make it oscillate correctly on power up, but when switched to the 1 MHz crystal position (that I had added) and then back, the resonator misbehaved again. Another 100pF fixed it.

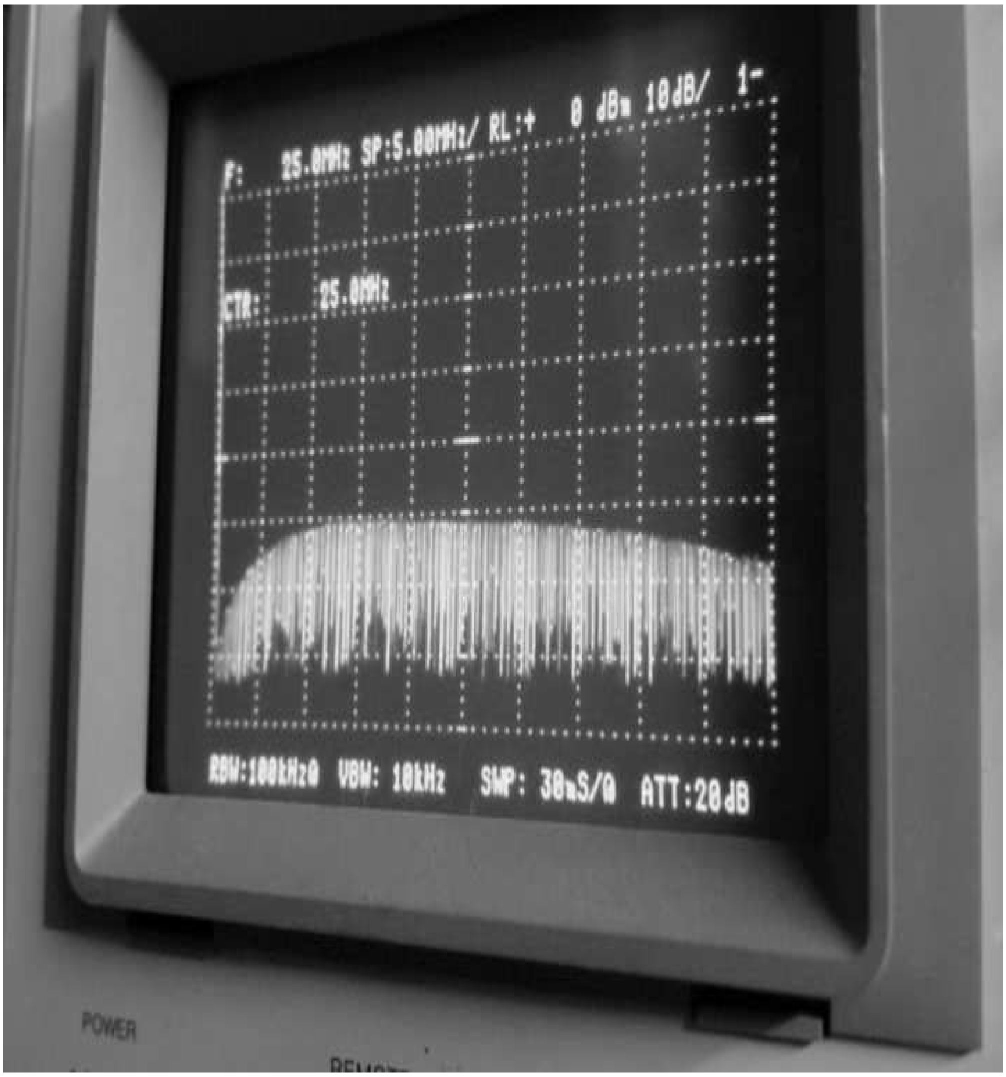


So it would seem that Gary's resonator and mine weren't quite the same and I had to modify his circuit. The resonator that you buy might need similar adjustments - or maybe none.

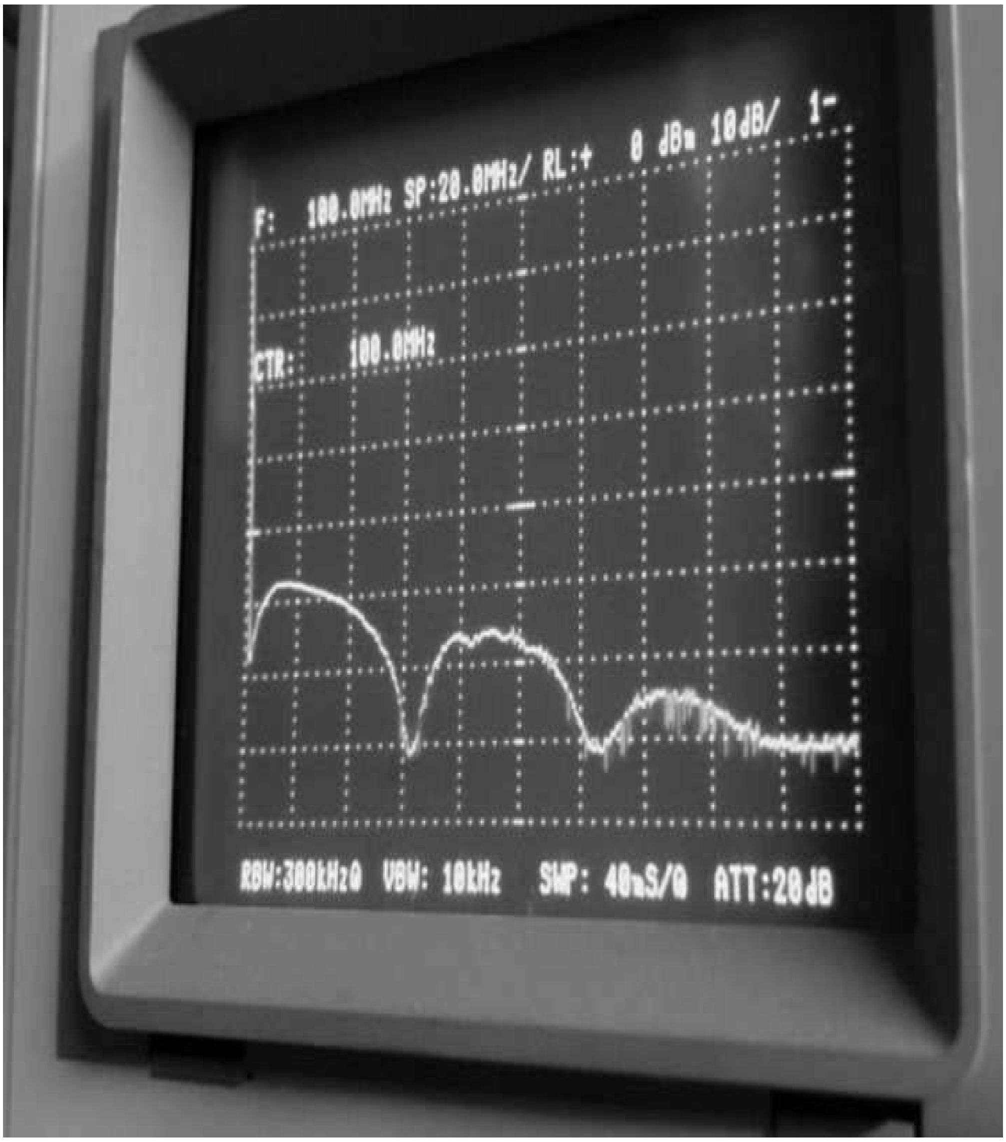
The 16 MHz crystal (for 1 MHz output) isn't bang on but close enough...



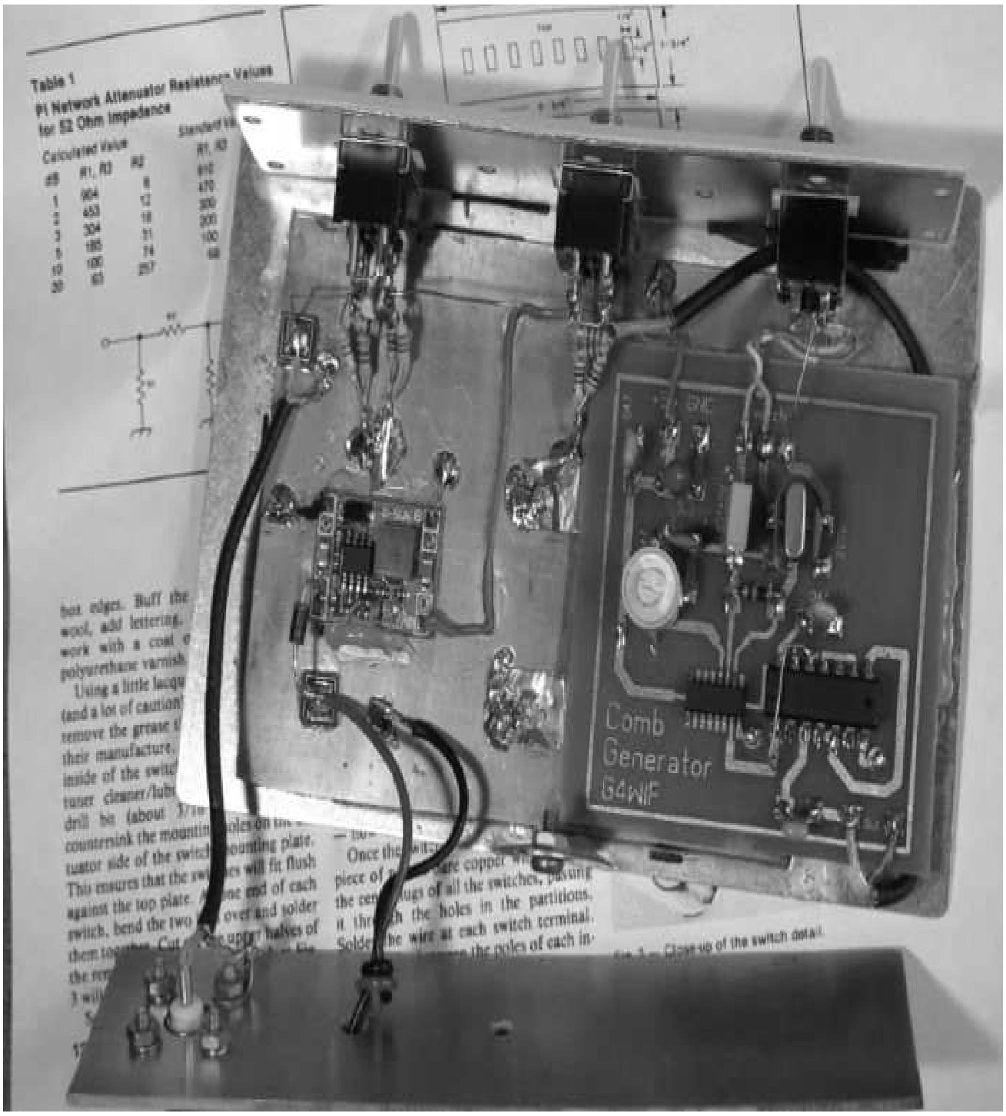
K9AY says that the comb generator "creates S9+ signals every 25 kHz from low frequencies to well beyond 30 MHz". He is being too modest because his design is much better than that and goes "very far beyond 30 MHz".
The spectrum analyser screenshot below is centred on 25 MHz with 5 MHz horizontal divisions. So you can see that there is a useful output way beyond the HF bands.



This other shot shows output to 180MHz with low points at 80MHz and 125MHz. This was a max signal trace to show more clearly the signal levels.

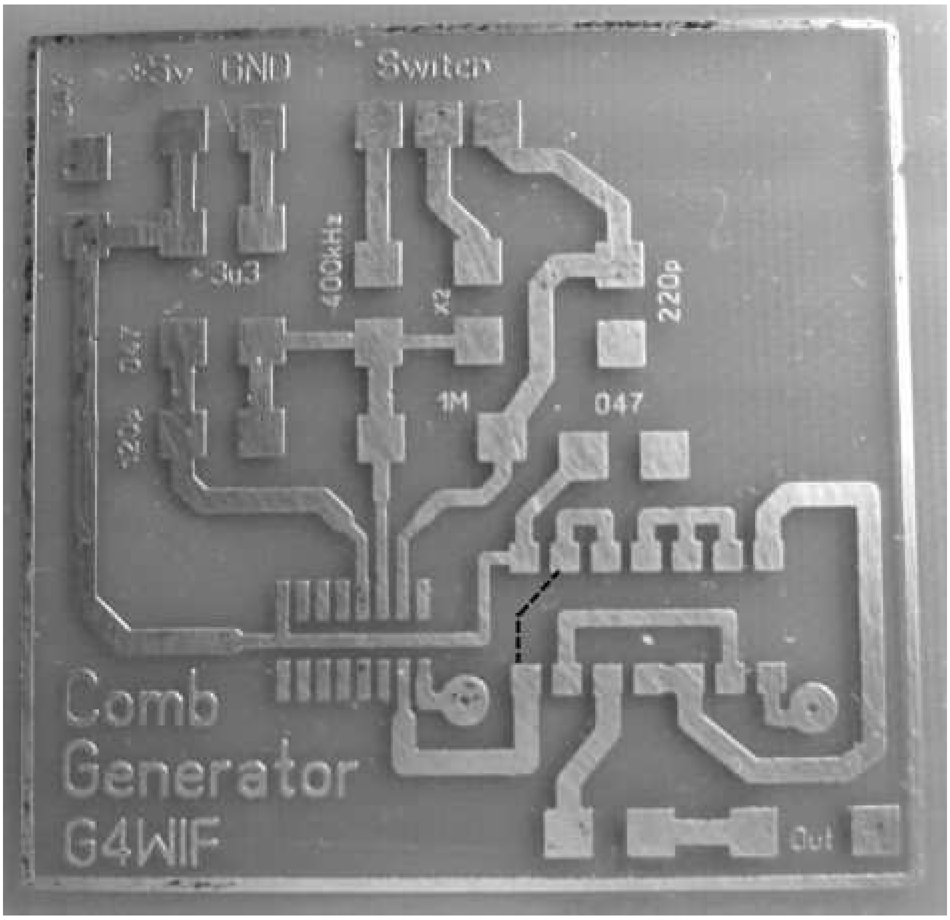


To vary the output I have added some switched attenuators to the K9AY design - which has as its signal source a 400 kHz ceramic resonator to provide 25 kHz signals (once divided down by the simple circuit).
I also added a 16 Mhz crystal to give me the alternative of 1 MHz signals via a switch. The attenuators provide 3dB and 10dB reduction in signal and the resistor values came from an article in September 1982 issue of QST. If you don't have the precise resistors in your junk box for the attenuator then this parallel resistor calculator will get you close.



The small (left hand side) printed circuit board which the red and black power leads attach to is a very inexpensive switched mode "buck converter". This takes the 12 volt input and provides the 5 volt supply to the generator. There is an idiot diode in the supply in the event of one of those senior moments when the leads get reversed.

This is the double sided printed circuit board etched using the toner transfer method.
Due to the way I designed the board, it must be double sided with connections to the reverse side ground plane. I've indicated in the Sprint Layout file where those connections are made.



You can see a black dotted line where I missed a track!

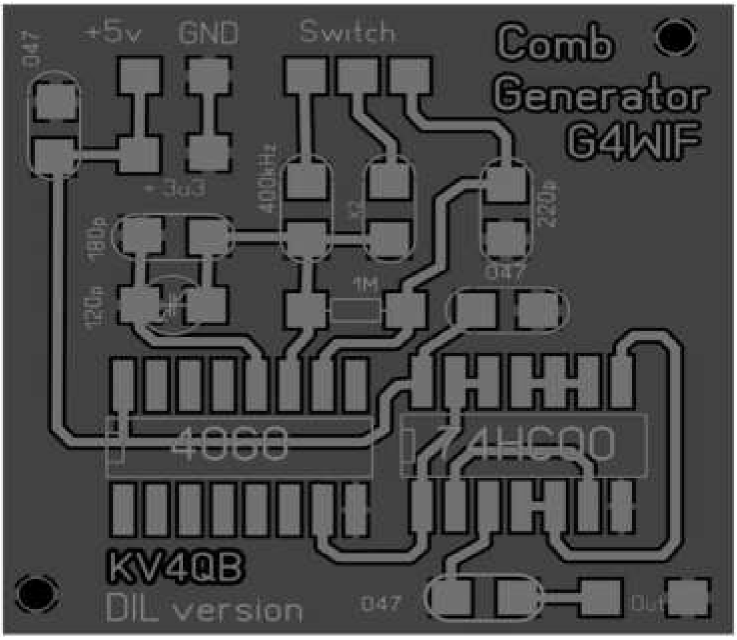
The more observant might notice that the 4060 chip is surface mount while the 74HC00 is D.I.L.

There is no special reason why I chose those package formats - other than when I ordered the chips, these were what was available at the right price and delivery time. The muppet building method is essentially surface mount and few of us older home constructors couldn't benefit from a decent bench magnifier anyway!

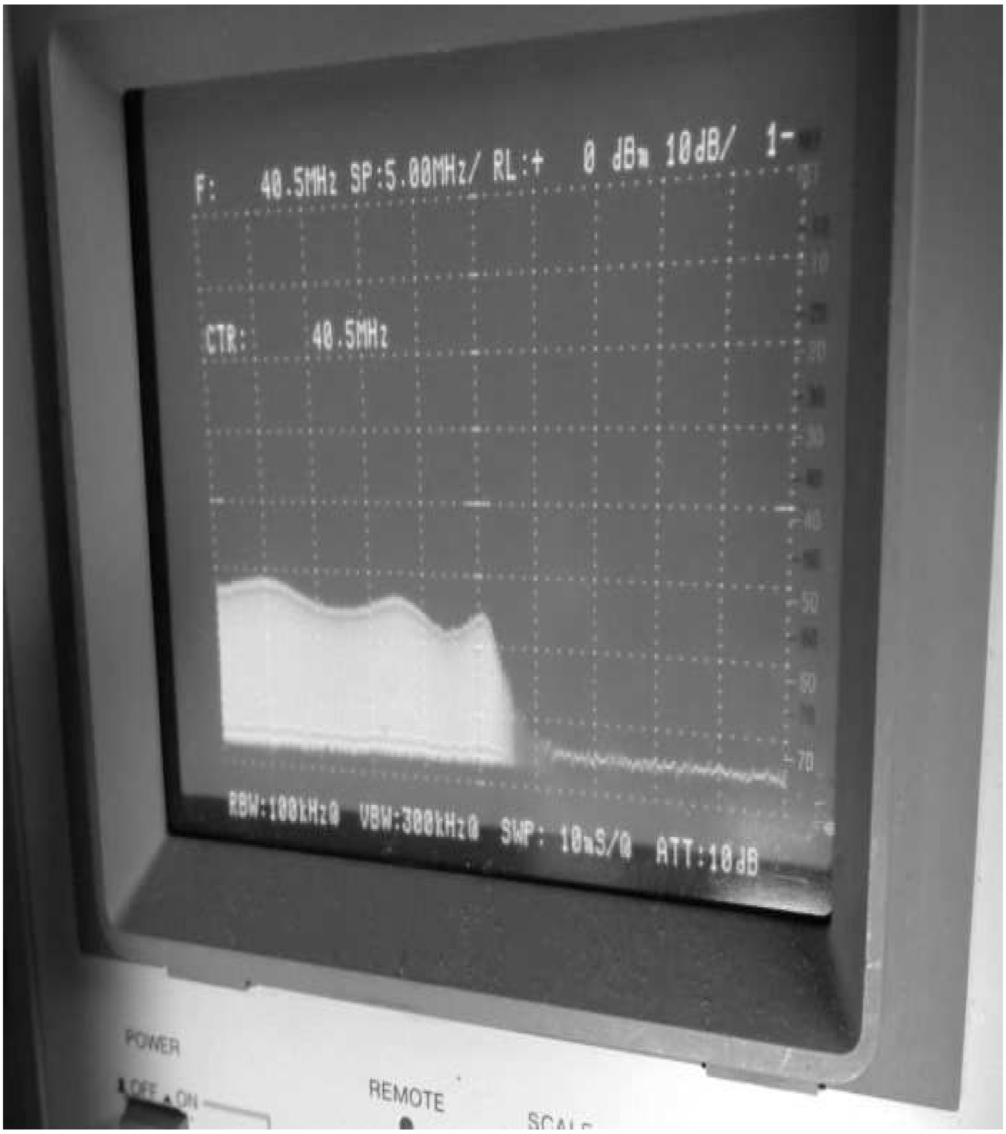
You will also note that as my home brew process doesn't do silk screen printing of component designation, I etch that in the top copper layer (as you can see above Sprint files).

You also might like to download a set of and reworked Gerber files by Terry, VK5TM.

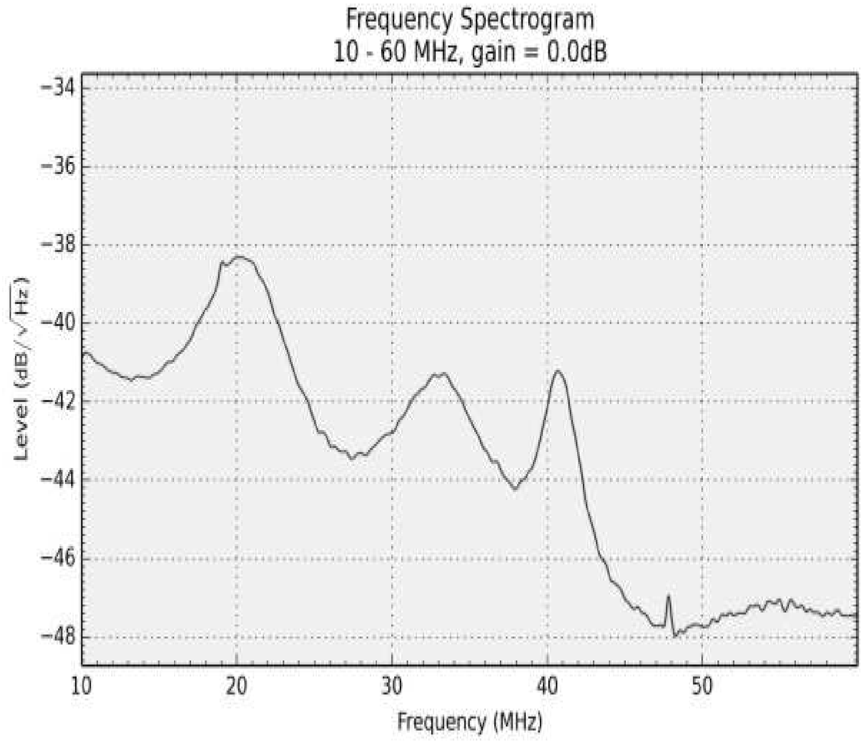
Another choice is the layout from DuWayne KV4QB. In his version he used 4060s that are 16 pin DIL type not SOIC. Muppet construction also modified to use a copper ground plane on the top and eliminate the need for any drilling.



I tried to test it using my zener noise generator which falls off in output as frequency increases. It was suggested to me that a comb generator would have a more consistent output - and that has proven to be so. With the output switched to the 25 kHz position, noise was injected into the filter and the output of the filter observed first on my spectrum analyser. Here is the result:



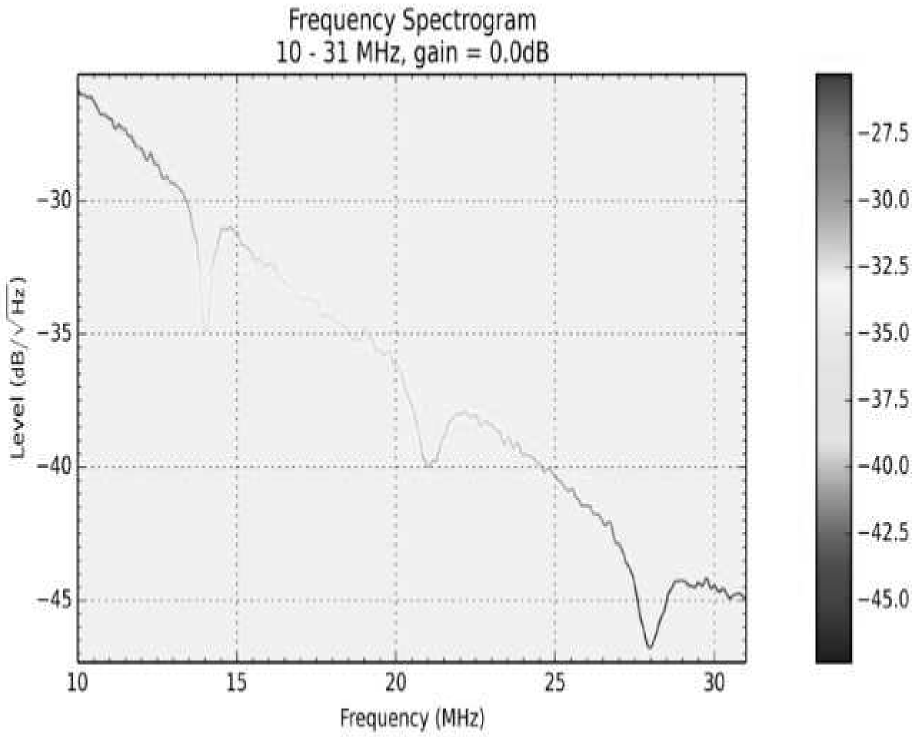
Clearly there is ripple and the cut-off comes a little higher than I would like - but the low pass filter can definitely be seen to be working and I can now make final adjustments to the filter.



My spectrum analyser is set to 10dB per vertical division while the dongle vertical scale is more “stretched”. So it looks more “hilly” - but essentially, it is telling the same story.

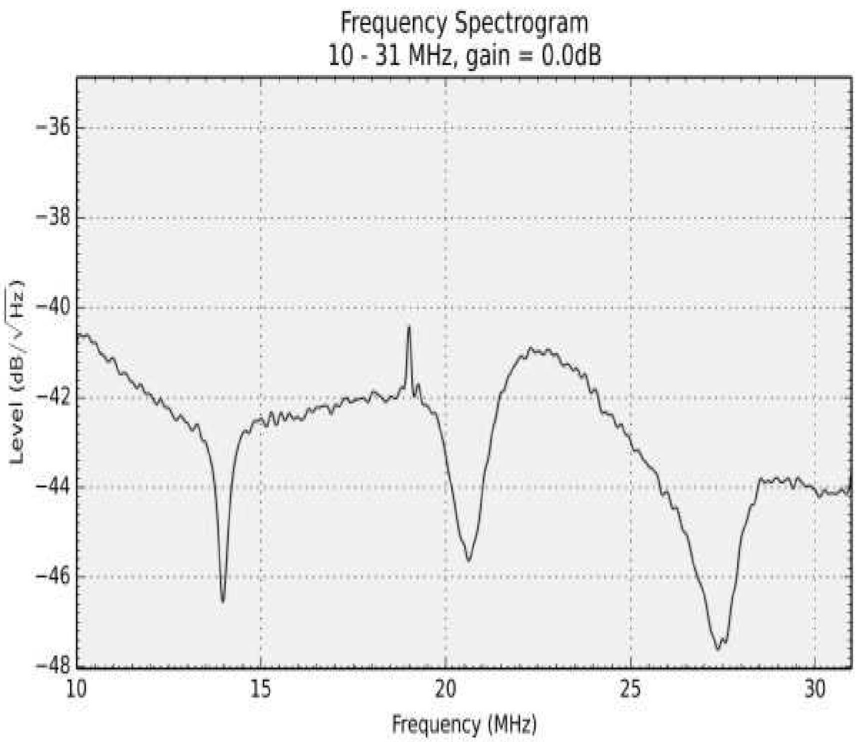
It it clear to see that this inexpensive set up is telling me much the same thing regarding the filter response - and for considerably less cost than a spectrum analyser. Certainly it isn't the precision instrument the real spectrum analyser is, but it doesn't do a half bad job.

A while ago I built a Return Loss Bridge and just for hoots I tried shining wide band noise from a zener noise generator into it and observing the result of a test of my tri-band trapped vertical antenna with a TV dongle spectrum analyser. This is the result:



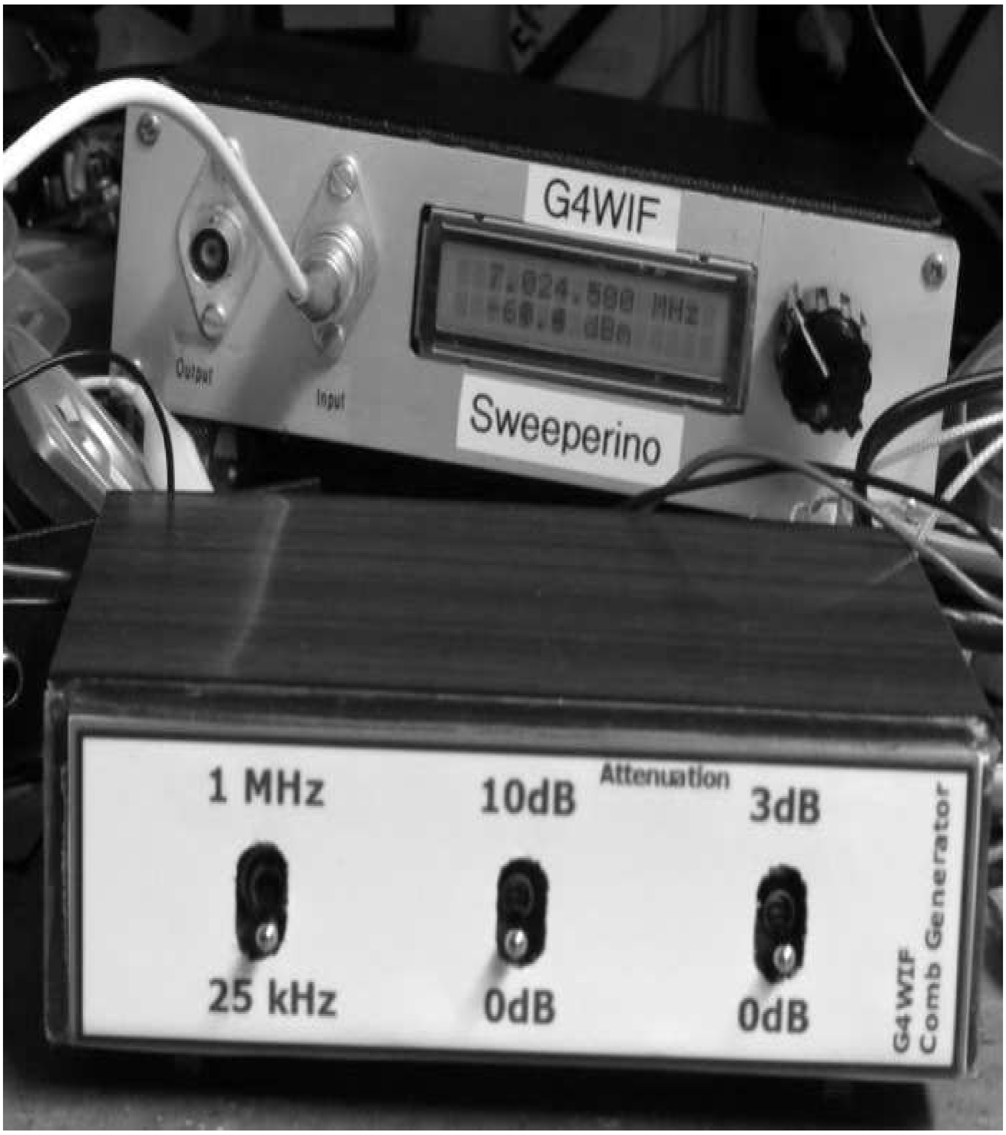
Well it worked after a fashion but of course, that fall off in signal level is due to the zener noise dropping off as frequency increases.

So I tried the experiment again, this time using the comb generator set to 25 kHz pulses:



This is a more useful result and while I wouldn't claim this is a measuring device, it does fall into the category of an "indicating device" - and one that provides some indication of return loss relative for each of the three bands. I'm waiting for warmer weather to work out why my antenna has shifted "LF" a bit. My antenna analyser is telling me a similar story.

Here is a picture of the finished project on the bench with the Sweeperino.



Antenna Topics

Auto RF changeover switches

Readers will recall I addressed this issue in a previous Hot Iron; here is slightly different approach that achieves the same end. The time delays are adjustable in both cases, so it's up to you!

TX/RX Sequencer

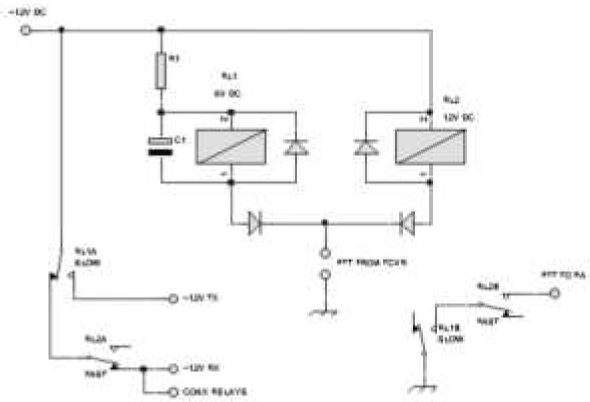
A simple, reliable sequencer

From The VHF/UHF DX Book, page 11-30

This sequencer is suitable for a lineup of HF transceiver - VHF/UHF transverter - PA, but it can be adapted for other systems too.

It allows key-controlled changeover or direct PTT without damage to the preamp, the coax relays contacts or the PA. I've used this sequencer for about 18 years with never a single failure.

The sequencer uses two DPDT relays. RL2 is a 12V DC relay and operates at normal "fast" speed. RL1 is the "slow" relay - a 6V DC relay with a dropping resistor R1 approximately equal to the coil resistance of RL1. Electrolytic capacitor C1 slows both the make and the break of RL1 by a few hundred milliseconds. Choose C1 so that the two relays produce an audible double "ker-lick" when the PTT line is grounded and ungrounded (about 470uF).



The way you interlink the "fast" and "slow" contacts on the two relays depends on your switching requirements. The sequence must be:

RX to TX
1. Mute receiver
2. Change over coax relays **quickly**
3. **Wait** for relay contacts to stop bouncing
4. Enable the PA
5. Apply RF drive

TX to RX
1. Remove RF drive **quickly**
2. Disable PA
3. **Wait** to be sure RF has gone
4. Change over coax relays
5. Enable receiver.

The diagram shows a system where the coax relays are **energized on RECEIVE**. This has the advantage that the preamp is disconnected and protected whenever the whole system is powered down, and if a masthead coax relay fails you can still use the antenna.

Interlinking the relays contacts as shown above will give the right sequence of changeover. The receiver and TX driver are enabled through the 12V RX and 12V TX lines.

You key the transceiver in the normal way, and the sequencer gets its PTT signal from the accessory socket on the rear of the transceiver. The PA gets a delayed PTT signal through RL1B and RL2B, and also the 12V TX line is delayed, so no RF can reach the coax relay until it has had plenty of time to change over.

When you release the main PTT, the transceiver cuts off the RF drive and releases the PTT to the sequencer. RL2B quickly disables the PA. The 12V TX line is still on, but that doesn't matter because there is no RF drive from the transceiver. After a short delay, the coax relays change over, the 12V TX line goes off, the 12V RX line comes on, and the receiver is working again.

Chinese Flag Pole Kits

From VK4TJ...

I purchased a 7.1 mtr "Aussie Flag" version, the tallest I could find. On arrival, it appeared to be quite well constructed, consisting of 5 tapered aluminium sections of approximately 1.8 mtrs each. The sections "lock" in rather the same fashion as a painters (or pool) pole. Although I did not test it, I rather suspect you have no choice over how much of it you deploy - the "twist and lock" internal connectors probably only function with every section fully extended. The first mild surprise was that there is no continuity between sections – obviously, the unseen internal "twist and lock" mechanism is plastic and insulating. Luckily, I had quite a few worm gear clamps of the appropriate size, so I made up short jumper wires and clamped them around each of the pipe transitions. One could do the same thing with a drill and self-tapping screws, but I wanted, initially at least, to ensure the I did not damage the unseen "twist and lock" mechanisms.

As found, the 7.1 mtr flagpole is resonant around 10 MHz, with VERY reasonable SWR across the 30 mtr amateur allocation. This is worked against my 10 x 12 mtr steel shed as a radial farm – really 10 x 14 mtrs, as there is a lean-to off the back which is almost certainly electrically bonded to the shed, and the antenna feedpoint at 4.5 mtrs above ground. So, if all you wanted was a good 30 mtr vertical, you could stop reading right now!

The only comparison antenna left standing at my shack after recent wind storms is a 55 mtr steel cable chucked over a tree to roughly the 20 mtr mark, with strong horizontal and vertical components. It is worked against the same 10 x 12 mtr metal shed radial farm as a sort of "semi-vertical". Initial impressions were that the flagpole is slightly better on 30 mtrs, but the 55 mtr random semi-vertical is noticeably better on 40 & 80 mtrs. The flagpole should be a pretty good player on 20 mtrs as well, as 7.1 mtrs must be getting pretty close to 5/8ths wavelength, though the feed impedance would be nothing like 50 ohms on 20.

Since the flagpole is conspicuously short of resonance on 40 mtrs and below, I then replaced my 4 non-conductive guys with conductive guys in electrical contact with the apex of the flagpole, of a "silly" length, nearly back to roof level, with just enough "paracord" to ensure that the shed roof was not part of the antenna. Once done, I could not find resonance ANYWHERE! Well, not quite true – the system was 1:1 at 19.5 & 20.7 MHz, but I'd expected something substantially lower than the starting point of 10 MHz. Not to worry – this antenna was envisioned as a sort of "all-rounder" for days when my fleet of tree-supported dipoles was grounded due to wind damage, so I knew my homebrew T-match tuner was always going to be part of the equation.

Impressions AFTER the addition of the conductive guys: Performance on 40 mtr is now roughly equal to that of my 55 mtr semi-vertical random wire. Performance on 80 mtrs is substantially worse. Nobody should be surprised at this – 7.1 mtrs is a pretty tiny fraction of a wavelength on 80! Performance is not so bad as to make the flagpole impractical, however.

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From Frank Barnes, W4NPN

I'm looking at the dipole drawings in Hot Iron 103. These show loading coils in each leg. Eliminating the loading coils and letting the extra length that will then be required drop down from each end of the antenna will make it easy to prune it to resonance and will probably not be quite so lossy as the loading coils. Not too much RF makes it out to the ends anyway. Complemented by...
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Inverted VEE Dipoles

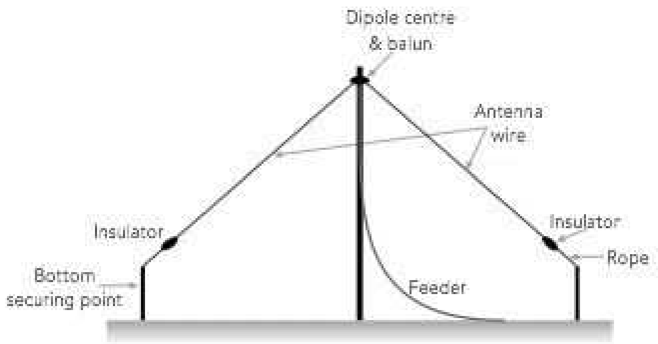
I waa emailed about "inverted VEE dipoles and the simplest way to build one. Below is the "standard" text on the matter; and following the VEE article is a beauty of a folded dipole that reducers the length to half that normally expected in any dipole.

From: www.electronics-notes.com

The inverted V dipole can form an effective antenna system for use on the HF amateur radio bands, or for other applications in many circumstances.
The advantage of the inverted V is that it only requires one high support whilst still achieving a high level of performance - the difference between an inverted V with its centre at the same height as a horizontal dipole is very marginal, and in most instances the difference in performance may not be detectable.

Normally the inverted V dipole is used for HF operation as the advantages of the single support are apparent on these frequencies.

What is an inverted V dipole?
As the name implies an inverted V dipole is a form of dipole that is in the form of a V which has been inverted. Instead of having two main supports - one for either end, both of which need to be as high as possible, the inverted V uses its main high support in the middle, having with ends having lower supports or anchorage points.



The inverted V dipole antenna has a number of advantages. One is that the maximum radiation from any antenna is from the points of high RF current, and a half-wave dipole has this maximum at its centre and for a few feet on either side of the feeder connections. Therefore it is best to make the centre of the dipole as high as possible.

If it is only possible to have one high support, an inverted-V arrangement is obviously ideal. In this way it is possible to use one fairly high mast in the centre of a garden or plot in locations where the erection of a pair of similar supports with their attendant guy wires would be difficult. A roof-mounted or chimney-mounted mast may also serve as the centre support for a 'V', and the two ends of the dipole can then drop down on either side of a house or bungalow roof. Such chimney mounting will allow the feeder to be dropped to the shack quite easily if it is located in the house.

Inverted V dipole performance

Although an inverted-V has its greatest degree of radiation at right angles to the axis of the antenna, its radiation pattern is more omnidirectional than that of a horizontal dipole as a result of the fact that the legs are angled downwards.

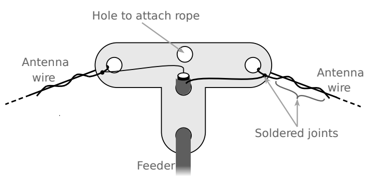
The inverted-V has an excellent reputation for long distance communication on the lower-frequency amateur bands where the installation of large verticals or high horizontal dipoles is not practicable.

As an example, the inverted V dipole performance very well at low frequencies and will give good results on the 3.5MHz ham radio band when the mast is only about 14 metres or 45 feet high. This makes it a very attractive proposition for many amateur radio stations. Similarly it inverted V dipole antennas for other bands also perform well.

Building an inverted V dipole for amateur radio

Building an inverted V dipole is very much like that of a standard dipole. There are several elements to the installation and erection of the inverted V dipole.

- ***Mast:*** One major requirement for the inverted V dipole installation is the mast. This should be robust and firmly mounted into the ground. If it is metal construction it is suggested that a good earth connection is provided. Also a pulley should be installed at the top to enable easy hoisting of the inverted V dipole antenna
- ***End anchor points:*** When building an inverted V dipole and erecting it, the anchor points for the two ends should be considered. These must be located so that they do not pose a hazard to anyone in the area. They should also be located so that the antenna wire ends are out of reach. In addition to this the inverted V dipole anchor points should enable the wires to subtend an angle greater than 90° at the top centre point.
- ***Antenna wire:*** The antenna wire should be of suitable quality for use externally. Ideally hard-drawn copper wire so it does not stretch, it can be single or multi-stranded.
- ***Dipole centre:*** Like any dipole there needs to be a centre piece. The centre of the dipole requires the coaxial or open-wire feeder to be connected to it and whilst it may be tempting to simply connect the feeder and let it take the strain, this is not particularly satisfactory when there is a long drop for the feeder – a dipole centre should be used. This will take the strain caused by the tension on the wire, thereby avoiding damage to the feeder over a period of time.

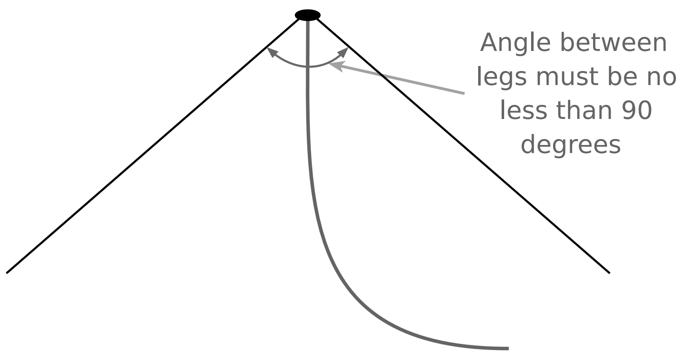


Strictly speaking a balun should be used but it is often omitted especially for receiving applications. The dipole centre (and don't forget the hose TEE piece dipole centre trick shown in Hot Iron #106!) will also provide a means of attaching a rope to enable the pulley system to hoist the antenna centre. A good quality centre should be used wherever possible (*readers of Hot Iron #106 might recall I suggested a plastic hose TEE piece filled with* *silicone bath sealer makes a doozy dipole centre piece; the suspension point is made by a simple loop knot around the "arms" of the TEE, double sided to keep the TEE orientated properly*).

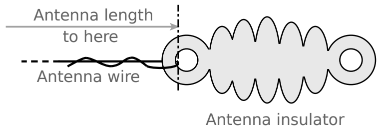
Inverted V dipole installation considerations

When considering erecting an inverted V dipole there are a number of considerations that should be kept in mind when its is being planned

- ***Angle between dipole legs:*** The angle between the sloping wires must be at least 90° and preferably 120° or more. This angle dictates the centre support height as well as the length of ground needed to accommodate the antenna.



- For example, when designed for the 3.5MHz band an inverted-V will need a centre support at least 14m (45ft) high and a garden length of around 34m (110ft). By contrast, a horizontal dipole needs at least 40m of garden and that neglects to take into account guys to the rear of the end support masts. Again, the inverted-V is ideal for portable operation because one for operation on 20m (14MHz) only needs a lightweight 5m (15ft) pole to hold up its centre.
- ***Dimensions need adjusting:*** The sloping of the dipole wires causes a reduction of the resonant frequency for a given dipole length, so about 5% must be subtracted from standard dipole dimensions. However as with an ordinary dipole it is always best to start with the inverted V a bit too log and trim it to operate with its best performance in the areas of the band most used. Also remember that the same amount must be trimmed from each end so that the dipole remains centre fed and there is not an imbalance.
- ***Length measurement:*** Remember when cutting he antenna wire, that the electrical length is measured from the centre of the antenna dipole centre piece to the furthest extremity of the wire.



- Any wire used to fold back around the insulator does not contribute to the electrical length, but needs to be considered when cutting the physical wire length. An allowance also needs to be made for the dipole centre piece as well.
- ***Radiation resistance:*** A further consequence arising from sloping the dipole wires is a change in its radiation resistance. The centre feed impedance of the inverted V dipole falls from the nominal 75 ohms of a horizontal dipole to just 50 ohms. This of course is ideal for matching the antenna to standard 50 ohm impedance coaxial cable.
- ***Bandwidth:*** An inverted-V dipole antenna has a higher Q than a simple dipole so it tends to have a narrower bandwidth.
- ***Keep inverted V dipole ends out of reach:*** It is not recommended that the ends of an inverted-V are allowed closer to the ground than about 3 metres or about 10 feet, even on the higher-frequency bands, because there can be a possible danger to people and especially children or animals touching the wire ends which will be at a high RF potential when energised. The effects, although not likely to prove lethal, nevertheless could result in a nasty shock or RF burn, and it seems unlikely that an insurance company would look kindly at any claims resulting from such an accident.

Coaxial feed is recommended with an inverted-V, and the low-loss heavier varieties of cable can be used to advantage, for there are no sag problems when the feeder is fastened up at the top and also down the length of the mast. The feeder will impose no strain upon the antenna or the soldered connections at its feed point. As with an ordinary horizontal dipole, a balun may be used, although they may operate satisfactorily without one.

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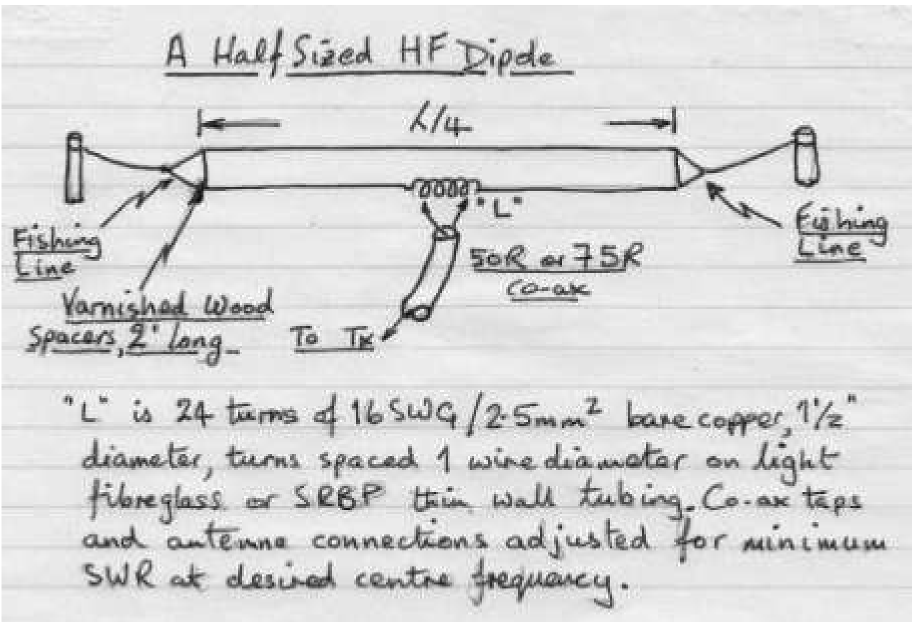
Folded dipole only ¼λ long in total

Also prompted by Frank Barnes, W4NPN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This half sized dipole gives excellent results, and makes matching easy (for cheap 75 ohm TV co-ax too!) with only one coil; but don't expect a wide bandwidth. The more you shorten an antenna, the "tighter" the resonance becomes; but for us A.M. nuts, with only one frequency slot in each band, the job's a good 'un! Keep the wires well separated, as high RF potentials exist along the wires.

Power Supply Topics

Class "X" and "Y" capacitors

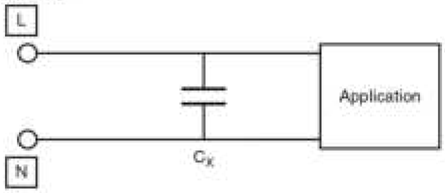
For capacitors connected onto / into a mains supply - a common requirement in this day and age considering mains noise from all the SMPS around the house - you MUST know exactly what capacitor to use. Below is an Application Note from a well known and respected manufacturer:

AC Film Capacitors in Connection with the Mains

Because of the high energy availability and the severe environment of surge voltages and pulses, applications of capacitors in connection with the mains must be chosen carefully. Two kinds of connections and thus two kinds of applications can be distinguished. One is where the capacitor is directly connected in parallel with the mains without any other impedance or circuit protection, and another where the capacitor is connected to the mains in series with another circuitry.

CAPACITORS DIRECTLY CONNECTED IN PARALLEL WITH THE MAINS WITHOUT ANY OTHER IMPEDANCE OR CIRCUIT PROTECTION (ACROSS THE LINE OR X CLASS CAPACITORS)

To help reducing emission and increasing the immunity of radio interference, electromagnetic interference suppression film capacitors (EMI capacitors) are playing a major role in all kind of applications. These capacitors are put directly parallel over the mains at the input of the appliances.



Several functions are combined in these small components: Excellent high frequency properties for short circuiting radio interference, being continuously stressed by the AC mains voltage and not at least having the ability to sustain transient voltages, caused by for example lightning strikes, switching, superimposed on this line.

For EMI capacitors it is a very difficult job to keep fulfilling the stringent requirements for safety and at the same time to miniaturize for offering customers benefits in terms of costs, functionality and mounting possibilities.

Five main characteristics can be seen for EMI-capacitors:

- Excellent capacitive filter: Low inductance and equivalent series resistance are preferred
- Withstanding pulse loads: Uncontrolled mains switching must be sustained
- Continuous biased by the mains voltage: A powerful energy supply is always available
- Withstanding surge voltages: High energy surge voltages could destroy the capacitors
- Safe end of life behavior

It has been noted by several national authorities that safety is top priority for these components. Therefore international safety standards have been developed like IEC 60384-14 (world standard) and UL 60384-14 (US standard). National authorities prescribe that EMI capacitors to be connected directly in parallel with the mains must be proved to fulfill these standards. Approved products receive safety certificates and are allowed to have following safety marks:

COUNTRY	SAFETY STANDARD	APPROVAL MARK
U.S.A.	UL 60384-14	
Canada	CSA E384-14	
U.S.A. and Canada	Combination Mark (UL 60384-14 + CSA E384-14)	c US
China	CQC	CQC
Europe	EN 60384-14 and IEC 60384-14	16

AC Film Capacitors in Connection with the Mains

Based on many years of experience Vishay has brought several EMI product series fulfilling these strong safety standards for across the line applications.

Depending on the customer's application needs following product series are recommended:

CLASS	X2	X1
VOLTAGE	≤ 310 V_{AC}	≤ 480 V_{AC}
Standard across the line applications, stability grade as per IEC 60384-14 [1]	MKP336-2 MKP338-2 MKP338-4 MKP339 F339MX2 F1778	MKP338-1 F339X1 330VAC
For continuous [2] across the line operation, higher stability grade than per IEC 60384-14 [1]	F1772	F339X1 480VAC

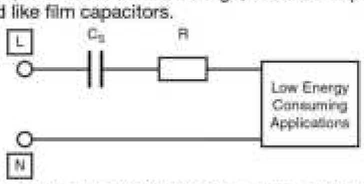
Notes

[1] IEC 60384-14 endurance test conditions require ± 10 % capacitance change after 1000 h testing

[2] Continuous in the meaning of uninterrupted connected to the mains, 24 h/day during several years

CAPACITORS CONNECTED TO THE MAINS IN SERIES WITH ANOTHER CIRCUITRY (SERIES IMPEDANCE APPLICATION)

In many appliances a low voltage supply is needed for simple low energy consuming functions like sensing, phase detection,... To reduce the voltage, reactive impedances are used like film capacitors.



In this case the capacitors are connected in series with the application to the mains and now the functions to be fulfilled are:

- Stable voltage dropper: A stable capacitance must be guaranteed over the total lifetime of the application
- An adjusted tolerance: To guarantee a well defined current supply
- Continuous biased by almost the mains voltage: Internal ionization must be avoided

But what about withstanding surge voltages? And what about safety?

As these caps are connected through another circuitry, the equivalent impedance of this circuit can protect the capacitor. A film capacitor could be destroyed when a high energy pulse is applied and the self healing properties are failing (self healing is the ability to recover after a breakdown). As general rule for standard capacitors, not approved according international standards for EMI capacitors, this can happen if surges occur higher than the guaranteed proof voltage. This is in general 1.6 times the rated DC voltage or 4.3 times the rated AC voltage. As it is generally accepted that surge voltage (1.2 µs rise time/50 µs duration) can occur at the entrance of appliances being 2.5 kV for installation category II and 4 kV for installation category III (IEC 60664-1), it must be verified by the customer that the impedance in series with the capacitor limits the over-voltage to these values. In general this will be the case because it can easily be calculated that equivalent impedances will be in the range of 220 Ω to a few kΩ depending on the low voltage application and by this the surge will be topped off to a few hundred volts maximum.

In all other conditions still an approved safety component must be used, but here the extra functions as stable capacitance and adjusted tolerance must be fulfilled as well. This can only be guaranteed by a different capacitor construction wherein two capacitor sections are internally connected in series.

Also for these series impedance applications Vishay can offer a wide range of products fulfilling customer's needs and requirements:

CLASS	WITHOUT SAFETY APPROVALS [1]	WITH SAFETY APPROVALS	
VOLTAGE	≤ 275 V_{AC}	≤ 310 V_{AC}	≤ 480 V_{AC}
Standard and continuous [2] in series with the mains operation	[3]	F1772	F339X1 480VAC

Notes

[1] The applicant must guarantee that the maximum continuous mains voltage is lower than the rated AC voltage and that maximum temporary over-voltages (< 2 s) are lower than 1.6 rated DC voltage or 4.3 times AC rated voltage. Instructions can be found in the application notes and limiting conditions in the detail specifications.

[2] Continuous in the meaning of uninterrupted connected to the mains, 24 h/day during several years

[3] For the right choice of the component, contact rfi@vishay.com

VISHAY. www.vishay.com

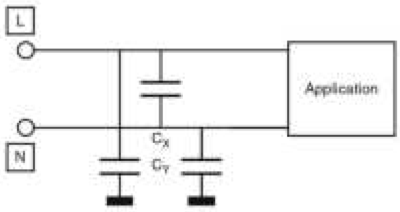
Application Note

Vishay

AC Film Capacitors in Connection with the Mains

CAPACITORS DIRECTLY CONNECTED IN PARALLEL BETWEEN THE MAINS AND GROUND (LINE BYPASS OR Y CLASS CAPACITORS)

To help reducing common mode electromagnetic interference, capacitors are connected between mains and ground. For these applications only approved safety components are allowed. Different safety classes and standards are defined in the same IEC 60384-14 and UL 60384-14 standards.



Vishay has following products in its film capacitor portfolio, adapted for the specific customers need:

CLASS	**Y2**
VOLTAGE	**≤ 305 V_{AC}**
Standard line bypass applications	F1710 MKP338-6
Line bypass application for continuous operation [1]	MKP338-6

Note

[1] Continuous in the meaning of uninterrupted connected to the mains, 24 h/day during several years

APPLICATION NOTE

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Valve Voltages Safety Note

From: http://philsvalveradiosite.co.uk/philsvalveradiosite/safety_issues_1.htm
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I recommend that you must read through this page very carefully before you even think of starting this exciting pastime hobby as there is a very dangerous side to it, regarding the use of high voltages and mains electricity. Mains electricity in the UK comes into the home at 240 volts AC, 60 cycles per second and there is a serious risk of electrocution and possible fires. Valve equipment, particularly high power audio amplifiers use double the voltage ranging from 500 to 1000 volts of DC current stepped up with a mains transformer. Direct contact can cause severe burns and your hands can also become locked and unable to let go until the power is turned off. The HT smoothing electrolytic capacitors can hold a lethal charge, many hours in some cases after equipment is turned off, so I recommend you discharge this voltage by using a bleed resistor of about 470K 1 Watt (*use 1/C (in μF) Meg-ohms to give a 1 second time constant is an industrial electronics axiom*) and a analogue multimeter to check that this voltage is fully discharged.

Please note that when testing and setting up your valve equipment there are times when the power needs to be turned on. It is essential that you keep one hand in the pocket when using high voltage test leads, with the negative lead earthed to the chassis when doing HT voltage measurements by using a crocodile clip and be very careful not to accidentally bridge components by short circuiting with test leads, leading to possible damage. Be also aware that you should keep young children and pets out of the same room you are working in, as they may not fully understand the dangers and keep unattended work areas out of children's reach by locking the place up when you have finished. Provided these rules are always followed, Constructing valve radios and amplifiers can give you many hours of fun and pleasure. Please take time to read the following rules and guidelines listed below.

Safety in the work area

1. Avoid temporary electrical hook-ups such as multiple double adaptors and trailing extension leads, as these over a short period of time, tend to become permanent.

2. Try make use of a suitable spare room for this sort of work. The use of a outside shed or garage is suitable, provided it is kept heated and no damp or wet weather can get in, during the Winter Season. If this is not possible then the kitchen is the only solution, provided you have followed the previous warnings.

3. It is also important to have adequate power and lighting facilities regarding your work area. Make sure all sockets are the switched 13 amp modern square pin type. Also have a master switch that is in easy reach, particularly when first testing equipment, so that you can immediately turn off the power, in the case of danger arising.

4. It is important that the electrical wiring is sound and up to standard. If your home was built before 1962, it is still possible that your house was wired using rubber sheaved cable. If so, it is worth getting advice from a competent electrician and having your home rewired, as it may not become immediately apparent, the installation can work well for many years but the hidden danger of a fire or electric shock is waiting there. The use of a socket tester, available from most DIY electrical stores can reveal if your sockets are wired correctly.

It is also very dangerous to not have any electrical safety earth. Under fault conditions it is possible for a metal case electrical appliance to become live without immediate warning. This is usually caused by a damaged flex or faulty mains transformer leading to a earth leakage.

Why fuses are very important

1. A fuse is designed as the weakest link in any electrical circuit for a number of reasons. It is a thin piece of wire enclosed in a ceramic tube or plug in type holder used in distribution boxes.

2. Without it, your electrical appliances would work OK, but should a fault, such a damaged cable or high current fault arise, there could be a high risk of a fire or electrical explosion.

3. The main function of a fuse, is when danger occurs the thin piece of wire melts, sometimes with a mighty bang, when a heavy short circuit occurs.

4. There is another two types of fuse that have been around for about the last 20 years or so.

5. Circuit breakers. A circuit breaker is a magnetic switch, now common in many household consumer units, it is designed to trip off and can be reset, should a fault or current overload occur and is more safer and reliable.

6. Residual Earth Leakage Current Breaker. Not strictly and not to substituted as a fuse, it used in many circumstances where water is involved such as electric showers and outdoor appliances. Should a outdoor appliance become faulty or the casing becomes live, it is designed to trip off, when there is a slight current leakage to earth of only 30 milliamps preventing a fatal electric shock.

7. Fuse rating. It is very important to use the correct size fuse for its protective purposes. For example mains plug fuses have about 3 different ratings. 3 Amps is uses on appliances up to 720 watts, such as hi fi equipment, table lamps and coffee makers. 5 Amps is used on appliances up to 1200 watts such as Vacuum Cleaners, small electric fires, computers and colour TVs. 13 Amps is used on appliances up to 3120 watts such as electric kettles, washing machines and heaters. Please note that this only protects the flex and the correct fuse in the appliance is probably lower, which should be the case, when valve equipment is concerned because it uses lower currents.

8. Mains and HT Fuses are usually employed in all high quality valve radios and Television Receivers. The purpose of the mains fuse is to protect the mains transformer from damage when a serious overload occurs, That can happen due to a faulty rectifier valve or smoothing capacitor. This is usually wired in the live side of the mains preferably before the mains switch of the equipment. However, This does not always give full reliable protection on the secondary side of things, as it is known that a output valve can fail, leading to burn out of the output transformer which can also lead a expensive repair on your hands. A HT fuse is usually wired in between the positive side of the second filter capacitor and the HT Rail on the equipment concerned to give complete protection.

Safety concerning Electrolytic Capacitors and the danger related with old Radio sets

As I mentioned earlier about safety regarding high voltages involved with valve equipment, electrolytic Capacitors pose the most danger. The reason being is that they behave like high voltage batteries which can store a very lethal charge over a considerable period, from months to even years when left idle. Also they can explode with a loud frightening bang, depositing there innards all over the place, particularly if connected in the Wong polarity or if the voltage rating is exceeded. Electrolytic Capacitors also deteriorate with age when not used for a long time resulting with the same similar circumstances. Although modern electrolytic capacitors are now very reliable, this is not the case with a radio that has been asleep in the loft for the last 30 years and regardless of the old guy telling you it worked brilliant when last used, the chances is are that if you restored power to it again, The capacitors could explode causing more damage to the set and there could also be a risk of fire, if the set is left unattended. Why does this happen? Electrolytic capacitors are made of aluminium foil, rolled in the insulation form of an electrolytic pastcompoundthat forms the dielectric capacitance and when not used for a long time the dielectric becomes fragmented, Causing breakdown of the dielectric insulation which leads to leakage and short circuits. It is possible to reform these components by steadily applying a low current, Which can except in some cases heal the capacitor back to its useful life.

Safety Precautions Regarding Live Chassis AC/DC Equipment

As recently up to the mid 1950s, many towns where not supplied with electricity by the National Grid and the mains was sometimes DC. Connecting a AC Mains set incorporated with a mains transformer to a direct current supply due to the incompatibility would cause serious damage, rendering the set useless and possible risk of a fire. To overcome this problem a series valve heater chain consisting of the heaters wired up like Christmas Tree bulbs was incorporated, often followed by a series high wattage resistor to make up the required voltage. The High tension side of things mostly consisted of a half wave valve rectifier and simple capacitor input filter, followed by a surge resistor to limit the current. As a result due to no mains transformer, one side of the mains is connected to the chassis and there is a serious risk of electric shock if the polarity of the mains is unknown. To correct this problem it is best to make sure that the mains lead is fitted to a none reversible plug with the black lead connected to the natural terminal. It is also safer to confirm this by touching the chassis with a neon mains test screwdriver. The aerial and gram pickup sockets used high voltage isolating capacitors and it is not unknown for these to breakdown, leaving an additional shock hazard on the horizon. Always make sure these capacitors are replaced with the proper 1000 Volt Class, designed for this purpose (*class X & class Y types*). Also beware of exposed metal knob shafts that can also be very dangerous by making sure the grub screws are tight and cant be touched by using special filler designed for the protective purpose. You will find in many old radio magazines some very tempting radio circuits that use this method as a way to cut cost, but my advice is to play it safe and build a design using a mains transformer.

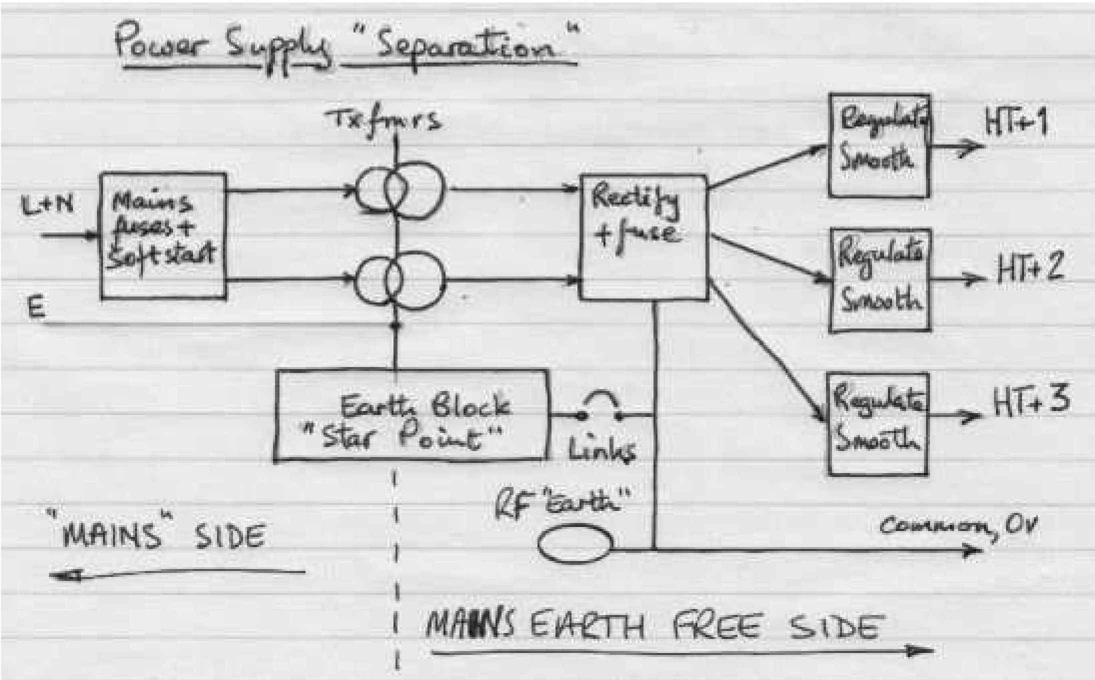
Heat and Component Reliability

Compared to transistor circuits, valves generate more heat because of the hungry current consumption regarding the valve heaters and high voltage HT Line. It is this problem that results in component failure, in these circuits over the years of there working life. As a rule of thumb I always replace the lower power resistors with no less the 1/2 a watt, for improved reliability and as another example I always substitute a 450 Volt electrolytic capacitor for the 350 Volt type, particularly in power supply circuits, as that way you gain improved reliability rather then working close to the limit. There is a excellent website run by Paul Stenning and can be found by clicking on the following link UK Vintage Radio Repair and Restoration . It has some useful projects such as a capacitor reformer and a series lamp current limiter. Useful when testing your newly constructed radio for the first time.

Power Supply Voltage "Separation"

If you look at any high power DC supplies if RF generators, you'll find the designers always separate the different voltage regimes: this means the mains side is separate from the HV AC transformer outputs; which are again separated fromn the regulators and fusing for the various DC outputs. The key is to separate the different voltages and types, as in the diagram below.

You'll notice the earth block / star point. This is a common feature; the RF earth, the rectifier "common" and the mains earth might have to be separated for safety or operational requirements. This is very good amateur policy: it's not a good thing having RF currents flowing in the domestic AC mains wiring, even if it's fun to see the cat getting an RF spark on its nose from a plug socket screw!



Data and Information

This information is for guidance only – you MUST comply with your local Electrical Safety Regulations! I have included information about AC power systems and conventions, as equipment can be bought from overseas nowadays and it's important to know how to connect it safely to our "home" supplies. Suffice to say, if there's ANY doubt - - - GET PROFESSIONAL, COMPETENT HELP BEFORE YOU CONNECT TO ANY ELECTRICAL SUPPLY!

Basic AC Relationships

Crest Factor for varuous waves. www.turneraudio.com.au

Wave type	Wave form	Mean magnitude (rectified)	Wave form Factor	RMS value	Crest Factor	Crest Factor
DC		1.00		1.00	1.00	0.0dB
Sine wave		$\frac{2}{\pi} \approx 0.6363$	$\frac{\pi}{2\sqrt{2}} \approx 1.1112$	$\frac{1}{\sqrt{2}} \approx 0.7071$	$\sqrt{2} \approx 1.4142$	3.01dB
Full-wave rectified sine wave		$\frac{2}{\pi} \approx 0.6363$	$\frac{\pi}{2\sqrt{2}} \approx 1.1112$	$\frac{1}{\sqrt{2}} \approx 0.7071$	$\sqrt{2} \approx 1.4142$	3.01dB
Half-wave rectified sine wave		$\frac{1}{\pi} \approx 0.3182$	$\frac{\pi}{2} \approx 1.5714$	$\frac{1}{2} = 0.50$	2.000	6.02dB
Triangle wave		$\frac{1.00}{2} = 0.50$	$\frac{2}{\sqrt{3}} \approx 1.1547$	$\frac{1}{\sqrt{3}} \approx 0.5773$	$\sqrt{3} \approx 1.7320$	4.77dB
Square wave		1.00	1.00	1.00	1.00	0.0dB

π = greek letter pye, = 22 / 7 = 3.142857134..... and is a mysterious and significant mathematical figure used in countless equations. $\approx$ = symbol for "approximately equal to".

The Unobtanium & Obsoletite files...

A list of those solid state parts made from Unobtainium and Obsoletite - please let me know your alternatives! **Note:** when Unobtainium and Obsoletite parts are overheated, over-volted or over-amped, the rare elements used inside the plastic / metal packaging react violently, emitting the "magic smoke" which renders any solid state device instantly useless. In a Yocto-second, no less.

Useful cross-reference web pages:

https://english.electronica-pt.com/components-cross-reference?ref=

https://archive.org/details/TowersInternationalTransistorSelector

For Solid State fans...

These are more or less equal equivalents, use in both directions i.e. BFY90 = 2N5178. Any more that have been proven in actual circuits, please let me know: the supplies of Unobtanium and Obsoletite is getting harder and harder to find, any help is always welcome.

2N5179	BFY90	½ watt VHF NPN
2N3866	BFY90	½ watt VHF NPN
2N4427	BFR91	1 watt VHF / UHF NPN

ZTX300	BCY70	0.3 watt HF NPN
OA91	1N60/61	Ge signal diode, 50v, 50 mA

Alternatives to ZN414 = MK484, YS414, TA7642, UTC7642, LMF501T, LA1050.

For Valve / Tube fans...

https://en.wikipedia.org/wiki/List_of_Mullard%E2%80%93Philips_vacuum_tubes

(Well, you *did* ask...)

http://www.angelfire.com/electronic/funwithtubes/tube_select_guide.html

(THE 'Magnum Opus' of bottle lists)

https://frank.pocnet.net/sheets5.html

(Is the broadest range of data sheets I've ever used, very helpful in finding usable alternatives)

Some not very obvious alternatives:

ECL 82 is an audio triode / pentode, much beloved in vintage radios, economy audio amps and the like. However... if you have 12v. ac heater volts available (or higher) then the bottles following can be useful with a dropper resistor to tweak the heater volts down (and get long heater life too). Don't forget that half wave rectified 12v. r.m.s. = 6v. r.m.s.; near enough for 6.3v. heaters; or strap two 6.3v. bottles in series if their heater currents are near equal, to run on 12v. AC - or a car battery.

ECL82 = LCL82 (10.7v heaters) = 11BM8 (10.7v heaters) or PCL82(16v) / UCL82(50v) / XCL 82(8.2v). There are dozens of equivalent or similar electrode structures but with different heaters. For instance: PCL82 = 16A8 = 30PL12 = 16TP12 = 16TP6 = 16Ф3П Different heater volts = 8B8 (8.3v ac)

Check the web page: https://www.radiomuseum.org/dsp_searchtubes.cfm where you can search for many different tubes, characteristics and equivalents. For instance, web searching for an ECL84 equivalent - typically LCL84 - yields dozens of hits. If you want an ECL84, which are as rare as hen's teeth nowadays because Audiophools buy them at nosebleed prices, try the different heater volts equivalents and alter the heater supply appropriately.

Keep to mind that 5v or 6.3 v AC heater supplies, if doubled or trebled, will yield higher heater volts if you don't want to modify an existing or historically important piece of kit - but take great care not over volt filaments / heaters! A true RMS multimeter is handy for this job.

HF & VHF Output Types:

Search as I might, I can't find a cheap alternative to a 4CX250B (or the bases)! My apologies... I'm still searching!

6146B = 8298A = S2001; or nearly so, YL1370 = 6146 = 6146A = 6146W

807 = VT-100 = QE06/50 = Г-807 = GL807 = RK-807 = A4051I = ZA3496 = CV124 = 5S1 = 4Y25N = VT199_GPO = 5B/250A = CNU-807; nearly so = 10E/11441 ; 4Y25 ; ATS25 ; ATS25A ; ATS25N ; CV1364 ; CV1374 ; FU-7 ; HY61 ; QV05-25 ; RK39 ; VT60 ; VT60A

Audio valves; useful for low band RF:

From an article by Robert H. Levi

"My Favorite Tubes"
by Robert H. Levi

Small Signal Tubes:

12AX7

Substitutes: ECC83, 12AX7A, 12AX7WA, 7025, 5761, 6057, 6681, 7494, 7729, 7025#, ECC83#, 6L13, 12DF7, 12DT7, 5751, 7025A, B339, B759, CV4004, E83CC, ECC803, M8137

The GE 5751 is a bargain basement musical giant! The Mullard CV4004 is still King of the Hill.

12AU7

Substitutes: 12AU7A, ECC82, 5814, 5814A, 5814WA, 6189, 6680, CV4003, E82CC, ECC186, ECC802, ECC802S, M8136, 7025#, ECC83#, B749, 6067, 6670, 7730, B329, 5963, 7316, 7489

I discovered the 5814A from RCA is a bargain and the best sounding 12AU7 made in the USA!

The Mullard CV4003 is still fairly cheap, plentiful, and magnificent.

12AT7

Substitutes: 6201,6679, ECC81, 12AT7WA, 12AT7WB, 6060, 6201, 6671, 6679, 7492, 7728, A2900, 8152, B309, B739, CV4024, E81CC, ECC801, ECC801S, M8162, QA2406, QB309

As good as the GE and RCA are, the Mullard CV4024 is not pricey and totally glorious.

6DJ8

Substitutes: ECC88, 6ES8#, 6ES8, ECC189, ECC189#, 6FW8, 6KN8, 6922, E88CC, CV2492

The bargain priced PCC88, the 7 volt version of this tube, works nicely in the vast majority of 6 volt applications. I use them in a cocktail with their 6 volt brethren all the time for top results. You can still actually afford the Telefunken, Dutch Amperex, and Siemens versions of the PCC88!"

Rectifier Tube:

5AR4

Substitutes: GZ34, 52KU, 53KU, 54KU,GZ30, GZ32, GZ33, GZ37, R52, U54, U77, 5R4GYS (from Philips) The Mullard GZ34 is King of the Hill. Buy it used, but checked, if necessary. The Philips 5R4GYS is a recent find by Upscale Audio in Upland. A killer tube, but huge and requires lots of space (bigger than a KT88.)

Other Dual Triode Tubes:

6SN7

Substitutions: 6SN7A, 6SN7GT, 6SN7GTA, 6SN7GTB, 6SN7W, 6SN7WGT, 65W7, 5692, B65, ECC33, 6SN7L, 13D2, B65, 6SN7GTY, 6SN7WGTA

The available brands of these tubes are highly variable musically and microphonically. The vintage GE and RCA are very fine if hand selected. The Electro Harmonix is very good, too.

6SL7

Substitutions: 5691, 6SL7W, 6SL7WGT, 6113, ECC35, 6SL7GT, 6SL7L

Same comment as 6SN7 type.

Output Tubes:

EL84

Substitutes: 6BQ5, 6P15, 6267, 7189, 7189A, 7320, E84L, EL84L, N709, Z729, 6BQ5WA, EL84M
I have had little use for these. Am told the NOS Mullard prices are strong, but worth it.

EL34

Substitutes: 6CA7, 7D11, 12E13, KT77

Lots to choose from. Usually your manufacturer tuned the gear to a certain brand of these. Be mindful of that before you spend tons of money on vintage NOS versions that end up not sounding as good.

6550

Substitutes: 7D11, 12E13, 6550A, 7027A#, KT88, KT90 Type 2 or 3, KT99, KT100, KT120/KT150 (only if sufficient bias is present) Unless forbidden by your manufacturer, I would try some of the high powered goodies on the market to boost performance. The EH KT90 or the new KT120 may be astounding in your amp. At least try KT88s!

6L6

Substitutes: KT66, 5881, 6L6S, 6L6G, 6L6GA, 6L6GAY, 6L6WA, 6L6WGA, 6L6WGB, 6L6WGC, 6L6WGT, 6L6GB, 6L6GC, 6L6GT, 6L6GX, 6L6Y, 1622, 5932, 7581, 7581A, WT6, EL37

Same comment as EL34 type.

KT88

Substitutes: 6550, 6550A, KT90 Type 2 or 3, KT99, KT100, KT12O/KT150 (only if sufficient bias is present) Though your manufacturer may have settled on a certain brand of these, the hunt for cool NOS types may be sonically worthwhile, or try switching to EH KT90s or bigger for more impact. I would!

Wire Information...

As used in Test Gear Maintenance at a factory I worked at:
Green (or green & yellow stripe) - Earths, Chassis connection

Blue	A.C. power lines (N, single Φ, inside machinery)
Brown	A.C. power lines (L, single Φ, inside machinery)

Note: 3Φ supplies external to machinery or distribution systems may use some of these colours; **check, check and check again** what the wiring is!
NEVER, NEVER, assume a blue wire is a neutral; you may have an old 3Φ installation which ran colours as follows:

Red	Phase 1
Yellow	Phase 2
Blue	Phase 3
Black	Neutral

Valve Electrode wiring:

Gray	heaters or filaments
Red	DC power supply positives (numbered sleeves indicating voltage)
Black	returns, commons, NOT grounded
Orange	screen grids
Yellow	cathodes
Pink	control grids
White	anodes
Violet	AC / DC control signals (AGC, etc.)

From Kevin, VK3DAP / ZL2DAP seen on a web page recently, is another wiring code - last seen in a Savage 5kW audio amplifier driving a vibration table for semiconductor testing:

Valve Electrodes:

Anode	Blue
Cathode	Yellow
Control grid	Green
Screen Grid	Orange
Suppressor	Grey

DC Supplies:

Chassis / Ground	Black
Positive to Chassis	Red
Negative to Chassis	Violet

Miscellaneous Wiring (control signals & the like):
White or mauve

AC Supplies (modern UK &European):

Active or Phase	Brown
Neutral	Blue

Earth	Green/Yellow stripe

AWG Table

1 AWG is 289.3 thousandths of an inch
2 AWG is 257.6 thousandths of an inch
5 AWG is 181.9 thousandths of an inch
10 AWG is 101.9 thousandths of an inch
20 AWG is 32.0 thousandths of an inch
30 AWG is 10.0 thousandths of an inch
40 AWG is 3.1 thousandths of an inch

The table in ARRL handbook warns that the figures are approximate and may vary dependent on the manufacturing tolerances. If you don't have a chart handy, you don't really need a formula.
There's several handy tricks:
Solid wire diameters increases/decreases by a factor of 2 every 6 gauges,
" " " " " 3 every 10 gauges,
" " " " " 4 every 12 gauges,
" " " " " 5 every 14 gauges,
" " " " " 10 every 20 gauges,
" " " " " 100 every 40 gauges,

With these, you can get around a lot of different AWGs and they cross check against one another. Start with solid 50 AWG having a 1 mil diameter.
So, 30 AWG should have a diameter of ~ 10 mils.

36 AWG should have a diameter of ~ 5 mils.	Dead on.
24 AWG should have a diameter of ~ 20 mils.	Actually ~ 20.1
16 AWG should have a diameter of ~ 50 mils.	Actually ~ 50.8
10 AWG should have a diameter of ~ 100 mils.	Actually ~ 101.9

If you are more interested in current carrying ability than physical size, then also remember that a change of 3 AWG numbers equals a doubling or halving of the circular mills (the cross sectional area). Thus, if 10 AWG is safe for 30 amps, then 13 AWG (hard to find) is ok for 15 amps and 16 AWG is good for 7.5 amps.
The wire gauge is a logarithmic scale base on the cross sectional area of the wire. Each 3-gauge step in size corresponds to a doubling or halving of the cross sectional area. For example, going from 20 gauge to 17 gauge doubles the cross sectional area (which, by the way, halves the DC resistance).
So, one simple result of this is that if you take two strands the same gauge, it's the equivalent of a single wire that's 3 gauges lower. So two 20 gauge strands is equivalent to 1 17 gauge.

Wire Gauge Resistance per foot

4	.000292
6	.000465
8	.000739
10	.00118
12	.00187
14	.00297
16	.00473

18	.00751
20	.0119
22	.0190
24	.0302
26	.0480
28	.0764

Current ratings

Most current ratings for wires (except magnet wires) are based on permissible voltage drop, not temperature rise. For example, 0.5 mm^2 wire is rated at 3A in some applications but will carry over 8 A in free air without overheating. You will find tables of permitted maximum current in national electrical codes, but these are based on voltage drop. Here is a current and AWG table.

AWG	dia mils	circ mils	open air Amp	cable Amp	ft/lb bare	ohms/1000'
10	101.9	10380	55	33	31.82	1.018
12	80.8	6530	41	23	50.59	1.619
14	64.1	4107	32	17	80.44	2.575

Mils are .001". "open air A" is a continuous rating for a single conductor with insulation in open air. "cable amp" is for in multiple conductor cables. Disregard the amperage ratings for household use.
To calculate voltage drop, plug in the values:
V = DIR/1000
Where I is the amperage, R is from the ohms/1000' column above, and D is the total distance the current travels (don't forget to add the length of the neutral and live together - ie: usually double cable length). Design rules call for a maximum voltage drop of 6% (7V on 120V circuit).

Resistivities at room temp:

Element	Electrical resistivity (micro-ohm-cm)
Aluminium	2.655
Copper	1.678
Gold	2.24
Silver	1.586
Platinum	10.5

This clearly puts silver as the number one conductor and gold has higher resistance than silver or copper. It's desirable in connectors because it does not oxidise so remains clean at the surface. It also has the capability to adhere to itself (touch pure gold to pure gold and it sticks) which makes for very reliable connections.

Thermal conductivity at room temperature

	W/cm²/°C
silver	4.08
copper	3.94
gold	2.96
platinum	0.69
diamond	0.24

bismuth	0.084
iodine	43.5E-4

This explains why diamonds are being used for high power solid state substrates now - that's man-made diamond. Natural diamonds contain flaws in the lattice that phonons (heat conductors) get scattered and substantially reduce the ability to transport the heat.

Copper wire resistance table

AWG	Feet/Ohm	Ohms/100ft	Ampacity	(mm$^{2)}$	Meters/Ohm	Ohms/100M
10	490.2	.204	30	2.588	149.5	.669
12	308.7	.324	20	2.053	94.1	1.06
14	193.8	.516	15	1.628	59.1	1.69
16	122.3	.818	10	1.291	37.3	2.68
18	76.8	1.30	5	1.024	23.4	4.27
20	48.1	2.08	3.3	0.812	14.7	6.82
22	30.3	3.30	2.1	0.644	9.24	10.8
24	19.1	5.24	1.3	0.511	5.82	17.2
26	12.0	8.32	0.8	0.405	3.66	27.3
28	7.55	13.2	0.5	0.321	2.30	43.4

These Ohms / Distance figures are for a round trip circuit. Specifications are for copper wire at 77 degrees Fahrenheit or 25 degrees Celsius.

Wire current handling capacity values

mm2	R/m-ohm/m	I/A
6	3.0	55
10	1.8	76
16	1.1	105
25	0.73	140
35	0.52	173
50	0.38	205
70	0.27	265

Mains wiring current ratings

In mains wiring there are two considerations, voltage drop and heat build up. The smaller the wire is, the higher the resistance is. When the resistance is higher, the wire heats up more, and there is more voltage drop in the wiring. The former is why you need higher-temperature insulation and/or bigger wires for use in conduit; the latter is why you should use larger wire for long runs. Neither effect is very significant over very short distances. There are some very specific exceptions, where use of smaller wire is allowed. The obvious one is the line cord on most lamps. Don't try this unless you're certain that your use fits one of those exceptions; you can’t go wrong using larger wire. This is a table apparently from BS6500, reproduced in the IEE Wiring Regs which describes the maximum fuse sizes for different conductor sizes:

Cross-section	Overload current

CSA / area	rating
$0.5mm^2$	3A
$0.75mm^2$	6A
$1mm^2$	10A
$1.25mm^2$	13A
$1.5mm^2$	16A

Typical current ratings for mains wiring

Inside wall

mm^2	Amps
1.5	10
2.5	16

Equipment wires

mm^2	A
0.5	3
0.75	6
1.0	10
1.5	16
2.5	25

Wire sizes used in USA inside wall

For a 20 amp circuit, use 12 gauge wire. For a 15 amp circuit, you can use 14 gauge wire (in most locales). For a long run, though, you should use the next larger size wire, to avoid voltage drops. Here's a quick table for normal situations. Go up a size for more than 100 foot runs, when the cable is in conduit, or ganged with other wires in a place where they can't dissipate heat easily:

Gauge	Amps
14	15
12	20
10	30
8	40
6	65

PCB track widths

For a 10 degree C temp rise, minimum track widths on 1 oz. copper are:

Current	width in inches
0.5A	0.008"
0.75A	0.012"
1.25A	0.020"
2.5A	0.050"
4.0A	0.100"
7.0A	0.200"
10.0A	0.325"

Equipment wires in Europe

3 core equipment mains cable

Current	3A	6A	10A	13A	16A
Conductor size (mm)	16*0.2	24*0.2	32*0.2	40*0.2	48*0.2
Copper area (mm^2)	0.5	0.75	1.0	1.25	1.5

Cable ratings for 3A, 6A and 13A are based on BS6500 1995 specifications and are for stranded thick PVC insulated cables.

Insulated hook-up wire in circuits (DEF61-12)

Max. current	1.4A	3A	6A
Max. working voltage (V)	1000	1000	1000
PVC sheath thickness (mm)	0.3	0.3	0.45
Conductor size (mm)	7*0.2	16*0.2	24*0.2
Conductor area (mm^2)	0.22	0.5	0.75
Overall diameter (mm)	1.2	1.6	2.05

U.S.A. Common Cable colour Codes

American electrical contractors and electricians are required to follow the National Electrical Code ("NEC") with regard to wiring colours. NEC imposes the following electrical wiring colour standards:

•**Ground wires:** green, green with a yellow stripe, or bare copper

•**Neutral wires:** white or grey

In theory, wiring conducting live current in the U.S. is permitted to be any other colour, although in practice, electrical contractors and electricians follow these local conventions:

•**Single phase live wires:** black (or red for a second "hot" wire)

•**3-phase live wires:** black, red and blue for 208 VAC; brown, yellow, purple for 480 VAC

Most countries in Europe, including the U.K., now follow the colour conventions established by the International Electrotechnical Commission ("IEC"). These colour conventions are as follows:

•**Earth wires** (called ground wires in the U.S. and Canada): green with a yellow stripe

•**Neutral wires:** blue

•**Single phase live wires:** brown

•**3-phase live wires:** brown, black and grey

Electrical wiring in Canada is governed by the Canadian Electric Code ("CEC"). The following wiring colour requirements apply in Canada:

•**Ground wires:** green, or green with a yellow stripe

•**Neutral wires:** white

•**Single phase live wires:** black (or red for a second live wire)

•**3-phase live wires:** red, black and blue

It's important to remember that the above colour information applies only to AC circuits.

A.M. Frequency slots in Amateur HF Bands

All Frequencies in MHz

160 Metres: 1.885, 1.900, 1.945, 1.985 (USA)

1.850 (W. Europe)

1.933, 1.963 (UK)

1.825 (Australia - daytime)

1.850 (Australia - evening)

80 Metres: 3.530, 3650 (South America)

3615, 3625 (in the UK)

3705 (W. Europe)

3.670 & 3.690 (popular AM frequencies, Australia)

75 Metres: 3.825, 3.870 (West Coast), 3.880, 3.885 (USA)

60 Metres : 5.317

40 Metres: 7.070 (Southern Europe)

7.120, 7.300 (South America)

7.175, 7.290, 7.295 (USA)

7.143, 7.159 (UK)

7.125 (Primary AM Calling, Australia)

7.146 (Secondary and WIA Sunday morning Broadcast, Australia)

20 Metres: 14.286

17 Metres: 18.150

15 Metres: 21.285, 21.425

10 Metres: 29.000-29.200

6 Metres: 50.4 (generally), 50.250 Northern CO

2 Metres: 144.4 (Northwest)

144.425 (Massachusetts)

144.28 (NYC-Long Island)

144.45 (California)

144.265 (Los Angeles, CA)

Other AM Activity Frequencies

AM activity is increasingly found on a number of other bands, in particular: 5317KHz, 7143KHz, 14286KHz, 21425KHz and 29000 - 29150KHz.
There are several local AM nets in the UK on top band.

FM Frequencies

For mobiles working into VMARS events, 2m calling in on 145.500MHz (S20) is usual, before QSY to a working frequency. At event locations where military equipment is in use, suggested FM "Centres of Activity" on VHF are 51.700Mhz, 70.425MHz (70.450MHz calling).

VMARS RECOMMENDED FREQUENCIES

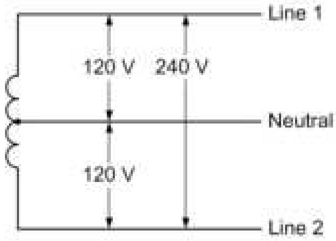
3615 Khz	Saturday AM net 08:30 – 10:30
3615 Khz	Wednesday USB net for military equipment 20:00 – 21:00
3615 Khz	Friday LSB net 19:30 – 20:30
3615 Khz	Regular informal net from around 07:30 - 08:30
3577 Khz	Regular Sunday CW net 09:00
5317 Khz	Regular AM QSO's, usually late afternoon
7073 Khz	Wednesday LSB 13:30; Collins 618T special interest group
7143 Khz	VMARS AM operating frequency
51.700 MHz	VMARS FM operating frequency, also rallies and events
70.425 MHz	VMARS FM operating frequency, also rallies and events

Electrical Supplies - Courtesy LEGRAND equipment

Common Electrical Services & Loads

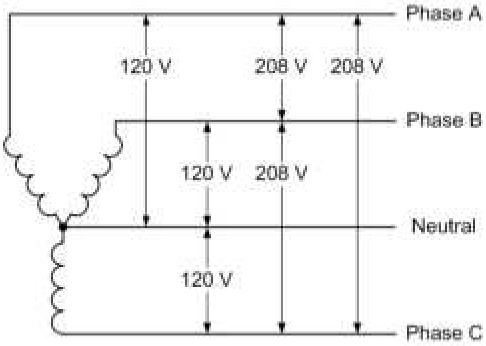
In the following drawings, the coil symbols represent the secondary winding of a utility service transformer or other step down transformer. Electrical code regulations in most jurisdictions require that the neutral conductor be bonded (connected) to the earth safety ground at the electrical service entrance.

Single Phase Three Wire



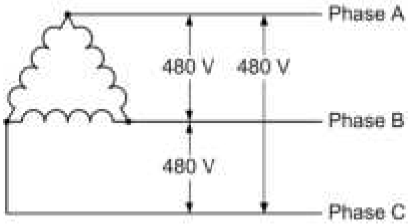
Also known as an Edison system, split-phase or centre-tapped neutral. This is the most common residential service in North America. Line 1 to neutral and Line 2 to neutral are used to power 120 volt lighting and plug loads. Line 1 to Line 2 is used to power 240 volt single phase loads such as a water heater, electric range, or air conditioner.

Three Phase Four Wire Wye



The most common commercial building electric service in North America is 120/208 volt wye, which is used to power 120 volt plug loads, lighting, and smaller HVAC systems. In larger facilities the voltage is 277/480 volt and used to power single phase 277 volt lighting and larger HVAC loads. In western Canada 347/600V is common.

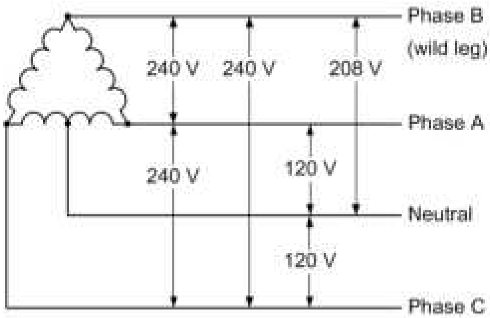
Three Phase Three Wire Delta



Used primarily in industrial facilities to provide power for three-phase motor loads, and in utility power distribution applications. Nominal service voltages of 240, 400, 480, 600, and higher are typical.

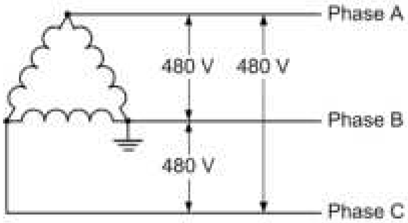
Uncommon Electrical Services

Three Phase Four Wire Delta



Also known as a high-leg or wild-leg delta system. Used in older manufacturing facilities with mostly three-phase motor loads and some 120 volt single-phase lighting and plug loads. Similar to the Three Phase Three Wire Delta discussed above but with a centre-tap on one of the transformer winding to create neutral for 120 volt single-phase loads. Motors are connected to phase A, B, and C, while single-phase loads are connected to either phase A or C and to neutral. Phase B, the high or wild leg, is not used as the voltage to neutral is 208 volt.

Three Phase Two Wire Corner-Grounded Delta



Used to reduce wiring costs by using a service cable with only two insulated conductors rather then the three insulated conductors used in a convention three phase service entrance.

International Electrical Distribution Systems

Description	L–N Vac	L–L Vac	Countries
1-Phase, 2-Wire 120 V with neutral	120	–	US
1-Phase, 2-Wire 230 V with neutral	230	–	EU, UK, Scandinavia
1-Phase, 2-Wire 208 V (No neutral)	–	208	US
1-Phase, 2-Wire 240 V (No neutral)	–	240	US
1-Phase, 3-Wire 120/240 V	120	240	US
3-Phase, 3-Wire 208 V Delta (No neutral)	–	208	US
3-Phase, 3-Wire 230 V Delta (No neutral)	–	230	Norway
3-Phase, 3-Wire 400 V Delta (No neutral)	–	400	EU, UK, Scandinavia
3-Phase, 3-Wire 480 V Delta (No neutral)	–	480	US
3-Phase, 3-Wire 600 V Delta (No neutral)	–	600	US, Canada
3-Phase, 4-Wire 208Y/120 V	120	208	US
3-Phase, 4-Wire 400Y/230 V	230	400	EU, UK, Scandinavia
3-Phase, 4-Wire 415Y/240 V	240	415	Australia
3-Phase, 4-Wire 480Y/277 V	277	480	US
3-Phase, 4-Wire 600Y/347 V	347	600	US, Canada
3-Phase 4-Wire Delta 120/208/240 Wild Phase	120, 208	240	US
3-Phase 4-Wire Delta 240/415/480 Wild Phase	240, 415	480	US
3-Phase Corner-Grounded Delta 208/240	–	240	US
3-Phase Corner-Grounded Delta 415/480	–	480	US

Note: regional variations may exist: if in ANY doubt, consult your Electrical Supply Authority.

Hot Iron 108 May / June 2020

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CQ-CQ-CQ

A Thank You...

Tony Fishpool, G4WIF, emailed me about my including his work in Hot Iron #107:

"*Hi Peter*

Thanks for sending hot Iron. It is always a good read and I know from my years of involvement with Sprat that it takes a lot of work to produce.

I don't mind that you (or someone) lifted the entire page off my January 2017 blog for the comb generator article - but I do think it would have been nice to have asked me – or at least acknowledged my work - and all the text and photos and screen grabs and PCB artwork - which was also mine. I would certainly have given my blessing http://www.fishpool.org.uk/

I noted that you wrote on page 7 "I always credit the original author of any information or web page I reproduce in Hot Iron".

You said "please let me know and I'll happily correct the situation" so I have - and trust that you will.

72/3

Tony G4WIF"

I am more than pleased to include Tony's email in Hot Iron #108. I am most grateful for the articles on the Internet in the public domain as it is a wonderful source of information: I attempt in Hot Iron to illuminate the remarkable work of the authors.

Inbox Limits?

I am reducing the Mb size of Hot Iron as I get many "bounced" emails after every issue of Hot iron is mailed out - either "detected as Spam" , "exceeds Inbox limits", "recipients inbox is full" and similar. So, to reduce the time taken to sort out the mess (and clear my inbox!) I'm deliberately reducing the Mb's in each Hot Iron edition by giving links to relevant sources, rather than copying and pasting the bits I want to illuminate.

This has several advantages for all concerned: you don't inadvertently miss an issue; I don't spend a week sorting out "bounced" emails; you have the original article so can follow the references and associated links; it saves the formatting problems and strange issues the inclusion of pictures and image files in the midst of text files can create (don't ask...!).

I hope it will produce a streamlined yet informative Hot Iron; as ever I welcome your comments and thoughts on this and any other issues you might have or wish to be addressed in Hot Iron. My over-riding desire is to "keep it simple" for all concerned.

A good way to start...

Whilst Hot Iron is the Constructor's Club Journal, it's always an idea to keep an eye open on routes into radio construction that are of similar cost to making your own gear. For most amateurs of my vintage (don't ask...!) just starting out it in radio it was always "build your own" unless you got to hear of a bit of commercial kit going for a song: my first receiver that really shone was an AR88LF. I'd saved up for months to buy the beast from a Manchester Radio Club and it was a wondrous performer - and weighed more than I care to remember. Nowadays, a quality receiver, spanning 30kHz to 30MHz, can be found for far less (taking inflation into account) than the old AR88 by keeping an eye on "Marine Radio" or "Boat Accessories" equipment listed on our favourite on-line auction house; HF receivers / transceivers are particularly good value as most marine service communications are on VHF nowadays - and are usually ruggedised and tropicalised for service on the briny.

I picked up an HF marine service SSB / A.M. receiver for a song recently; I will be building an external audio filter to screw the bandwidth down from 3kHz (SSB, Usb & LSB on all frequencies) and 6kHz (A.M., all frequencies) for CW and RTTY. This, with an active (tuned pre-selector) antenna, will be a perfect companion for my "Pink Brazilian" 80m, 60m and 40m A.M. transmitter; as well as A.M. HF broadcasts, of which I'm a regular listener. The receiver has a switched antenna selector that in the "active" position, puts +12 volts DC onto the antenna jack via a choke; absolutely ideal for my home made active antenna using an LM733 balanced video amplifier without needing to modify the receiver or make a "hot" interconnect for the antenna jack.

I'm using a "security" (burglar alarm) power box for supply: it has a 4 Amp-Hour battery and a switch mode trickle charger. Thus when running the receiver, it's on a quality (and quiet!) voltage supply that will hold up for at least 12 hours, SMPS charger off, no mains connected. The cost of the security power box? A few ££'s, in a neat painted steel box, from my local security supplier. The batteries are available from our favourite on-line auction house, or my local security supplier again, to avoid the "heavy" postage and packing for a gel cell.

Most amateurs I know who build their own gear usually have a mixture of "bought" and "home made" - since a commercial product can't be as specialised as a specific amateur design - unless you're prepared to pay kilo-bucks for the "all bells and whistles" features you only use once every Preston Guild*. I'm looking at a home brewed Fliege audio filter for the audio processing as they are very easy to set up and adjust; the preselector will be a double tuned top coupled bandpass design switched to cover the three bands I'm interested in for A.M. service, and another three for the RTTY and digital modes I'm looking into for QRP purposes (yes; RTTY: I know, I know...!).

The whole assembly will give me good results for minimal outlay, by using my construction skills to adapt the marine receiver to my individual requirements - and I have a tunable "I.F." for down-converters to cover other frequencies I'm interested in. It's a modular approach, very easily adaptable and a lot of fun too.

*Preston Guild meetings are every 21 years.

Tim's Topics

I've not had any notes from Tim for this issue: I know he's rushed off his feet with many things presently, I'm sure he'll have plenty to say when he gets some time! As ever, I extend my very grateful thanks to Tim, he's always welcome to contribute, criticise and correct me!

Components

Back to Basics

I note from various places that some radio amateurs don't have a working grasp of the basics - the estimation of capacitance, inductance, and the like. Whilst you won't need this kind of information every day, it's still a basic requirement to building radio gear, especially if you're working on limited budgets or working from a modest "junque box". The simple basics are more than adequate for most jobs, the basic approximations with their magnificent calculations built in fit the bill without straining the grey cells too much.

Capacitance:

C = Eo.Er.A / D

where

Eo = 8.85 x 10-12 F/m (the Permittivity of free space);

Er = the Relative permittivity of the dielectric (i.e. what's between the capacitor plates)

For example, Air = 1; FR4 pcb board = 5; water = 80

A = area of the capacitor plates (in square metres)

D = the spacing between the plates (in metres)

OR... use http://www.66pacific.com/calculators/capacitor-calculator.aspx

Inductance

Of a single layer air cored solenoid = Radius^2 x Diameter^2 / 9xRadius x 10xLength

With dimensions all in inches OR centimetres

OR... use http://www.66pacific.com/calculators/coil-inductance-calculator.aspx

You can find the inductance of any toroid core here:

http://www.66pacific.com/calculators/toroid-coil-winding-calculator.aspx

OR

https://www.daycounter.com/Calculators/Air-Core-Inductor-Calculator.phtml

You can select the toroid material (iron powder for HF, ferrite for LF)

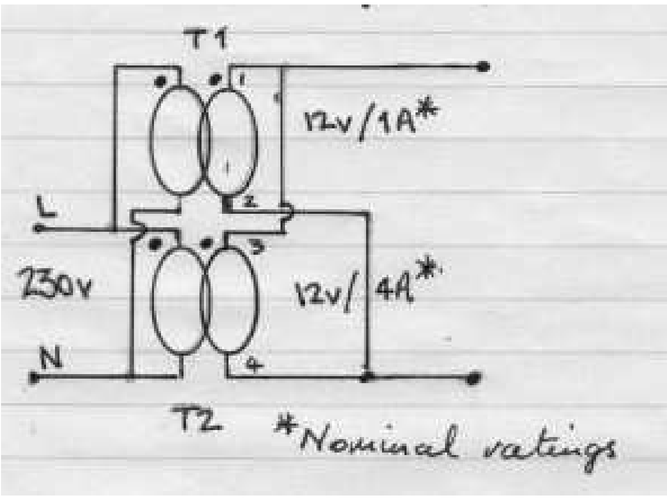
OR for air cored / non magnetic toriods μr = 1

https://www.easycalculation.com/engineering/electrical/toroid-inductance-calculator.php

Power Supplies

Albert's Power Supply

Albert had a conundrum. It had him flummoxed; his "dull lamp" safety device* (an incandescent lamp in series with the "live" line, as per Hot Iron # 101, pp28) lit up every time he tried his new power supply. He wanted to use two junque box transformers in his power supply: he needed 15v AC (rms) at 5 Amps. Albert had a chunky 4 Amp 15 volt transformer (T2) and a small 1 Amp 15 volt transformer (T1) so reasoned he could connect them in parallel to get his 5 Amps. Being a conscientious amateur, Albert tested stages as he wired them up to avoid having to modify his handiwork when all was built - so his AC power circuits, mains and low volts, were connected as he thought correct, and were the first to be checked, no load connected to the paralleled secondaries.



On went the AC mains; "all lit up" went his "dull lamp", indicating significant current demand! Albert then (logically) suspected one or even both his transformers might be faulty, he carefully removed T1 and T2 and tested them on his bench with his multimeter to see if any winding showed leakage to earth; to his surprise, all windings read clear, no shorts to the frame or core. Albert then wired each individual transformer to mains supply via his "dull lamp" with a few car lamp bulbs as a load - and both performed perfectly. Since no other components existed in Albert's power supply at this stage, it *had* to be - as per Sherlock Holmes - "with the impossible eliminated, what remains are the only possible solutions" - which leaves just the wiring? So Albert conscientiously checked, end to end, every wire in his power supply. Reconnected, to his dismay, on power up, he was greeted with his dull lamp once again "all lit up".

Albert, had learned from previous projects the sensible way to do things: he had wired his transformers to and from a screw terminal block*, so removal, rewiring or modification was simple and easy and they were tested in a jiffy. A multimeter ohms test of the windings showed the following results (having taken his multimeter lead resistances into account) when measuring the windings end-to-end:

T1 primary: 350 ohms; secondary: 0.2 ohms and labelled as 15v / 1A, 15VA

T2 primary: 110 ohms; secondary: 0.1 ohms and labelled as 15v / 4A, 60VA

Albert had already noted that his multimeter leads had a resistance of ~ 0.2 ohms, and so was reasonably confident his measurements were near as dammit - within the capabilities of his multimeter. Albert reconsidered: could it be the "phasing" of the windings, that funny stuff he'd heard about somewhere?

Albert sought advice, not being too confident and after all, this was mains powered stuff and he always erred on the side of caution - that's why he always used* his "dull lamp". Thus entered Stan the (Maintenance) Man, who, on seeing Albert's notes* asked Albert to measure the open circuit secondary volts of T1 and T2, "on no load, please, Albert". This Albert did, and with these results:

T1 o/c sec'y volts = 16.6v (RMS)

T2 o/c sec'y volts = 15.3v (RMS)

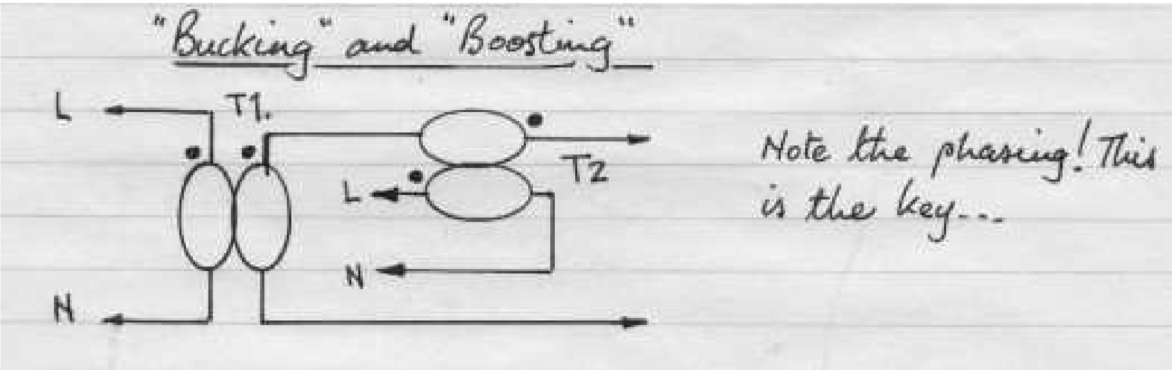
Stan had a probable solution: the transformer secondary voltages were unequal, which - assuming Albert had wired them in opposition (i.e. winding starts together, so the voltage of T1 opposed the voltage of T2) gives a potential difference of 1.3 volts around the paralleled secondaries (on no load, mind) resulting in a circulating current *with no load attached* - which was probably causing saturation in the iron core of T1.

As a rough approximation, not counting things like inductive reactance or leakage flux, the loop current will be roughly 1.3v through (0.2 ohm + 0.1 ohm) which is 1.3v / 0.3 ohms = 4.33 Amps. T1 being specified at 1 Amp (rms), was likely saturating it's core; thus the primary current in T1 was probably way too high.

Stan explained a few more transformer fundamentals to Albert, after Albert suggested paralleling the supplies after rectification and regulating. Stan had seen this tried; it inevitably ended, quoth Stan, “like marriage to the most beautiful girl in the village - heartbreak and tears”. Stan explained: “you’ll always end up with circulating currents in any circuit if you parallel low impedance supplies, be they AC, DC or anywhere in between; not always obvious but very likely”.

Stan went further: “on DC, paralleling ostensibly equal output 78XX three terminal regulators can cause problems: because the ‘common’ leads, if not earthed to a star point, can cause offsets in the multiple regulator’s output voltages, due to difference in volt drops in the common return lines: and there you go, one regulator - the one with the highest output volts - will end up driving all the load; the lower output regulators will contribute little or nothing. The lesson’s simple: don’t parallel power supplies.”

“One exception though, Albert: toroidal transformers - from the same maker, of identical ratings and of the same batch, can be paralleled: they are far better matched than traditional rectangular ‘E & I’ transformers and will parallel - usually - without trouble. Some amateurs use Buck or Boost connection to solve problems of not having the right transformer: by adding a second transformer



you can either throttle back a higher voltage transformer or increase the output volts by connecting in Buck or Boost, (diagram above) by observing the phasing. For instance, we had a job to replace a Radyne 150kW RF Generator filament transformer, rated 15 volts 160 Amps. We couldn’t get the manufacturer’s replacement for 6 weeks; so we had to improvise to get production running. A stud welding transformer rated at 20 volts 180 Amps and a 4.5v / 200 Amp electroplating transformer from the ‘Black Hole’ (the professional engineer’s equivalent of the amateur’s junque box...) and Bucked the 20v winding down to 15.5 volts by wiring the two transformers in opposition. We did this by wiring the secondary windings in series, and measuring the resultant voltage: it would be either 24.5 volts in “Boost” connection, or 15.5 volts in “Buck” connection. We got lucky, and got 15.5 volts first time; with unknown transformers this is the only sure way to find out the phasing. The only caveat on this job was to be sure both transformer secondary windings could carry the full 160 Amps, whether you Bucked or Boosted. We ran temporary wires to the filament in 6mm^2 cable, and got dead on 15 volts at the valve terminals, the 6mm^2 dropping a few hundred mV’s”.

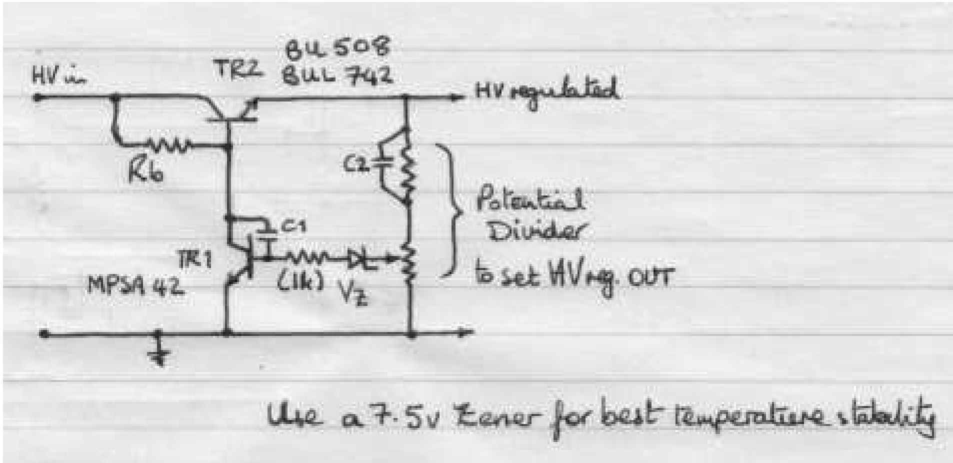
“The phasing of windings is the key: keep this simple rule to mind and you won’t go wrong. *Current entering a ‘dot’ will make all other magnetic coupled ‘dots’ positive*. A remarkable man called Augie Hand used just this method to identify the 9 (unmarked) leads of a USA dual voltage 3 phase induction motor - with nothing more than a 6 volt battery and an analogue multimeter. He's well worth a quick search on the Internet; these things are always useful to know...".

And I can state without doubt - that during one of those lonely12 hour night shifts - funny how you always end up working on your own when trouble strikes on a night shift - simple tests, like those Augie documented, applied to machinery designed for servicing*, is truly a blessing...!

* These are very sensible ideas, adopt them...!

HV regulated PSU's for pennies

Shown below is a simple HV regulator circuit that uses very cheap components - the HV bipolar transistors are very cheap, or free if you break open a dud LED or fluorescent lamp base. You'll find a handfull of goodies in there; in fact a useful 80m transmitter was created by that RF genius, Mike Rainey, AA1TJ, called "Das DereLicht", from a compact fluorescent lamp parts rip down.



The diagram has a couple of points worth noting. First is Rb, the base bias transistor for TR2. By making Rb a high value, the bias current into TR2 base can be limited: thus the emitter current (which is the output current) is limited to TR2's hfe (current gain) times the base current. This renders the output short circuit proof if Rb is chosen to be sufficient to feed your circuit(s), plus a little more for good measure; any further current demand is impossible as TR2 cannot pass any more current - a bit rough and ready, but it works. If you need an electrolytic across the output, this "built in" current limiting will allow controlled charging of the electrolytic, thus avoiding the surge of charging current that can pop upstream fuses.

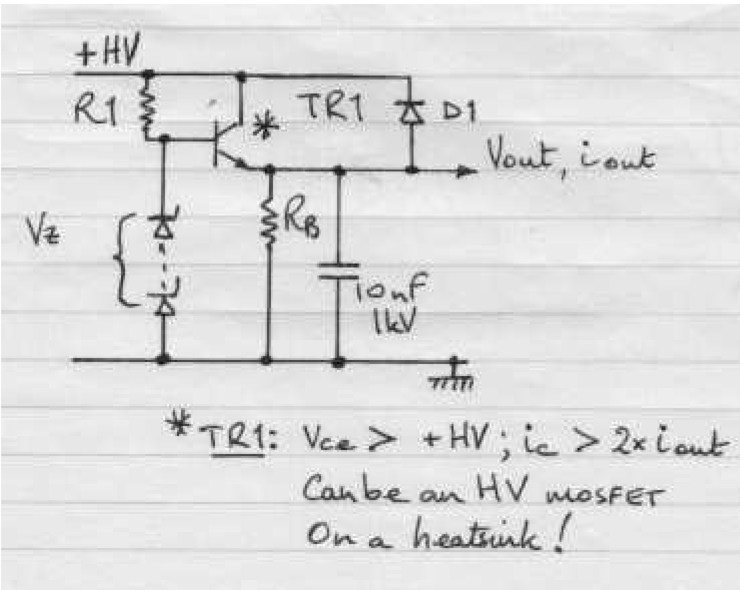
The BUL 742 is a monster of a transistor; but any NPN with sufficient Vce rating is good to go in this position but be aware a chunky series pass transistor is rugged - and experimental HV electronics can be somewhat destructive! Line output transistors (for those of you who remember TV's with cathode ray tubes) are an excellent choice here. For my money - and the umpteen car and motorbike electronic ignitions I've built with it - you'll find it damned hard to beat a BU508 transistor. Rugged, reliable, capable of gross overload, it's a superb workhorse in any rugged HV circuit. The BUL742 family are a modern device just as rugged, used in lamp ballasts running directly off the mains - so these babies have to be tough.

The potential divider reduces the output to an exact fraction of the main HV; this value is applied to zener diode Vz (7.5v nominally, but any between 4v7 and 12v will work fine) - the temperature co-efficient of a base emitter junction is -2mV / °C; the 7v5 zener is + 2.5mV / °C). If the output voltage rises for any reason, the zener breaks down and applies base current to TR1. TR1 collector sinks some of the base current applied to TR2, thus shutting off TR2, lowering the voltage out - compensating exactly the rise which originally overcame the zener barrier voltage. The potential divider also applies a ballast load to the regulator, ensuring that any current from the load (i.e. the screen grid of a tetrode, for instance, can *source* mA's as well as *sink* them) has a path to ground.

By it's very nature, a potential divider resistor dropping (say) +300v to less than +20v or so at the hot end of the potentiometer will be quite a high value; this means the stray capacitance around the base circuit of TR1 can form an RC low pass filter - sudden voltage changes or loading will not be compensated quickly. So C2 is shunted round this high value resistor so fast load changes are reflected into the error amplifier TR1 promptly. 470pF / 1kV is typical for C2. Note the gain of TR1 compensates for the loss of sensitivity created in potential dividing the HV output - in fact the voltage gain, with a high value for Rb, more than compensates for the potential divider losses. Thus C1 is a loop compensation capacitor; it effectively adds to the Miller capacitance of TR1 to roll off the HF response and stabilise the control loop. Typical values are 47pF / 1kV ceramic, but it's not always necessary if TR1 and TR2 are low Ft rated devices - which HV power transistors commonly are. It's a balancing act: C2 feeds the fast changes to TR1; C1 slows TR1 down a touch.

Simple HV Regulator

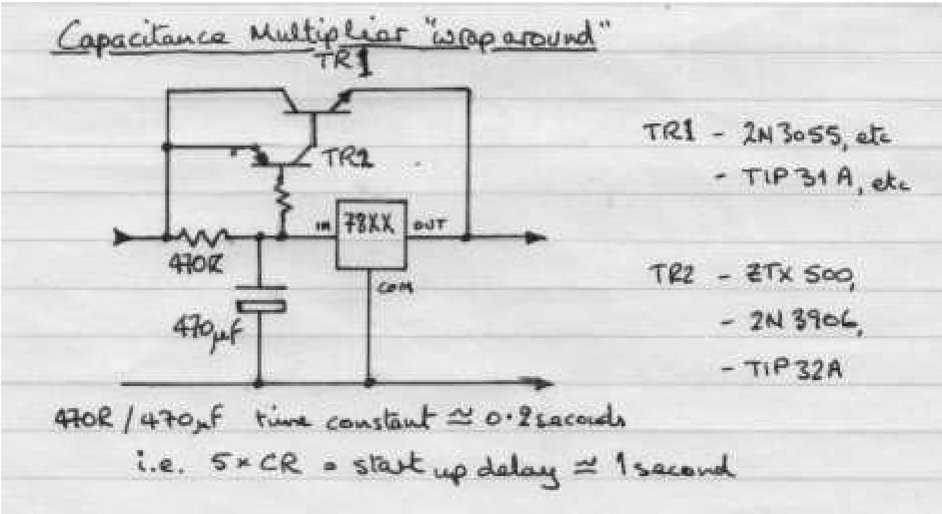
This circuit will give good results too, so long as you keep current demand low; and that goes for sinking current too - you need to scale resistor Rb appropriately. Diode D1, whilst looking somewhat redundant, is a safety measure, guarding against mains failure or upstream feed fuses blowing. The load may well have full charged HV electrolytics embedded: D1 shunts any back feeding voltage around TR1, preventing any damage to either junction. If you use a power MOSFET for TR1, you'll have the diode built in; it's part of the manufacturing process (though manufacturers will tell you it's an added feature...).



Capacitance multiplier & Sziklai complementary wrap around... two jobs in one

Most constructors consider integrated circuit voltage regulators (78XX types typically) as being a sort of electronic “guillotine”, in that they chop off the awkward bit at the top: if your DC feed to the regulator has ripple or noise, then a voltage regulator will surely “chop it off”, yes? Well, I hate to tell you... NO it won’t! The “Ripple Rejection” capabilities of most voltage regulators is not too good; sure they will cut it down, but certainly won’t yield that “flat as a millpond” DC level.

A way to get far better results from a simple 78XX regulator is to use a PNP / NPN wrap-around circuit detailed in previous Hot Iron #106, pp22, but add a *capacitance multiplier* to the input.



This circuit electronically “multiplies” a capacitor to be very much larger than the actual value: you don’t really get free µF’s, but the effect is the same. The diagram shows the added 470µF electrolytic, and the line resistor is a bit higher than you’d expect at 470 ohms; but this is how it works. You’ll see similar circuits in Direct Conversion receiver schematics, feeding the post mixer diplexer amplifier to guarantee low noise performance.

Basically, the base of a TR1 is slugged with a hefty electrolytic which means the emitter current is similarly slugged - but because the Hfe of TR1 multiplies the base current into the emitter - so the regulator and it’s wrap around are fed current derived from a very low frequency filter. With a 470 ohm sampling resistor and a 470 µF capacitor you have a time constant of ~ 0.2 seconds; resulting in a low pass frequency $\omega = 1/CR = 5$ rads/second, about 30Hz. Ripple from a full wave rectifier is 100Hz (in UK; 120Hz in USA) so the filter makes a good job of ripple reduction. The small resistor in TR1’s base is a 100 ohms or so; it’s a bit of protection for TR1’s base - emitter junction.

The only penalty is the start up time delay: you have to wait for the electrolytic capacitor to charge on power up. You could make the capacitor 1000 µF, the sampling resistor 1k, but you’d be waiting a while for the supply to run up: use 5 x CR as an estimate for start up time. As ever, it’s a trade off!

Compliance: constant amps and infinity gain amplifiers

Consider a power supply on your bench. You are wanting to pass a constant *current* through a load (maybe a NiCd battery to be charged; or a high power laser LED for that optical comms project) and you need a simple design. You look at some circuits for constant current generators, utilising maybe a 78XX regulator or a transistor or three, and you keep seeing the term “compliance”. Just what is this “compliance”? Well, consider the following:

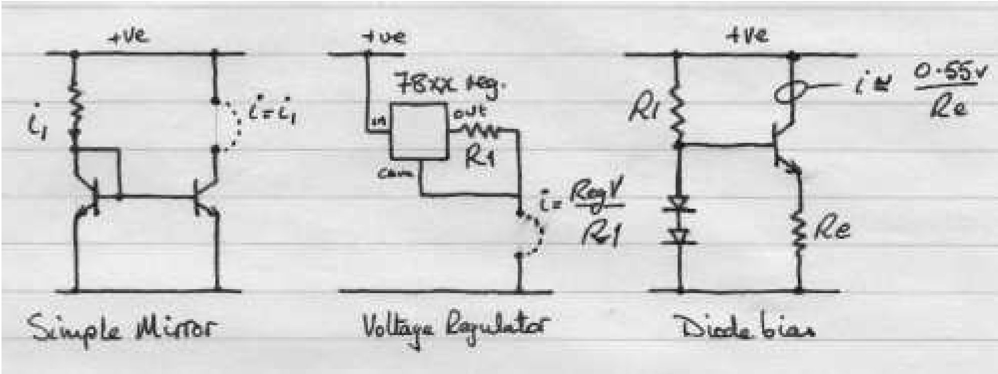
Supposing you want a fixed current of 1 Amp to flow in ANY load resistance you connect into your circuit - be it 1 ohm, 10 ohms, 100 ohms, whatever - the voltage across each of these loads would therefore be 1 volt, 10 volts, 100 volts. So for your circuit to work, assuming it needs a few volts extra to bias everything and run the clever bits, for the above you’d need a supply feeding your constant current generator of well over 100 volts. The “compliance” is the maximum voltage available to drive 1 Amp through any load: if the constant current generator is designed to drive 1 Amp, and has “compliance” of 100 volts, you can only connect a load up to 100 ohms, before the constant current generator “runs out of headroom” and doesn’t have enough volts to drive 1 Amp through any load greater than 100 ohms.

All this leads to some strange territory for the circuit designer. As a theoretical example (not that I’d suggest you try this - but, if you must - on your own head be it...!) let’s consider a 1kV DC power supply, with it’s positive output feeding a load via a series connected 1 M-ohm resistor. If the load end of the 1 M-ohm resistor is shorted to the negative terminal of the power supply, the current flowing = 1 mA. Now, insert in series with the 1 M-ohm resistor a 1 k-ohm load resistor. The current will be 0.999 mA, near as makes no difference to 1 mA. Now remove the 1 k-ohm and replace it with a 10 k-ohm resistor in series with the 1 M-ohm: the current will be 0.9901 mA - still very close to 1 mA. Replace the 10 k-ohm with a 100 k-ohm, and the current is 0.909 mA, still not too far from 1 mA.

Now we shift up a gear, replace the 1 kV supply with a 10 kV supply; and replace the 1 M-ohm resistor with a 10 M-ohm, and repeat the previous test: with a 1 k-ohm in series with the 10 M-ohm, the current is 0.999900009 mA. Replace the 1 k-ohm with a 10 k-ohm current = 0.999000999mA; now the 100 k-ohm: current = 0. 99009901mA.

We therefore conclude that the higher the SOURCE RESISTANCE the more accurate is the circuit behaving as a CONSTANT CURRENT generator.

Not everybody has 10 kV power packs to play with, nor would relish working with source resistances of 10’s of M-ohms; so we use semiconductors to simulate an infinite resistance, and create our constant current sources with them.



These are easily constructed constant current generators that are reliable and easy to set up or adjust - and, incredibly, within reasonable operating parameters, exhibit almost INFINITE source resistance, as the current is very nearly constant for any load - keeping ‘compliance’ in mind. So, let’s use this feature to make a very high gain amplifier, that can drive real loads.

Recall that as a rough approximation, the voltage gain of a bipolar transistor amplifier is proportional to the (hfe) x (collector load resistance). If the load resistance is INFINITY the voltage gain is also INFINITY! If we make the collector load a constant current generator, this simulates an INFINITE resistance and the gain is - well, so high, instability is almost guaranteed - unless the amplifier has lashings of negative feedback and sufficient roll-off to get the gain / phase inside the Nyquist -1,180° locus point.

You can see current mirror constant current generators in op-amp amplifiers at:
https://www.me.psu.edu/cimbala/me345/Lectures/Inside_the_741_Op_Amp.pdf

you’ll see “Current Mirror” constant current circuitry coloured red, acting as infinite impedance loads in the transistor collectors for input pins 2 and 3. The article describes the current mirror action far better than I can - but suffice to say that changing the bias on one transistor in a mirror causes an identical change in the other. These are precision constant current sources; for “odd job” roles like battery charging, and the like, a simple transistor or 78XX regulator will do the job nicely, and deliver a hefty current too.

The only downside to using a 78XX regulator as a constant current generator is the loss of compliance; a mirror or diode bias circuit has compliance equal to the supply voltage less collector to emitter volt drop - about 0.2 volts or so for a saturated silicon transistor. If you experiment with a mirror made from two discrete transistors, it’s a good idea to clamp the two devices together so they are thermally bonded; the current will track far more accurately in the mirror “halves”.

All these circuits can be “inverted” if you wish: simply replace all transistors with PNP types. If you prefer a voltage regulator circuit, exchange the 78XX positive type for a 79XX type.

Components...

Valve / Tube chassis holes...

I measured the bases I have and these are the sizes. No doubt there are dimension drawings and preferred hole sizes on the web somewhere; I'm happy with those listed below most of the time - but I have a dandy half round file in my tool kit, just in case.

The one thing I miss in my home building stocks are the once-common Octal plugs, which were a rugged, robust, reliable and cheap means of making power supply and module interconnecting cables. I uses DIN audio types nowadays, but they aren't a patch on the old Octal beasties.

Valve / Tube base	Hole diameter	Preferred metric size
B7G	15mm (½")	15mm
B9A	19mm (¾")	19mm
International Octal	28.3mm or 1⅛" *	29mm**

* Note: 5U4G (and many other) rectifiers fit "International Octal" sockets, but often, not all pins are implemented; the valve / tube is orientated correctly by the key on the octal base spigot.

** If you can find one on your locale, that is. I found one in the UK at:

https://www.toolstoday.co.uk/q-max-sheet-metal-punches-metric

...but for our non-UK readers it might be a bit of a tussle - but then again, you'll likely have the Imperial sizes available? Octal and other valve bases were specified in "feet and inches", so those of you fortunate enough not to have to deal with Metrication have a flying start.

Octal socket holes are "usually" 1⅛" diameter; but beware, some ceramic holders may need different sizes, to accommodate clamp rings and mounts.

Class X and Class Y capacitors... another aspect

I had some emails asking for clarification of "X" & "Y" class capacitor failure mechanisms; so from:

https://www.allaboutcircuits.com/technical-articles/safety-capacitor-class-x-and-class-y-capacitors/

below is an excerpt that will help clarify. In simple terms, a class X capacitor will fail SHORT CIRCUIT as it's meant to be connected line-to-line; the short will quickly blow the upstream fuses and clear the circuit. A class Y capacitor will fail OPEN CIRCUIT, as it's meant to be connected line-to-earth - which, if it failed short circuit, could make the earthed metal of a machine, tool, or equipment assume a high, possibly lethal, potential if the earth loop impedance is more than a few ohms. The passage below will explain better than I can:

"*Applications for Class-X and Class-Y Capacitors*

Subclass X2 and Y2 are the most commonly used safety-certified capacitors. Depending upon your own application and requirements, they are probably the ones you'll want to use. This is assumed because X2 and Y2 safety capacitors are used in common appliances that operate from ordinary household wall outlets. ***To be clear, you should select your Class-X and Class-Y capacitors according to your design's purpose and requirements.***

Whereas X2 and Y2 caps are appropriate for household applications, X1 and Y1 safety capacitors are used in industrial settings. As an example, a subclass X1 safety capacitor would be used for an industrial lighting ballast that is connected to a 3-phase line.

Of course, you could always use subclass X1 and Y1 in non-industrial applications, but you'll be spending more money and the larger sizes may prove inconvenient.

You might be asking, are X2 and Y2 safety capacitors interchangeable?

A Y2 capacitor can safely be used in place of an X2 capacitor, but an X2 capacitor should not be used in place of a Y2 capacitor. This is because, although an X2-type capacitor would work and filter noise sufficiently, it would not meet the line-to-ground safety standards. Y2 safety capacitors are more robust, are able to withstand higher peak impulse voltages, and are designed to fail ***open circuit*** *as opposed to failing short circuit.*

There are also safety caps that combine aspects of X and Y types, such that they have met both X and Y safety requirements and standards. So for an X1/Y1 combination, this simply means that the capacitor can be used either as an X1 capacitor in a line-to-line application or as a Y1 capacitor in a line-to-ground application. Examples include the following:

- *Vishay (PDF) offers their VY2 Class X1 (440 VAC) / Class Y2 (300 VAC) capacitor.*
- *Kemet (PDF) offers both X1/Y1 and X1/Y2 class combinations.*"

These capacitors are often seen in synchronous motor starters to give a phase shift voltage to a start winding. They can be very useful too as surge limiters in place of power resistors in HV power supplies, as described in Hot Iron #101, pp24; use class Y, to "fail open circuit" for safety.

Test Gear

Using a digital multimeter

For those who only have a digital multi-meter, rather than the much more friendly analogue instrument, trying to "peak" a circuit or tune an antenna you need to "de-jitter" those dancing digits with a simple low pass filter. LPF's are especially useful (unlike those useless Digital bar-graph readouts) in circumstances where the readings are never *quite* settled.

Recall the input impedance of a digital multi-meter is often 10 meg-ohms or more - so the inclusion of a 10k - 100k ⅛watt series resistor in the positive lead, won't make a ha'porth of difference; and a 100nF to 1μF HV capacitor to the negative lead completes the set-up. TV repair men in the halcyon CRT and PL504 "fizzing" pentode days had this little circuit built up on a bit of scrap PCB material, or perspex offcut, with 4mm plugs set 20 mm (¾") apart to plug directly into their "digital dancer" -

thus removing the 15.625kHz line timebase crashing hash when peaking up a stage. I used 4mm brass nuts and bolts, 25mm long with solder tags to mount the resistor and capacitor rather than specific 4mm plugs; the current is very low so the threaded sections don't cause any trouble.

The inclusion of a small neon bulb across the disc ceramic also protects your nosebleed expensive Fluke or HP digital Wonder Wobbler (other makes are available) from the hefty ZAPP! from an inadvertent touch on a 2kV B++ line. Yes, I know digital multimeters are *supposed* to be protected, but....! The ⅛ watt series resistor doubles as low pass filter and safety fuse in the event of a misplaced "prod".

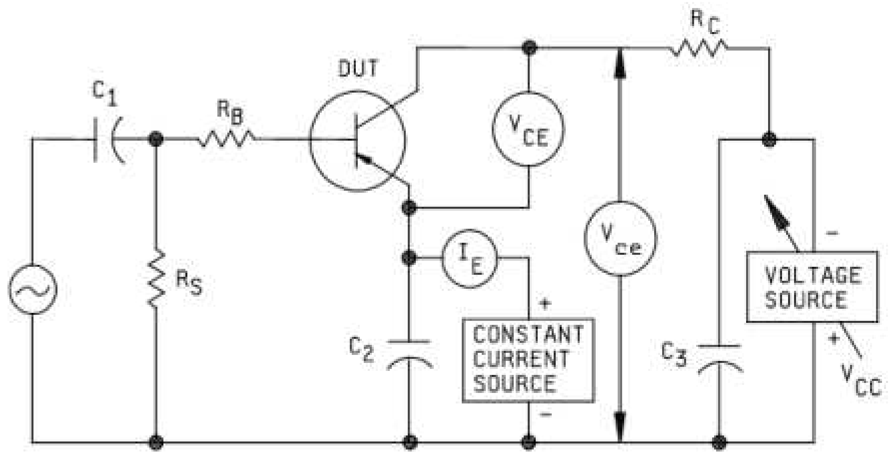
Measuring transistor ft (2)

I have had a few emails about my commenting on the method I used in Semiconductor Manufacturing for measuring Ft using the voltage gain and frequency method, outlined in the last Hot Iron. Of course, it IS possible to measure Ft via S parameters, network analysers and suchlike esoteric beasties: but when you've 7.5 million to test every 24 / 7 / 365, with fractions of a penny profit* on each device, time is of the essence; as is robust, rugged and reliable (simple and cheap!) test gear. Anything otherwise increases equipment set-up times, maintenance and operator fatigue which loses all the profit from the job. Of course, amateurs aren't concerned with this production trivia, but **are** concerned with paying no more than absolutely necessary for a 2N3904. It's canny production and test engineering why you pay only pennies for a 2N3904! Somebody in a factory somewhere has to make these little beggars and test them by the million to be certain you get exactly what you pay for.

* If you're lucky...

Below is an extract from the MIL-SPEC Transistor Test directory:

2. Test circuit. The circuit shown on figure 3306–1) and procedure in 3 are for common emitter configuration. For other parameters the circuit and procedure should be changed accordingly.



NOTE: The biasing circuit shown is for purpose of illustration only. Other stable biasing circuits may be used.

FIGURE 3306–1. Test circuit for small-signal, short-circuit forward-current transfer ratio.

3. Procedure. Capacitors C_1, C_2, and C_3 shall present short-circuits in order to effectively couple and bypass the test signal at the frequency of measurement. The value of R_B shall be sufficiently large to provide a constant current source. Resistor R_C shall be a short-circuit compared to the output impedance of the device. With the device removed from the circuit, a shorting link is placed between the base and collector and the output voltage of the signal generator is adjusted until a reading of one (in arbitrary units) is obtained on the high-impedance ac voltmeter, Vce. With the device in the circuit and biased as specified, the reading on voltmeter V_{CE} is now equal to the magnitude of (h_{fe}). (NOTE: Care must be taken to assure that the output signal is not clipped.)

HV diodes cheap!

https://www.ebay.co.uk/itm/5Pcs-CL01-12-Microwave-Oven-Induction-Cooker-High-Voltage-Diode-Rectifier-P-lq/123960643597?hash=item1cdca1500d:g:hfwAAOSw0GNbCMpP

These "diodes" are, in fact, stacks of silicon diodes - just the silicon dies, no wires or casings - electrically and mechanically bonded together in a series string. They are very conservatively rated in voltage terms; a typical domestic microwave oven transformer giving 1500 - 2500 volts AC on the secondary, and the silicon diode / capacitor network forming a voltage doubler using the magnetron as the second diode in a conventional doubler circuit makes about 5kV, but this doesn't take in account the mismatch the magnetron faces with varying loads in the oven chamber; the HT can rise to very much more that 5kV sometimes.

As amateurs, if we need some hefty B++ volts for our 4CX250B linear, we'll probably build our own series strings of 1N4007 diodes: in which case we can add 10M HV resistors and a 10nF HV disc ceramic capacitor in parallel with each 1N4007 to act as RF decouplers and voltage equalising resistors. If space is tight, however, CL01-12 diodes yield a big space saving - but keep in mind you can't fit those (sometimes vital) parallel 10M //10nF, but **can** use strings of kV rated ceramic capacitors in parallel with CL01-12 diodes to shunt any RF.

R & D Dept.

This section is included as I'm still in mid house move and have no bench facilities to try anything or build test circuits. COVID-19 has kyboshed a lot of other activities, so I've listed a few of the thoughts that swill around the darker areas of my imagination for those more fortunate than I, who are not in the midst of the seething inactivity lawyers engage in regarding house sales - to have a go at and see if anything of interest emerges. I'd be most grateful if you have any ideas about these odd corners of amateur RF for inclusion in the next Hot Iron - no matter how "off the wall", they might just have that touch of genius that moves our technology forward.

Compulsory Safety Note: *all that follows in this section of Hot Iron is EXPERIMENTAL. It's not proven or assured designs or techniques! Enjoy experimenting, it's great fun, but I'm not responsible in any way, shape or form for the bangs, whistles, burnt fingers or smoke that can (and probably will) occur if you push the boundaries of sensibility too far in a blasé fashion!*

In my semiconductor manufacturing days, "R&D" was that mysterious department behind the painted out windows where mysterious BANGS, occasional smoke and strange sizzling noises emanated. To that end, this section is presented with the philosophy "try it; never mind what the theory says".

If you recall the theory that bumble bees shouldn't fly, it dates back to the 1930s, when the French entomologist, August Magnan, stated that because of the haphazard way their wings flapped around they couldn't possibly fly. The bees, however, not having known August Magnan's theories, just flapped their wings, and fly they did. Just because it isn't mainstream design and accepted principles, it doesn't mean that it's pointless. You might just discover "the next big thing" in your experiments - now that's REAL amateur radio.

So, out with your soldering irons and junque boxes, and have at it with a will! Please let me know if you find any anomalies, mysterious behaviour and other "interesting" effects. I'll very gladly publish your results!

- DC bias on Ceramic Resonators for accurate but small shift frequency shift keying / data modes
- Ditto on quartz crystals
- Ditto on ceramic capacitors
- Tx / Rx switching using pencil ("Sputnik") tubes; switch the filaments on / off for easy and total isolation, they heat up in a second. Or using them as series / shunt switches?
- Crystal / ceramic resonators - limiting the dissipation by fitting the ceramic resonator between base and collector of a transistor with a 10M-ohm resistor in parallel and using the collector and emitter as the resonator's "terminals" for valve or HV solid state roles

- 4 x crystal Colpitts a-la Peter Parker’s VK3YE ideas... more than 4 = bigger stable frequency swings?
- If super vxco Ceramic Resonators / crystals are of different frequencies, what output frequency do you get?

Test Gear / Maintenance

Simplest ESR tester for electrolytics

Equivalent Series Resistance is a measure of the current capability and life left in an capacitor, oiled paper, ceramic, or electrolytic and is a “go-to” wonder for the service technician. You can buy hand held gizmos to do this... but we prefer to make our own from junque!

https://www.homemade-circuits.com/esr-meter-circuit/

I don’t think I’ve seen a simpler method? Much to recommend it for high ripple rated power supply electrolytics removed from circuit for testing, but watch back-biasing electrolytics. I think I’d drop the transformer secondary to 3 volts or so to reduce the back stress on the electrolytic.

OR... https://ludens.cl/Electron/esr/esr.html which is an in-circuit tester using only a few hundred mV of drive applied to the capacitor. This is almost THE standard for bench ESR testing; most of the small gadget gizmos use this approach.

Oscillators...

The Resistance Stabilised Oscillator

Whilst this oscillator is commonly used for Audio and LF duty, there is no reason why the principle cannot be extended to crystal or ceramic resonator circuits; nor limited to valve technology. A jfet (with a gate diode for the “grid current” circuit) or indeed a bootstrapped bipolar gain stage (with a similar diode clamp) would most likely work equally well.

From: https://www.radiomuseum.org/forum/klirrarmer_oszillator.html

The resistance-stabilized oscillator is widely used for the generation of audio and low radio frequencies. Typical circuit arrangements are shown in Fig. 147 [Fig. 12-7 from 2nd ed.] and are seen to be conventional oscillator circuits with the addition of a "feed-back" resistance located between the plate of the oscillator tube and the tuned circuit.

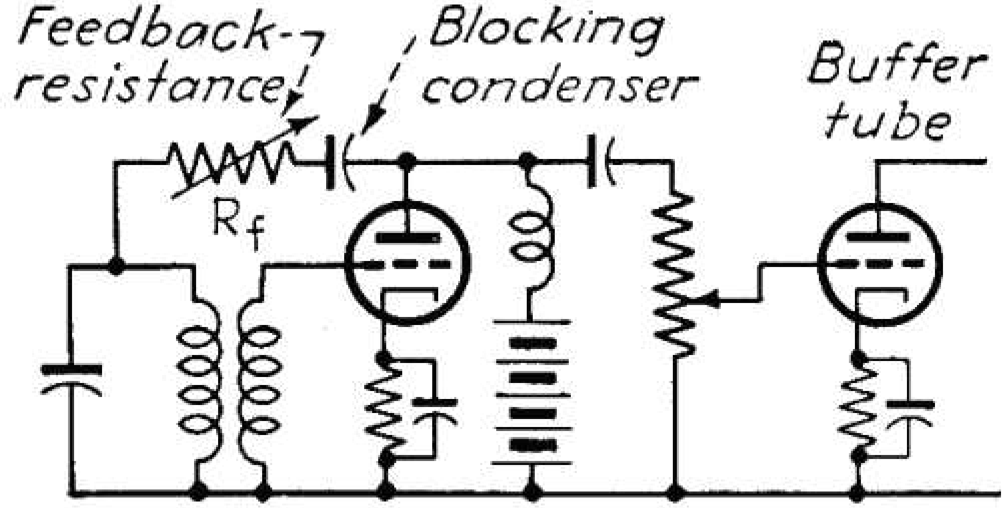


Fig. 12-7. Typical circuit diagram of resistance-stabilized oscillator.

This feed-back resistance must be high compared with the plate resistance of the tube and has two primary functions. First, it makes the resistance which the tuned circuit sees when looking toward the plate substantially independent of the electrode voltages; and, second, it provides a means for limiting the amplitude of oscillations to the straight line part of the tube characteristic.

The tube in a resistance-stabilized oscillator is adjusted to operate as a Class A amplifier, and the feed-back resistance is made so high that oscillations are just barely able to start. Under these conditions, oscillations start with minute amplitude and build up until there is grid current, which introduces additional losses that increase rapidly with further increase in amplitude. If the feed-back resistance is so high that oscillations are barely able to exist with no grid loss, an equilibrium will be reached at an amplitude which drives the grid only a few volts positive. It will be noted that a fixed grid bias such as obtained from a biasing resistance is necessary, and that the grid-leak bias arrangement commonly used with power oscillators is not permissible.

The wave form is determined by the linearity of the tube's dynamic characteristic over the range of voltage which the oscillations apply to the grid. It is apparent that for good wave form the tube when considered as an amplifier must be so adjusted that it will amplify without distortion an alternating-current voltage on the grid having a crest value slightly greater than the grid bias. This means that the oscillator tube should be operated at a grid bias that is slightly less than the bias that would be used for Class A amplifier operation at the same plate voltage.

Best results are obtained when attention is paid to certain circuit details. The circuit proportions should be such that the feed-back resistance required is at least twice, and preferably over five times, the plate resistance. The blocking condenser in series with the feed-back resistance must have a low reactance compared with this resistance in order to avoid phase shifts, while the shunt-feed choke should have a reactance that is high compared with the plate resistance of the tube for the same reason. The frequency stability is also helped greatly by making the coupling between plate and grid coils as close as possible. Two possible methods of connecting a buffer tube are shown in Fig. 148. The arrangement at Fig. 148a is usually preferred because it gives the best wave form, although the circuit of Fig. 148b has the advantage of developing greater output voltage.

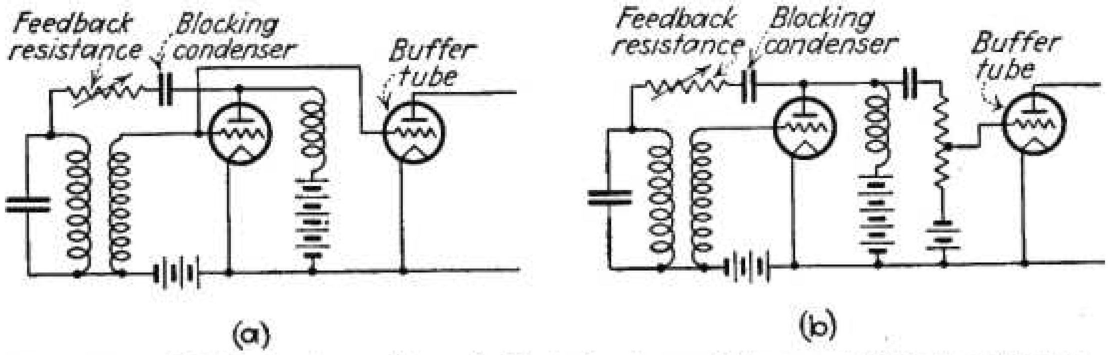


FIG. 148.—Methods of coupling a buffer tube to a resistance-stabilized oscillator.

The most satisfactory tubes for resistance-stabilized oscillators are those having amplification factors in the range of 4.5 to 8, together with the highest possible mutual conductance. With such tubes, the grid and plate coils should have approximately unity turn ratio.

Design of Resistance-stabilized Oscillators

When the characteristics of the resonant circuit are known, it is possible to lay out a resistance stabilized oscillator on paper and predict accurately the amplitude of oscillations and the circuit conditions required for proper operation. For example, assume that it is desired to set up an oscillator employing a tuned circuit that develops a parallel-resonant impedance between plate and filament taps of 50,000 ohms. Assume further that the ratio between plate and grid coils is 1 to 1, that a Type 89 tube operated as a Class A triode amplifier is to be employed, and that an amplitude of oscillations of 10 volts crest is desired. The first step is to select a grid bias that will be 2 to 3 volts less than the crest amplitude, so that 7.5 volts bias will be satisfactory. The plate voltage is now chosen so that the operating region is located on a straight-line part of the tube characteristic. This calls for the highest plate voltage that will not give excessive plate current with the grid bias, which for this case is about 110 volts.

The feed-back resistance that will just barely enable oscillations to start has a value such that, when 1 volt is applied to the grid of the tube, exactly 1 volt will be developed across the tuned circuit by amplifier operation. If the impedance of the shunt-feed choke is very high compared with the plate resistance of the tube, the feed-back resistance at which oscillations will just start is given by the formula

Starting feed-back resistance = $R_L(\mu - 1) - R_p$

where R_p is the plate resistance of the tube, R_L the load resistance offered by the tuned circuit, and μ the amplification factor of the tube. In the case at hand $R_L = 50{,}000\ \Omega$, while reference to a tube chart shows $\mu = 4.7$ and $R_p = 3000\ \Omega$. The critical feed-back resistance hence works out to be

182,000 ohms, and the value actually employed should be 5 to 15 per cent less, or roughly 165,000 ohms. In practice the resistance is usually adjusted experimentally by setting it at a value about 10 per cent less than that at which oscillations start, but calculations such as have been outlined are of considerable aid in establishing the limiting values that will be needed.

From Eq. (59) it will be noted that the feed-back resistance that is required will be nearly proportional to the tuned-circuit resistance RL, and this fixes limits to the allowable L/C ratio in the tuned circuit since RL is proportional to sqrt(L/C) when the circuit Q is constant. It is undesirable to use feed-back resistances higher than about 500,000 ohms at audio frequencies, and higher than 50,000 to 100,000 ohms at the lower radio frequencies. At the same time, the L/C ratio must not be too low, since it is desirable that the feed-back resistance be at least twice, and preferably over five times, the plate resistance of the tube. The most suitable values of tuned-circuit resistance are in the range 10,000 to 50,000 ohms.

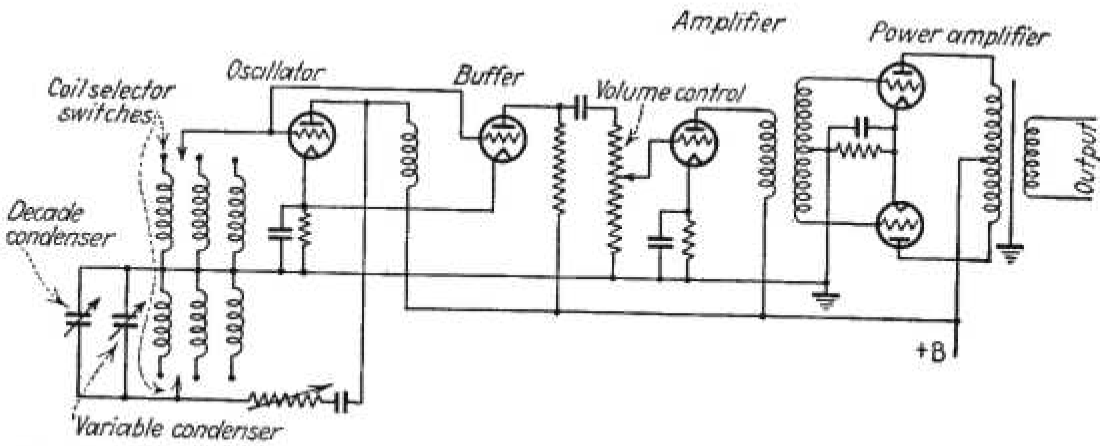


Fig. 149.—Circuit diagram of typical resistance-stabilized oscillator for covering the audio-frequency range.

A complete circuit diagram of a resistance-stabilized oscillator for generating audio and carrier frequencies to be used in laboratory measurements is shown in Fig. 149. Continuous variation of frequency is obtainable by using a continuously variable tuning condenser consisting of a decade condenser supplemented by a variable air condenser to interpolate between the smallest steps, together with provision for switching various coils in and out of the circuit. The feedback resistance can be a tapped or adjustable commercial wire-wound resistance arranged with a tap switch so that the feed-back resistance can be varied in increments of about 10 per cent. The proper setting of the feedback resistance will depend upon the frequency and can be given on the frequency-calibration chart.

The resistance-stabilized oscillator is the most satisfactory type of tuned circuit oscillator available for generating audio frequencies in the laboratory. The amplitude of oscillations is constant over the entire frequency band (assuming the feed-back resistance is readjusted as necessary), the wave form is practically perfect except for distortion that may be introduced by the output amplifier, and the frequency is practically independent of tube voltages and tube replacements. Resistance-stabilized oscillators are also simple to build and easy to adjust. They are used primarily for audio and carrier frequencies and can be employed up to 100 to 200 kc. At frequencies higher than this, stray capacities tend to by-pass the feed-back resistance and thereby nullify the advantages of the circuit.

"Pulling" and "Pushing" Crystal oscillators

Whilst most of us have probably heard of adjusting the frequency of a crystal oscillator - oft referred to as "pulling" the frequency - there are techniques not often mentioned in literature that can help us build an effective "VXO", namely "**pulling**" a crystal oscillator (NOT tweaking the crystal with a series capacitor or inductor combination) or "**pushing**" a crystal oscillator. What's all this about, and is it any use for amateur service?

Well, from https://www.w4npn.net/wp-content/uploads/2020/01/Pushing-and-Pulling.pdf, you'll find Pushing and Pulling crystal oscillators described in depth!

"Pulling" the oscillator is the amount the frequency shifts according to the load presented to the oscillator; a slugging resistor to alter the load is a way to do this, but to be honest I've never come across this technique in my working (or amateur) life. The point is though, it should be a way to shift the crystal oscillator's frequency in a controlled manner.

"Pushing" by oscillator supply voltage control is a technique I have seen used in film thickness monitoring in high vacuum metal evaporators and sputterers, used to create metal interconnects on silicon (and other) semiconductor materials. It enables frequency control without adding L or C in the crystal circuit.

To "push" a crystal oscillator the supply voltage is varied - a variable voltage regulator is ideal. Please note, however, the amount and direction depends on the oscillator configuration; but keep it in mind as an extra tweak to get that few kHz from a "conventionally" shifted L/C VXO that can't quite get you to the "sweet spot".

Receiver Topics...

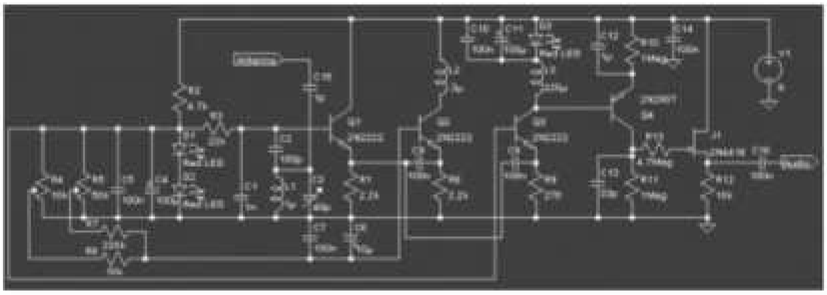
A Regenerative receiver that does not "block" on strong signals

I have often wondered if the gain compression ability of a long-tail pair connection (a differential amplifier) could be used to create a regenerative receiver that, on receiving a strong signal, didn't block: the higher the input signal, the lower the gain of a long-tail pair (it's actually a shift in transconductance, but amounts to the same thing). I have reproduced some pages with my grateful thanks below so you can see what all this is about.

from https://hubpages.com/technology/The-TriStar-Regenerative-Receiver

As a further evolution of the differential regenerative receiver the TriStar design improves a number of issues. Careful consideration and testing points toward using a high impedance AM detector and asymmetrical collector currents for better stability and control.

The TriStar circuit



The TriStar regenerative receiver circuit.

Circuit description

L1, C2 and C3 are the main frequency determining components in the circuit. The ratio of C1 to C2 is important as it creates an impedance transformation from the high impedance resonant circuit to the relatively low input impedance of Q1. The 10 to 1 ratio is enough to prevent damping of the resonant circuit and provide maximum selectivity. You can alter the values of L1 and C3 to change the frequency range of the receiver. The transistor Q1 works in differential mode versus both Q2 and Q3. When the collector current of Q1 is increasing the collector currents of both Q2 and Q3 are decreasing. When the collector current of Q1 is decreasing the collector currents of both Q2 and Q3 are increasing. Also the emitters of both Q2 and Q3 present a low impedance (of a few ohms) to the emitter of Q1 via both C8 and C9.

This allows Q1 to have much higher gain that if it was working through the emitter resistor R1 alone. In fact the low impedance created is not exactly constant with signal level giving the circuit a compressive open loop gain characteristic. This is vital to smooth control of regeneration. In particular the asymmetry in the collector currents of Q1 and Q3 allows for very smooth control of regeneration and helps stabilize the circuit greatly. L2 is the so called tickler coil which provides positive feedback (regeneration) when wound on the same former as L1. If L2 is connected the wrong way around it will instead cause negative feedback and the radio will not work. The exact number of turns required for L2 is best determined by experimentation. The higher tap ratio makes the circuit more linear. This narrows the the transition zone between the non-oscillating and oscillating state making the circuit more sensitive to supply line noise and stray pickup of hum etc.

Conclusion

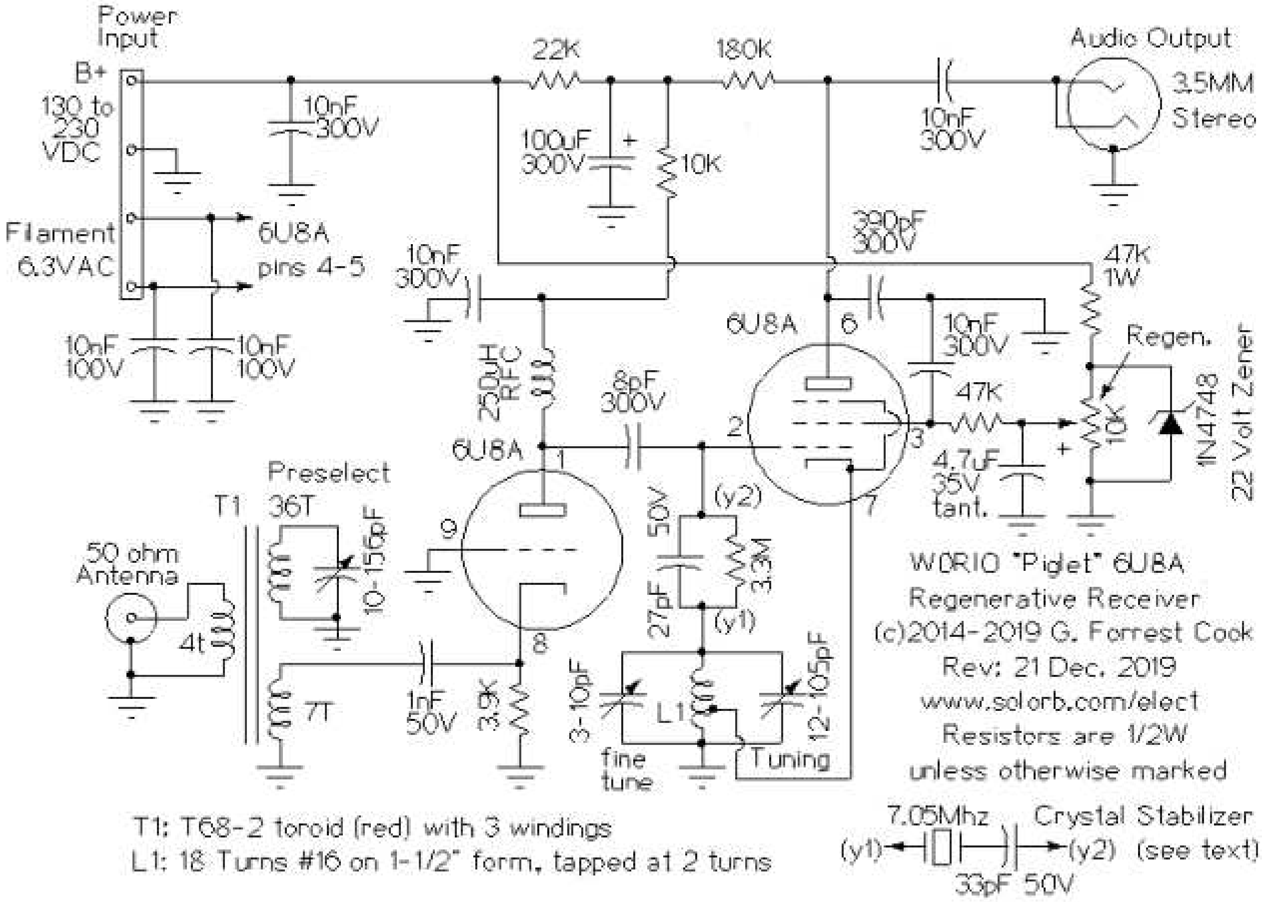
The further refinements in circuit design and component values continues to provide marked improvements in the performance and stability of the differential regenerative receiver. Hopefully you will find this circuit useful and a good basis for both experimentation and creating practical radio receivers.

The Piglet - a superb (and simple) receiver

Probably the best “simple” regenerative receiver ever designed - my thanks to W0RIO, G. Forrest Cook for his permission to reproduce his article. It clearly illustrates the vastly simpler construction and excellent performance valves / tubes offer the amateur constructor.

The design shows how a crystal or ceramic resonator can be connected in parallel with the grid resistor / capacitor combination (see the points labelled Y1 and Y2 in the diagram): this gives crystal control of the receiver, a method reminiscent to the “Goyder Lock” technique, oft employed in early crystal controlled transmitters.

Schematic:



Note points y1 & y2, shunting the 27pF // 3.3Meg RC network for grid leak biasing. Forrest connects, in shunt, a crystal: and this becomes the defining “tuned circuit” for reception. The original L // C components are now effectively in series with the crystal, and “pull” the crystal for a slight amount. Those of you who have seen the “super VXO” principle - using several crystals of the same frequency in parallel - will be able to try such ideas in this circuit; as will those who favour ceramic resonators, which will yield much wider (but perhaps less stable?) frequency swings.

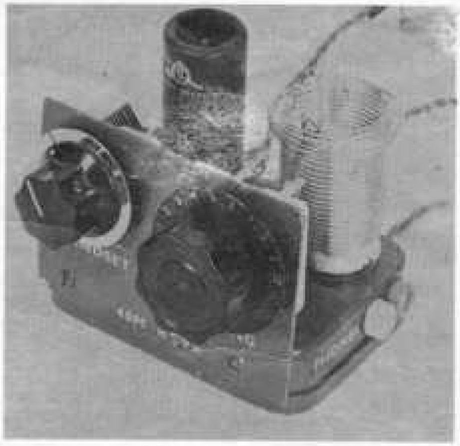
Some years ago I tried the “super VXO” idea with multiple ceramic resonators, and achieved enormous (in crystal frequency shift terms, that is) reasonably stable frequencies and this would make the Piglet a very potent receiver - especially so if it was the detector core of a “tunable IF” receiver, with a down converter(s) for the band(s) required. Choose an IF frequency using easily available and cheap ceramic resonators, for decent portions of any HF band and the frequency stability derived from the regulated screen supply would make the Piglet really shine.

The WeeCeiver - a hybrid design that has much to recommend it

I don't know the original source of this dinky receiver, but if anybody can enlighten me I'd very much appreciate it! I like this design as it illustrates the simplicity of valve design for simple receivers, with a solid state "impedance transformer" to drive the 'phones. I would guess that some high voltage NPN transistor(s) - MPSA42 and their like - would work very nicely in this position, and eliminate the need for a separate "audio" supply; low current high voltage mosfets could be used too. If two such devices were wired as a two stage audio feedback amplifier, you could drive (hi-Z) 'phones (or an output transformer for a loudspeaker) quite nicely.

The design would transfer to "Sputnik" tubes easily I think, and yield a very neat, portable, yet rugged design if the tubes are mounted carefully - with the added plus of battery operation being very easily arranged with four PP9 batteries clipped together. An added RF stage would make for sensitivity and isolation - and yield opportunities for reflexing to squeeze the last drop out of the design.

I apologise for the image size and quality; images and text are not good bedfellows in my word processor! Use your "zoom" control to help.



Front view of the 40 meter QRP receiver shows the coil mounted on the stand-off insulator and the 3V4 to the left, under the shield. The bandset capacitor is on the left and the bandspread capacitor (two stator and one rotor plates) provides smooth tuning requiring no vernier dial. Phone jacks are on the side of the Sucrets chassis.

A 40 METER "WEE-CEIVER"

BY BYRON C. WEAVER,* WB2HAL

This 40 meter QRP receiver, the "Wee-Ceiver," is battery operated and built into a Sucrets box. It is a regenerative job that tunes from 5.5 to 12.5 mc and is ideal for Field Day or emergency work.

WAIT! Don't let my size and simplicity fool ya! I'll pull in a signal loud enough to make your eyes squint, tune 5.5 mc to 12.5 mc, operate over 100 hours continuous on inexpensive batteries, won't cost ya a fortune to build, and because of my size you'll want to take me with you on a field trip or just a picnic outing!

Having promised myself and others many times that I would write on some of my small projects, I've finally brought myself up to it. The receiver shown in the pictures is simple to construct, utilizes a Sucrets pill box for the chassis and is very comparable in signal reception to the "Novice Special"[1] without taking up the room, expense, or the current. Although primarily designed for 40 meters, it should not be difficult to change the coil for other bands.

The receiver performs extremely well even though no vernier dial is used and the

*15 Lake Ave., Hazlet, New Jersey 07730.

[1] Mix, D., "The Novice Special," QST, June 1956, p. 34.

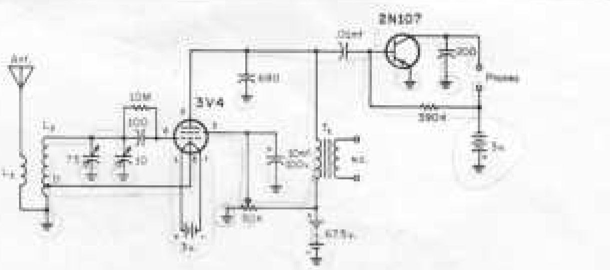


Fig. 1—Circuit of the QRP 40 meter receiver. Transformer T_1 is a miniature unit with a 15K primary (UTC 0-5 or equivalent). The coil construction is described in the text. All capacitors are in mmf unless otherwise noted and all resistors are ½ watt.

antenna wire is only 18 feet long. There are no effects of hand capacity and the stability is very good if the antenna is unable to swing. Microphonics have not been noticed. There is ample room in the chassis so that with suitable parts even the beginner should encounter little or no difficulty in building the receiver.

Circuit

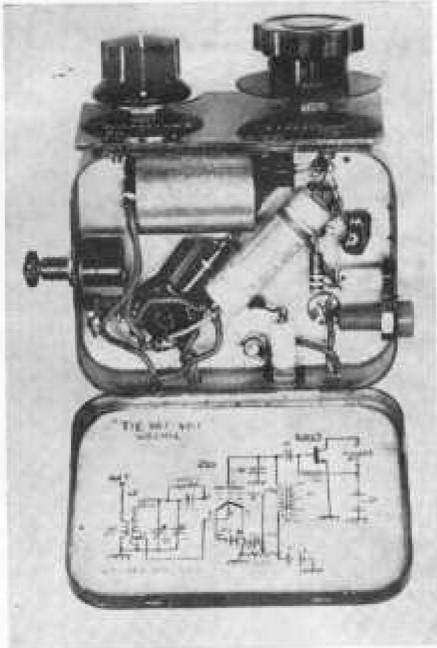
Looking at the schematic, a 3V4 is used as the regenerative detector because of its low current drain and power output capabilities. Two regular size flashlight batteries in series will heat it for well over 50 hours and by using four, and paralleling two, well over 100 hours continuous operation can be expected. Burgess battery No. XX45 is used for the plate supply although any battery between 45 and 90 volts will work well. The tube draws only about 4 ma depending on the point of regeneration. A 2N107 is used as an audio amplifier and draws 0.5 ma from two flashlight batteries in series. A 4.5 volt battery has been used with the 2N107 with no appreciable gain in audio output. A battery pack can be made taping the batteries together which takes up a minimum amount of room.

Rear view of the receiver.

Inductor L_2 is 22 turns of B&W coil stock #3015 (1" dia., 16 tpi). To make L_1, proceed as follows: Assuming you had a 3 inch length of coil to start with, strip off about 8 turns of wire from the left-over portion of the remaining coil stock after making L_2. Cut off the four plastic support strips you have just removed the wire from and glue them to L_2 as shown in the photographs. Next, straighten the wire that you have striped off the coil and rewind 3 turns on the glued strips of plastic, placing a coat of glue on top of the strips, after you have wound L_2, to hold it in place. Coils L_1 and L_2 are mounted on a stand off insulator but could be modified for plug-in coils if preferred. The tap for the cathode is one turn from the ground side (top in photo) of L_2. (The top of both coils are ground as shown in the photograph.)

The 75 mmf bandset capacitor was originally 100 mmf with several rotors and stators removed until it fitted in place without hitting the tube behind it. The tuning capacitor is only about 10 mmf (two

Bottom view of the receiver shows the regeneration control on the left and transformer T_1 up at the top. A spare transistor is taped to the end of T_1.



stators and a rotor) and spreads so well that no vernier drive is used. Small size components were used throughout.

A large value resistor (10 meg) is used in the grid for a noticeable increase in sensitivity. The signal handling capabilities for strong signals could be improved by a smaller value resistor but I am interested in receiving the weaker signals (QRP stations) anyway.

The transformer, in the plate circuit of the 3V4, was originally an 18K ohm resistor which worked fine but I decided to try the small transformer that I had in my junk box. This increased the output so much that I decided to mount the transformer underneath the chassis, cutting a hole large enough to permit it to protrude through the top of the chassis. This component is quite expensive ($6.50) but was given to me in some surplus equipment. It has a primary impedance of 15K, and therefore any small transformer or audio choke with a high audio reactance should work equally well. The secondary is not used.

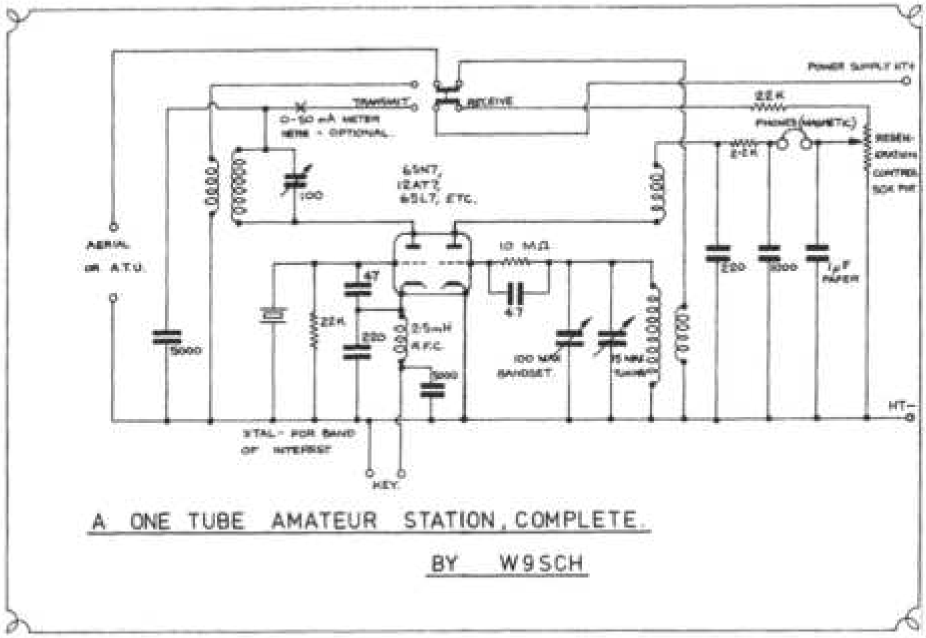
Operation

Any high impedance magnetic earphones may be used, the author using a pair with a 5K ohm impedance. An earth ground connection may be made at the negative side of the 67½ volt battery or to the positive side of the transistor battery. Small alligator clips are connected to all external leads for convenience in making connections. The other construction details can be seen in the photographs.

Needless to say, I am very satisfied with the receiver and it was well worth the time to build. It is also ideal for foreign broadcast reception (loud!), the traveling bag, or as a portable receiver for the home station. Although it appears a novelty, the Wee-Ceiver performance will definitely surprise you. ■

One Valve Amateur Stations

These are presented as basic building blocks: the theme has been taken up using single transistor designs like the Pixie, OXO, and the like; but for my money the valve circuits, whilst needing a heftier power supply, are far better performers. Alternatively, try some Sputnik tubes: a really neat and miniature station could be built. Try some and see!

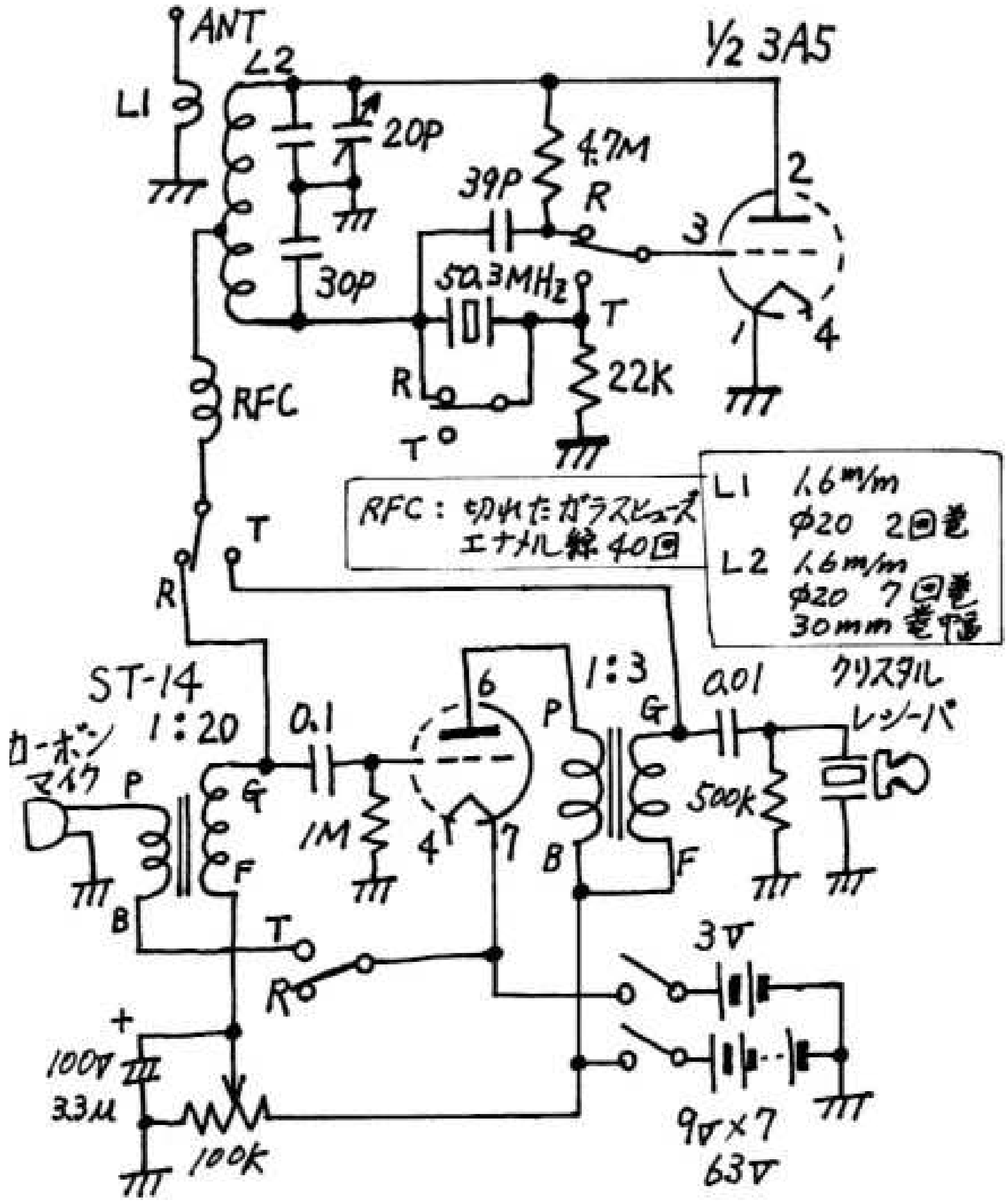


A ONE TUBE AMATEUR STATION, COMPLETE.
BY W9SCH

This circuit is from Chas. Rockey W9SCH and was published in SPRAT #7, the GQRP club's magazine with details of the coils and general construction. It's of more or less generic design; not too critical in any way, but, with good construction and high Q coils, will perform admirably.

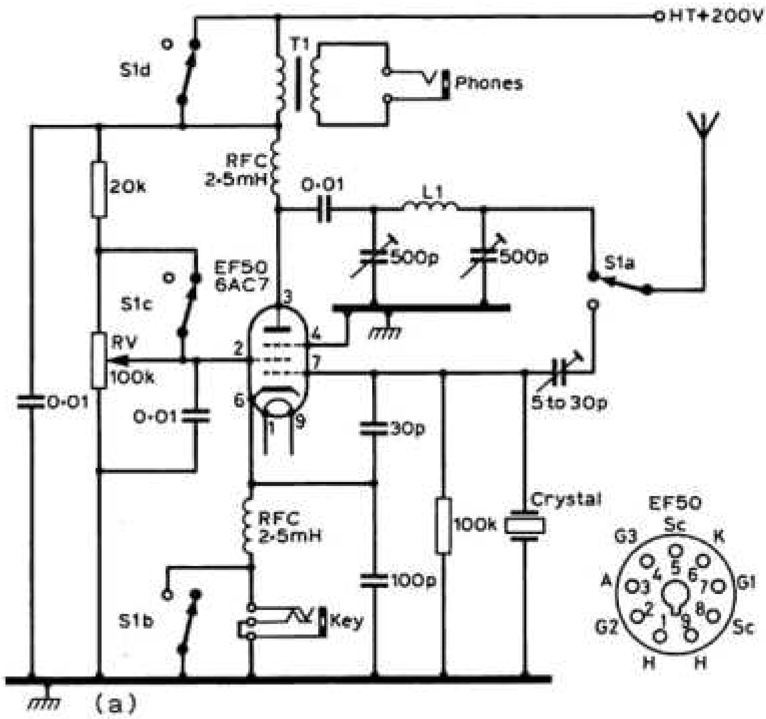
Use a 12AT7, and adapt for HF / VHF band(s) of your choice in the A.M. slots. With a 12AT7 it is a very capable and reliable design; up the HT to 250v but watch that crystal current! A tiny "pee-wee" incandescent bulb (from an old Christmas tree light set perhaps?) in series with the crystal will indicate drive level and (to some extent) loading and tuning.

This next transceiver was shown in Hot Iron #107 as an indicator of bidirectional design; here it's shown to demonstrate simplicity. I'm not sure where the design comes from but suffice to say it is very reminiscent of the "walky-talky" mobile transceivers from WW2. It's a crystal oscillator / carbon microphone modulated transmitter and a super-regen receiver, and is typical of valve designs - simple & capable. You might consider a "solid state" replacement for a carbon mic, though.

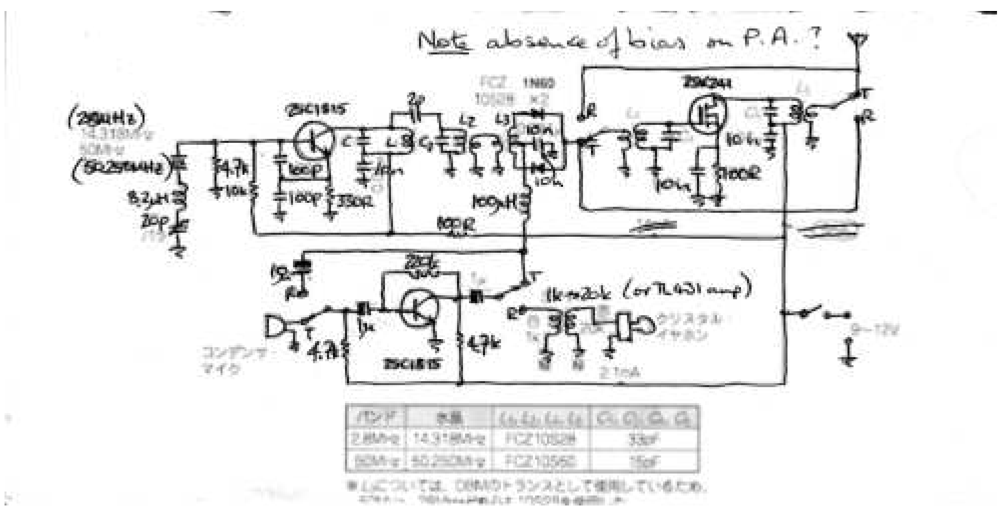


ANT
L1
L2
20P
30p
1/2 3A5
4.7M
39P
R
T
50.3MHz
22K
RFC
RFC：切れたガラスヒューズ
エナメル線 40回
L1 1.6m/m
φ20 2回巻
L2 1.6m/m
φ20 7回巻
30mm 巻幅
ST-14
1：20
カーボン
マイク
P
G
F
B
0.1
1M
1：3
0.01
クリスタル
レシーバ
500k
3V
+
100V
3.3μ
100k
9V×7
63V

This is a design I saw in Pat Hawker's (G3VA) "Amateur Radio Techniques"; it will modulate very nicely with a carbon microphone (substitute circuit) in the "key" jack. Expect at least 3 watts out, it's a very reliable circuit. Any of the "EF" range of Octal or B9A pentodes will run sweetly in this circuit with a bit of tweaking.



To finish off, here is a design using (alright, I admit it - TWO devices) semiconductors; I've built it from junque - and it works just fine. From that Japanese marvel JF10ZL - his web pages are a veritable goldmine of elegant and simple RF technology - and please forgive my scribbled notes on the diagram! Substitute with transistors and mosfets you have to hand.



Antenna Topics

PA0RDT Mini-Whips and all that

An active receiving antenna can be a saviour in some circumstances. For those with extremely constrained areas for antennas, some form of “active antenna” for receiving can be the only hope. The well-known Mini-Whip, first shown by PA0RDT many years ago, is a reliable performer for reception, equalling or better than long wires - which, of course, capture every sparkle of noise that’s going!

The Mini-Whip has some very interesting (and strange!) properties, as shown by Peter Parker, VK3YE in a video at:

https://www.youtube.com/watch?v=MTkVGN9tgQg&feature=youtu.be

Some of his performance checks - practical as ever - show some distinct anomalies. The received signal is markedly improved as the Mini-Whip is lowered to ground level - near concrete paving flags, immersed into shrubbery, and held in near contact with his ground cover plants (species unknown!). Peter shows how the “sampling” of the electric field with a Mini-Whip high above ground level collects more noise, thus degrading the S/N ratio and readability.

One section of Peter’s video especially caught my eye. Many years ago I in my employment I often had to work with low-level signals buried in noise. Stan, my mentor, emphasised that it’s as much about selecting and enhancing the signal you want, whilst rejecting the others you don’t want (i.e. noise!). In other words, a preselector always helps in reception.

In Peter’s video he holds his Mini-Whip in close proximity to a tuned loop - the improvement in S/N ratio is outstanding! A preselector, especially of the larger area of a MW / LF loop, can capture and select the frequency desired, and delivers many more “clean” µV’s than the unadorned Mini-Whip.

Others have worked with very low (in height) antennas; in some cases **negative** heights! Roger Lapthorn, G3XBM, at:

https://sites.google.com/site/g3xbmqrp3/antennas/earth-electrode-antennas

has shown some remarkable results on LF / VLF; which should (in theory...!) be transposable to HF: 160m / 80m / 60m / 40m are likely candidates for experiment. Roger has had remarkable reception results right down to 8kHz with his “E-Field” antenna; and, indeed, by driving RF into two spaced ground electrodes - the multiple ground paths between two electrodes form an infinite number of conductor paths, in theory creating parallel multiple “conductors” much akin to the strands in a multi-cored cable. Though predominantly aimed at VLF / ELF service, the Wikipedia article:

https://en.wikipedia.org/wiki/Ground_dipole#Receiving_antennas

gives excellent descriptions of the principles involved.

From Martin Ehrenfried, G8JNJ, is an excellent and comprehensive article about common forms of active antennas:

https://www.g8jnj.net/activeantennas.htm

which is a valuable "go-to" source for active antenna designs; including "improved" Mini-Whip designs. Martin's article covers monopole collectors, dipoles and loops, with the pro's and con's of each design commented on. One item Martin commented on that I have had personal experience using is the "dipole" type collector, feeding a VHF / Video differential amplifier. Martin comments that the short dipole must be balanced; this includes stray capacitance thus predicating a wide open spaces Mount - you can't expect a short dipole to be balanced if it's near (i.e. within a few metres) of a building, gutter, roof, or whatever constitutes an electrical influence; it has to be high wide and handsome for good results.

The "dipole" active antenna design by Marco Eleuteri, IK0VSV, published in SPRAT (GQRP Journal) issue #101, pp14, which uses an LM733 differential video amplifier fed via a high pass filter to eliminate strong / local MW signals entering the amplifier (the "preselector" principle scores again..!). Marco describes using "North - South" and "East - West" orientated dipoles, switched for best reception. The LM733 is a very capable device, and can give good results from kHz to 50MHz and possibly more.

Below the surface...?

The transmission of radio waves through the Earth has long been though a practical means of communications, but no real effort has been given to the topic professionally (as far as I know, which isn't a lot). Amateurs however have been driving amps of RF into the Earth with some success: as mentioned above, that master of the art, Roger Lapthorne, G3XBM has done some experiments in this quarter with good success. I came across an article whilst researching how to construct a good "radio earth" - which makes me think that the success Peter Parker found (above) might well be an example of signals coming from below, not above: the corresponding earth currents from our antennas have got to go somewhere! The article at:

https://nvlpubs.nist.gov/nistpubs/jres/65D/jresv65Dn2p189_A1b.pdf

I found fascinating; I wonder if there is a radio "Whispering Gallery" right below our feet? This is an area amateur radio experimenters might be able to make significant strides forward, where the "professionals" have no time or enthusiasm. Recall that amateurs were once granted all those "useless" wavelengths below 200 metres?!

Do I really NEED and antenna analyser?

"*I've been a ham since 1963 and have built all my own antennas. Yagi beams—wire beams—loops—verts, etc. Back in those days all you had was a SWR bridge and maybe a grid dip meter. The most important thing, I think, is a booklet or some kind of articles on antenna design. They will give you accurate lengths and feed line info that should get you up and running in no time. There's plenty of info on the internet, although my personal favorite source is Bill Orr, W6SAI; his antenna books and very entertaining antenna articles in CQ magazine circa 1970's are great.*

My first antenna was made of electric fence wire and a second hand hunk of RG-58 in an inverted vee configuration. It is supremely simple to build. One support pole, one hunk of 50 ohm coax, balun or not, 120 degree spread between the legs, gives you 50 ohms. Make it about three feet longer than formula and trim it to resonance using an el cheapo used ($10) SWR bridge.

A used grid dip meter ($30.00) will let you get the resonant frequency—not necessary here—and a used ($30.00) noise bridge will let you deal with impedance issues, but is not necessary with simple antennas like this. Simple antennas are easy to build and work well. Height is a big plus. Just get in there and klutz around until it works. You can build anything easily with the three pieces of test gear mentioned here and they will do a lot more things than help set up antennas. Simplicity is bliss.

WB0SNF"

A different approach

Here's an old fashioned way to tune an antenna; you might have seen previously in "Parasets", or Chas. Rockey's W9SCH small "soup loop lamp" to indicate RF current? Well, there is a way you can "modernise" this approach, yet maintain the functional efficiency and ease of construction a lamp RF indicator offers: build an RF ammeter with a difference, it barely loads or wastes power (as a directly inserted panel lamp does).

First, find a **ferrite** toroid core. I use a salvaged ring from an ex-PC power supply - then wind on it about 5 - 10 turns of enamelled copper wire, stiff enough to hold it's shape. On the end of the winding, solder a 4 volt 25mA pee-wee incandescent bulb, or similar: the voltage isn't critical but it must be low current (check your favourite on-line auction house: they have plenty). You can use an ordinary LED here if you wish, polarity doesn't matter, but go easy on the transmitter power when you key! You might like to look at Peter Parker's video at: https://www.youtube.com/watch?v=NjHyXi1SrZs

or, a similar idea, but clip-on style by AC2RJ at:

https://www.youtube.com/watch?v=ltZLxdEteBY

The theory bit: the ferrite toroid forms a current transformer, the primary is a single antenna feed wire through the centre; the secondary is your winding. The resistance inserted in the feed line is proportional to the square root of the turns ratio multiplied by the secondary load resistance: i.e. a 100 ohm bulb, and 5 turns of secondary = 4 ohms added to the feedline. 10 turns would be 1 ohm inserted into the feedline, and so on. Somewhere between 5 and 15 turns on the secondary winding is about right, and is relatively non-critical. A LED, being a (non-linear) diode, might - but I don't know this for sure - create some low level harmonics in the output, but it's a lower loading on the feedline needing only a couple of mA's to illuminate - hence the warning above to go easy on the wampum you bung up the spout! Some toroid RF ammeter designs also use a diode rectifier to drive a meter; these might be studied for low level harmonics too. If anybody has any definitive results re. harmonics from the LED or diode versions, please let me know.

Fit the toroid onto the "hot" feed (or co-ax centre conductor) to your antenna, between the antenna tuning unit ("ATU") and the antenna - and key your transmitter. Adjust the antenna tuning unit for maximum brightness, which indicates maximum RF amps into the antenna - the best match / lowest SWR with your transmitter and feedline system at that frequency. Job done!

Baluns and losses

Much is written about these little beasties, and I'm not going to spend too much time on them as many yards of text are already swilling about on the Internet; and I apologise if you're a dedicated QRP(P) man, the following might not be up your street. Suffice to say, the "acid test" is to observe the balun's temperature after a transmission: if it's lossy, it'll be warm (and that's an understatement if you're a QRO operator).

That's physics; it tells the truth, no matter what the gadgets and gizmos you put so much faith in might tell you. Run plenty of power up the spout for 10 minutes, then nip out and check the balun. Cold = Good; Hot = Lossy!

Data and Information

This information is for guidance only – you MUST comply with your local Electrical Safety Regulations! I have included information about AC power systems and conventions, as equipment can be bought from overseas nowadays and it's important to know how to connect it safely to our "home" supplies. Suffice to say, if there's ANY doubt - - - GET PROFESSIONAL, COMPETENT HELP BEFORE YOU CONNECT TO ANY ELECTRICAL SUPPLY!

Basic AC Relationships

Crest Factor for varuous waves. www.turneraudio.com.au

Wave type	Wave form	Mean magnitude (rectified)	Wave form Factor	RMS value	Crest Factor	Crest Factor
DC		1.00		1.00	1.00	0.0dB
Sine wave		$\frac{2}{\pi} \approx 0.6363$	$\frac{\pi}{2\sqrt{2}} \approx 1.1112$	$\frac{1}{\sqrt{2}} \approx 0.7071$	$\sqrt{2} \approx 1.4142$	3.01dB
Full-wave rectified sine wave		$\frac{2}{\pi} \approx 0.6363$	$\frac{\pi}{2\sqrt{2}} \approx 1.1112$	$\frac{1}{\sqrt{2}} \approx 0.7071$	$\sqrt{2} \approx 1.4142$	3.01dB
Half-wave rectified sine wave		$\frac{1}{\pi} \approx 0.3182$	$\frac{\pi}{2} \approx 1.5714$	$\frac{1}{2} = 0.50$	2.000	6.02dB
Triangle wave		$\frac{1.00}{2} = 0.50$	$\frac{2}{\sqrt{3}} \approx 1.1547$	$\frac{1}{\sqrt{3}} \approx 0.5773$	$\sqrt{3} \approx 1.7320$	4.77dB
Square wave		1.00	1.00	1.00	1.00	0.0dB

π = greek letter pye, = 22 / 7 = 3.142857134..... and is a mysterious and significant mathematical figure used in countless equations. $\approx$ = symbol for "approximately equal to".

The Unobtanium & Obsoletite files...

A list of those solid state parts made from Unobtainium and Obsoletite - please let me know your alternatives! **Note:** when Unobtainium and Obsoletite parts are overheated, over-volted or over-amped, the rare elements used inside the plastic / metal packaging react violently, emitting the "magic smoke" which renders any solid state device instantly useless. In a Yocto-second, no less.

Useful cross-reference web pages:

https://english.electronica-pt.com/components-cross-reference?ref=

https://archive.org/details/TowersInternationalTransistorSelector

For Solid State fans...

These are more or less equal equivalents, use in both directions i.e. BFY90 = 2N5178. Any more that have been proven in actual circuits, please let me know: the supplies of Unobtanium and Obsoletite is getting harder and harder to find, any help is always welcome.

2N5179	BFY90	½ watt VHF NPN
2N3866	BFY90	½ watt VHF NPN
2N4427	BFR91	1 watt VHF / UHF NPN
ZTX300	BCY70	0.3 watt HF NPN
OA91	1N60/61	Ge signal diode, 50v, 50 mA

Alternatives to ZN414 = MK484, YS414, TA7642, UTC7642, LMF501T, LA1050.
For Valve / Tube fans...

https://en.wikipedia.org/wiki/List_of_Mullard%E2%80%93Philips_vacuum_tubes

(Well, you *did* ask...)

http://www.angelfire.com/electronic/funwithtubes/tube_select_guide.html

(THE 'Magnum Opus' of bottle lists)

https://frank.pocnet.net/sheets5.html

(Is the broadest range of data sheets I've ever used, very helpful in finding usable alternatives)

Some not very obvious alternatives:

ECL 82 is an audio triode / pentode, much beloved in vintage radios, economy audio amps and the like. However... if you have 12v. ac heater volts available (or higher) then the bottles following can be useful with a dropper resistor to tweak the heater volts down (and get long heater life too). Don't forget that half wave rectified 12v. r.m.s. = 6v. r.m.s.; near enough for 6.3v. heaters; or strap two 6.3v. bottles in series if their heater currents are near equal, to run on 12v. AC - or a car battery.

ECL82 = LCL82 (10.7v heaters) = 11BM8 (10.7v heaters) or PCL82(16v) / UCL82(50v) / XCL 82(8.2v). There are dozens of equivalent or similar electrode structures but with different heaters.

For instance: PCL82 = 16A8 = 30PL12 = 16TP12 = 16TP6 = 16Ф3П Different heater volts = 8B8 (8.3v ac)

Check the web page: https://www.radiomuseum.org/dsp_searchtubes.cfm where you can search for many different tubes, characteristics and equivalents. For instance, web searching for an ECL84 equivalent - typically LCL84 - yields dozens of hits. If you want an ECL84, which are as rare as hen's teeth nowadays because Audiophools buy them at nosebleed prices, try the different heater volts equivalents and alter the heater supply appropriately.

Keep to mind that 5v or 6.3 v AC heater supplies, if doubled or trebled, will yield higher heater volts if you don't want to modify an existing or historically important piece of kit - but take great care not over volt filaments / heaters! A true RMS multimeter is handy for this job.

HF & VHF Output Types:

6146B = 8298A = S2001; or nearly so, YL1370 = 6146 = 6146A = 6146W

807 = VT-100 = QE06/50 = Г-807 = GL807 = RK-807 = A4051I = ZA3496 = CV124 = 5S1 = 4Y25N = VT199_GPO = 5B/250A = CNU-807; nearly so = 10E/11441 ; 4Y25 ; ATS25 ; ATS25A ; ATS25N ; CV1364 ; CV1374 ; FU-7 ; HY61 ; QV05-25 ; RK39 ; VT60 ; VT60A

Audio valves; useful for low band RF:

From an article by Robert H. Levi

"My Favorite Tubes"
by Robert H. Levi

Small Signal Tubes:

12AX7

Substitutes: ECC83, 12AX7A, 12AX7WA, 7025, 5761, 6057, 6681, 7494, 7729, 7025#, ECC83#, 6L13, 12DF7, 12DT7, 5751, 7025A, B339, B759, CV4004, E83CC, ECC803, M8137

The GE 5751 is a bargain basement musical giant! The Mullard CV4004 is still King of the Hill.

12AU7

Substitutes: 12AU7A, ECC82, 5814, 5814A, 5814WA, 6189, 6680, CV4003, E82CC, ECC186, ECC802, ECC802S, M8136, 7025#, ECC83#, B749, 6067, 6670, 7730, B329, 5963, 7316, 7489

I discovered the 5814A from RCA is a bargain and the best sounding 12AU7 made in the USA!

The Mullard CV4003 is still fairly cheap, plentiful, and magnificent.

12AT7

Substitutes: 6201,6679, ECC81, 12AT7WA, 12AT7WB, 6060, 6201, 6671, 6679, 7492, 7728, A2900, 8152, B309, B739, CV4024, E81CC, ECC801, ECC801S, M8162, QA2406, QB309

As good as the GE and RCA are, the Mullard CV4024 is not pricey and totally glorious.

6DJ8

Substitutes: ECC88, 6ES8#, 6ES8, ECC189, ECC189#, 6FW8, 6KN8, 6922, E88CC, CV2492

The bargain priced PCC88, the 7 volt version of this tube, works nicely in the vast majority of 6 volt applications. I use them in a cocktail with their 6 volt brethren all the time for top results. You can still actually afford the Telefunken, Dutch Amperex, and Siemens versions of the PCC88!"

Rectifier Tube:

5AR4

Substitutes: GZ34, 52KU, 53KU, 54KU,GZ30, GZ32, GZ33, GZ37, R52, U54, U77, 5R4GYS (from Philips) The Mullard GZ34 is King of the Hill. Buy it used, but checked, if necessary. The Philips 5R4GYS is a recent find by Upscale Audio in Upland. A killer tube, but huge and requires lots of space (bigger than a KT88.)

Other Dual Triode Tubes:

6SN7

Substitutions: 6SN7A, 6SN7GT, 6SN7GTA, 6SN7GTB, 6SN7W, 6SN7WGT, 65W7, 5692, B65, ECC33, 6SN7L, 13D2, B65, 6SN7GTY, 6SN7WGTA

The vintage GE and RCA are very fine if hand selected. The Electro Harmonix is very good, too.

6SL7

Substitutions: 5691, 6SL7W, 6SL7WGT, 6113, ECC35, 6SL7GT, 6SL7L

Same comment as 6SN7 type.

Output Tubes:

EL84

Substitutes: 6BQ5, 6P15, 6267, 7189, 7189A, 7320, E84L, EL84L, N709, Z729, 6BQ5WA, EL84M
I have had little use for these. Am told the NOS Mullard prices are strong, but worth it.

EL34

Substitutes: 6CA7, 7D11, 12E13, KT77

Lots to choose from. Usually your manufacturer tuned the gear to a certain brand of these. Be mindful of that before you spend tons of money on vintage NOS versions that end up not sounding as good.

6550

Substitutes: 7D11, 12E13, 6550A, 7027A#, KT88, KT90 Type 2 or 3, KT99, KT100, KT120/KT150 (only if sufficient bias is present) Unless forbidden by your manufacturer, I would try some of the high powered goodies on the market to boost performance. The EH KT90 or the new KT120 may be astounding in your amp. At least try KT88s!

6L6

Substitutes: KT66, 5881, 6L6S, 6L6G, 6L6GA, 6L6GAY, 6L6WA, 6L6WGA, 6L6WGB, 6L6WGC, 6L6WGT, 6L6GB, 6L6GC, 6L6GT, 6L6GX, 6L6Y, 1622, 5932, 7581, 7581A, WT6, EL37

Same comment as EL34 type.

KT88

Substitutes: 6550, 6550A, KT90 Type 2 or 3, KT99, KT100, KT12O/KT150 (only if sufficient bias is present) Though your manufacturer may have settled on a certain brand of these, the hunt for cool NOS types may be sonically worthwhile, or try switching to EH KT90s or bigger for more impact. I would!

Wire Information...

As used in Test Gear Maintenance at a factory I worked at:
Green (or green & yellow stripe) - Earths, Chassis connection

Blue	A.C. power lines (N, single Φ, inside machinery)
Brown	A.C. power lines (L, single Φ, inside machinery)

Note: 3Φ supplies external to machinery or distribution systems may use some of these colours; check, check and check again what the wiring is!

NEVER, NEVER, assume a blue wire is a neutral; you may have an old 3Φ installation which ran colours as follows:

Red	Phase 1
Yellow	Phase 2
Blue	Phase 3
Black	Neutral

Valve Electrode wiring:

Gray	heaters or filaments
Red	DC power supply positives (numbered sleeves indicating voltage)
Black	returns, commons, NOT grounded
Orange	screen grids

Yellow	cathodes
Pink	control grids
White	anodes
Violet	AC / DC control signals (AGC, etc.)

From Kevin, VK3DAP / ZL2DAP seen on a web page recently, is another wiring code - last seen in a Savage 5kW audio amplifier driving a vibration table for semiconductor testing:

Valve Electrodes:

Anode	Blue
Cathode	Yellow
Control grid	Green
Screen Grid	Orange
Suppressor	Grey

DC Supplies:

Chassis / Ground	Black
Positive to Chassis	Red
Negative to Chassis	Violet

Miscellaneous Wiring (control signals & the like):

White or mauve

AC Supplies (modern UK &European):

Active or Phase	Brown
Neutral	Blue
Earth	Green/Yellow stripe

AWG Table

1 AWG is 289.3 thousandths of an inch

2 AWG is 257.6 thousandths of an inch

5 AWG is 181.9 thousandths of an inch

10 AWG is 101.9 thousandths of an inch

20 AWG is 32.0 thousandths of an inch

30 AWG is 10.0 thousandths of an inch

40 AWG is 3.1 thousandths of an inch

The table in ARRL handbook warns that the figures are approximate and may vary dependent on the manufacturing tolerances. If you don't have a chart handy, you don't really need a formula.

There's several handy tricks:

Solid wire diameters increases/decreases by a factor of 2 every 6 gauges,

" " " " " 3 every 10 gauges,

" " " " " 4 every 12 gauges,

" " " " " 5 every 14 gauges,

" " " " " 10 every 20 gauges,

" " " " " 100 every 40 gauges,

With these, you can get around a lot of different AWGs and they cross check against one another. Start with solid 50 AWG having a 1 mil diameter.

So, 30 AWG should have a diameter of ~ 10 mils.

36 AWG should have a diameter of ~ 5 mils.	Dead on.
24 AWG should have a diameter of ~ 20 mils.	Actually ~ 20.1
16 AWG should have a diameter of ~ 50 mils.	Actually ~ 50.8
10 AWG should have a diameter of ~ 100 mils.	Actually ~ 101.9

If you are more interested in current carrying ability than physical size, then also remember that a change of 3 AWG numbers equals a doubling or halving of the circular mills (the cross sectional area). Thus, if 10 AWG is safe for 30 amps, then 13 AWG (hard to find) is ok for 15 amps and 16 AWG is good for 7.5 amps.

The wire gauge is a logarithmic scale base on the cross sectional area of the wire. Each 3-gauge step in size corresponds to a doubling or halving of the cross sectional area. For example, going from 20 gauge to 17 gauge doubles the cross sectional area (which, by the way, halves the DC resistance).

So, one simple result of this is that if you take two strands the same gauge, it's the equivalent of a single wire that's 3 gauges lower. So two 20 gauge strands is equivalent to 1 17 gauge.

Wire Gauge Resistance per foot

4	.000292
6	.000465
8	.000739
10	.00118
12	.00187
14	.00297
16	.00473
18	.00751
20	.0119
22	.0190
24	.0302
26	.0480
28	.0764

Current ratings

Most current ratings for wires (except magnet wires) are based on permissible voltage drop, not temperature rise. For example, 0.5 mm^2 wire is rated at 3A in some applications but will carry over 8 A in free air without overheating. You will find tables of permitted maximum current in national electrical codes, but these are based on voltage drop. Here is a current and AWG table.

AWG	dia	circ	open	cable	ft/lb	ohms/1000’
	mils	mils	air Amp	Amp	bare	

10	101.9	10380	55	33	31.82	1.018
12	80.8	6530	41	23	50.59	1.619
14	64.1	4107	32	17	80.44	2.575

Mils are .001". "open air A" is a continuous rating for a single conductor with insulation in open air. "cable amp" is for in multiple conductor cables. Disregard the amperage ratings for household use. To calculate voltage drop, plug in the values:

V = DIR/1000

Where I is the amperage, R is from the ohms/1000' column above, and D is the total distance the current travels (don't forget to add the length of the neutral and live together - ie: usually double cable length). Design rules call for a maximum voltage drop of 6% (7V on 120V circuit).

Resistivities at room temp:

Element	Electrical resistivity (micro-ohm-cm)
Aluminium	2.655
Copper	1.678
Gold	2.24
Silver	1.586
Platinum	10.5

This clearly puts silver as the number one conductor and gold has higher resistance than silver or copper. It's desirable in connectors because it does not oxidise so remains clean at the surface. It also has the capability to adhere to itself (touch pure gold to pure gold and it sticks) which makes for very reliable connections.

Thermal conductivity at room temperature

	$W/cm^2/°C$
silver	4.08
copper	3.94
gold	2.96
platinum	0.69
diamond	0.24

bismuth	0.084
iodine	43.5E-4

This explains why diamonds are being used for high power solid state substrates now - that's man-made diamond. Natural diamonds contain flaws in the lattice that phonons (heat conductors) get scattered and substantially reduce the ability to transport the heat.

Copper wire resistance table

AWG	Feet/Ohm	Ohms/100ft	Ampacity	(mm2)	Meters/Ohm	Ohms/100M
10	490.2	.204	30	2.588	149.5	.669
12	308.7	.324	20	2.053	94.1	1.06
14	193.8	.516	15	1.628	59.1	1.69
16	122.3	.818	10	1.291	37.3	2.68
18	76.8	1.30	5	1.024	23.4	4.27
20	48.1	2.08	3.3	0.812	14.7	6.82
22	30.3	3.30	2.1	0.644	9.24	10.8
24	19.1	5.24	1.3	0.511	5.82	17.2
26	12.0	8.32	0.8	0.405	3.66	27.3
28	7.55	13.2	0.5	0.321	2.30	43.4

These Ohms / Distance figures are for a round trip circuit. Specifications are for copper wire at 77 degrees Fahrenheit or 25 degrees Celsius.

Wire current handling capacity values

mm2	R/m-ohm/m	I/A
6	3.0	55
10	1.8	76
16	1.1	105
25	0.73	140
35	0.52	173

50	0.38	205
70	0.27	265

Mains wiring current ratings

In mains wiring there are two considerations, voltage drop and heat build up. The smaller the wire is, the higher the resistance is. When the resistance is higher, the wire heats up more, and there is more voltage drop in the wiring. The former is why you need higher-temperature insulation and/or bigger wires for use in conduit; the latter is why you should use larger wire for long runs. Neither effect is very significant over very short distances. There are some very specific exceptions, where use of smaller wire is allowed. The obvious one is the line cord on most lamps. Don't try this unless you're certain that your use fits one of those exceptions; you can't go wrong using larger wire. This is a table apparently from BS6500, reproduced in the IEE Wiring Regs which describes the maximum fuse sizes for different conductor sizes:

Cross-section	Overload current
CSA / area	rating
0.5mm²	3A
0.75mm²	6A
1mm²	10A
1.25mm²	13A
1.5mm²	16A

Typical current ratings for mains wiring

Inside wall

mm^2	Amps
1.5	10
2.5	16

Equipment wires

mm2	A
0.5	3

0.75	6
1.0	10
1.5	16
2.5	25

Wire sizes used in USA inside wall

For a 20 amp circuit, use 12 gauge wire. For a 15 amp circuit, you can use 14 gauge wire (in most locales). For a long run, though, you should use the next larger size wire, to avoid voltage drops. Here's a quick table for normal situations. Go up a size for more than 100 foot runs, when the cable is in conduit, or ganged with other wires in a place where they can't dissipate heat easily:

Gauge	Amps
14	15
12	20
10	30
8	40
6	65

PCB track widths

For a 10 degree C temp rise, minimum track widths on 1 oz. copper are:

Current	width in inches
0.5A	0.008"
0.75A	0.012"
1.25A	0.020"
2.5A	0.050"
4.0A	0.100"
7.0A	0.200"
10.0A	0.325"

Equipment wires in Europe

3 core equipment mains cable

Current	3A	6A	10A	13A	16A
Conductor size (mm)	16*0.2	24*0.2	32*0.2	40*0.2	48*0.2
Copper area (mm2)	0.5	0.75	1.0	1.25	1.5

Cable ratings for 3A, 6A and 13A are based on BS6500 1995 specifications and are for stranded thick PVC insulated cables.

Insulated hook-up wire in circuits (DEF61-12)

Max. current	1.4A	3A	6A
Max. working voltage (V)	1000	1000	1000
PVC sheath thickness (mm)	0.3	0.3	0.45
Conductor size (mm)	7*0.2	16*0.2	24*0.2
Conductor area (mm^2)	0.22	0.5	0.75
Overall diameter (mm)	1.2	1.6	2.05

U.S.A. Common Cable colour Codes

American electrical contractors and electricians are required to follow the National Electrical Code ("NEC") with regard to wiring colours. NEC imposes the following electrical wiring colour standards:

•**Ground wires:** green, green with a yellow stripe, or bare copper

•**Neutral wires:** white or grey

In theory, wiring conducting live current in the U.S. is permitted to be any other colour, although in practice, electrical contractors and electricians follow these local conventions:

•**Single phase live wires:** black (or red for a second "hot" wire)

•**3-phase live wires:** black, red and blue for 208 VAC; brown, yellow, purple for 480 VAC

Most countries in Europe, including the U.K., now follow the colour conventions established by the International Electrotechnical Commission ("IEC"). These colour conventions are as follows:

•**Earth wires** (called ground wires in the U.S. and Canada): green with a yellow stripe

•**Neutral wires:** blue

•**Single phase live wires:** brown

- **3-phase live wires:** brown, black and grey

Electrical wiring in Canada is governed by the Canadian Electric Code ("CEC"). The following wiring colour requirements apply in Canada:

- **Ground wires:** green, or green with a yellow stripe
- **Neutral wires:** white
- **Single phase live wires:** black (or red for a second live wire)
- **3-phase live wires:** red, black and blue

It's important to remember that the above colour information applies only to AC circuits.

A.M. Frequency slots in Amateur HF Bands

All Frequencies in MHz

160 Metres: 1.885, 1.900, 1.945, 1.985 (USA)

1.850 (W. Europe)

1.933, 1.963 (UK)

1.825 (Australia - daytime)

1.850 (Australia - evening)

80 Metres: 3.530, 3650 (South America)

3615, 3625 (in the UK)

3705 (W. Europe)

3.670 & 3.690 (popular AM frequencies, Australia)

75 Metres: 3.825, 3.870 (West Coast), 3.880, 3.885 (USA)

60 Metres : 5.317

40 Metres: 7.070 (Southern Europe)

7.120, 7.300 (South America)

7.175, 7.290, 7.295 (USA)

7.143, 7.159 (UK)

7.125 (Primary AM Calling, Australia)

7.146 (Secondary and WIA Sunday morning Broadcast, Australia)

20 Metres: 14.286

17 Metres: 18.150

15 Metres: 21.285, 21.425

10 Metres: 29.000-29.200

6 Metres: 50.4 (generally), 50.250 Northern CO

2 Metres: 144.4 (Northwest)

144.425 (Massachusetts)

144.28 (NYC-Long Island)

144.45 (California)

144.265 (Los Angeles, CA)

Other AM Activity Frequencies

AM activity is increasingly found on a number of other bands, in particular: 5317KHz, 7143KHz, 14286KHz, 21425KHz and 29000 - 29150KHz.
There are several local AM nets in the UK on top band.

FM Frequencies

For mobiles working into VMARS events, 2m calling in on 145.500MHz (S20) is usual, before QSY to a working frequency. At event locations where military equipment is in use, suggested FM "Centres of Activity" on VHF are 51.700Mhz, 70.425MHz (70.450MHz calling).

VMARS RECOMMENDED FREQUENCIES

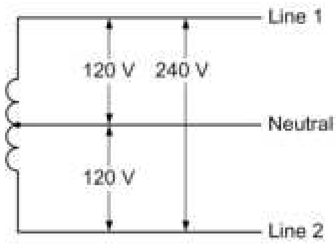
3615 Khz	*Saturday AM net 08:30 – 10:30*
3615 Khz	*Wednesday USB net for military equipment 20:00 – 21:00*
3615 Khz	*Friday LSB net 19:30 – 20:30*
3615 Khz	*Regular informal net from around 07:30 - 08:30*
3577 Khz	*Regular Sunday CW net 09:00*
5317 Khz	*Regular AM QSO's, usually late afternoon*
7073 Khz	*Wednesday LSB 13:30; Collins 618T special interest group*
7143 Khz	*VMARS AM operating frequency*
51.700 MHz	*VMARS FM operating frequency, also rallies and events*
70.425 MHz	*VMARS FM operating frequency, also rallies and events*

Electrical Supplies - Courtesy LEGRAND equipment

Common Electrical Services & Loads

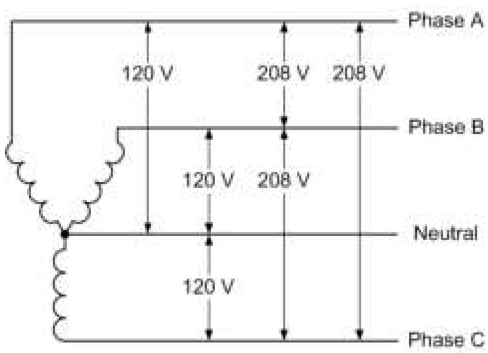
In the following drawings, the coil symbols represent the secondary winding of a utility service transformer or other step down transformer. Electrical code regulations in most jurisdictions require that the neutral conductor be bonded (connected) to the earth safety ground at the electrical service entrance.

Single Phase Three Wire



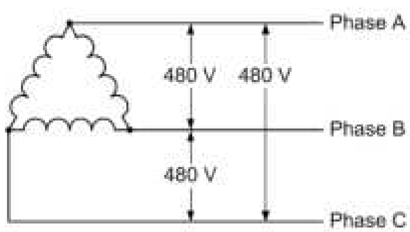
Also known as an Edison system, split-phase or centre-tapped neutral. This is the most common residential service in North America. Line 1 to neutral and Line 2 to neutral are used to power 120 volt lighting and plug loads. Line 1 to Line 2 is used to power 240 volt single phase loads such as a water heater, electric range, or air conditioner.

Three Phase Four Wire Wye



The most common commercial building electric service in North America is 120/208 volt wye, which is used to power 120 volt plug loads, lighting, and smaller HVAC systems. In larger facilities the voltage is 277/480 volt and used to power single phase 277 volt lighting and larger HVAC loads. In western Canada 347/600V is common.

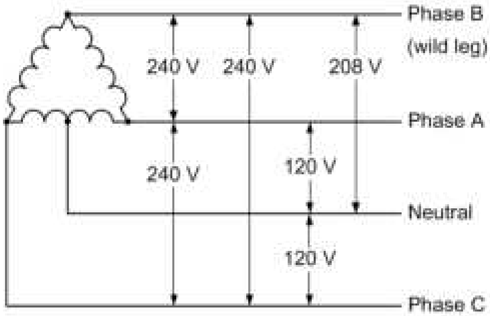
Three Phase Three Wire Delta



Used primarily in industrial facilities to provide power for three-phase motor loads, and in utility power distribution applications. Nominal service voltages of 240, 400, 480, 600, and higher are typical.

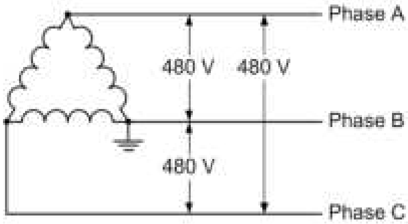
Uncommon Electrical Services

Three Phase Four Wire Delta



Also known as a high-leg or wild-leg delta system. Used in older manufacturing facilities with mostly three-phase motor loads and some 120 volt single-phase lighting and plug loads. Similar to the Three Phase Three Wire Delta discussed above but with a centre-tap on one of the transformer winding to create neutral for 120 volt single-phase loads. Motors are connected to phase A, B, and C, while single-phase loads are connected to either phase A or C and to neutral. Phase B, the high or wild leg, is not used as the voltage to neutral is 208 volt.

Three Phase Two Wire Corner-Grounded Delta



Used to reduce wiring costs by using a service cable with only two insulated conductors rather then the three insulated conductors used in a convention three phase service entrance.

International Electrical Distribution Systems

Description	L–N Vac	L–L Vac	Countries
1-Phase, 2-Wire 120 V with neutral	120	–	US
1-Phase, 2-Wire 230 V with neutral	230	–	EU, UK, Scandinavia
1-Phase, 2-Wire 208 V (No neutral)	–	208	US
1-Phase, 2-Wire 240 V (No neutral)	–	240	US
1-Phase, 3-Wire 120/240 V	120	240	US

3-Phase, 3-Wire 208 V Delta (No neutral)	–	208	US
3-Phase, 3-Wire 230 V Delta (No neutral)	–	230	Norway
3-Phase, 3-Wire 400 V Delta (No neutral)	–	400	EU, UK, Scandinavia
3-Phase, 3-Wire 480 V Delta (No neutral)	–	480	US
3-Phase, 3-Wire 600 V Delta (No neutral)	–	600	US, Canada
3-Phase, 4-Wire 208Y/120 V	120	208	US
3-Phase, 4-Wire 400Y/230 V	230	400	EU, UK, Scandinavia
3-Phase, 4-Wire 415Y/240 V	240	415	Australia
3-Phase, 4-Wire 480Y/277 V	277	480	US
3-Phase, 4-Wire 600Y/347 V	347	600	US, Canada
3-Phase 4-Wire Delta 120/208/240 Wild Phase	120, 208	240	US
3-Phase 4-Wire Delta 240/415/480 Wild Phase	240, 415	480	US
3-Phase Corner-Grounded Delta 208/240	–	240	US
3-Phase Corner-Grounded Delta 415/480	–	480	US

Note: regional variations may exist: if in ANY doubt, consult your Electrical Supply Authority.

Table of Contents

CQ-CQ-CQ

Apologies for the scant Hot Iron; I'm in the throes of moving house, COVID 19 and all the trials and tribulations that family life brings. I've no workbench; my soldering gear is cold, lifeless. No rosin fumes; no swarf or saw shards litter my vice. All is packed away "until further notice", to re-emerge once I'm happily ensconced on Western slopes, overlooking the Irish Sea with County Wicklow in Eire on the horizon.

I take some comfort in my copy of "HF Aerials for all Locations" by that wonderful man, Les Moxon, G6XN, who tells me I'll be moving to a perfect spot for low angle radiation from simple wire antennas - if only I had the garden space to erect something that Les refers to as "simple"! The antenna "rule of three" is as valid now as ever: you can choose two from gain, bandwidth and small size.

I'm sure I'll get *something* up that will radiate; meantime I'm "BRS", and enjoying quietly trawling around the HF bands listening to whatever stations I find. Luckily, I have a very neat and invisible HF receiving antenna: for details, you'll have to peruse the "Antenna Topics" in this edition!

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Credits for some items mentioned in Hot Iron 108, via John Kirk, VK4TJ, to whom I am most grateful.

Mentioned in Hot Iron #108 were the "Wee-ceiver"; this was designed by Weaver, B. WB2HAL, and was featured in CQ Magazine, November, 1967.

The 3A5 Transceiver is credited to JA3TZZ, https://www.asahi-net.or.jp/~ and I'm most grateful to be able to direct Hot Iron readers to his web pages - a plethora of RF design and technology.

I should emphasise that I'm only human, and sometimes I miss references or get them wrong - those who previously copied or used somebody else's work for instance, I might (unknowingly) attribute their work when it should really be the originator's credit. I do check as best I can, and welcome any corrections from Hot Iron readers - as I do ANY feedback or notes from readers.

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Recent OFCOM prognostications in the UK about reducing amateur radio RF power levels, in response to (I assume) their molly-coddling those who believe that all modern ills - including COVID 19 - are caused by G5 mobile phone technology or any other technology that mentions the word "radiation". The depth of misunderstanding of these "foil hatters" is incredible. The more that these folk hear about electromagnetic radiation the more they fear it; "It's RADIATION!!!!", they scream, "IT KILLS YOU!". This weird and wonderful prognostication struck me as odd, but strangely familiar. Let me explain...

In my industrial years I worked for a - shall we say - "seasoned" chief engineer who encouraged me in all things RF; so long as I kept the "amateur" side of my thoughts separated from my "work" tasks! We had many long discussions about RF electro-magnetic radiation and the human body; he emphasises the inverse square law, and oft quoted Pat Hawker, G3VA's notes about this subject, these being the introductory years of popular hand-held ("talky-walky" he irreverently called them) transceivers that the wisest idea was to keep intense RF fields away from the head as par as woas possible and practicable. With modern GHz transmitters in mobile phones, I think this a wise idea; my grey cells are sparse enough without voluntarily knocking off a few more with every phone call.

With that end in mind (or rather, what's left of it in my case) I use the "loudspeaking" function when "dialling"; and switch back to earphone when the call connects. Then I bring to mind the volts per metre my Chief used to tell me about in the transmitter halls at Rugby (60kHz, running C.W. time data) and Droitwich (200kHz / 198kHz Radio 4, long wave A.M., full carrier): the fluorescent overhead lights - that weren't wired into the mains in any way - lit to full brilliance and gave a dazzling indication of the RF output. The RF generators I worked on day in, day out, running between 80kHz and 500kHz up to 500kW would light a 5 foot fluorescent leaning against the wall behind me indicating high energy electric RF fields being present in a very visible way - I limited my time with the covers off at full power to as short as possible; a flashover at those powers is not only visible, it made my ears sing with the noise for a few minutes too!

Best thing to do as amateurs: keep to mind and limit your time exposed to high RF fields, both inside the transmitter and near the antenna(s). But do try to avoid the neighbours seeing you wearing a tin-foil hat; it does upset them!

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That magnificent man, Frank Barnes, W4NPN, has catalogued, sorted and shunted into logical order my ramblings in Hot Iron on his web page, www.w4npn.net, and has done a superb job in splitting out the Technical & Data section: he has set up a separate tab for the information which is usually appended to every edition of Hot Iron.

All our old friends are there; Unobtanium, Obsoletite and valve equivalents, all the favourites. If you have more to offer on these "data" topics please let me know and that section, now available for all, can grow and become a reference for years to come. It will out-survive me, I know that; and that's just how it should be. it's a source of useful information for anybody, anywhere, to access and use - and long live the free dissemination of the basic knowledge of our trade.

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Tim's Topics

I failed to contribute to the last Hot Iron due to a mess-up on my part over Peter's publication dates! Hence two items this time!

Small QRP Matching Bridge and AMU

I frequently need a small unit for all sorts of experiments with a new random 'long wire' aerial that is unlikely to be naturally resonant on any band and a probably dubious RF earth! It had to cover a wide range of feed line impedances – maybe balanced or not – primarily for the main lower HF bands and needed to include some sort of match indicator. The easy bit is the match indicator; for QRP levels a resistive matching bridge has many advantages – simplicity and always being safe for the TX being the most important! When in circuit, the load on the transmitter has to be between 33R and 100R for any antenna line actual impedance (shorts to open circuit) – so this is should not blow the TX output stage! The unit's circuit is given below with the restive bridge in the left half. Such bridges usually feature a double pole switch in the RF path to include the circuit but that is not necessary if you re-arrange the circuit a little! But do keep the second pole of the switch to choose between a red (bad) or green (good) LED to indicate the best match conditions! They can be separate LEDs or a tri-colour one. I have given the RD LED a slight lower series resistor to compensate for the lower RF voltage when the bridge is in circuit, compared to full out output to the antenna when matched with the GN LED. This helps with determining the optimum matching point when the red LED is extinguished! The three 50R bridge arm resistors should be rated to suit the anticipated dissipation over a few seconds while adjustments are made. Six 2W 100R resistors is good for use up to 20W or so if you are quick! Another advantage (maybe) of using LED for the match indication is that you don't need any large meters, or calibration to account for transmitter Pout variations.

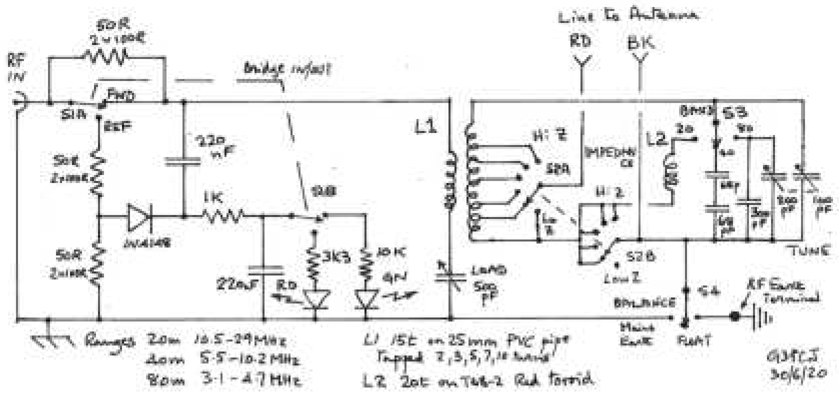
The matching part is a little more complicated – I much prefer a series or parallel resonant circuit because this will help reject out of band signals which can pass through simple L match circuits. I also like the aerial circuit RF 'earth' to be separate from the rigs input 'earth' or 0 volts which is often connected to the electrical mains safety earth – these two aspects lead to a design using a resonant RF transformer with taps for load impedances of a few KOhms down to 10 Ohms; and if isolated from any form of RF earth, it can 'float' to feed a balanced line or aerial despite not actually having a balanced circuit internally. To cover the wide frequency range, the inductor needs to be resonant in the middle of the intended frequency range (say for 40m) with a smallish capacity that can be added to for 80m, and with a lower inductance for 20m by paralleling a smaller inductor, while still allowing the main inductor to remain as a variable turns ratio RF transformer. I had a small air spaced variable capacitor with 100 and 200 pF sections for the main tuning; you should always collect these valuable items! I used another 500 pF variable for the input 'load' one but it is debatable if this is really needed. On 40m I added a fixed 34 pF (2 x 68 in series) across the 100 pF variable to bring the band more to the centre of its rotation; for 80m, the bandswitch connects the 200 pF section with extra fixed capacity to obtain 4 times the capacity on 40m. L1 is wound with 15 turns (tapped at 2, 3, 5, 7, & 10 turns) on a 1 inch plastic water pipe with loads of holes drilled in it to secure the windings; taps are made with a short twisted 'nib' that is soldered down its length to reduce excess winding length/inductance. The primary has 4 turns tight against the low Z end of the secondary. Five positions of S2 give increasingly low tap positions for decreasing impedance loads using parallel tuning; the sixth position alters the circuit to series tuning for very low impedance loads. L2 is a plain winding of 20 turns on a red T68-2 toroid. The last facility is a centre off switch which can connect one side of the antenna feed line to a genuine RF earth or the incoming screen from the TX. With the values shown, the AMU works from 3 to 29 MHz. The picture (below) shows its internal construction. G3PCJ

Stop Press!

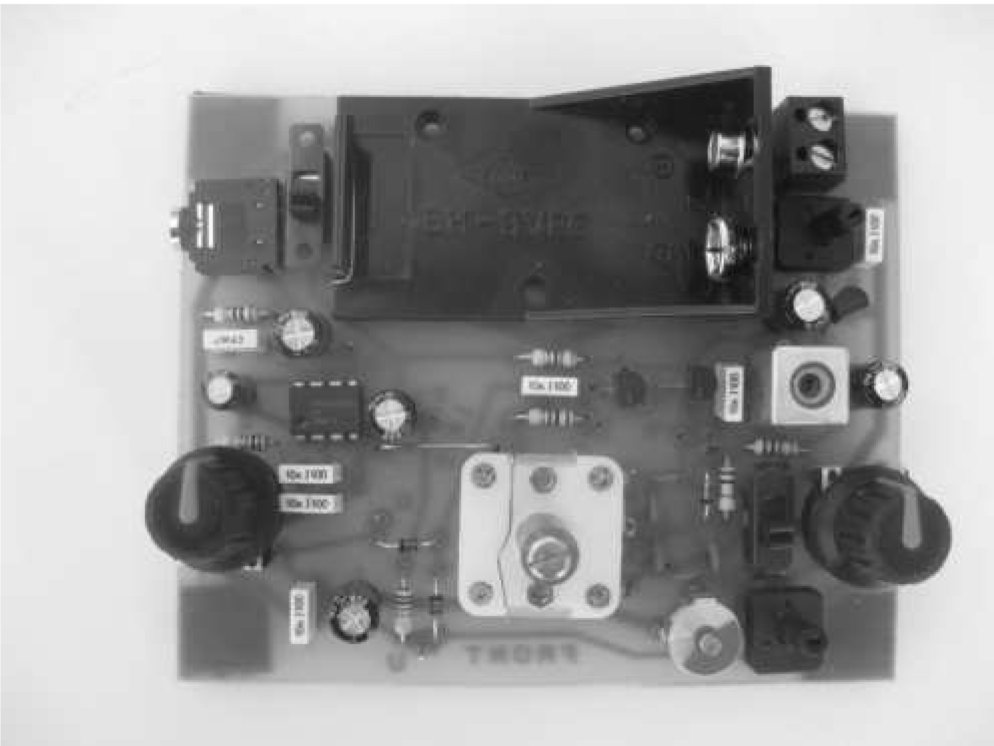
I have long been a fan of Regenerative RXs because they can exhibit remarkable performance for simple circuits! My latest is a project called the Bramwell. The prototype (see Photo) has undergone extensive testing here but I need four early builders to help prove it and the instructions for the kit. It has two switch selected bands which are normally set for 40m, with their broadcast stations, and for most of the amateur 80m band. To allow the full beauty of a Regen to be explored it has two large knobbed presets for the frequently used Regen and AF gain controls, with two small presets for the less used RF gain and Oscillation controls – in effect providing coarse and very fine control of the critical oscillation level to suit to AM or CW/SSB reception. The RFG preset is also important to minimise any tendency of strong stations to pull the oscillator frequency which can make the CW beat note sound very rough! After these 'RF' aspects, it has a strong full wave diode amplitude detector with phone bandwidth audio filtering, then the AFG control feeding into a

LM386 power amp that can drive modern 32R phones. The whole is powered from a 9v PP3 battery and will normally be sold for £24 via my website which will automatically add £5 for UK postage. As a special deal for Hot Iron readers, the first four UK orders that come in will be treated as early builders and will qualify for a discount to £22 plus £5 P and P. First come first served so let me know asap if you want to take advantage of this offer BEFORE via my website.

Tim G3PCJ www.walfords.net



SMALL MATCHING BRIDGE and ANTENNA MATCHING UNIT



Test Gear & Maintenance

The Technical Thump

The “Technical thump” - that which cured many a misbehaving valve TV set, and it’s modern brother, the “IC push” - that which sets the wayward little beggars back in their sockets and “wipes” the contact area free of oxide and corrosion are old friends.

Wayward IC’s make a satisfying “crunch” as they reseat. It’s that “crunch” that lets you know the little beggar has been thwarted in it’s efforts to mislead the wayward, and cause untold mayhem and disruption due to intermittent connections.

Before you reach for your meters and tools, , try the IC Push. Works wonders!

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Surface Mount Electrolytics and such

Removing surface mount electrolytics is rendered far easier if you approach the job with a little forethought. Grip the recalcitrant cylinder - after duly noting the correct orientation of polarity - with pliers, and give a firm twist and lift which will peel the stubby leads clean off the pads (with luck). But... beware on cheap pcb’s, you’ll likely lift the pads, so I recommend a touch on one lead with an iron whilst “twisting and lifting” one side at a time.

A dodge to remove those blasted multi-legged flat pack IC’s with more legs than a millipede, is to use children’s modelling clay to make little “coffer dams” all around the flat pack IC, then melting solder inside the barriers to flood the pins with molten solder. With a gentle pry upwards whilst you melt the solder and keep moving round (it’s an “Isle of Man” technique, it needs 3 hands!) you can keep circling the IC with your soldering iron and keep a fair section of solder molten. With patience the IC will gradually lift away clean as a whistle, and the solder can be mopped up with a sucker and fluxed braid to clean up the pcb. I would strongly suggest that a quality temperature controlled iron is used for this job; and don’t take too long or you’ll either fry the pads off or do an “oooh, nasty!” to the IC’s innards. Go forth bravely and without hesitation: all will be well!

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Low Pass Filter for DVM’s

Below is a picture of the low pass filter for my digital multimeter to “average out” rapidly varying signals to kill the “dancing digits” I mentioned in Hot Iron #108. You can see the 4mm plugs partially inserted into my DVM beneath the 3mm thick Tufnol base plate, and the stubby 4mm sockets immediately to the right of the capacitor for my probe’s 4mm plugs - a 1.5 µF, 650v (NON-POLARISED) polypropylene, fed by a 680k-ohm 1kV rated resistor is buried in the epoxy resin covering insulation from one 4mm socket (it doesn’t matter which). I always secure my DVM to an insulating board (elastic bands are ideal) when using it on 50 volts AC/DC or more, and NEVER touch the DVM (or change range) whilst connected to ANY voltage.

This RC combination is ideal for most of my jobs, slowing down those dithering digits and settling quickly to a steady(ish) reading.

I ALWAYS wait a few minutes before unplugging the LPF module from my DVM; the 10 Meg-ohm DVM input resistance forms the bleed resistor for any charge left in the 1.5 µF capacitor once the measurements have been made, and I ALWAYS short my probes together. Why? A 1.5 µF capacitor charged to 600v gives a fair bite! YOU HAVE BEEN WARNED....!

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Audio matters...

Tuning Headphones & Select-o-Ject
During WW2, Tuning high impedance headphones for added weak signal clarity was a dodge used in some of those mysterious huts at Bletchley Park. The basic idea was to add non-polarised capacitors in parallel (or series...?) across the voice coils of each individual 'phone, to get resonance at the frequency the operator preferred - nominally 800 Hz, but everyone has different preferences.
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The capacitor resonates with the voice coil inductance, giving a useful boost to the signal and simultaneously reducing extraneous noise, it's a simple band pass filter.

An interesting thought is why resonate in parallel; a series resonant circuit would give the same "Q" and peak the current through the voice coils. Or, of course, resonate one phone slightly higher than the other: then you'd get a bin-aural "peaks" so receiver tuning wouldn't be over critical, and you'll have a spatial awareness of the received signal if it drifts.

A modern equivalent for low resistance headphones could be an add-on audio "select-o-ject" circuit, beloved of valve days - an audio notch / boost filter of adjustable Q and centre frequency, applied just after the audio pre-amp and before the power amp stage. The original select-o-ject from RCA is shown at: https://www.w7ekb.com/glowbugs/rx/SOJ/soj.htm ; and some very tasty other projects and designs on his web page are well worth looking at.

You'll find a simple solid state design, aimed at radio reception, at https://www.electroschematics.com/dx-audio-filter/ . This is a simple design, but I can't comment on it's performance as I haven't built it; but it follows the accepted style of these things so should give a good account of itself if built carefully - and as always with these things, quality components of tight tolerances are used.

If I need audio designs my immediate "go to" resource is Rod Elliott's web pages; you'll get the truth, the whole truth and nothing but! Take a look at the magnum opus of variable state filtering at https://sound-au.com/project75.htm or any other of Rod's filtering / crossover / notch / peak projects. If it's audio you're after, you'll find all you'd ever need in Rod's pages, believe me!

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Sliding Bias audio output stages

The principle of "sliding bias" isn't new. It's been around for many years in one form or another; the general idea being that for low level outputs, Class A is for best quality, the superb audio enriching any low level signal and making copy easier. Once the signal has risen in magnitude (maybe due to less fading or shifting ionosphere) then the amplifier "slides" into class AB then straight into Class B on high level signals. This saves power supply watts, and gives a much more comfortable listening experience. It's akin to Auto Volume Control; it makes the listening far more comfortable.

You can find more about "Sliding bias" class A amplifiers on page 53 of https://nvhrbiblio.nl/biblio/boek/The-Transistor-Radio-Handbook-Donald-Stoner.pdf

and it reminds me of Tim's method in some of his designs for biasing the gates of RF power mosfets. The forward bias of the mosfet is derived from the input signal: if the drive fails, the bias shuts off, but under normal drive conditions the gate is biased to bring the mosfet into conduction at the appropriate bias point.

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Components

The "Earthy" foil of capacitors

When you're building sensitive or critical audio amplifier chains - typically Direct Conversion receivers, for instance - it pays to note the "earthy" foil of a rolled film type capacitor. Yes, those ubiquitous epoxy coated chunky capacitors beloved by audio designers! In fact, any capacitor of "rolled up" construction - polystyrene types are another instance - the "earthy" foil is the outermost foil of the "rolled up" construction. The outer foil should ideally be the "earthy" foil to avoid pick up, hum, and undesired feedback, often attributed to poor layout but perhaps because the outer foil in the capacitor is the signal foil and thus unshielded by an "earthy" foil.

The easiest way to find which foil is outermost is to couple one lead of the capacitor to your scope probe, the earth clip going to the other capacitor lead. Then grip with your fingers the capacitor on test: note the "pick up" volts displayed on the scope. Reverse the capacitor connections and repeat; the outer foil will pick up more "hum" from your fingers, as seen on the scope.

For those without a scope, an audio amplifier can be used: earth one capacitor lead, and connect the other to the amp input. Now grip the capacitor in your fingers, and note the "hum". Reverse the capacitor connections and compare the "hum" level - if you earthed the outer foil the "hum" picked up should be notably less.

Of course, not every circuit will need such esoteric thoughts - but at least, now you know the score and can save it for the times you might need it.

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LED photodiodes

LED's make very good photodiodes; and so do 1N4148 or other glass body diodes, where stray light can get in and illuminate the junction. If your design has an incurable "hum" problem, try shading it and mounting it in a die-cast box. That way you'll guarantee no external pick up from RF interference OR light - if your die-cast box is earthed properly, that is! Keep to mind too, if your design proves light sensitive, you can get problems from fluorescent and LED lamps, as they flash at a rate faster than your eye's response time - in my day, this was known as the "fluorescent buzz", the stray light from the overhead fluorescents getting into the glass diodes and injecting a nice little "untraceable" signal which mysteriously stopped when the circuitry was shadowed or in darkness.

You'll find this phenomenon multiplied nowadays when working near mains driven LED's: these not only flicker at odd frequencies, but spit out plenty of RFI too, just to make life even more interesting! If earthing and all the other conventional "cures" don't help, look for light ingress.

A reference to all this is at: https://www.analog.com/en/analog-dialogue/raqs/raq-issue-108.html#

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Modern single rail op-amps

Thinking of light and photo-diodes, optical comms links using silicon photodiodes (or LED's) often call for single rail op-amps to create current to voltage converters which are often required for optical comms experiments in the receivers. The tiny currents generated by silicon (or LED) photo devices are fed into the summing junction at the inverting input of a very high input impedance op-amp; thus the feedback resistor from the op-amp output to the summing junction defines the "volts per µA". The photo junction effectively runs it's tiny current into a virtual earth resulting in minimal loss that the usual resistor load creates. For instance, if the feedback resistor is 1 meg-ohm, you'll see 1 volt per µA at the op-amp output: 1mV output therefore is equivalent to 1nA photo current, without having to resort to a 10 meg-ohm load resistor.

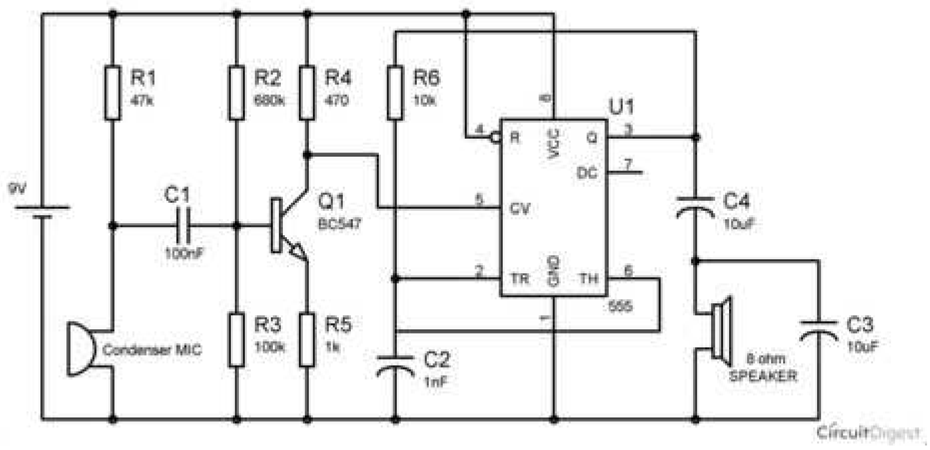
Take a look at page 4 of http://ww1.microchip.com/downloads/en/appnotes/00682c.pdf These modern op-amps are superb performers, require low supply current to run to full spec. and often only require single rails so the circuitry is simplified; a real boon for the "field" operation optical comms almost always demand.

Magnificent experiments set up by Roger Lapthorn, G3XBM, using "cloud bounce" and powerful LED's running pulse modulation has shown significant distances can be achieved - and those 4 inch / 100mm lenses from bench magnifiers are excellent for these jobs, as well as A4 sized Fresnel lenses. They are optical Yagi antennas!

Roger's page at https://sites.google.com/site/g3xbmqrp3/optical shows a very straightforward transmitter using a K1EL code generator; I've always hankered after trying a 555 with audio applied (suitably scaled and processed to get 50/50 mark space with no audio input) to pin 5 in a circuit like this. It should work a treat, and follows a proven design which you can see on pages 30 and 31 of the Radio Shack book, "Engineer's Mini Notebook, Communications Projects" by Forrest M. Mims III and would form the basis of a quite sophisticated comms link if modern components were used and high power LED's for the Tx with substantial optics as per G3XBM.

The basic 555 LED driver shown in the article could be improved by using the 555 to drive the gate of a power mosfet; this then switching the LED would allow significantly more powerful LED's to be driven, but the power supply will need to be beefed up a bit!

A typical circuit for a 555 pulse width modulation audio amplifier is below. This circuit has appeared in many web pages and articles; I believe it was from a Signetics application note back in the 1970's, but if anyone knows more about this reference I'd be glad to know and happy to publish any further information. My personal interest stems from efficient modulated output stages for A.M.; the audio modulator being a "high side" HV mosfet feeding the Class C / D / E stage via a low pass filter.



It’s easy to see from the above diagram how a power mosfet could be uses to replace the speaker. The 555 is a meaty little chip, it’s bipolar version easily capable of 300mA output current at nigh on TTL edge speeds, so driving the gate charge demand of a power mosfet shouldn’t be to tricky.

The Rx features a threshold discriminator (a “bit slicer” as it was called in my day) which improves the S/N ratio and acts as squelch; the use of a 741 as the photo-diode high gain pre-amplifier could be improved by employing a current to voltage converter (as discussed previously) and would probably improve the S/N dramatically by removing high value resistors from the signal path.

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Inductors for free

Relay coils culled from burned out relays - whose contacts are shot but all else otherwise OK - make good substitute A.F. chokes. The astute will note that the magnetic circuit in an de-energised relay has an air gap, when the relay armature is away from the coil core: this gives a clue as to increasing the inductance of the coil dramatically, by wedging or otherwise closing the armature onto the coil core. This closes the air gap and the inductance rises significantly.

With a spring or something similar to push the armature away from the core, and apply pressure via a simple screw mechanism to vary the air gap, and le voila! An adjustable inductor.

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Transformers and all that...

Transformers, 50 / 60 Hz, and such... a note from Ross Whenmouth, ZL2WRW and most gratefully accepted! Ross comments:

“Hi Peter,

Re: USA vs. European Mains transformers

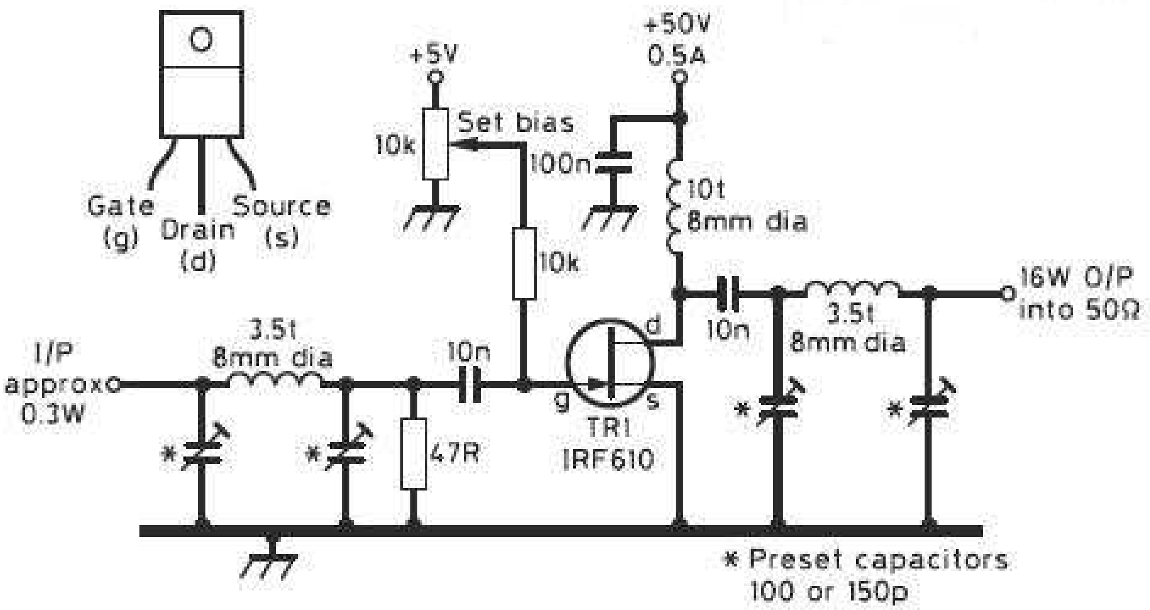
In response to Martin Boardman's article on page 23 of Hot Iron #104:
I understand that a common industrial voltage in North America is 480V 3-phase 60Hz with 277V line-neutral voltage. A transformer with a winding rated 277V 60Hz should be quite happy with 230V 50Hz energisation because both the voltage and frequency are reduced by ~ 20% - thus the core flux density will be same as when energised with 277V 60Hz. However, the output voltage will unavoidably be reduced by 20% (but maybe you can get lucky and source a 277V to [desired output + 20%] transformer ?)

73 ZL2WRW
Ross Whenmouth"

Many thanks Ross for your contribution. This is exactly what Hot Iron is all about: open knowledge sharing and helping constructors get "junk" working in a useful scenario. Many transformers (and what other components?) from industrial control panels and other commercial electrical / electronic equipment - which probably cost an arm and a leg brand new - turn up in the most unusual places, and can be adapted into good service rather than cluttering up land fill or otherwise dumped.

For our thermionic aficionados, UK 415v to 230v control panel transformers make superb HV supplies, run backwards; and with a voltage doubler - another use for those microwave oven HV capacitors paralleled for some serious high voltage µFreds! - will make some hefty 1kV rail power amplifiers.

Or 230v to 32v transformers beloved by stepper motor drive designers for MOSFET PA's running a 48 volt rail? You would be well on the way to very simple mosfet linear amplifiers; the higher supply radically improving the linearity and gain, as per the schematic below by VA3IUL:



Just a matter of keeping an open mind and lateral thinking. It's tempting to start a radio constructor's junk yard, concentrating on stripping all the useful parts from failed projects and old control cabinets and the like - a collection of old, non-functional radio gear for spares or repairs? Got a empty barn for me to rent, Tim? Hah!

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"Dull Lamp" Test for unknown Txfmrs

Trying to identify and test unknown, unmarked transformers can be made much easier (and with less blown fuses) with a "Dull Lamp" test set. The gist of a dull lamp test set is a 40 or 60 watt lamp wired in series with the live feed; any disastrous shorts or crossed wire / windings cause a bright lamp; a correctly wired "tranny" will show little or no glow when the secondary winding is
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disconnected from the load - al the primary side draws is the magnetising current and in a decent tranny, that's just a few mA's.

A good start identification is to measure the DC resistance of the windings. Not only can you pair off the wires and windings this way, and you get a good idea of which winding is the primary. On a step down transformer it will probably have the highest resistance of all the windings; the logic being the high voltage winding will have many turns of fine wire which reads high resistance, whereas a secondary of lower voltage has much thicker wire hence reads significantly lower resistance.

Energize the each winding identified with your Dull Lamp test set. The voltage across the winding is (approximately) the rated voltage of the winding. What's happening is that when the applied voltage is higher than the rated voltage of the winding, the core saturates, and its impedance drops, which tends to clamp the voltage across the winding. If you read full line voltage, you've got either the primary winding or an HV secondary; the lamp won't light, because the (unloaded) primary or HV winding inductance is usually a good few Henries, thus the magnetizing current is tiny and the light bulb barely glimmers.

This is a safe test for the primary; if the bulb doesn't light, then there will be minimal current drawn when that winding (all other windings unloaded) is connected to the line. Beware though a transformer with higher voltage (than the line) windings: this test can't discriminate the high voltage winding(s) from the primary. Again, resistance checks will help; a txfmr with (say) 230v primary and 350-0-350 secondary will show significantly more resistance in each of the secondaries than the primary winding, and you'll have a clue from the overall resistance (350 to 350) resistance. You'll only struggle when the primary and secondary windings have similar voltage ratings.

Once the primary is located, then you can apply line voltage to the primary and measure the secondaries, with the Dull Lamp tester. If you've confused an HV winding with the primary, the resultant voltages measured on the previously paired windings will usually show odd values, so try the other HV windings as the primary to see if the paired windings now produce more sensible voltage readings.

Weigh the transformer, then reckon 20VA per lb weight or 45VA/ kg. You won't be far off.

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Transformer Calculations

The whole skedaddle of designing transformers is a mystery to many - and I'm one of 'em! I can work my way through the basic calculations, but one we get into the "magnetic circuit", reluctance, remanence, and a host of other weird and often unknown variables ("Oersteds", anyone?) we're in weird and wonderful surroundings.

I worked alongside some magnetic designers, whose expertise was in 3-dimensional magnetic field analysis for Cathode Ray Tube deflection coils, saturable reactors and voltage stabilising transformers, amongst many other strange devices of unknown utility. These people were so far out, they were very close to coming back in by the back door! They worked in the midst of 200kV AC / DC power supplies, insulators the size of small pine trees, coils, cores, copper wire by the mile, flashes, bangs and clouds of smoke that had to be witnessed to be believed. I was immensely impressed!

This is not to encourage you to follow these wonderful displays, but below is some sound basics from the wonderful world of the magnetic masterminds:

https://ludens.cl/Electron/Magnet.html

(yes, he of the capacitor ESR instrument design). This will tell you all you could possibly want to know (if you value your sanity) and I can recommend reading it thoroughly!

Replacing Ge transistors with Si PNP's

From https://forum.allaboutcircuits.com/threads/looking-to-replace-hard-to-get-germanium-transistors-with-silicon-ones-is-this-possible-please.160821/

Quoth the author of the article - "*I worked for a famous Hi.Fi amplifier company that produced a stereo 30 watt amplifier. The noise level of the pre-amp transistors was quite high so they re-called many of them and replaced the original germanium transistors with silicon and simply doubled the emitter resistors. After this, the noise level was very much lower.*

Back in the day when silicon started taking the place of germanium, there was a generally accepted rule that ***doubling the value of the emitter resistor was way to obtain the correct bias conditions, (within limits) In a great number of cases with old radios and amplifiers etc. this worked. whilst not absolutely theoretically correct, it is worth trying****. As most germanium transistors where PNP, be sure to select the correct type of silicon replacements as some of those in your schematic are NPN, substitute one at a time and check operation before going on to the next stage."*

The OC71 is being used to set the bias for the output transistors with temperature compensation, is it mounted on a heatsink with them? If you change the output transistors to silicon, you will need to use a silicon transistor (or diode, Ed.) *here to and re-set the bias to reduce crossover distortion".*

Of course, sourcing Germanium transistors held as "New Old Stock" would help...

https://www.utsource.net/sch/AC176?link=OC21%7CAC128%7CAC176

Notes from: https://www.vintage-radio.com/repair-restore-information/transistor_transistor-faults.html

Or make your own Ge transistors (Hah! Now there's an idea - I knew all those years working in a wafer fab. would come in useful one day!). See:

http://www.thevalvepage.com/trans/manufac/manufac1.htm

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Asian pet Rocks

From John Kirk, VK4TJ - with many thanks!

I've always had an infantile fascination with crystals – probably because most of my crystal-controlled projects WORKED, and virtually none of my VFO projects ever did. You buy a capacitor, and you are lucky if you know where you are within 10%. You buy a surplus rock out of the far east for pennies, and you get what – a few PPM? This led me to peruse Aliexpress, to see what, if any projects employing cheap rocks might suggest themselves. What a mess! These vendors clearly don't know what is in the bins. Sometimes, you can weasel a frequency out of them by hovering over the "extended" product description, but more often than not, you must drill down right into the item. Do that a few hundred times, and you'd happily hire someone to do the rest for you! A bit of COVID-inspired boredom inspired me to spreadsheet the lot, which I am happy to share with you here:

https://vk4tj.blogspot.com/

You will note on arrival, that I have also categorised clock oscillators and ceramic resonators, though I am less certain that I have captured 100% of either.

I have only listed one vendor for each frequency, even though virtually all the listed frequencies are available from multiple vendors, so, once you have worked out a suitable search term, shop around! Some offer pretty good quantity breaks. Others are happy to pony up for free freight.

Getting started: Cut and paste this URL into your browser:

https://aliexpress.com/store/624531

This will bring you to the "Hengdashengdianzi Store", one of the more prolific sellers of surplus rocks. Search WITHIN his store for the desired frequency. If Mr Hengdashengdianzi cannot help you, edit the above URL with another store number from the right-hand column of the list. Lift a suitable search term for the wider Aliexpress pedler community from Mr Hengdashengdianzi, as plagiarism is rampant amongst Alibaba's 40 million thieves.

Try to fix in your head the difference between "Search In This Store" and the more global Aliexpress search, or you'll spend fruitless hours wading through crystal pendant necklaces that will cure psoriasis, gain you financial independence, and ensure you never sleep alone, all in one go! (Now there's an added attraction for Amateur Radio aficionados! Ed.)
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Cut to the chase: Yeah, there are some promising crystals available, like 10.111, 7.159 & 7.200 etc. Years babysitting the VK QRP Club's crystal stash have revealed that most of us have, in fact, moved on from simple MOPA rigs, however, so "out of band" rocks suitable for ladder network filters etc. are often the new "movers". I was delighted to find both 6.4 & 3.2 MHz rocks, as my old Yaesu FT-7 need a new 12.8 MHz crystal for the 100 kHz marker generator. A straight swap for 6.4 MHz yielded 50 kHz markers, and 3.2 MHz, 25 kHz markers.

Cast your mind over Alibaba's trove of treasures – hopefully the fruits of your labours will turn into projects to grace the pages of this journal….

VK4TJ

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Construction Notes

Stainless Steel Soldering

Soldering stainless can be a daunting task: the trick is to pre-coat the stainless with a wetting agent that can break through the ultra tough oxide layer on the surface - it's that (amongst other things) that gives stainless it's wonderful properties. A mixture of phosphoric and hydrochloric acid was one flux I've used previously; but in this "Elf-N-Safety" age I can't honestly recommend you mix your own.

In the UK we have https://www.cupalloys.co.uk/soft-solder-fluxes/; I have seen similar products on various on-line market places based in the USA and Canada. I'd suppose similar are available in the Antipodes, too.

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Q-max cutters

The circular hole wonder tool (and other profiles are available, too)

Grease is the word! Apologies for reminding you of John Revolta and Olivia Neutron-Bomb in that 1978 insult to music lovers, but all those who have used Q-Max cutters in anger will know the score - grease and plenty of it makes for an easier life.

These wonderful time savers cut perfect holes in aluminium chassis oh so easily; so long as you don't rush, or try to cut anything on the really "beefy" scale. I once had to cut 64 off 20mm holes in a stainless steel cabinet as air holes for cooling; it took all day and the screw in the Q-Max had to be replaced several time. That's because 18 SWG stainless is near the limit of a Q-Max cutter's capabilities, though the cutter die and stock were well up to the job, the compression bolt gradually stretched until the thread pitch changed and the consequent friction became intolerable.

The answer, as I was taught all those years ago, when cutting anything beefy with a Q-Max, is to go s-l-o-w-l-y, and on bigger diameters (say 1½" and up) use a ring of small holes just inside the finished hole periphery to reduce the strain on the cutter. You can get roller bearings instead of washers to reduce the compression screw's friction, and to help the standard steel washers liberal applications of pencil lead or locksmith's graphite powder lubricant as well as conventional grease and oil really helps. Pete Insley - an old pal of mine who worked in the Maintenance crew in the CRT Department - had phosphor bronze “Oilite” washers he kept specially for beefy Q-Max-ing; and he had a small squirt bottle of white spirit (turps sub) mixed 50-50 with red diesel and this, he said, really did the trick.

Whilst working for Stone-Platt Industries in St. Louis I was introduced to a solvent based cutting fluid called “Relton TAPTITE” which proved very efficacious in any cutting, drilling or tapping operation in stainless steel; I guess in chunky mild steel chassis bashing for Octal, B9A or B7G valve holder holes that TAPTITE would work well too. I never found out what the actual TAPTITE fluid was; but it was very effective in any stainless cutting. Perhaps one of our US readers could shed some light on TAPTITE?

I kept a short length of ½” stainless gas pipe in my tool box; not for extra leverage, but to make turning a hex Allen key a bit more comfortable. In theory a hex Allen key (“Unbrako” in Scandinavia) is an “easy on the hands” tool - but once you’ve done an hour or two with a Q-Max cutting hefty steel you’ll appreciate any bit of help!

Where you will need every ounce of subtle attack and leverage is getting the disc of waste metal out of the stock part of the cutter once the hole is cut. The metal disc is distorted; any attempt to bash it out will result in the disc becoming solidly jammed in the stock. Use gentle persuasion with a drill shank in the hole left by the compression bolt and waggle the waste piece out. Patience is the key; don’t ever try to cut another hole until you’ve cleared the waste from the last hole. The two pieces will unite in sympathy against you, and defeat your best efforts to shift ‘em: the combined outward pressure will lock them in solid and it’s a blacksmith’s job (i.e. big hammer, punch and anvil with Hardie hole) to get the damn things out.

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Tank Cutters
These I will warn you about - the use of “tank cutters” (sometimes called “fly cutters”) for chassis holes. These are Devices of the Devil and will have your fingers a’fore you know it. They comprise a cutter mounted on the end of a bar, set into a mandrel that fits into a power tool. Fine if your slicing a 3” hole in a large water tank or other heavy and solidly mounted sheet metal object; but woe betide you if you try it on a small sheet of steel or aluminium hand held in a small drill press. If the metal job isn’t secured with multiple clamps, the moment the cutter breaks through the back surface, the job will be ripped off the drill press table and whizz at great speed across the room akin to a flying guillotine blade. You MUST use plenty of hefty bolts / clamps / TEE nuts, whatever - don’t underestimate the forces involved. They will rip to pieces anything not 100% secured down, and have absolutely no respect for human flesh. Don’t chance it unless you’re well versed with machine tools and the forces involved.
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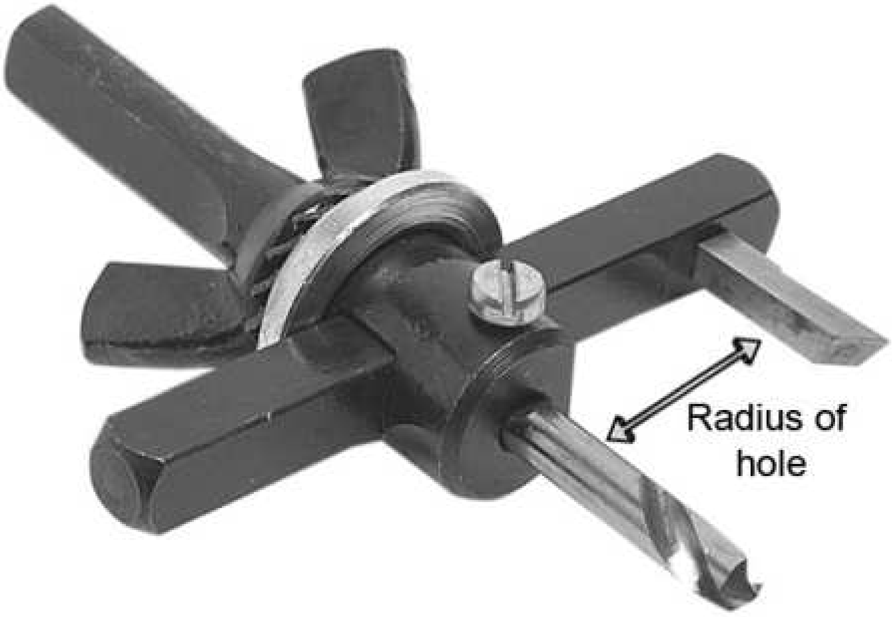

Image from: https://www.wonkeedonkeetools.co.uk/media/wysiwyg/TC-Tank-Cutters-Jenna/TC1/TC-1-6.jpg

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Hole Saws

A slightly different Spawn of Beelzebub live in the hole saws much beloved of our "sparks" electrician compatriots: these are marginally safer than Tank Cutters, but you'll be finding razor sharp bits of swarf under your finger nails, down your shirt, up your sleeves and stuck in any soft skin you let them near. And that's not mentioning the racket these hole saws make when cutting: infuriated banshees, they rip and scream through mild steel; on stainless they fling red-hot swarf everywhere you really don't want it - and generally after cutting one or two holes all the teeth have gone anyway. They don't like stainless! Aluminium is fine, as is FR4 pcb material, but go easy, take your time - it's NOT a race. And you'll have the now familiar job of getting the waste out of the cutter, too....

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Terminal rail construction

Making life easier is always thought a good thing at G6NGR. If you look at a well designed electrical control cabinet, you'll see the power supplies, signal wiring and other (non-RF) wiring set out for easy test and isolation purposes, and amateur radio gear can well follow suit, albeit in the power lines and control signals, if not the RF connections. In valve days tag strips and solder tags were commonplace; nowadays it's a good idea to use screw terminals for power and control signal wiring - you can slip the wire out and isolate for fault finding a "suspected-of-instability" or other misbehaving section.

The easiest way to do this is to use the brass innards of "choc-bloc" connectors, cut in half, and soldered down the the PCB "islands" used for Manhattan construction or pcb strip power "rails". Unscrew and remove the screws from a section of choc-bloc (your side cutters are ideal for this to chop off the plastic shroud that contains the screws) and release the brass tube that connects the wire cores. Cut the tube in half. Solder one half section down on the "Manhattan" islands, and use as the power supply connection to that stage; you can clamp a resistor or RFC "leg" (or whatever feeds power to that stage) in one end of the clamp tube and PVC equipment wire carrying the DC supply / control signal in t'other.

Voila! Now you can isolate each stage, easily and safely with little fear of a short to ground.

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Strange QRM?

Most amateur radio constructors will have heard a strange high pitched whining noise, that comes after spending hours messing about with bits of home made radio gear on the kitchen table (or wherever you pursue your RF). This whine is ubiquitous; it's whenever your XYL sees your lovely metal chassis sat on the polished table top, worktop or chair. The whining goes on, and on, AND ON... no amount of filtering, audio processing (though I did know one deaf amateur who switched his hearing aid off) or other solution will be found.

Well, help is to hand to stop this "worse-than-heterodyne" whining: search on your favourite online auction site for "Rubber Bumpons", and you'll find some these wonderful self-adhesive rubber domes stuck on the bottom of our magnificent creations will quench the QRM whine in a jiffy.

They have other excellent properties too: for paddles, keys and anything else that wants to stick where you put it, they are made of a "grabby" rubber, so once placed, they tend to stay put.

No more scratched table tops. No more whining. All is tranquil, all is peace. For a few minutes, at any rate... until the inevitable "you've been at that for 3 hours now, when are you going to.... (fill in as appropriate)". That is the ultimate QRM, believe me!

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R&D Dept.

"Share the love"

John Kirk, VK4TJ, suggested, in a fine example of lateral thinking, using multiple crystals of identical frequencies as a means of increasing the allowable dissipation of our beloved crystals. "Share the love" as John put it, by assembling multiple crystals in series / parallel. This sounds a good idea to me if we happen to have a good few identical crystals on the frequency we want; not always possible as the calling frequencies on each HF band tend to be non-standard frequencies as far as crystal manufacturers are concerned. But if you've a good few crystals on the frequency you want, why not?

I’ve long had ideas about using some sort of amplifier stage to “beef up” crystals, so modern micro crystals can be used in much more demanding circuits: typically those “MOPA” valve circuits that can give crystals a fair hammering. My idea is to put the crystal between the collector and base of an HV NPN transistor, shunted by a meg-ohm bias resistor. When placed in circuit, as a two terminal device, the transistor does the bulk of the work, the crystal only running the base current and thus “sharing the love”, giving the crystal a far lower power dissipation.

Doug DeMaw, W1FB, used a trick to clean crystal oscillator outputs up - another crystal of identical frequency in the output, acting as a band pass filter to remove harmonics the oscillator created (and Pierce oscillators a very good at crunching waveforms). This prompted the G6NGR grey cells to wonder... what happens if the output filter crystal is radically *different* in frequency? This led me down the rabbit hole into a Carrollian “wonderland”, where all sorts of abstruse ideas float around. Read on, and see what you think.

Think of a simple Pierce transistor oscillator, or, if you prefer, a CMOS gate biased into linear with a 1 meg-ohm feedback resistor. Now let us place a crystal in parallel with the feedback resistor. Voila! A crystal oscillator, well known to most. Now here come the first twist: in parallel with the first crystal, put another crystal of *different frequency*. What frequencies will we see now at the output? Just one, that of the most “lively” crystal? Two, perhaps, distinct frequencies, one from each crystal? A “sum and difference” product(s) of multiple frequencies?
So we now throw in a third crystal in parallel, of different frequency than the first two. What output do we see now?
If the crystal frequencies are harmonically related I’d guess a dominant frequency that “fits” all three would appear; depends on each crystal’s activity and the harmonic relations - as overtones in crystals (depending on cut) tend only to run on odd frequencies.

Now, let’s put the crystals in series; the CMOS gate is biased linear as before. They are (for instance) harmonically related - let’s say 1 MHz, 2MHz and 4MHz. What output will I see? (if any?) And... what happens if we now add parallel crystals - a veritable field of crystals - of different, non-harmonically related frequencies?
I leave this experiment to you to put together and see - as this particular Mad Hatter’s Tea Party has no references I can find in any of our usual amateur radio literature , or, come to it, my professional RF literature either. Just where would this multiple crystal approach lead? An oscillator which

simultaneously runs on 80m, 40m, and 20m? Am I glimpsing spread spectrum, or similar? Chaotic oscillators? Over to you, readers! Let me know what you find, please!

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Ft measurements for amateur purposes

As amateurs we often find ourselves without the data and information the professional designer has to hand - our salvaged components, unmarked, or just plain unknown, mean we often give it a go without knowing the full characteristics of a transistor. The responses I got about transistor Ft measurements in a recent Hot Iron prompted me to dig out an amateur approach I saw used many years ago for approximating Ft. For those wanting a fully comprehensive explanation of Ft, an excellent article is: https://www.nxp.com/docs/en/application-note/AN139A.pdf which will give you the full unexpurgated story from a manufacturer's point of view.

As amateurs, we only need to know a few basic features of a transistor. Typically, you'd need the maximum collector current, collector - emitter voltage, device dissipation, the gain at the frequency of operation you want and the input / output capacitance. This will get us most of the way, and is fine because we don't work to timescales, budgets or manic sales departments.

If you measure the voltage gain of a common emitter amplifier stage at various frequencies you'll see (if the drive waveform is a clean sine wave) the gain rolls off with frequency in a linear manner; this is the Collector - Base capacitance and Miller effect in play, and it's these that sets the frequency where the device has unity gain. Circuit designers use a simple rule of thumb for a first approximation when designing an amplifying stage: Ft should be > 10 times the operating frequency. For example, if you want a transistor to run at 21MHz, choose a device that has an Ft of 210MHz or more: the gain at 21 MHz will be near enough 10.

An easy way to estimate Ft is to build an L/C oscillator, with plug in inductors, to cover expected frequencies up to about 800MHz. This is the realm of free-running UHF oscillators, and they are very strange beasts compared to their HF brethren! A superb example - and useful too in this context - is to be found at: https://www.instructables.com/id/UHF-oscillator/ and this article includes a pick up coil to measure the oscillation. The article shows how different loops for the inductor can be used, and a Lecher line to find the frequency: https://www.instructables.com/id/Frequency-measurement-by-Lecher-Line/

So the answer for easy amateur Ft measurement is to hand: it's a simple oscillator. You'll note the oscillator is running in *common base* mode: you'll get higher frequencies out of transistors running common base than you will in common emitter (common base exhibits far less Miller effect). It will give you a fair guide for common emitter Ft if you reduce the common base maximum frequency of oscillation by 25% or so; this figure is a reasonable "guesstimation". For example: a transistor to run at 21MHz, I'd be looking for a transistor that could run 250 - 300MHz in the common base test circuit.

To meet the Nyquist criterion for oscillation, the gain must be above unity and the phase of the feedback must be somewhere around 180 electrical degrees (i.e. the -1 point on the horizontal axis
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of the Nyquist diagram) must fall inside the plot of gain vs. phase of the circuit. This means you'll only get oscillation when the gain is > -1, so making the oscillator inductor less and less until oscillation ceases gives you an indication of the frequency capability of a transistor in common base. A set of hairpin loops or a sliding shorting bar arrangement facilitates rapid "go / no go" testing of unknown transistors; if you're one of the blessed you could use a UHF frequency counter to measure the frequency where oscillation just stops - you've found the unity gain point and thus the Ft.

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Using fuses as both protection and current sensing

Any radio amateur who has memories of repairing TV sets that contained Cathode Ray Tubes, line output stages that generated 25kV or more at a hefty number of mA's will recall the subtle (and not-so-subtle) circuit tricks and techniques that wrung every last ounce of performance from the fewest components. The early solid state TV chassis were fine examples of the circuit designer's arts; to keep those pcb's running in such hostile conditions the design had to be minimal, robust, yet economic and business-like in manufacturing. Not easy bedfellows as many a "Muntzed" design proved.

Below, for your delectation, is a circuit I spotted whilst carousing around looking for some fuse information (don't ask...). Having been (RF) educated in the days of using a wire-wound resistor on the anode cap as both damping resistor and an RF choke parasitic stopper, I like a component to deliver as many functions as possible yet live it's little life happily and contented knowing it's doing a good job comfortably within spec. When I saw the circuit below (from https://www.edn.com/pwm-circuit-uses-fuse-to-sense-current/) my heart gladdened: here is a designer squeezing more function from that most unlikely component, a fuse. Absolute elegance and function: what more could you ask?
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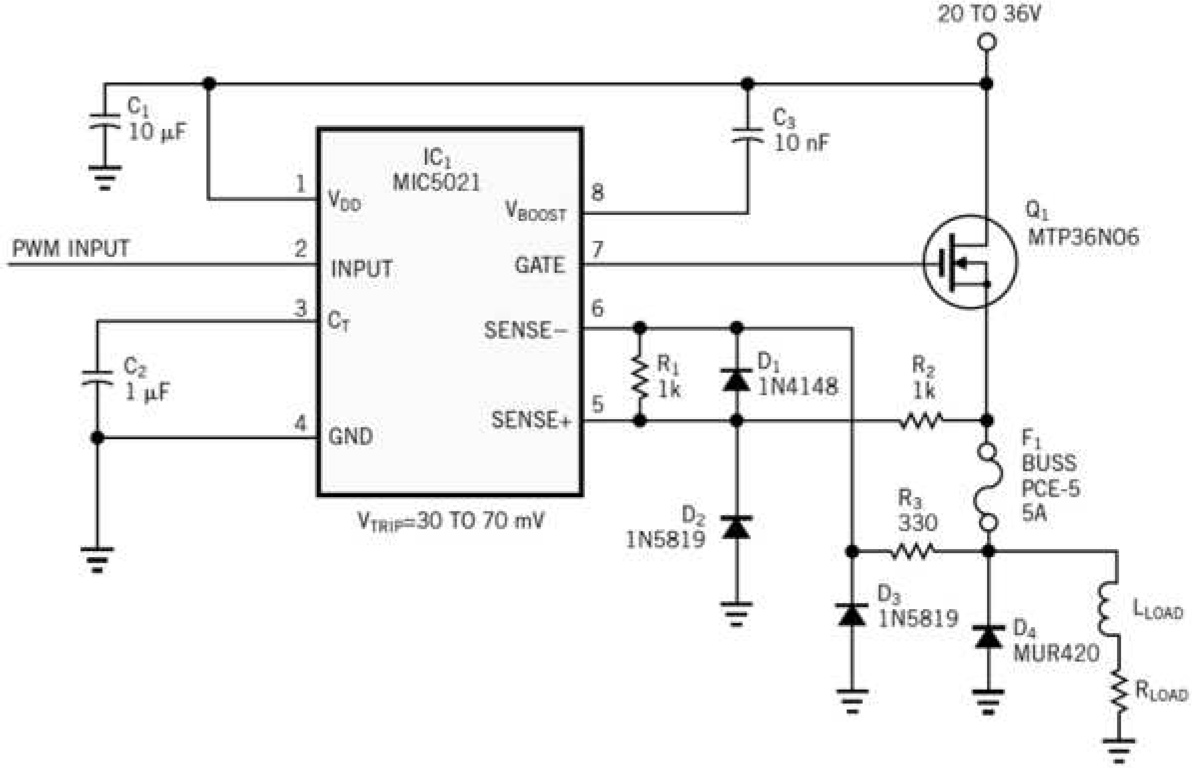

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Receivers

Synchronous Detection and freebies?

I have always found that coherent detection of A.M., though more complicated than the usual diode, pays significant dividends in higher S/N ratios, more robust capabilities in drifting and fading signals and audio quality. I came across several interesting designs which use the carrier to synchronise the local oscillator; by amplifying and clipping the A.M. signal, the carrier can be stripped out and applied to sync the local oscillator.

Alan Yates, VK2ZAY, uses a different approach - he uses a long tail pair oscillator with the constant current "tail" modulated by the incoming RF signal. Thus the incoming RF mixes with the local oscillator, and when the two are close in frequency (within the "capture range" as PLL designers call it) the local oscillator locks on - synchronises - to the incoming carrier. Alan uses this "lock" capability to strip out the precision carrier frequencies from WWV and broadcast signals - free-of-charge top notch frequency standards from a handful of components.

Alan calls up a CA3046 transistor array; if you could get your hands on some CA3086 transistor arrays, these would work just as well. Add a tuned RF amp, a decent quality audio pre-amp and power amp and you'd have a very potent receiver.

Alan comments on using his design for CW reception too; whilst I'm more interested in A.M., so if you want to follow up Alan's CW ideas, please let me know what success you have!
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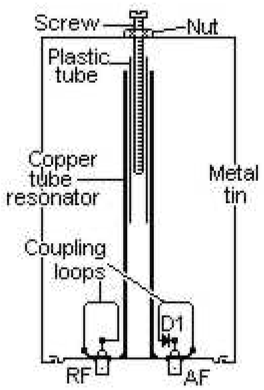
Alan Yates' 30m coherent autodyne receiver and his ancillary notes at:
http://www.vk2zay.net/article/154

That man of many and varied talents, Harry Lythall, SM0VPO, has some remarkably simple ideas and designs that really perform on his web pages. One which I've used very successfully is his VHF UHF resonator receiver, covering 6m to 23cms, which uses a copper pipe resonator as the selective tuned circuit. I've always hankered after using a BF199 transistor to apply some "regen" to this design; it should be reasonably easy to do (he sayeth, knowing that "in principle" is often very different than "in practice"!).

Harry's design is ideal as a local station monitor. He uses a Germanium diode detector; in the past I've used an OA81 type glass diode, but... and it's a BIG "but"... I took very great care in soldering the Ge diode - tricks I learned during Klystron / Wave Guide 16 days: I chilled the diode in a freezer overnight, attached "fine wire" croc clips to the 2mm diode leads, and a 200 Watt temperature controlled soldering iron completed the soldering as fast as humanly possible.

Another solution, which avoids soldering to the diode at all, was culled from Wave Guide 16 days, by using the brass innards of choc-bloc connectors (alluded to earlier in this edition of Hot Iron) to mechanically mount the diode *without* soldering the leads of the oh-so-delicate Ge diode. I'm sure the more adept among you will come up with some simple mechanical means to mount the diode and it's short leads far better than my meagre attempts!

You'll find this article in the "Projects" section of http://sm0vpo.altervista.org/ ; in the "Receivers" tab look for "Cavity Rx" in the left hand side list. Below is a diagram from Harry's web page showing the general assembly.



Power Supplies

The "Silent" Power Supply

When measuring very sensitive parameters of silicon devices, be they transistors, diode reverse leakage, mosfets, what-have-you, then noise picked up from nearby electricity distribution cables, atmospherics, signal generators, chattering thermostats, ADSL routers and the like can cause havoc - just listen to any frequency below 14 MHz and you'll see what electrical interference really is.

Noise signals are induced in ANY conductor - if it carries electricity, it will act as an antenna, that's simple physics truth. Problem is, silicon , being such a good material for building semiconductors with, when being leakage tested, you're looking at giga-ohms equivalent resistance in reverse diode junctions, gate isolation oxide insulation layers, and similar constructions. The merest sniff of induced noise RF in a device leads obliterates the tiny currents you're trying to measure!

This is solved in production environments by building seriously hefty Faraday cages: screened rooms, with very carefully designed lighting and ventilation inside which produce zero emitted noise. In my day these were powered by banks of NiFe cells, creating only pure noiseless DC; indeed, when trying lead acid truck and bus batteries for "clean" DC power you could detect tiny bubbles of hydrogen being forming on the plates with the electrometer instruments we used!

Zero noise means no relays, contacts or mechanical switches; every wire, cable, conductor must be screened - multiple layers of 100% cover screening, too - so some of the more critical test jigs were machined from solid copper blocks and plates, bolted to solid copper bench tops to ensure absolute grounding to the inner earth system inside the screened room.

But... the problem remains of how to get the devices (and operators!) in and out of the screened room, or, in the case of automated test equipment, how to design test equipment that creates zero electrical interference. Not easy when you're trying to test several million devices every week - which means auto loading and unloading into categorised bins, with minimal human intervention. The human body is a 220pF capacitor as far as static electricity is concerned, and a hefty 10kV (or more) discharge built up by friction causes very fast edges and consequent RF inside the screened room when spark discharged. If the operators wore conductive shoes, the discharge currents generated by overalls, lab coats and the like, moving about within the screened room, caused currents to be induced just where you don't want them. The control systems that ran the test equipment and external signalling to and from the outside of the screened room was done by air signals, the control pipes being copper alloy (car brake pipes) fed through via brass clamp gland fittings to air logic modules (yes, some industrial "digital" systems use air operated logic gates and flip flops!) so the integrity of the Faraday cage was not breached.

This meant the electrical supplies for the test gear and the test signals themselves had to be absolutely clean DC - large NiFe cells (700mm long, 450mm wide and 500mm deep) did the job nicely - we had spare NiFe cells charging outside the screened room, to be exchanged at shift change-over.

Which brings me to the whole point of this diatribe: the need for a "silent" DC power supply for your amateur radio experiments. Any of those who have built a "direct conversion" receiver will know exactly what I'm talking about, it's the dreaded "DC receiver HUM" oft quoted as being caused by local oscillator leakage getting into mains power supply rectifiers, but it can also be from a myriad of other places: earthing, earth loops, mains wiring pick up, and more other reasons than you can shake a stick at.

When I first faced this problem, that of a high gain audio amplifier, Stan (my mentor), simply dragged out a 12v NiFe battery and bade me “try it on this!” And lo, once connected, quoth Stan “I bet the HUM has gone, yes?” and so it was: dispatched to a place of beautiful silence, just the faint hiss of the audio amplifier (I’d scrounged some lovely low noise prototype ZTX951 transistors from the Application Lab, very low Rbb values). And, what’s more, it proved that my star point earthing was good, too: no sign of instability even with the gain flat out.

You can make a “silent” power supply for very little money, using the very good value sealed lead acid batteries beloved of burglar alarm designers. They are small, cheap, and very effective, and long lived if you use a careful designed charging circuit to make sure they aren’t over-charged. The nominal 12 volt cell has a maximum charging voltage of around 14.2 volts, so a bit of juggling boosting a 7812 regulator - or if you’re very posh, an LM317 - will do the job with bells on, and can be found in just about every burglar alarm panel you care to mention. Then a current limit circuit would be required, whilst it’s not dangerous to charge sealed lead acid batteries with fairly hefty current (but ALWAYS check the manufacturer’s data sheet). Of course, here at G6NGR such casual (and costly!) frippery is taboo: how can it be done with what’s to hand, the simplest possible way?

Answer: a 15 volt DC / 300mA “wall wart” power supply, a couple of 1N4007 diodes and a 47 ohm 5 watt resistor, that’s how. First I measured the open circuit output volts of the wall wart: 15.2 volts DC. Thus I reckoned a pair of 1N4007 in series with the output, assuming a forward drop of ~0.5v to 0.6v per diode, would reduce the output to something like 14.0 volts. That will do nicely, thank you!

A 47 ohm resistor in series would limit the current if a dead flat cell was connected: you’ll never get less than 10.5 volts or so from a discharged (but still viable) sealed lead acid gel cell, so the current maximum would limited to approximately 3.5 volts across 47 ohms = 74mA. Again, that will do nicely. I intend to leave the silent supply charging whenever it’s not in use, so I measured the current at 70mA (dead flat) to 12mA (full charged). Easily within the cell’s ratings and data sheet figures.

As with all lead acid batteries I included a 2 amp fuse. Small these sealed lead acid cells might be, but a short circuit across one of these little blighters will run many tens of amps! ALWAYS include a fuse, as close to the “hot” terminal as you can: that way any shorts or chafed wires won’t do any destructive damage.

How does it perform? Superbly! It’s very portable, small, safe and can be used to verify wiring and design of a direct conversion receiver, or a general purpose “bench” power supply. Sure, a good quality 12v bench power supply would be better; but you seen the price of a quality, lab standard power supply recently? I case my rest, M’Lud!

The “Economy” Valve Power Supply

For our hot cathode brethren out there, the power supply is usually an expensive bit: that big lump of iron and copper that makes boat anchors boat anchors, is the problem, so any means of reducing this item in size, cost, bulk, weight, is to be appreciated.

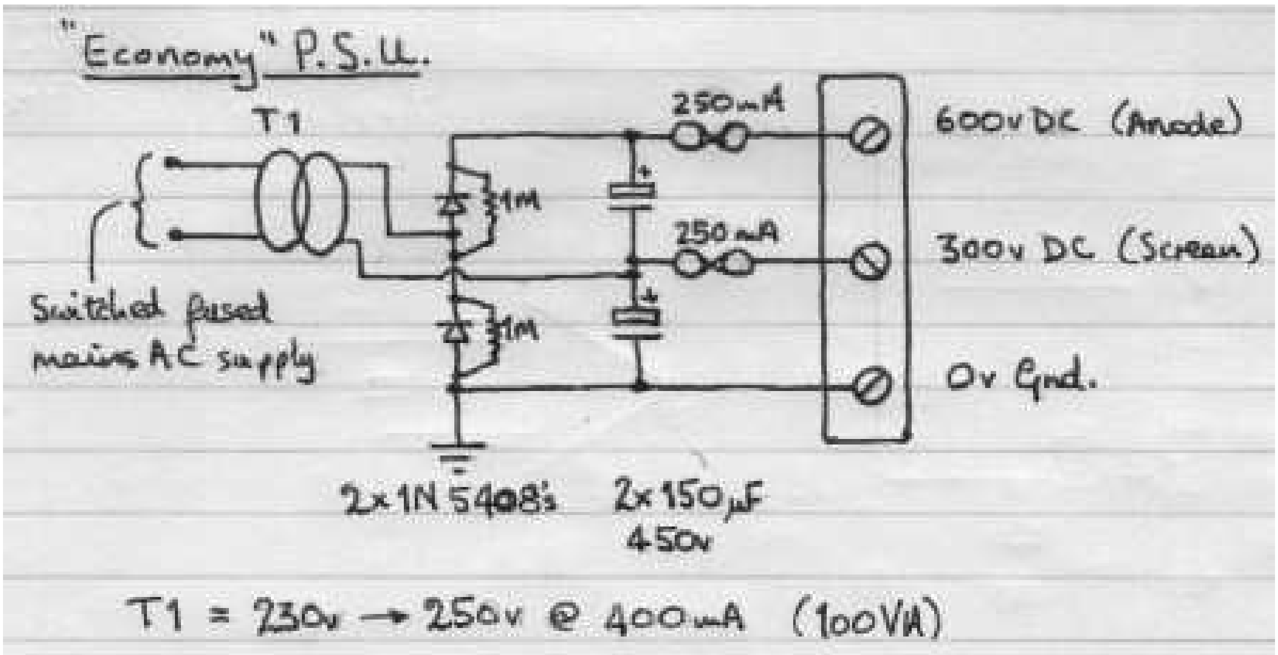
The simplest - and kindest to the transformer - is a full wave voltage doubler circuit; but because that features a single high voltage output, and you need a screen grid supply of roughly half the B+ positive rail. It's tantamount to a criminal offence nowadays to use whopping screen "dropper" resistors to chuck away those unwanted watts (even though they kept your tin mug of tea hot on top of the PSU).

Some simple circuitry comes to the rescue: a power supply that delivers both the screen and anode supplies from one transformer, runs on both half cycles so no DC currents in your transformer, and is cheap, simple and easy. I included 230v AC neon indicators on primary and secondary for safety, and I prefer LED indicators on the (separate) transmitter so I know immediately the PSU and the link cable are in good order.

I prefer 1N5408 1kV P.I.V. diodes rather than the ubiquitous 1N4007's because the much higher surge current capability of the 3 amp 1N5408's is valuable in capacitor input smoothing circuits like this. The 1 Meg-ohm diode balancing resistors also act as bleed resistors for the smoothing capacitors, via the transformer secondary.

I know it's a "golden oldie" standard circuit, but in these silicon daze (yes, "daze") of wonder microcontrollers and the like, these simple techniques are sometimes lost - especially for those who think 24v DC is "high voltage"!

Below is the schematic of the HV DC section; the filaments are fed from a separate 6.3v AC, 8 amp transformer powered from the primary side of T1, the HV transformer.



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Antenna Topics

In Hot Iron 108 I mentioned Peter Parker's, VK3YE, experiments with active antennas of the "E Field" probe type, and how he found that with the probe very close to the dround he found much better reception S/N. This prompted me to do some in-depth research on this - and related - topics; and lo! Antenna "gold" was discovered.

At: http://www.kk5jy.net/LoG/?fbclid=IwAR0dDk21M6XqZg7IwQ5NE7ggmS5Ux6Ivc_-_gtSZpE9Qbeu4EB9h5T4NGyU I found, that on the low bands, this "ground effect" as illustrated by Peter Parker, VK3YE, is real: a lossy Rx antenna can improve signal to noise! I'll not go into too much detail here, best to see the web pages at KK5JY; but this again reflects the practical findings our erstwhile radio operators 100 years ago took great advantage of - that lower frequencies do, by diffraction, follow the curvature of the earth and will be found close to the surface of the globe at great distances. That is why wavelengths shorter than 200 metres *in toto* were given to amateurs: they were considered useless for any long distance communication as the ionosphere was unknown to those early pioneers.

The gist of all this I suppose is that experiments that are, in "theory", pointless, aren't always necessarily so: in true amateur terms, "give 'er a bash and see what happens".

OK, so it didn't work out that time; but keep the "suck it and see" mindset and keep trying. There is more often than not "gold" at the end of the experimenter's "rainbow"; the hard bit is finding the exact "end" and sometimes the search for the rainbow's end in our offbeat experiments will lead to a very different (and remarkable) results than you expected!

And don't throw away the notes you made (you *do* make notes, don't you....?) on the way. Odds on next week / month / year you'll run into something that is distinctly similar and wish you'd kept better records!

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Active Rx antenna

Chas. Wenzel's active Rx antenna is similar in principle to PA0RDT's design, the "Mini Whip". I don't know which came first: Chas.' design or PA0RDT's? I liked Chas. Wenzel's design as I had the components to hand, and it suited my purposes - I wanted to extend or retract a telescopic antenna as an active RF gain control and besides, I had a neat and very robust 1.2m long telescopic antenna I could use. The Mini Whip uses a tiny square of pcb material as the E-Field probe; I wanted a bit more control of the size of the "probe" to control the signal induced at the input to the jfet impedance transforming stage.

I used a coil from a 6v relay of about 120R for the power supply feed choke, some commonly available ("Bartol" in the UK) plastic pipe fittings, and TV co-ax downlead. Perfect! You can see Chas. Wenzel's antenna designs - and they are a veritable treasure trove - at:

http://www.techlib.com/electronics/antennas.html

The active Rx antenna I built is below:
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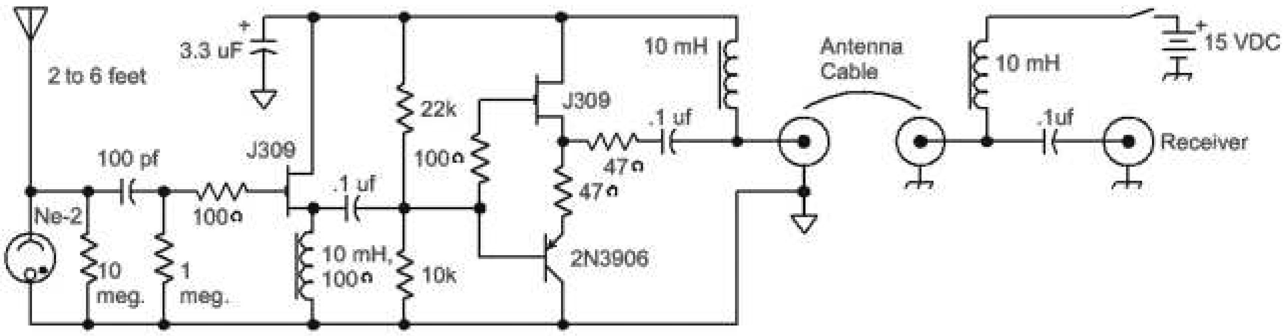

Figure 8: Improved Antenna Buffer.

Note the use of a neon for voltage clamping and a 10 Meg static bleed, and the jfet / PNP emitter follower "totem pole" buffer. Build it tight over a ground plane for operation above 100MHz; I had some 2N4957's (Ft = 1600MHz) which I used instead of the 2N3906 as I want marine VHF channels received, and I increased the supply voltage to 24 volts. The 10mH choke in the J309 source **must** have DC resistance 100 ohms or more to limit the J309's current safely. Add resistors in series to increase if required.

For the LF and MW / Top Band enthusiasts, Chas. also describes a tapped Rx antenna loading coil: a very good idea from a hundred or more years ago, and a proven improvement for Rx antennas on longer wavelengths, where you've no space for a decent length of wire. He shows a simple rotary switch inductor which can be a real space saver; two of these in series with 10 off 220µH chokes on one and 10 off 470µH on the other will cover down to 100kHz with reasonable antennas.

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Stripline SWR thoughts...

You may have come across the "stripline" SWR measuring method, which can be implemented very easily using a scrap of FR4 double sided pcb material, or a short(ish) length of "low loss" air-spaced TV downlead - you can push lengths of fine wire through the "air holes" in the dielectric to create the "forward" reflected lines, and avoid disturbing the braid covering. This reminded me of another very simple method of making "stripline" SWR meters: perforated copper strip prototyping board (Veroboard, other makers are available). Fine for HF and low VHF, and if some plain copper wire salvaged from mains "T&E" cable earth conductors is straightened by gently stretching it, one end held in a vice, the other gripped with pliers, is cut carefully so as to sit on top of the copper tracks and solder (sparingly!) run into the joint to secure the copper wire to the track, significant power can be successfully passed through the construction. You'll need some "slug and snail repellent" self adhesive copper tape from your local garden centre to make the underside earth plane, and a couple of coax line connectors of your choice to finish the job off.

A full reference to the stripline swr system can be found in an excellent article by John Langsford, VK5AJL at http://vk5ajl.com/projects/swrmeter.php where you'll find all the information you need and a very good (simple!) explanation of what swr really means.

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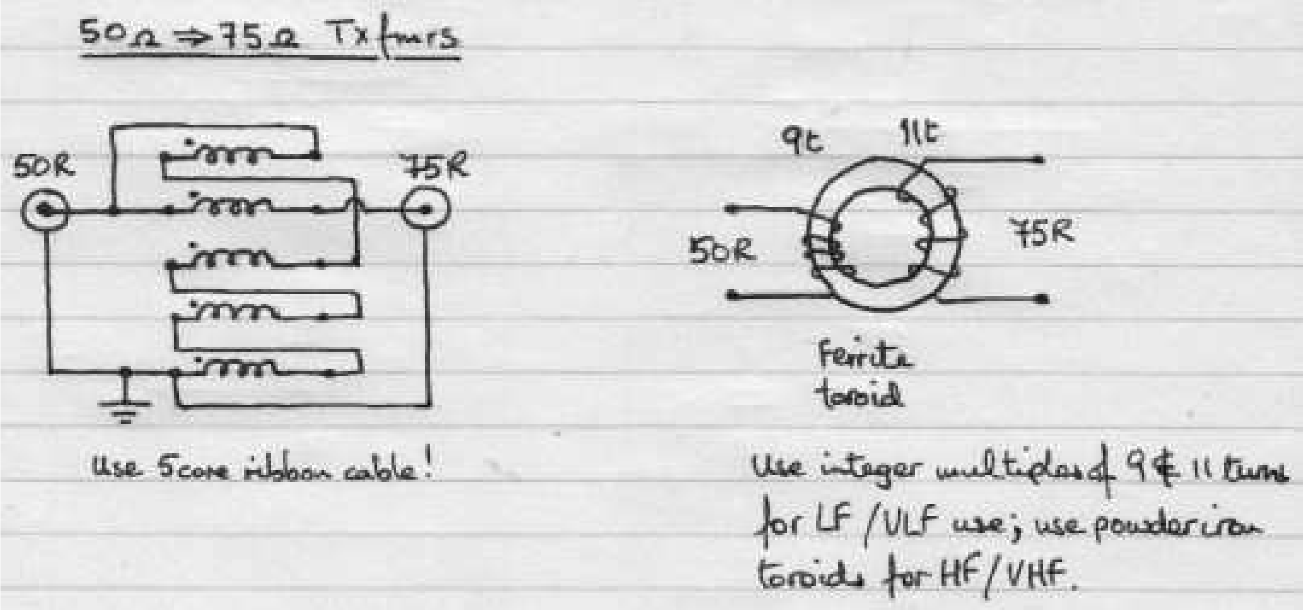
TV aerial downlead co-ax - it's cheap and effective!
But.. "it's 75 ohm isn't it?" Yes it is; and for those constructors amongst us who can add or remove a turn or two from the P.A. output link coil (or what-have-you) it's wonderful stuff. For those of you afflicted with the strictures of 50 ohm, "like it or lump it" equipment, then likely you'd find the diagrams below useful; they're low loss if built carefully, bi-directional (i.e. 50 to 75 ohm one road, 75 - 50 ohm, t'other road round) and can handle all the power you'll ever need as an amateur if you use a big enough core.

For the "balun" approach, 5 way mini-ribbon cable can be used, and it's good for HF / VHF without fuss with a few turns through a suitable toroid core; for the "isolating" transformer use integer multiples of 9 and 11 windings for low HF / MW / LF / VLF, and use a powder iron core for high HF / low VHF. The ratio of 9 to 11 gives impedances of 50 to 74.42 ohms one way round, or the other way round, 75 ohms to 51.7 ohms. Near enough in practice, and very easy to construct.

I use salvaged ferrite toroids from PC power supplies for isolated type transformers on 80m, 60m and 40m; if it proves a bit lossy I grab another off the pile and try that.


50Ω ⇒ 75Ω Txfmrs
50R
75R
Use 5core ribbon cable!
9t
11t
50R
75R
Ferrite
toroid
Use integer multiples of 9 & 11 turns for LF / VLF use; use powder iron toroids for HF / VHF.

HOT IRON issue 110

End November / start December 2020

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CQ-CQ-CQ

From Lachlan...

Hi!Thank you,an excellent read! Could I ask if you have any suggestions on "combining" two articles...soldering stainless steel and 75 ohm co-ax. I use RG-6 a lot,a nice cheap relatively low loss co-ax.,75 ohm, no problem, but it would be nice to be able to solder the multi outside braids. I have soldered normal Al quite well, using some clean engine oil,carefully scraping the oxide layer away under the oil,and using a large hot iron and rosin core solder. Years ago I replaced one of the relays in my first car, a soft top Morris Minor,with a stud diode on a piece of Al, and soldered to the aluminium... but that method does not seem suitable for the thin braid/foil on co-ax. Any suggestions? Thank you again for adding me,and taking the time to reply. You are a true gentleman! Cheers Lach VK3ALM

OK, Lachlan: no worries, check these references out:

https://www.harrisproductsgroup.com/en/Products/Alloys/Soldering/Fluxes/Stay-Clean-Aluminum-Flux.aspx

https://soldersandfluxes.co.uk/p586/Aluflux-Aluminium-Flux.html

This product has is listed as good for soldering co-ax aluminium foil...

https://www.amazon.com/Uniweld-P4KD9S-Aluminum-Solder-Applicator/dp/B010UMSB9Y/ref=sr_1_2?dchild=1&keywords=Aluminum+Soldering+Flux&qid=1603457772&sr=8-2#descriptionAndDetails

OFCOM and EMR proposed power limits

OFCOM are moving in their mysterious way with amateur radio - as well as marine radio users, PMR taxi operators and countless others who use RF in their everyday life: they are apparently worried about exposure to RF causing illness, presumably through RF heating, rather than ionising effects you'd see with X-Rays and the shorter wavelengths.

My father (rest his soul) warned me that the most frightening words a person at your door can say are: "I'm from the Government, and I've come to help you..." and he's been proved right time and time again.

The details are here: https://www.ofcom.org.uk/consultations-and-statements/category-1/limiting-exposure-to-emf . The penalties for disobeying this are 51 weeks imprisonment, unlimited fines (England & Wales); 6 months prison (Scotland) [*At the time of writing; but things could change.*]

As amateurs we have always been naturally careful about exposure to RF radiation; warnings issued in my apprentice days about not looking into waveguides for fear of damaging eyes, or approaching too close to RF transmission lines to prevent RF arcs causing deep burns. The first inkling I recall about RF radiation being a health hazard was Pat Hawker's (G3VA) note many years ago about mobile phones running a watt or so of UHF right next to the operator's head and eyes; history has proved that mobile phones, or should I say the RF emanating from them - is more or less benign.

Well, to sum up, ALL UK amateurs of every license class will be required to work out the hazard potential, an OFCOM spreadsheet is available for this purpose.

My advice is "Keep Calm and Carry On". Once the paperwork and associated bumff is completed, as per OFCOM requirements, we can get on with amateur radio as we know it.

Oh Dear...

For some reason, Andrew Woodfield's email address is corrupted in my files. If anybody knows Andrew please ask him to email me at equieng@gmail.com and I'll correct the problem.

Tim's Topics

Transistors and the fakers

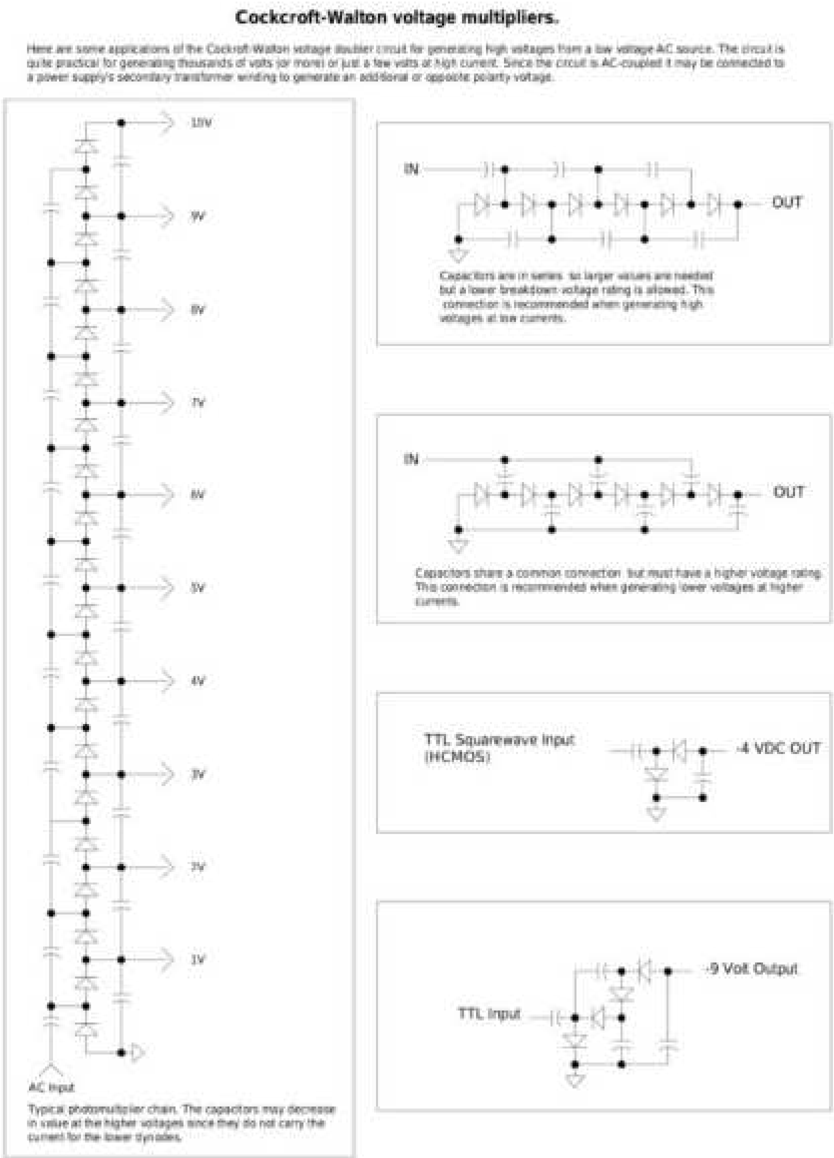
Tim asked me recently about fake transistors, knowing I've been involved with semiconductor production most of my working life. The faking Fakirs manufacture transistors that are not as marked, using much inferior - but still functioning and the right polarity - dies packaged up as exotic and expensive devices. For the average amateur, a quick multimeter test will show a working device, but put into service, sorry chum, no can do!

Testing discrete transistors as the genuine manufacturer does requires some hefty test gear; not the sort of thing that an amateur would have readily to hand. I'm thinking of capacitance bridges that can resolve fractions of a pF, electrometer leakage tests to Femto amps, signal generators for Ft test to GHz, that sort of thing. But - as amateurs, can we can cobble something together that will find the fakes?

The simplest approach I think is that fakes are (almost) always smaller, cheap dies, to maximise the faker's profit. Smaller dies = lower power dissipation capability, so a simple high dissipation circuit (i.e. regulator "wrap around"service) will find the fakes by over heating small dies to the maximum junction temperature, usually 150°C. This will work fine with bipolar transistors and power mosfets; though for mosfets you'll have to increase the sense resistor in a wrap around circuit to get enough gate bias. A positive regulator "wrap around" will dissipation test PNP's directly; a negative regulator will test NPN's.

Step up the device dissipation in easy stages; the die inside will heat up faster than the case - especially in fakes, where they rarely (if ever) fit the proper heat spreader pads under the die. The device will most likely go "phutt" at a far lower dissipation than the spec., when the die melts or the bond wires burn open.

Another give-away is the Vceo / Vds breakdown tolerance: the smaller, cheaper dies and the uncontrolled home-brew manufacturing process reduces the breakdown voltage, collector to emitter, drain to source. To test breakdown voltage you need a low current, high voltage power supply: a half wave voltage quadrupler and a simple variable voltage control will do nicely. The available current from the HV power supply only needs to be a few µA; more in this case is definitely not better, it's just volts you need for this job. The following image is from Chas. Wenzel's Tech Lib superb web pages, take your pick to suit your test voltage required. I often used the photomultiplier chain, shown delivering 10x Vin, when building leakage Test Gear for bipolar transistors, as you can use lower voltage capacitors in each stage..



IC's pose an altogether different problem; no simple "Kwik-Sorta" test will root out the rogues. Some good approaches can be found at: https://www.allaboutcircuits.com/news/how-to-spot-counterfeit-electronic-components/ . This topic is *vast*; manufacturers spend large amounts of money devising sure fire test techniques to identify fraudulent copies of their chips.

One technique is to build in functional but redundant bits of circuitry, that go unnoticed in the reverse engineering Fakir's labs ripping off IC's, or an extra via (link from one layer to another in a multi-layer IC chip) that had no function but could be sensed if the right data words appear at appropriate timing on the data, control and address lines. I used a simpler technique in some of my circuits - I would make a placement on the pcb for a 1N4148 diode, that had no function whatsoever as it would always be back biased (usually on the output of a gate or op-amp to a rail). The counterfeiters would slavishly copy the diode, thinking it must have a purpose - so if this diode was fitted in warranty claims we knew we had a counterfeit board. Gotcha!

Some references that might help you:

https://www.eevblog.com/forum/beginners/fake-transistors/

https://www.eevblog.com/forum/repair/warning-fake-mj16012-transistors-on-ebay/

OnSemi technical article about breakdown voltage, etc.
https://www.onsemi.com/pub/Collateral/AN1628-D.PDF

Transmitter Topics

Screening - why it works

Transmitters have to have screened compartments, to keep “near” electromagnetic fields from affecting the more sensitive parts - like oscillators, VFO’s, Synthesizers, DDS’s and PLL’s. Screening - how does a screen work? Well... the magnum opus is https://w8ji.com/skindepth.htm where skin effect is found to be the prime mover (or stopper, in this case).

Of course, here at G6NGR, our old friends still do valiant service: heavy kitchen scissors and steel (baked bean) cans make wonderful screening, custom built and soldered in at almost zero cost. Another approach, especially useful for valve / tube circuits is to use individual boxes (conduit “adaptable” boxes?) for each stage with the power wiring for the stages going to common star points to eliminate earth (and power!) loops. You also have the opportunity to improve a stage without losing your existing design - build the new stage up in it’s box and it’s a one-for-one swap out job.

The Michigan MONSTER Mite?

From John Kirk, VK4TJ: “*Incidentally, If you'd like to experience the thrill of crystal cracking without the pain, switcher FET’s show great promise. I cobbled together a 25 watt 1-FET transmitter around an MTP3055E and an HC-18/U colour burst crystal. The FET eventually expired of unnatural causes, but that little crystal is still singing up a storm*.”

I have always had a fascination for simple one transistor transmitters: arguably the best of the bunch is the Michigan Mighty Mite. I’ve amplitude modulated one and it was pure fun! Made a very good test signal source too, mounted inside a screening box driving an external lamp load, for receiver testing.

If you can blow up a switcher FET in such circuits, without cracking the crystal, your circuit’s a good ‘un, but as often as not that tiny sliver of quartz - especially in bipolar designs - will go pop.

So, adopt John's other plan: get a good few of them, connected in series / parallel, up the supply volts and blast away!

I must admit I've a mind to try a power mosfet Michigan MONSTER Mite on a valve HT supply (with bypassed resistor biasing in the source to set the DC drain current) as modern power mosfets are as near a solid state pentode as you'll get.

Receiver Topics

Direct Conversion

An excellent discussion about simple direct conversion receivers can be found here: https://www.raynetrepair.us/circuit-design/some-practical-design-approaches.html

In which you'll find some wonderfully explained fundamentals about the structure of direct conversion receivers, and some useful notes about "diplexers" (sometimes known as "DC to Daylight" bandwidth circuits). I personally hanker after a 50 ohm resistor feeding a virtual earth amplifier input, but that's just me and my curmudgeon.

A complete radio receiver on a chip

See: https://www.silabs.com/audio-and-radio/multiband-radios from Silicon Labs. I'm not going to describe much here about this little chip, having played with ZN414's all those years ago and one transistor super-regenerative broadcast VHF receivers, but I do appreciate how powerful the silicon digital designer's art has become. The sheer fact that all the signal processing can be done digitally, with ne'er an IF transformer in sight, I find nigh on miraculous.

It won't be long before a chip appears in a big square ceramic package with umpteen solder bumps below that is a complete top performing HF / VHF receiver - with a matching transmitter section needing only a power amplifier adding for a complete QRO transceiver. If such a chip can be done for $100.00 apiece then I reckon the (radio) World will beat a path to the manufacturer's door!

The Ultimate receiver

A book called "Surviving Technology" might seem somewhat incongruous in this "systems on silicon" era; but there is much the constructor can learn from Bruce Vaughan's (NR5Q) book of that title.

Whilst the bulk of the book contains tales from Bruce's experiences over the years, and how he learned to repair radio sets that had been struck by lightning (!!), he gives the diagrams for his "Ultimate Regen" design. Nothing spectacular; but, like most things in this life, "it's not what you do, it's the way that you do it". He describes a design - a word that syntactically embodies construction - that has evolved over more than 60 builds of the original circuit to include all the improvements that put his regen receiver in a class of it's own: one that can give superb results up to and including 15m operation - and for a simple but well built valve regen that's some going.

Superb results from a simple regen design indeed: most home built regens, because they haven't evolved over this number of iterations, can't hope to compete with commercial black boxes on today’s bands, but Bruce has stuck to his circuit over the years and the overall design has been developed so that every component’s position, mounting and orientation has been tried, tested and adopted or discarded. The result is a sweet, capable and elegant design that is so simple and economical it’s within the reach of even the most thrifty amateur (and that sums up G6NGR quite nicely).

For instance, the mounting of the detector valve in a shock absorbing sub-chassis gave a major improvement, the antenna coil coupling to the detector tuned circuit is a simple mechanical variometer that gives superb control of the input signal thus avoiding the regen’s curse: overload blocking. A practical demonstration of mutual inductance.

Bruce followed the effective expedient of separating the audio output stages, where large signal volts and mechanical / acoustic vibration exist that wreaks havoc with sensitive detector stages, by fitting the 6V6 output pentode (for a fair ‘switch hitter’, try the more available B9a EL84) inside the PSU module and linking the sensitive RF chassis to the PSU / audio chassis with an umbilical cable. This keeps the “hefty” PSU and audio power section well away from the “sensitive” RF section.

Cost? A few $$’s for some screw terminals and a some PVC wire to run power and screened cable for the low level audio. If you really want to push the receiver’s boat out, there is an easy option to slot in a “Select-O-Ject” circuit giving a receiver bandwidth of a few tens of Hz or to “notch out” nearby interfering signals.

Bruce’s years in a radio shop showed him how manufacturers got superior performance with minimal - but ingenious - design, something all constructors should keep to mind; the technique of “Muntzing” is very applicable. “Radio construction can be divided into three parts: mechanical construction, circuit design and wiring, and the cosmetics of the finished radio” and in that order, too. Heavy and solid RF sections, vibration mounting of detector valves, sensible component placement with well thought out wiring harnesses all mounted in a properly finished straight, square, ergonomic layout that graces the quality of the design and build are just as important as the electronic wizardry within.

As Bruce comments: “*a well constructed regenerative receiver can receive almost any signal you can receive on your $2,000 solid state rig*”. And that’s why I like building them!

Bruce’s book, “Surviving Technology” is published by Farmhouse Books, and I strongly recommend you buy yourself a copy or borrow one from your local library. The circuit schematics, chassis layouts and coil details can be copied with pencil and paper in minutes, they are that simple; but the real knowledge that makes the “Ultimate” receiver are in Bruce’s words.

A note from Harry Lythall, SM0VPO

I asked that amazing gentleman, Harry Lythall, about using his “pipe” resonators as a basic regenerative receiver, the idea being to open up 23cms band for simple A.M. / C.W. using cheap and easily available parts. The transmitter could be a simple 48MHz crystal oscillator and a diode multiplier (a-la a 23cms test signal source) feeding the resonator for basic spectral purity - just about acceptable if the power is under a µW or two - and feeding a decent home made Yagi this would give some interesting "pre-booked" contacts from a local high point.

Below is Harry's reply:

"Hello Peter,
I have been thinking about your request "how about fitting a BF199 to your tin can resonator Rx for a regen... or dare I suggest a super-regen... for 23 cms?" and I have a suggestion.
I created a simple resonator that has the same properties as a cavity. This I used to make an oscillator in the article: http://sm0vpo.altervista.org/use/resonator_1.htm .

It would not take much "fiddling" to build the oscillator inside a cavity, then reduce the supply voltage to the point of oscillation. The output loop can be connected to ground by a feedthrough capacitor so you can stuff some power into the oscillator. With this arrangement it should be possible to make a regenerative receiver, or a self-oscillating mixer/down-converter. The TDA7000 will make a good NBFM receiver by changing capacitors. AN193 (http://www.electroscheme.ru/datasheet/TDA/TDA7000%20for%20narrowband%20fm-recieving.pdf) has been written specifically for the TDA7000 and NBFM operation.

A little caveat would be the possibility of unwanted radiation from the input port.

Unfortunately I do not have the time to work on this, but this could be an idea for further experimenting?

Very best regards from Harry Lythall - SM0VPO"

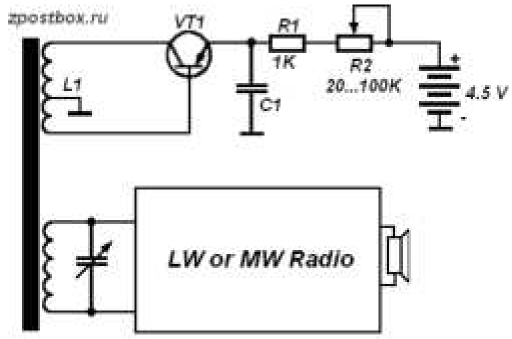
Unfortunately, neither do I have any time or construction opportunities, I'm moving house soon (hopefully....) so I pass it on to Hot Iron readers for experimentation. Please let me know if you build one!

The simplest Q multiplier?

This is a design from Viktor Polyakov (if not Viktor, please let me know!) that shows how minimal a Q Multiplier can be; and how simply it can be added to a tuned circuit to peak up the "Q".

What struck me was that the Q multiplier doesn't have to be employed (as it usually is, in simple regenerative receivers) in the detector stage; it will work wonders in any of the signal path tuned circuits, from the pre-selector , RF amp input or RF amp output tank. All that's needed is to link couple the Q Multiplier coil to the signal path tuned circuit - a single turn link at either end will probably suffice for 40m and above; below that you'll probably need more turns at either end of the link, at a guess 3 turns for 60m, 5 turns for 80m and 10 turns for 160m.

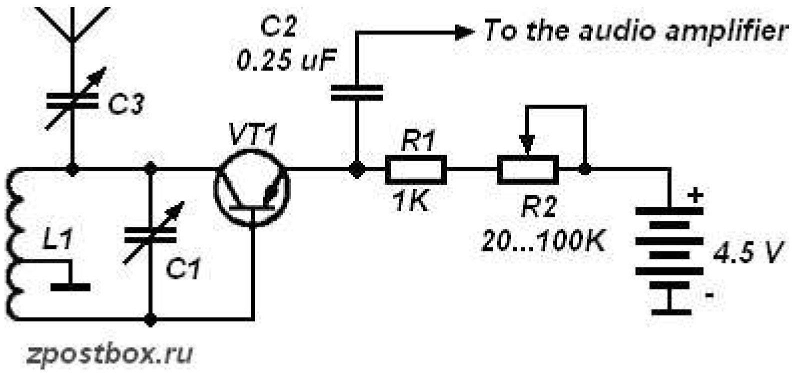
The tap on L1 is ~ 10% up from the base connection, and you'll need to cut and try the turns on L1 for coupling to an outboard tank. For Q multiplier service, remove C1. The audio appears across R1 (substitute your Hi-Z phones for R, or try a miniature audio transformer, 2k to 8 ohms.)



Viktor notes:

"*This regenerative circuit can increase the quality factor Q in any frequency range, from Long Waves (LW) to Very High Waves (VHF). It is not necessary for the coil L1 to be a resonant tank - it can be used as a coupling coil* [or try an old fashioned valve 'coupling link' or even close proximity to the antenna lead? Or a perhaps a toroid with the antenna wire running through it? Ed.], *it will provide coupling with any other resonant tank (in this case remove the capacitor C1 from the circuit). This coil can be wound on a ferrite rod of a magnetic loop antenna of any LW or MW radio, the number of turns needs to be only 10...20% of number of turns of the magnetic loop antenna. So we get a Q-multiplier for any LW or MW radio, this Q-multiplier circuit, based on a bipolar transistor is much simpler than any other Q-multiplier ... based on a FET transistor."*

Viktor shows how the circuit adapts to become a regenerative receiver:



"*A regenerative receiver suitable for short wave reception, it takes an antenna, connected to the resonant tank L1C1 through a coupling coil or through a capacitor with small value (less than 1 pF)* [or toroid link coupling / antenna lead in close proximity? Ed.] . *An audio signal can be taken from the emitter of the transistor VT1 and applied to an audio amplifier using a capacitor of 0.1...0.5 µF. Sensitivity of this regenerative receiver is high enough - for AM radio stations it is 10...30 µV (adjust the feedback just below the point of oscillation), for SSB, CW radio stations some µV (adjust the feedback above the point of oscillation).*"

This is surely the dinkiest regenerative receiver! A 2N3906 with careful construction and supply decoupling this would make a neat "/ P" or "/ M" receiver?

Audio Topics

A simple question that's rarely answered

This item could well be part of Antenna Topics, as I've been investigating "active" antennas recently and the amplifier requirement for which are either of high input impedance for the "E" field, or low input impedance for "Mag" loops. J-fets or mosfets (both discrete and op-amp type) cope admirably with the high impedance side of the job; common base connection bipolar transistor amplifiers, including noise cancelling types, or "virtual earth" op-amps, deliver the low input impedance loop antenna amplifiers demand.

The question here is how to estimate the AC signal input impedance of an amplifier, be it common emitter or common base - and this is the connection with audio topics, as many amateur audio amplifiers don't perform properly when the input impedance of a stage isn't taken properly into account.

Many web pages and text books I've seen over the years fudge this calculation; or gloss over it by implying the DC bias resistors form a parallel loading, and completely ignore the base - emitter shunt path the AC input signal takes for the stage to work. The concept is the dynamic base region resistance ("r_e"); this is the slope of the base emitter diode forward bias curve, and is an easy value to estimate if you have a few basic facts to hand.

If you imagine an AC signal (AF or RF) flowing into the base terminal lead and out the emitter lead, the internal base resistance ("r_e") boils down in practical terms to a simple approximation: it's β (the transistor's current gain at that particular collector current) multiplied by 26 then divided by the emitter current in mA's - this equals "r_e" in ohms. There is an argument that β x 25 is a more accurate estimate, but since β is given plus or minus a country mile, I'm not too fussed either way, and β is different for varying emitter currents anyway. The point is that you put this value of "r_e" in parallel with the base bias chain to get an idea of the loading the previous stage has to drive (common emitter connection) or in parallel with the emitter resistor (common base connection).

Thus estimating the actual AC input impedance allows us to build amplifiers with an input termination of 50 or 75 ohms - give or take - or really low impedances for loop antennas and similar jobs.

An excellent reference describing this far better than I can is at:

https://www.electronics-tutorials.ws/amplifier/input-impedance-of-an-amplifier.html

...which shows clearly and simply how these calculations can be done to get a circuit running to expected specifications.

Power Supply Topics

Adaptable boxes for all?

Conduit "adaptable boxes" are the power supply builder's friend: good weight steel, easy knock-outs that eliminate a lot of drilling (and take a B9a valve base nicely), galvanised or black finished, they are absolutely ideal for the job - and at a price which makes diecast box manufacturers weep. I've used hundreds of adaptable boxes over the years, with good result, the steel is a superb electromagnetic screen. They are commonly available at most electrical trade suppliers, DIY outlets and other similar suppliers.

A simple but very effective piece of advice came to my attention recently about low noise linear power supplies and earthing. It commented about where the earth stud should be placed for best performance - and considering how we as amateurs try to keep RF out of where it shouldn't be and maximise it where it should be, it was an interesting read. Now I know why those superb linear power supplies by our beloved manufacturers like HP, Advance, and the like, have those complicated earthing arrangements, internal screening and solidly clamped wiring looms!

No doubt you'll be aware of "skin effect" where RF currents travel on the outer skin of a conductor, and - by the magic of RF - stay there, even on a good conductor like copper. The proposal was that the station RF "earth" should be connected to a stud, connected electrically only to the **outer** of the power supply case, or a tag connecting on the outside by scraping the paint off and using a (power transistor) stepped insulating washer to stop the retaining bolt contacting the **inner** of the power supply case - see https://www.youtube.com/watch?v=SvSP3kQQYMg; from https://www.pa0nhc.nl/cobra80/index.htm .

The transformer inside the case should be similarly fixed; the core and winding screen should be earthed **only** to the mains earth OUTSIDE the metal box, **NOT** to the inner of the power supply, as a "screen" winding or capacitance primary to secondary will reverse couple noise from the mains earth. Similarly, the output terminals should be well isolated from the case. Fitting "delta" 0.1µF capacitors, plus to minus, plus to earth and minus to earth, usually a good idea, and should be done with similar due diligence: only earthing to the **outer** of the power supply case. Thus we keep our RF earth **inside** the enclosure clean and clear of all the noise and rubbish on the mains earth **outside** the power supply enclosure.

Your "shack" RF earth should be based on a hefty earth spike walloped deep into the ground near your antenna feed point, and connected to your shack RF earth buss with some hefty copper cable (16mm² welding cable from welding consumables is a good idea).

It's good practice for safety to have your local "sparky" test the earth loop impedance of the antenna ground spike to the incoming TNC-S / P.E.N. earth bar at your electricity meter (temporarily disconnect the spike from ANY gear in your shack). You should be able to achieve a loop impedance of a few ohms or less, but it does depend on your local ground conditions and moisture levels. It's not unknown for some "salty liquid" (ahemm...) to be applied to ground spikes to get a low impedance reading once it's soaked in a bit.

The earth spike is the cleanest earth you'll have; not perfect though as the mains distribution system does run earth currents back to the star point in your local supply sub-station, but usually far better than the mains earth in your house.

Transformers - take two...

I recently made a comment about an "unknown" transformer, in this case a hefty 6.3v AC filament transformer that had an unknown or ambiguous reference number on it, on how to assess the current it could comfortably drive. In Hot Iron 109 I mentioned a rule of thumb, "20VA per lb., or 45 VA per kg"; this gets you close to the rating, however if this transformer is a valuable or rare item, then a more engineered approach might be preferred.

The clue is - as almost always in basic physics - to be found in *heat*. Discuss with any physicist "The Laws of Thermodynamics" and you'll soon see what makes this Universe behave as it does, and gain a glimpse of the inner working of Quantum mechanics!

If the unknown transformer is set to driving a dummy load, be it lamps, resistors, tanks of acidified or salty water, or whatever else you can dream up to absorb some watts, with a temperature sensing element attached to the winding cover insulation (to get the quickest report of rising temperature) then you have all you need to find a reasonable estimate of working current. This is taken from:

https://www.electrical4u.com/transformer-oil-and-winding-temperature-rise-test/

and:

https://www.ecmweb.com/content/article/20885885/the-basics-of-transformers-part-2

which refer to windings withstanding a 55°C rise over ambient - which, from experience, is not an untypical figure. DC testing is another option on power transformer windings; you could probably adapt the scheme to smaller transformers, as per:

https://www.hightest.co.uk/temperature-rise-heat-run-test/

...the general idea being to run DC amps through a winding, and note the consequent temperature rise; but this of course identifies just the winding under test's heat contribution, not the whole gallimaufry. This might be just what you're looking for; I don't know. Who am I to say?

Transformers - take three...

ON NO ACCOUNT USE WHAT FOLLOWS ON ANY VOLTAGE ABOVE 50 VOLTS AC. SERIOUSLY, DON'T DO IT! USE THIS FOR LOW VOLTAGE AC ONLY AND ALWAYS USE A "DULL LAMP" TO LIMIT THE CURRENT FROM THE MAINS WHEN TESTING HOME ADAPTED TRANSFORMERS.

Sometimes, it really helps if you know the "turns per volt" of the secondary winding of a transformer. Maybe you've a 4.5 volt transformer you'd like to use for the 6.3 volt heaters of a valve Rx, and don't know how to get those extra few volts... 4.5 volts just doesn't cut it for you.*

(*see the end of this article for more on this subject).

What can sometimes be done is squeeze some extra windings through the core apertures and connected in series with the existing secondary, to get your desired 6.3 volts. That's if you've guessed the "phasing" right: if you connect your added winding the wrong way round it will reduce the total volts out! Reversing your extra coil's connections resolves this. Known in the trade as "bucking" or "boosting" this is a good way to get the volts you want without the expense of a custom transformer.

The question is, though - how many turns will you need, to get that extra 1.8 volts from your under volt tranny? Well, here's a handy rule of thumb.

Most transformers cores are made of alternate "E" and "I" laminations, stacked together alternately with the winding bobbin on the middle limb of the "E"s and it's the magnetic flux induced in this centre limb that does the transforming magic (thank you, Mr. Faraday). You need to measure this centre limb. If you're stuck and can't measure the centre limb any which way, don't panic: the outer limbs are usually about 60% of the larger centre limb, so measure them to estimate the cross sectional area of the centre limb, even though you can't get at it.

Now the hard bit: calculate the cross sectional area of the centre limb IN SQUARE INCHES. Suppose the centre limb is 3/4” by 7/8” then the cross sectional area (CSA) = 3/4” x 7/8” = 0.75” x 0.875” = 0.65625 square inches. OK, here’s the whizz-bang moment: **divide 9 by the CSA in square inches: this estimates the turns per volt of the transformer**. In our case it’s 9/0.65625 = 13.7143 turns / volt. We were 1.8 volts short at 4.5; so we need to add 1.8v x 13.7143turns /v = 24.6857 turns. Make that 25 turns and I bet you’ll be within spitting distance of 6.3 volts when your extra turns add to the existing 4.5 volt output. This will have professional transformer designers curling a lip; as it’s not the most efficient or accurate method - it works near enough.

Adding a few turns is a doddle with toroidal transformers, but watch you don’t draw too much extra juice and saturate the core. You’ll soon know; the transformer will get stonking hot rather quickly!

OK, so you can’t get any more turns through the core apertures? Another solution is possible. Have you a similar sized (equal or a touch bigger) burned out or otherwise scrap transformer to hand?

Strip off the existing windings, keeping the winding bobbin intact as best you can, and dismantle the “E” and “I” laminations. It’s a sticky job, but reasonably easy provided the whole thing’s not been drowned in varnish or pitch - but in dire emergencies, a hot oven will soften the varnish (but they don’t half smoke at 120°C!) or a carefully applied blowtorch will do the job. Don’t burn the winding bobbin, but, if times are really hard, and you can’t resurrect the bobbin, or you can’t strip the laminations, you can cover the core limbs with insulating tape and wind directly onto that, without a bobbin - but you’d have to be a masochist to do this as you’ll need to load up a shuttle with wire and pass it through the core windows without kinking or damaging the enamel coating - never easy and very time consuming.

Work out for your extra transformer the turns per volt as above - we’ll assume it’s about 25 turns / volt. Calculate how many turns you need for a 6.3 volt winding by multiplying the turns / volt by 6.3 = 157 (rounded up to 160 for good measure). Work out how many turns represent 4.5 volts similarly: 4.5 x 25 turns / volt = 112.5, round up to 115 for good measure.

Now with some enamelled copper wire of appropriate ampacity (use the wire tables in the Hot Iron Data section at www.W4NPN.net), solder a PVC insulated flying lead to the end of the copper wire which is to be the the start of the winding, then wind on 115 turns and tap the winding by looping up a bit of the enamelled copper wire, twisting it with pliers, and tinning and soldering another flying lead. Then continue the winding (in the same direction as before!) until you’ve 160 turns on, and solder a lead to the end. Tape up the windings to secure them, and re-stack the core. You should have three wires: start, tap and finish. Write down the start, tap & finish wire colours!

You’ve just made an **autotransformer.** Connect 4.5 volts AC from your original transformer to the start and tap wires. Test the voltage when powered up (via a dull lamp!) between the “start” and “finish” wires: it should be 6.3 volts (or most likely a bit more) if all’s well. You should have two wires connected to the “start” (one for the input 4.5 volts “cold” and one for the output 6.3 volts “cold”) and one wire to the “tap” (4.5 volt drive) and one to the “finish” (6.3 “hot” volts output). Check it on load to your heater / filament and I’ll bet it will be just fine. If needs be, if the voltage is too high, you can strip off a turn or two or use a dropper resistor - whatever is easiest for you. Job done!

SAFETY NOTE: always check that ALL windings are not shorting to the core or other windings before powering up. A 500 volt insulation tester is the minimum; a multimeter on "ohms" just isn't adequate!

* Running a regenerative detector valve on low filament volts can turn a *temperamental* Rx into a silky smooth delight. The valve, running at rated heater / filament volts will have full μ and Gm; running the heaters / filament a bit low can "soften" the gain and makes the regeneration control smoother and less sensitive. The onset of oscillation is sometimes accompanied by a hysteresis effect as the impedances around the circuit change with the loop gain approaching infinity; low heater / filament volts can help reduce this malady. No guarantees, mind, and don't reduce the cathode heat too much; running cathodes too cold can poison them.

Another good way to drop heater volts is to insert a pair of inverse parallel connected silicon diodes in the 6.3 volt AC heater line to the detector valve, with a shunt switch to short them out if needs be. The 0.6 volt drop in each diode will soften the detector valve's heaters only leaving full volts on the other valves in the circuit.

An e-Mail from Alan Gale, G4TMV...

Hi Peter,
Since the EU in its wisdom decided that all small power supplies should be of the Switched Mode variety to protect the environment (I'm not sure how polluting the airwaves with them achieves that aim), it's now almost impossible to buy the smaller clean 'wallwart' types, which are something that was always very useful in shacks, so something like a design for some of them might be useful.

I've always referred to my very old Babani book called 'Power Supply Projects' by good old R.A. Penfold, that was always a good source of 3 and 4 terminal regulator designs, but something along the lines of a 'Build your own clean Wallwart' might be something that would be useful to a lot of people. Hams are often far too concerned with big PSUs like the 20 or 30 Amp types for use with their transmitters, but it's still easy to get those, it's the smaller ones that are more of a problem.

No problem, Alan: here's how you design power supplies that are cheap, functional and effective - using junk transformers too, that will save bits of electronics going to land fill. You can buy empty wall wart cases or build in a separate enclosure - it's up to you. Ex-PC psu cases are useful too.

You have a choice between the "classic" approach and what I term the "modern".

The classic approach is to find a suitable 50/60Hz transformer with sufficient volts and amps to run the regulation circuit - regulators need headroom volts for them to perform properly. For instance, if I were to be designing a 13.5v DC supply, I'd be looking for a transformer of at least 15 volts RMS secondary; but no more than 20 volts, as too high a secondary voltage can lead to dissipation problems in the regulator. Then I'd look at the amps I wanted: for general bench work, an amp or two is adequate.

The LM317 is ideal for this job, so the transformer I'd need is 15v rms x 2 amps = 30VA rated. If we wanted more amps from a bench supply, a PNP "wrap-around" (as previously discussed in Hot Iron) can be used to drive almost any current you want - limited only by your transformer, rectifier, power transistor(s) and heatsinks.

Below is a diagram showing in blocks a reliable LM317 regulator circuit used in a "classic" power supply. I've not indicated any particular devices or construction; the design is very tolerant and will work with almost anything, providing the components can withstand the volts and amps.

Note the "slump" diode (D1 below) around the LM317 for protection if the input voltage fails. D2 is another protection diode: it provides a discharge path for C_{adj} if the output is shorted, otherwise C_{adj} forces short circuit current through the "Adjust" pin, and, like so many solid state devices, "they don't like it up 'em"!

"Extralytic" very low ESR and high temperature electrolytics are useful in any power supply; look out for these specs when choosing your smoothing and decoupling capacitors in any power supply application.

The "Classic" LM 317 regulator circuit:

R1 is typically 220R or 240R

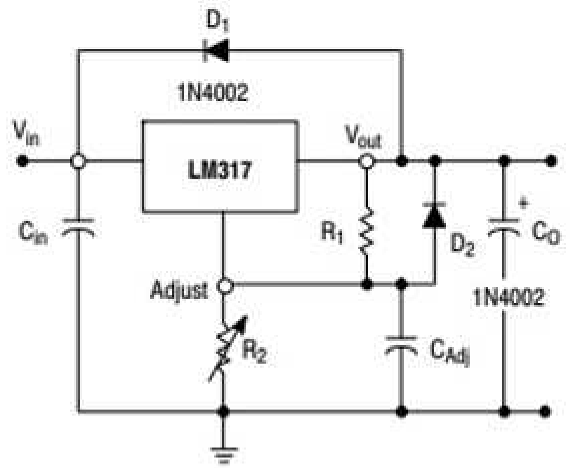
R2 is typically 5k

C_{adj} is 10 to 100 µF, 25 vDC

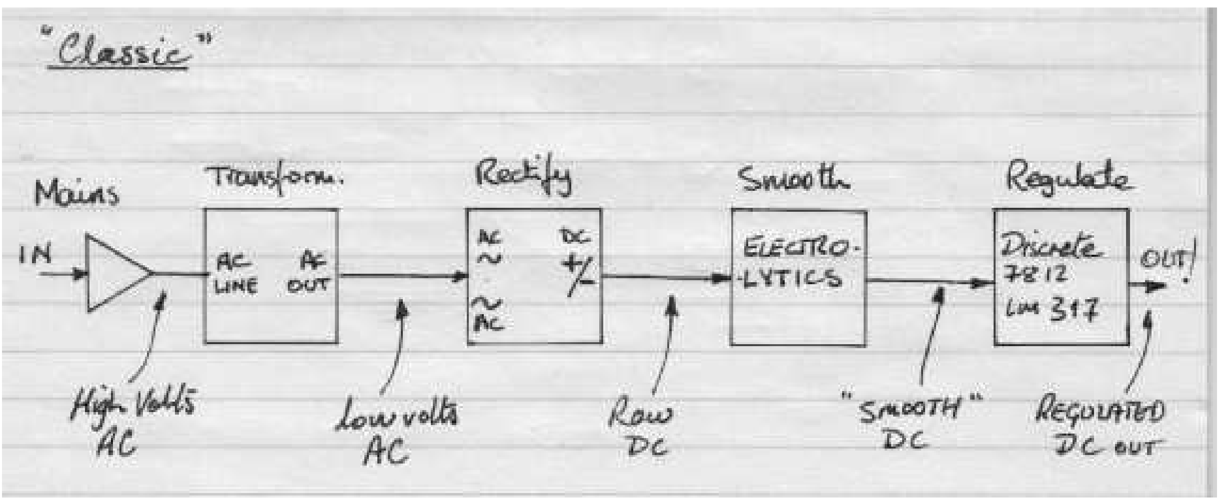
C_{in} & C_{out} = 1000 - 4700µF 50vDC

C_{in} is the main smoothing,

C_{out} is the output reservoir



The "Classic" approach... if you can get a decent mains transformer at the right price!

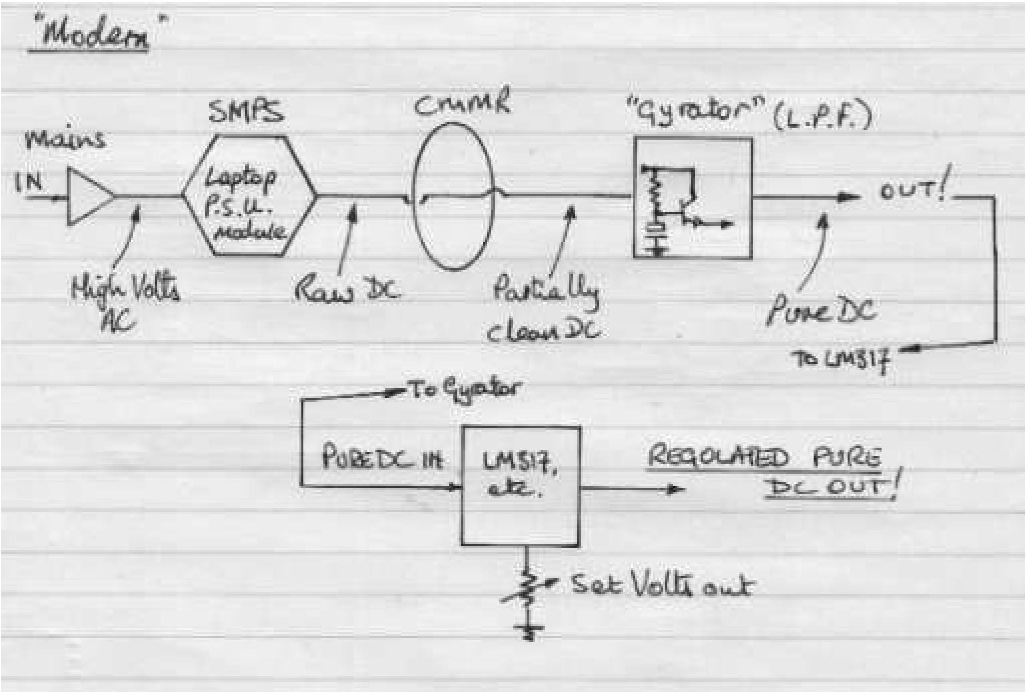


This is the basis of every linear power supply - time tested, reliable and quiet. Fit 10nF / 350v ceramic capacitors in parallel with the diodes in the Rectifier section if RF pick-up is a problem.

There is one major snag with the classic power supply: the transformer. Unless you have one in your junque supply, they are expensive, heavy and getting a bit rare in amateur terms. This prompted the "modern" approach: it's cheaper, smaller and has easily obtained parts: but you have to pay attention to the noise reduction techniques this approach demands. They aren't always required; modern switch mode (laptop) power packs are very much quieter than the more elderly, and the definite ones to avoid are the switch selectable output types.

You're looking for a 15 to 19 volt DC output, at 90 watts or thereabouts (the power's not too important) and our friendly online auction house can oblige nicely: I found a fixed output 96 watt / 19 volts laptop power supply - complete with IEC mains inlet and lead with moulded UK plug - for £6.99. Compare that to a 100 VA transformer from a reputable component supplier at £48.99!

The block diagram is below:



The "Raw DC" is described in our radio terms: it ideally needs processing and regulating to polish it up a bit before letting it loose on pet projects. I'll run through the blocks:

The mains in and PSU module are a given - that's what you get for your £6.99. The first de-noising is by mounting the PSU module in a steel box (mains plug wall socket boxes are ideal) then a Comon Mode Choke (CMC), labelled CMMR in the diagram. I wound this with an offcut of heavy (2.5mm^2) twin "figure of eight" speaker cable wrapped on a scrap 50/60Hz toroid transformer core, I got 36 turns on. You could use a scrap transformer, a ferrite ring core, or even (yes, it works!) a thick handfull of iron nails bound together as a rough cylinder with PVC insulating tape. Just wind the twin cable round and round, secure the ends, job done. It's not critical; the DC current going one way is balanced by the returning current so the core never saturates, but common mode noise is rejected (i.e. noise equally present on both wires). Virtually anything magnetic will do the job.

The next block is often called a gyrator but in reality it's a capacitance multiplier configured as a Low Pass Filter. It's three components: R, C and a pass transistor. You'll need a hefty darlington power transistor here, but feel free to substitute. Just keep in mind it has to carry a fair number of amps, the output current divided by the Hfe (guess around 500 - 1500). The resistor feeds the base current to the darlington; if it's too high a value, the output current will be cut - hey, that's automatic current limiting! - but you want it low enough to start up the output in a reasonable time. Cut and try 1k, 10k, what have you and see what suits. And... it slows the output volts rate of rise on switch on, a "soft start"... we'll keep that idea, three jobs for the price of one is fine by me!

The capacitor is the highest value 'lytic you have; 1000µF / 50 volts is fine here, the more µF's the better. Feel free to try whatever you have to hand, just stack 'em up in parallel.

The final polish is put on by the LM317, as in the classic design. Modern LM317's have good ripple and noise rejection - so you might not need the CMC or the gyrator. If it works fine for you, job done; if you detect a sniff of noise, then in with the extra bits.

You *could* make a useful power supply by just using a 12 volt / 5 amp laptop supply, with the output via a hefty CMC; but this approach doesn't give you a variable output and 12 volts is a bit low for amateur use, 13.8 to 14.3v is more typical for a lead / acid battery for mobile operation.

You can get small digital readouts for voltage and current from our favourite online auction house, very useful and only a few ££'s, that add functionality to the basic design - go ahead, it's your project, but be warned: some of these readouts are electrically noisy little beggars.

Note earthing from mains side should only be to OUTSIDE of the METAL (steel) case as discussed elsewhere in this issue: plastic cases offer no screening whatsoever. See: https://www.youtube.com/watch?v=SvSP3kQQYMg from https://www.pa0nhc.nl/cobra80/index.htm .

Some laptop power supplies have the mains input Earth pin bonded internally to the negative pole of the output: most of the time this isn't a problem as the CMC and gyrator will eliminate noise coming from the mains Earth. One thing I have noticed though with laptop power supplies: they need to feed a minimum current to run quietly. A bleed resistor - a filament lamp with series resistor (they don't make 19 volt bulbs!) indicating power "on" right at the raw DC output can reduce noise.

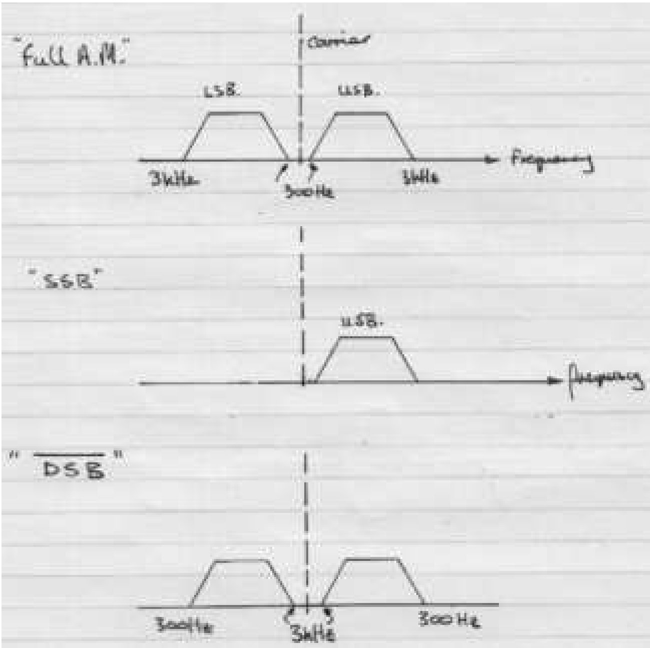
R&D Topics

Peter Parker VK3YE DSB to DSB transceivers

I've recently had some fascinating dialogue with that Antipodean Human Dynamo of RF Design, Peter Parker VK3YE, about Double Sideband (DSB) transmitters and receivers. He's dug out some references from the 1950's, from the dawn of SSB replacing full carrier A.M. as the amateur telephony mode of choice. It wasn't always SSB as first choice: DSB Suppressed Carrier transmitters were much easier than SSB to build in the technology of the day but they couldn't be received on an ordinary (A.M. receiver with a BFO) as the speech comes out garbled.

The apparent downfall of the DSB system is that a DSB transmitter can't be received on an existing receiver as the re-inserted carrier has to be not only the correct frequency, but also the exact phase of the original carrier that created the double sidebands. The Costas Loop receiver overcame this but was mighty complicated and difficult to capture stable lock when tuning. What was required was a standard A.M. receiver with BFO (or Product Detector), that could demodulate DSB sidebands and present clear speech with no kerfuffle. And that's exactly what they did in the 1950's! Studying the frequency plane diagrams of an A.M. signal yields the clue: for an unmodified A.M. receiver, the DSB sidebands are the wrong way round, as the receiver tunes up the band, the 3kHz end of the spectrum is where the 300Hz end should be; and moreover, tuning down the band from a higher frequency presents the same problem! Where the receiver is expecting low audio frequencies (close in to the carrier), DSB presents high audio frequencies; and vice versa, so the speech comes out "the wrong way round". So... how to "invert" the sidebands in frequency terms?

The whole idea - which can be used either at the DSB transmitter or receiver - relies on "inverting" the sidebands in the frequency plane using an audio frequency carrier and a mixer. If you imagine a standard A.M. signal frequency spectrum with each sideband 300 Hz to 3kHz wide, centred around the carrier that created them, then to invert the sideband in frequency means exchanging the 300Hz and 3kHz points around the (re-inserted) carrier. In the diagrams I've labelled the inverted sidebands with a logic "NOT" bar to indicate the "inversion".



If we imagine a receiver with a BFO making a re-inserted carrier tuning up scale from a lower frequency, the inverted lower sideband now presents itself in the correct orientation to the receiver's bandwidth: 300Hz is now close to the (re-inserted) carrier and the 3kHz point is at the upper frequency relative to the (re-inserted) carrier. Thus the receiver demodulates the lower sideband exactly as an SSB signal would be demodulated! Similar reasoning also demodulates the upper sideband, the receiver tuned down scale from above finds the 300Hz and 3kHz points in exactly the right place in the frequency plane, and demodulates it as an SSB signal.

Frequency spectrum inversion using an SA612 mixer and LPF's

Unlike the 1950's, the frequency inversion can be done with a couple of common silicon IC's: an SA612 double balanced mixer followed by a switched capacitor low pass filter (or op-amps if you prefer analogue filters). The trick is to mix the incoming audio (from the microphone in the transmitter or recovered audio in the receiver) with a local audio carrier of 3.3kHz, then filter out the "sum" and accept the "difference" frequencies. If the incoming audio is 3kHz, mixed with 3.3kHz local carrier, the LPF delivers a 300Hz audio signal; if the incoming audio is 300Hz, the

LPF delivers a 3kHz audio signal. The sideband is inverted, and thus rendered, the sideband is receivable as an SSB signal. All that's required for signal processing in the receiver is a reasonably good RC oscillator (even a 555!) running at 3.3Khz - no demand for super stability or phase - driving an SA612 double balanced mixer followed by a switched capacitor Low Pass Filter (SCF), with suitable input and output coupling capacitors to establish the 300Hz lower cut off and appropriate clocking the SCF to give 3kHz top cut off (a MAX 7409 perhaps?).

There you have it: build the simplest DSB transmitter of your choice, and with it a simple receiver with audio inversion circuit after the detector / product detector and you have a full DSB transceiver. A stable Direct Conversion receiver will demodulate the inverted sideband as an SSB signal - this makes for ultra simple DSB transceivers. Not quite Costas Loop 6dB gain over SSB, but a superb and simple way to get DSB to DSB compatibility with simplicity.

Not content with solving a 70 year old problem with modern technology, Peter Parker has found a novel, ready made sideband inversion gizmo that can be used: a "Dr. Who" Dalek Voice Modulator kit that has the mixer and oscillator built in: just change one capacitor to get the 3.3kHz local audio carrier, and the job's a good 'un. See (and hear!) Peter's results at https://www.youtube.com/watch?v=Y7DQa2kTx9w and https://www.youtube.com/watch?v=J-QmZOrL-lA

As they say in Rock-N-Roll, "follow that if you can!"

Diplexers...

https://www.qsl.net/g3oou/mixerterminations.html gives an explanation of the need for diplexers, but discards the 50 ohm resistor termination as "inefficient". But, asks G6NGR, just what **does** "inefficient" mean in our amateur reality? We can apply a little audio gain after the mixer at the cost of adding a sniff of noise, but a resistor and amplifier stage is considerably less bother than most of the diplexer designs I've seen. 88mH inductors, commonly mentioned in USA diplexer designs, are as rare as Hen's teeth in the UK & Europe!

A simple common base stage, of ~ 50 ohm input impedance, with LF and HF roll-off applied to define the audio bandwidth, will do nicely for a simple Direct Conversion receiver. Gain is available to make up for any "inefficiency" and give - if the LF and HF roll off characteristics are well designed - champion performance.

I note too the addition of a "gyrator" in some instances, where the supply to the stage following the diplexer is fed from a transistor emitter follower whose base if heavily "slugged" with an electrolytic to eliminate any rail noise. This creates a noise elimination stage; a real gyrator, simulating a giant inductor, might prove a better bet - see
https://www.epanorama.net/documents/telecom/gyrator.html

for the schematic. It needs a current flowing through it to be effective - so a suitable load needs connecting below the diagram, like the 50 ohm Zin common base amplifier mentioned above.

A single transistor bistable?

Yes! This was a challenge issued many years ago, and caused many hours of soldering and fizz-buzz effects on the G6NGR bench (ahemm). It can be done! A better question, perhaps, would be "why?!"

See: https://hackaday.io/project/112126-one-transistor-flipflop

The one transistor twin lamp dimmer - with a twist!

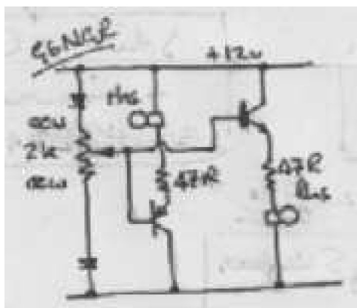
Here's a neat conundrum from many years ago, when an ancient HP signal generator was to be refurbished as a standby for some production equipment. The beast had an illuminated horizontal "slide rule" frequency scale, and it was suggested I modify the twin lamp supply so that when the frequency was set low (to the left hand side of the scale), the left hand scale lamp lit brightly and the right hand scale lamp was (almost) extinguished. As the frequency was adjusted upscale, at mid frequency both left and right lamps were lit at ~ 50% brilliance. At maximum frequency, the right hand lamp was lit brightly and the left hand lamp (almost) extinguished to give clear visual indication of where the pointer was positioned. The lamps, by the bye, were 6v / 120mA rated, originally connected in series across the 12 volt supply rails.

A pot was fitted to the end of the frequency control shaft - the question was how to do the "moving" illumination job? I reckoned I could do it neatly with an NPN and a PNP transistor, running as emitter followers: with the pot at the low frequency end of scale, the PNP would be "on" and the NPN "off"; mid way both would be half conducting, and at maximum frequency the NPN would be "on" and the PNP "off". Job done... until Brian G., the demon designer of CRT scan coil amplifiers, sayeth unto me: "I can do that with ONE transistor...!"

After pondering this in between doing my routine jobs, I composed a way with one transistor; but it didn't perform as well as Brian's, and, just to stick it to the man, Brian had potted his circuit in black resin with ONE transistor poking out the top, so I never saw his circuit.

Of course, all this kerfuffle inevitably came to my mentor Stan's ears: he promptly said: "you don't need transistors. You always jump to the transistor solution, before considering the simpler options. I'll do it with NO transistors, just one pot., and I'll bet you'll never see a blown bulb in that rig ever again!" And, beggar me, he was dead right.

Can you figure out how Brian and Stan did it? Below is my two transistor design, which I thought rather nifty, nay, dare I say, elegant, at the time... and it's a great way to make your tuning dial scale illumination "move" in sync with the knob movement.



It's complementary emitter followers, buffering the voltage on the pot. wiper. When the pot. is set fully counter clockwise (at the top of the track) the NPN emitter follower puts the pot. voltage on the "lhs" lamp - fed via a 47R resistor so as not to blow the 6.0v lamp. Similarly, when the pot is at the bottom of the track (fully clockwise) the PNP applies 12 volts to the rhs lamp. Job done! The two diodes in the pot. chain are to compensate the base - emitter volt drops, so the pot. has no “dead” zones on the track at the top or bottom.

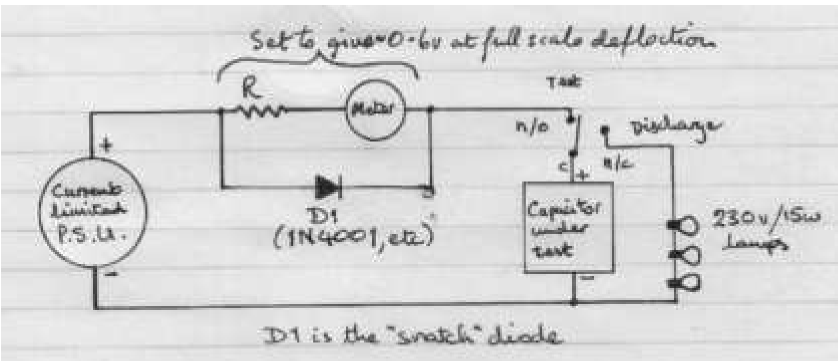
Identifying the polarity of unmarked Electrolytic Capacitors

Why these beasts ever survive I don’t really know; but more than once in my working life I’ve been asked to identify the polarity of unmarked electrolytic capacitors - typically 47,000μF, at 450 volts was one recent candidate. NO polarity marking visible anywhere on the thing; but it promised (so sayeth its owner) “good smoothing for my latest power supply... and it was very cheap...”. Nuff said! But how to identify the correct polarity?

There are a couple of measurements that will help - but with a potential bomb like 47kμF charged up to 450 volts it’s for you to ensure yours (and anybody else’s) safety! Put the electrolytic in a steel box, or other robust enclosure with secure lid, and run wires out to a safe place. Remember the energy stored in Joules is ½CV², so do the sums first before turning on the power. Calculate the explosive power from watts = Joules per second; a ‘lytic explodes in under 0.1 seconds, so multiply the Joules by 10 and you have watts. So ½ x 450 x 450 x 0.047 Farads = 4758.75 Joules = 47.58 kWatts if the charge is dumped in 0.1 seconds! You have been warned!

First, remember the fundamental principles of an electrolytic: if it’s biased with correct polarity, the chemistry inside the thing creates a very thin insulation layer between the capacitor plates, and it’s this insulating layer that creates the capacitor. Bias it the wrong way round, and it leaks like a proverbial colander - but the snag is so does an old electrolytic, it has to re-form the oxide insulating layer, so apply some test volts and monitor the current. If it’s wrong road round, it will leak, and carry on leaking at an ever increasing rate - and get HOT. This gives you two weapons in your armoury: leakage current and temperature rise.

So... attach a thermocouple, or infra-red thermometer (so beloved in these COVID-19 days!) or other means of measuring temperature onto the beast under test; then measure the leakage as you S-L-O-W-L-Y charge the thing up, from a current limited (a series connected “dull lamp” feeding a rectifier is a **very good idea**) DC supply, and using a very well protected μA meter (not your very best expensive multimeter). Use an old VU meter or similar with a series resistor of a few ohms to get a full scale deflection of ~ 0.6 volts, and wrap around the whole shebang a snatch diode, so if the ‘lytic goes short, the meter doesn’t explode.



Don’t forget that every time you raise the voltage, a current will flow to charge the capacitor, as the plate oxide layer re-forms. Wait a minute or two and let the current settle back to indicate the leakage. The function of the "test" and "discharge" switch is self explanatory; tungsten lamps are excellent self indicating discharge devices. Series them up to match the expected voltage, or use a dropper resistor. 6k8 at 20 watts in series with a 5 watt pygmy lamp is good for 600v or so.

If the leakage rises on charge, towards 10 - 20 µA or so, all's fairly reasonable; but any sudden rises of current, with a corresponding rise in temperature, you've got a banger biased with that polarity. STOP IMMEDIATELY, switch off all power and let the 'lytic calm down for an hour or two.

Once you have the polarity fairly certain, re-form the plates by charging up to rated voltage - in gradual steps - via a current limited DC supply ("dull lamp" as above) and hold the full rated voltage for a few hours, keeping an eye on the leakage current. It should drop to a few 10's of µA fairly quickly; and drop eventually to a lower settled value.

Here's a note from Stack Exchange which is useful for all you low voltage electrolytic wallahs:

From: https://electronics.stackexchange.com/questions/35480/polarity-of-unmarked-smt-electrolytic-capacitor

"If they really are unmarked polarised (extremely unlikely) then a possibly destructive method of testing for polarity is to gradually apply a current limited voltage (e.g slowly up to ~25% of rated voltage, limited to ~10mA) in both directions across the cap whilst measuring current - if polarised and the wrong way round you should start to see a steadily rising current flow. Can be done with a bench power supply, and put a shield of some sort over the cap just in case it decides to detonate ;-)

I tested with the bench supply, above ~7V across reverse polarity with a 100uF/35V aluminium electrolytic, the leakage current rises above 1mA (measured using bench display) and quickly starts to accelerate upwards.
I also just tested this with a multimeter in series with the bench supply (more sensitive than the bench supply measure) measuring current across the same capacitor:

- *Using 5V with correct polarity produced ~1uA leakage.*
- *With 5V and reverse polarity the leakage started at around 25uA and gradually got higher, after around 30 seconds it was at 50uA.*
- *Even at 3V it was reasonably obvious which way round it was - the reverse leakage was at least twice that of the correct polarity."*

The *magnum opus* of all this is at: https://tadiranbatteries.de/pdf/applications/leakage-current-properties-of-modern-electrolytic-capacitors.pdf

A useful end note: 'lytics that have been accidentally back biased usually recover if biased forward for a period of time at low voltages; build the voltage up S-L-O-W-L-Y, watch the leakage current with your bomb proof leakage meter and all - if you're lucky - will likely be fine.

A link

Here's an article about audio amplifiers (and much, much, more) you might like. I really enjoy trawling round these darker corners of electrical,electronic and radio engineering - I keep the motto "don't knock it till you've tried it"!

https://www.aes.org/aeshc/pdf/how.the.aes.began/vincent_magnetic-audio-fundamentals.pdf

Mag Amps

I first came across magnetic amplifiers when repairing the 15kV, 3.5 Amp DC power supply in a Perkin-Elmer high vacuum evaporator. The design engineers had used a 24v DC control signal feeding this monster lump of iron and copper, which in turn controlled the 3Φ input power to the main HV transformer. I'd never met one of these beasts before, so was unsure of how they functioned: it was obvious the control signal could be anywhere between 0 volts and +24 volts - but did +24 volts equal zero power or full? I didn't want to energise this dangerous old beast at full bore; I wanted to ramp the thing up slowly to see where the flashover was, and hopefully prevent a lot more damage. 15kV with amps behind it can go places and do things that just aren't sociable before the over-current trips can open the main HV 3Φ input contactor!

A trip to see my mentor, Stan, soon brought an answer. "No volts = no output; +24 volts = full output". Job sorted: control card removed, a bench PSU rigged up and wired in, and off we go. Yes, one of the HV feedthroughs was flashing over, deep inside the ceramic insulating sleeve. The thing lit up like a miniature lightning display, and I very quickly knew the problem. The solution was, however, another story... but the fact that the magnetic amplifier (commonly known as a "mag amp") had survived multiple short circuits with ne'er a quibble, full power flashovers, which impressed me mightily. As Stan mentioned in the canteen at lunch time, he'd never known a mag amp turn up it's toes - they were "nigh on indestructible" quoth he, "just like this pie crust on my plate").

So, me being an A.M. nut, when I was trawling through my notes about mag amps, VLF transmitters, Alexanderson alternators and the like I came across the references below:

(https://en.wikipedia.org/wiki/Magnetic_amplifier#Applications)

"Magnetic amplifiers were important as modulation and control amplifiers in the early development of voice transmission by radio.[2] A magnetic amplifier was used as voice modulator for a 2 kilowatt Alexanderson alternator, and magnetic amplifiers were used in the keying circuits of large high-frequency alternators used for radio communications. Magnetic amplifiers were also used to regulate the speed of Alexanderson alternators to maintain the accuracy of the transmitted radio frequency.[2] Magnetic amplifiers were used to control large high-power alternators by turning them on and off for telegraphy or to vary the signal for voice modulation. The alternator's frequency limits were rather low to where a frequency multiplier had to be utilized to generate higher radio frequencies than the alternator was capable of producing. Even so, early magnetic amplifiers incorporating powdered-iron cores were incapable of producing radio frequencies above approximately 200 kHz. Other core materials, such as ferrite cores and oil-filled transformers, would have to be developed to allow the amplifier to produce higher frequencies."

From:

https://ham.stackexchange.com/questions/14674/is-it-practical-to-use-a-magnetic-amplifier-as-an-am-modulator-in-a-transmitter

Magnetic Amplifiers
From

https://www.nutsvolts.com/magazine/article/the_magnetic_amplifier,

with many thanks.

“A magnetic amplifier uses the change in inductance that occurs when an inductor's core is magnetically saturated (with a relatively small DC current through a high number of turns on the same core) to control an AC current.

This works because the inductor (L1) is designed to have high impedance at the frequency of the current that it is required to control when no control current is flowing, and low impedance if sufficient DC control current is flowing.

Due to the use of a core material with the right saturation characteristics it is possible to reduce or remove the magnetic effect of the core by passing a DC control current through a second winding and progressively saturating the core, so that the core contributes less and less to the inductance of L1. This lowers the inductance of L1 and therefore the impedance to the controlled ac. The resistance of L1 to DC is not changed.

There are several ways to stop induced emf from the (controlled) ac current from feeding back into the control circuit, all involving 2 magnetic fields or 2 emfs cancelling each other e.g. 2 identical magnetically separate saturable core inductors with the control windings in series and oppositely phased.

Simplicity
The mag amp, like the vacuum tube and transistor, is an electrical control valve. When a smaller circuit controls another circuit’s larger flow, that’s the definition of an “amplifier.”

A mag amp can be put in series with any circuit carrying an alternating current and control that flow. No external power supply is required to run the device. The simple mag amp is just a core of iron or ferrite with some coils of wire wound around it.

One other basic component is the rectifier. Today, rectifying diodes are compact, easily available, and cheap. The old selenium rectifiers used back in the 1950s were large, cumbersome, and expensive. A variety of ferrite core materials are also available to today’s builders. With some spools of wire, a ferrite rod, and a couple of diodes, you can throw together a little high-frequency mag amp on a Sunday afternoon. Compare the construction challenge of a vacuum tube or transistor. And the mag amp can handle voltages and currents that you would never put into the average transistor or tube.

How it Works
The mag amp is a … variable choke. It controls the impedance (opposition) to alternating current in a coil by controlling the magnetic condition of the core on which the coil is wound. This is done by energizing another winding on the core called a control coil. Depending on the energy in the

control coil, the core's permeability (its receptivity to magnetism) can be varied by degrees, thus controlling a larger AC flow.

Fully energized, the control coil can reduce the permeability of the core to zero, in which case the core is said to be saturated. Then it becomes so magnetically unresponsive it's like the core has been removed.

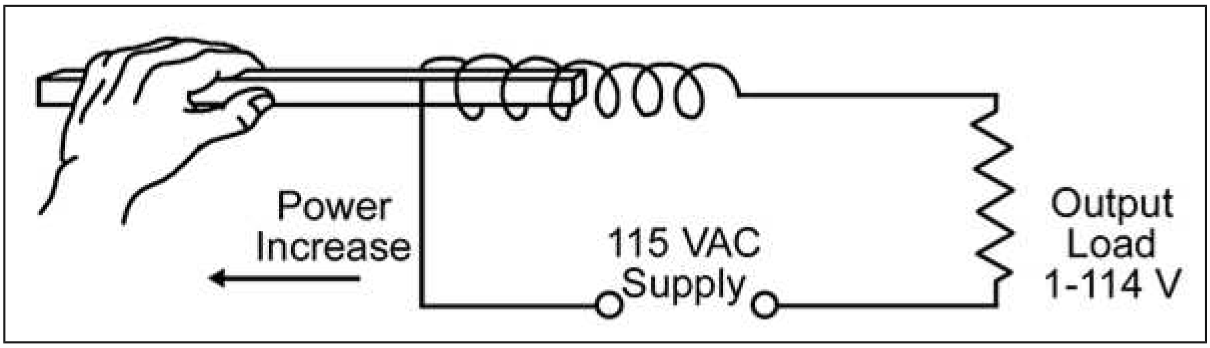


FIGURE 1. Principle of Operation.

Figure 1 *is a way of showing the principle. With the core completely within the coil, the impedance to the flow is high, permitting perhaps only a fraction of a volt to appear across the load. Pulling the core out causes the load voltage to rise progressively to 115. Since it took only a few watts of muscular energy to move the iron core within the coil, which may, in turn, control several horsepower, the device is an amplifier.*

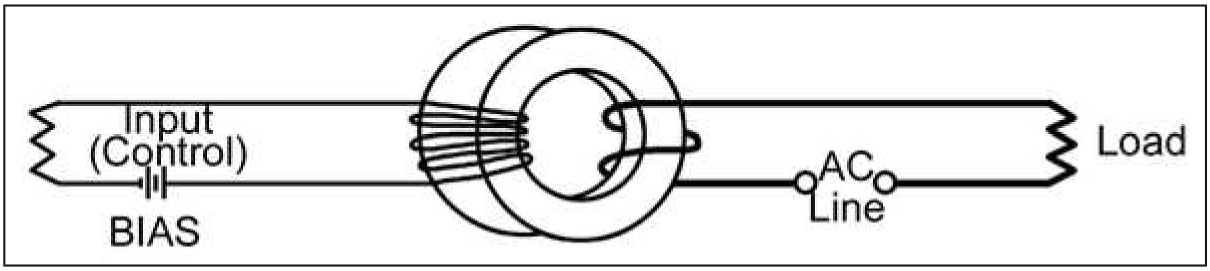


FIGURE 2. Saturable Reactor

Figure 2 *is another demonstration. This qualifies as a saturable reactor. This circuit could be for a dimmer for theatre stage lighting. Add a diode, and you have a basic mag amp (see* ***Figure 3****). The larger coil is the control coil. The smaller is called the loading coil.*

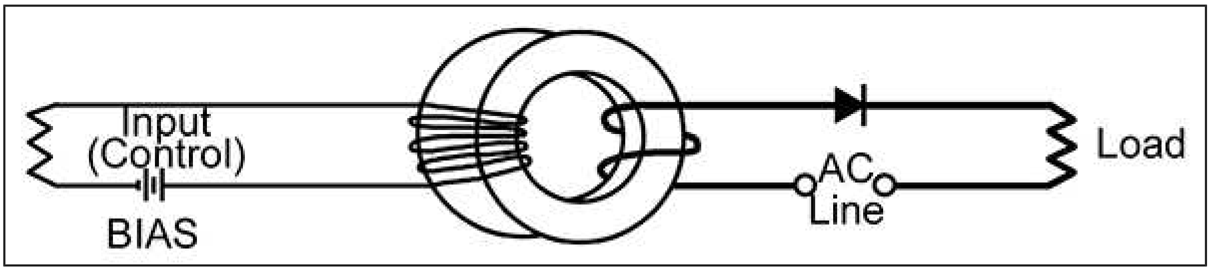


FIGURE 3. Mag Amp.

The diode rectifier makes the load current unidirectional, which assists the control winding in saturation. Considerably less power is now required, making it a more potent amplifier.

This mag amp, however, will function as a step-up transformer, which would be undesirable since it would send energy back into the control circuit. This effect is cleverly cancelled by running the AC through a pair of parallel loading coils which are wound in opposite directions.

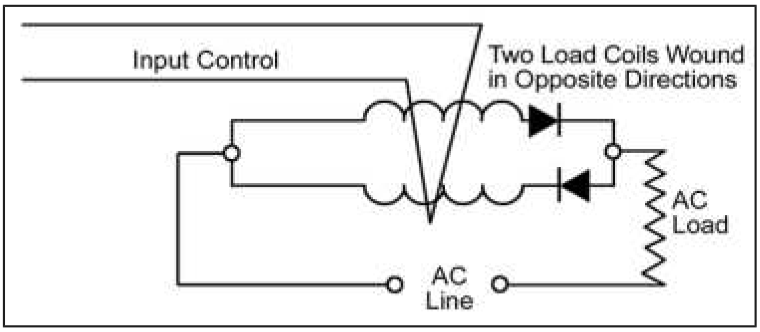


FIGURE 4. Functional Mag Amp.

Figure 4 *is your basic functional mag amp represented by the appropriate schematic symbols. The control coil symbol is a single sharp angle-line, but the control coil actually has many more turns than the loading coil.*

How many turns? The rule of thumb is control-coil ampere-turns equals loading-coil ampere-turns plus sufficient extra turns to saturate the core. (Much of the how-it-works above is from Magnetic Amplifiers by the US Navy, 1951, recently republished.)

Uses

The mag amp still has industrial uses in the control and regulation of power utilities and big electric motors, as in locomotives, but its most fascinating applications — mostly forgotten — are in electronics.

The mag amp can modulate, switch, invert, convert, multivibrate, audio-amplify, radio-amplify, frequency-shift, phase-shift, and multiply. Stages can be cascaded. Simple feedback techniques enable gains in the millions.

The mag amp can even compute. Trouble-proof magnetic binaries replaced the less reliable vacuum tubes used in some early digital computers.

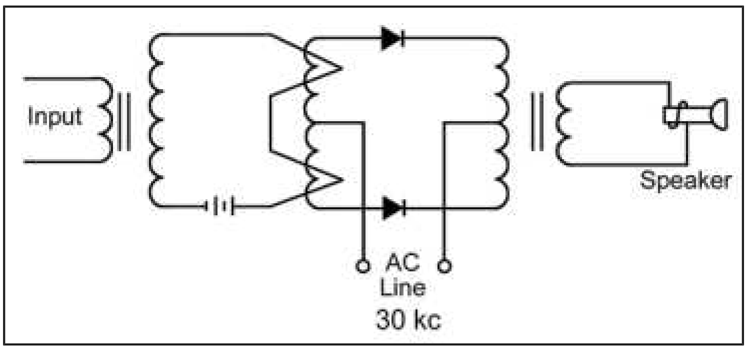


FIGURE 5. Mag-amp Audio Amplifier (push-pull).

Figure 5 *shows the incredibly simple circuit for a mag amp audio amplifier. Mag-amp audio would be a challenging pursuit for some adventurous audiophile.*

Mag Amps in Radio

The first patent for a mag amp was in 1903, but little attention was paid until 1916 when radio pioneer E.F.W. Alexanderson seized on the idea as a means of controlling the giant rotary alternators he was using for high-power radio transmitting (at 10,000 to 100,000 cycles). The Magnetic Amplifier Bibliography (by the US Navy, 1951) lists three Alexanderson patents in 1916 and three more in 1920, the last titled "Transoceanic Radio Communication."

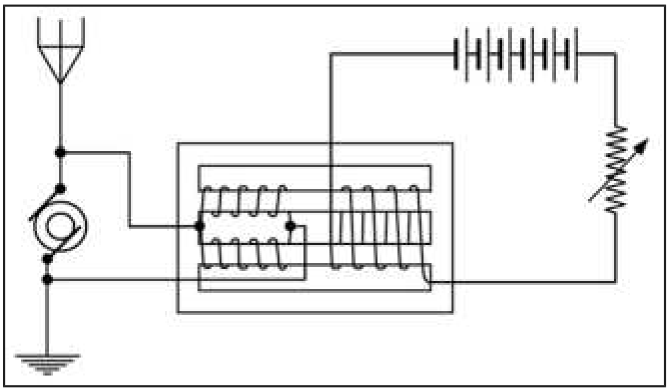


FIGURE 6. GE Mag-amp Modulator by Alexanderson.

The mag amp can turn the alternator on and off for telegraphy and vary the signal for speech modulation (see ***Figure 6****).*

The frequency limits of an alternator are low, so the mag-amp was reinvented in that era as a frequency multiplier (doubler, tripler), as seen in ***Figure*** *7. The Bibliography cites many radio-transmitter frequency-multiplier patents up through the 1920s. These are simple circuits compared to those of vacuum-tube frequency changers that came later.*

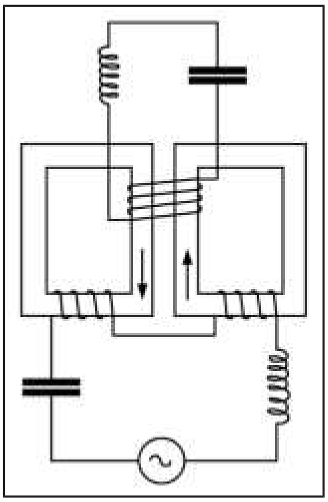


FIGURE 7. Frequency Multiplier.

Early mag amps with solid iron cores never got above a few hundred kilocycles. Powdered-iron cores, the ceramic-iron-oxide composition known as ferrite, and later the ultra-thin magnetic tapes liberated the mag amp, so by the 1950s the limit was up to a megacycle and switching rates were in microseconds, suitable then for computer applications. Techniques for the modulation even of microwave frequencies were also developed in the 1950s (see ***Figure 8****).”*

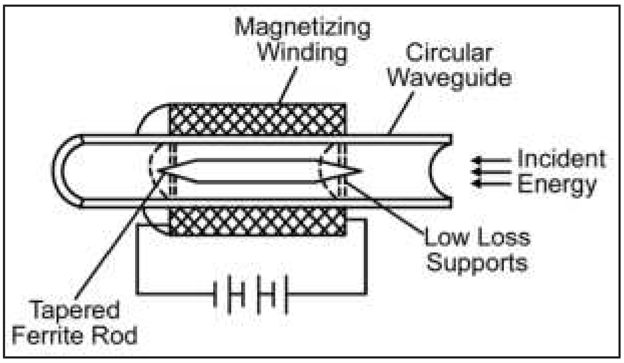


FIGURE 8. Microwave Mag Amp.

Here’s an article by that very practical gentleman, of “Easy Ten” transmitter fame, Nyle Steiner K7NS. Nyle lists two mag amps, one built with common 12 volt transformers and another using “junk box” toroid cores at: http://www.sparkbangbuzz.com/index.html

My Home-built Mag Amp by K7NS

By Nyle Steiner, K7NS

“I wanted to see if a mag amp could modulate a Tesla coil (see ***Figure 9****), as Alexanderson modulated his big alternator-transmitter. I used the schematic in* ***Figure 4****. The Navy booklet, Magnetic Amplifiers served as a reference.*

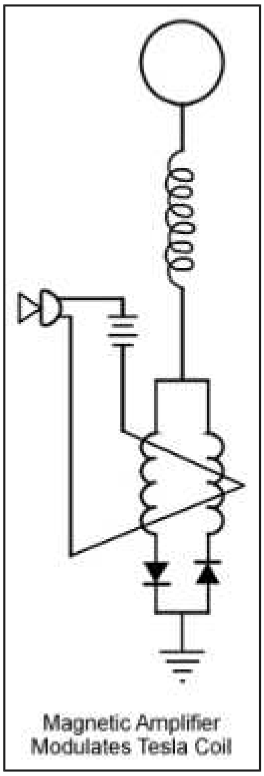


FIGURE 9. In Tesla Coil Circuit.

*I first obtained a ferrite rod (material #33), six inches by just under 1/2-inch diameter. I got it surplus from Alltronics, for about $5, but it's no longer available, though they do carry a four-inch for $5 (**www.alltronics.com**.) Another source for rods is Surplus Sales of Nebraska (**www.surplussales.com**). From Alltronics I also got spools of magnet wire — #26 for the two loading coils and #30 for the control coil.*

I wound my coils, not directly on the ferrite, but on acrylic tubing, 1/2 inch inside diameter (from Tap Plastics), which I could slip over the rod. A section of the tubing and a couple of nylon fender washers from the local hardware store made a well insulated spool or coil form on which to wind the coils on my winding jig. The loading-coil spools were 1-1/8 inch wide, the control coil two inches wide. For the loading coils, I wound 13 layers, 860 turns of the #26 wire, laying on some electrical tape for extra insulation between each layer. I wound the two loading coils in opposite directions. The control coil took 400 feet of the #30 wire.

A mag amp is frequency specific according to the size of its loading coils. (Thus, an audio amp would be quite large.) I wanted 180 kilocycles, and I determined the number of turns experimentally.

*For the rectifiers, I used eight 1,000-volt, three-amp 1N4008 diodes, four in each leg (three for a $1.00, from All Electronics, **www.allelectronics.com**). The mag amp was now safe to 4,000 volts and could handle the output of my solid-state Tesla coil."*

Performance

So that I could observe the mag amp's performance with my signal generator and oscilloscope, I replaced the 1N4008s with two low-power signal diodes. In series with the control coil, I put a 12-

volt battery and a telegraph key, as a convenient switch. The mag amp is frequency-specific; you design it for a particular range. Keyed on and off, the mag amp showed response from 155 to 200 kilocycles (a range that happens to fall within the license-free experimental radio band called LowFER).

What a versatile device! At a particular frequency, operating the key would increase or decrease the amplitude of the wave as traced on the scope. At another frequency, the keying would shift the frequency back and forth, and at another it would shift the phase. So this one little device, depending on how it was tuned, could do on-off keying (CW), amplitude modulation (AM), frequency-shift keying (FSK), frequency modulation (FM), or phase-shift keying (PSK), including bi-phase-shift keying (BPSK), which is a common mode of digital transmission. Placed in the ground circuit of my solid-state Tesla-coil, the little mag amp showed that it could do all of the above with more than 3,000 oscillating volts running through it. This would be quite a task for a vacuum tube and probably beyond any transistor."

Keying a transmitter

This should really be in the "transmitter" section, but since we're playing with big boy's electronics here - mag amps and all that - a thought came to my mind that could be used for keying a transmitter without back wave issues or chirp and the like. My thoughts ran thus:

Why switch off the P.A., or driver or oscillator at all? Why not build a mag amp change-over switch, and divert the transmitter output into a well screened and matched dummy load for the spaces? Sure it isn't energy efficient, but it would mean the P.A. runs continuously into a matched load. No back wave (if the switch is a good 'un) and no chirp from stop / starting sections of the transmitter. This sounds perfect for a complementary mag amp switch pair?

Construction

Building using separate "modules"

When cheap aluminium boxes were available from Maplin (now sadly defunct) UK constructors had the luxury of building in "modules". You built each stage in it's own little screening box, and used a common power supply philosophy: screw terminal blocks on each box, which allowed easy testing, and coupled the stages together with signal cables on plugs and sockets (phono plugs / sockets were great on 7MHz and under; BNC above). Though a bit more costly, it provided a superb way to make individual stages improvements / alterations and allowed easy performance comparisons.

Nowadays finding cheap aluminium boxes for projects like this is not easy - they are rarer than hen's teeth. Why not try the 4" square steel boxes available from electrician's suppliers? Galvanised or black painted, they are meant for housing terminal blocks and the like, and are as cheap as chips. The steel backing boxes used to mount UK mains wall sockets make for ideal "cover" style screening (as in Alan Gale's PSU previously in this issue) and you get screw mounting tabs thrown in for free, but beware: they are an odd thread, 3.5mm.

Electrician's suppliers sell 3.5mm taps mounted in a plastic handle to clear mushed threads in wall boxes. Used with gentle care, these will cut neat 3.5mm threaded holes, ideal for all those screws that you religiously save from scrapped boxes and (UK) electrical equipment, don't you?

Hook up wire reclamation by Frank Barnes, W4NPN

"If you can obtain a junked PC, it will have a great deal of multi-colored wire in the various harnesses inside it. The only drawback, for some uses, is that it is stranded wire. Even though a PC uses low voltage, this wire is quite satisfactory for use in a receiver. I've used it to carry well over 600 volts with no problem - I do not know the wire's technical specs but so far no problems have occurred. I like the fact that many colours are available."

1/8" bore aquarium PVC pipe, is ideal for a "second skin" sleeving over much cheaper thin insulation (or doubtful spec.) wire, culled from scrap PC's, washing machines, microwave ovens and the like. Cheap as chips, too! For hot environments, glass fibre sleeving slipped over PVC insulated wires is excellent: it doesn't matter if the PVC melts, the sleeving insulates (to 2.5 kV) at 200°C continuous, 600°C for a few minutes. For deep freeze duty, silicone rubber sleeving will get you from -60°C to +180°C; for the real hot stuff, to upwards of 1000°C, it's "fish spine" beads - Steatite ceramic beads with interlocking concave and convex ends, so that wires can run round curves without the bare inner conductor being exposed.

Keep in mind though that copper wire will be of much higher resistance per foot at these elevated temperatures, so scale up the cross section adequately and remember copper melts at 1083°C!

Below is a calculation showing how copper wire can change with temperatures not uncommon in valve chassis:

From: https://www.engineeringtoolbox.com/resistivity-conductivity-d_418.html with many thanks.

Change in resistance with heat can be expressed as:

$dR / R_s = \alpha.dT$

where

dR = change in resistance (ohm)

R_s = standard resistance according reference tables (ohm)

α = temperature coefficient°f resistance ($^\circ C^{-1}$)

dT = change in temperature from reference temperature ($^\circ$C)

rearranging:

$dR = \alpha.dT.R_s$

The "temperature coefficient of resistance" - α - of a material is the increase in resistance of a 1Ω sample of that material when the temperature is increased 1°C.

Example - Resistance of a copper wire in a hot chassis

A copper wire coil with resistance 500Ω at normal operating temperature 20°C is in a hot chassis at 80°C. The temperature coefficient for copper is 4.29×10^{-3} (per °C) and the change in resistance can be calculated as:

$dR = (4.29 \times 10^{-3} \text{ per } ^{o}C) \times ((80°C) - (20°C)) \times (500\Omega)$

$= (4.29 \times 10^{-3}) \times 60 \times 500\Omega$

= <u>128.7</u> (Ω)

The resulting resistance for the wire will be:

R = (500Ω) + (128.7Ω)

= <u>628.7</u> (Ω)

~ <u>630</u> (Ω)

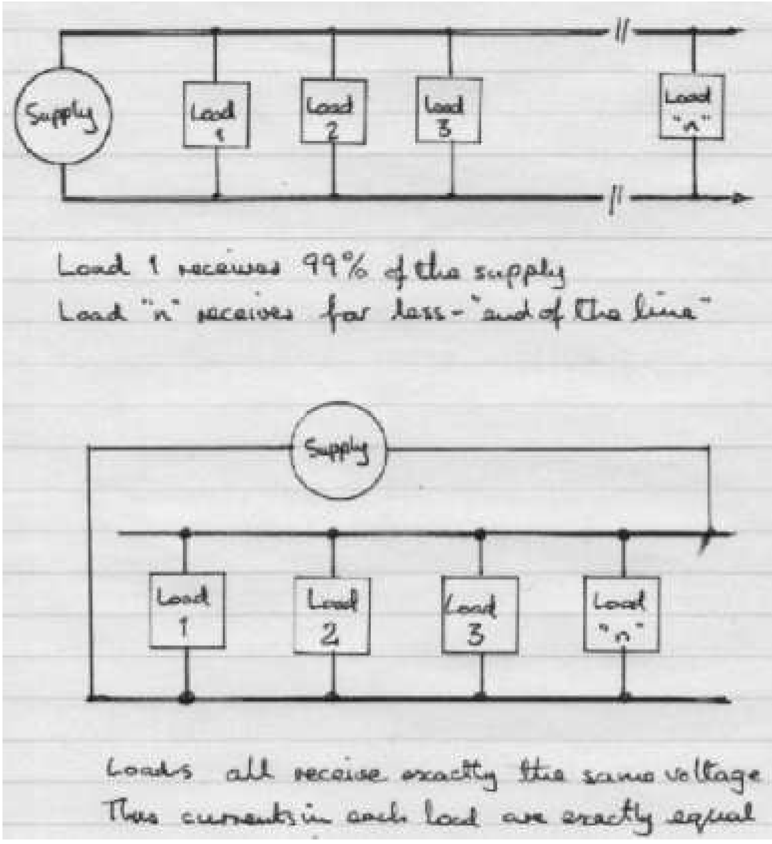
The point to note is that this copper wire could well be a transformer winding; on heavy load the efficiency drops due to the higher resistance of the winding, and the output voltage drops. This is reflects the *regulation capability* of the transformer.

Electrolytics (or loads) in parallel

It's often required to run loads in parallel to absorb the power, similarly to feed power from multiple paralleled electrolytic capacitors, cells, what-have-you. But how do you guarantee that each and every one of the loads or electrolytics contribute exactly the same energy?

This is a very real problem in places like electro-plating shops or power inverters where multiple loads or electrolytics are banked up that must have contribute or absorb exactly equal voltages and currents. In the electro-plating shop every cathode station must plate exactly the same thickness of metal; in a power inverter (or a solid state QRO power amplifier?) every electrolytic must contribute to the load equally to prolong the working life of the electrolytics.

The diagram below shows two scenarios: the top drawing shows a supply feeding two buss bars with loads strung in parallel between them. Load 1 gets virtually the full supply volts, but Load "n" at the end of the line suffers considerable volt drops - the sum of both the feed buss bar drop and the return buss bar drop. If, instead of loads, these were electrolytics feeding a high current system, then the electrolytic nearest the "power supply" (in this case the "supply" would really be the high current load) would be doing the bulk of the current delivery; those down the line would contribute less and less to the load. Odds on the first electrolytic to fail would be that in position "load 1".

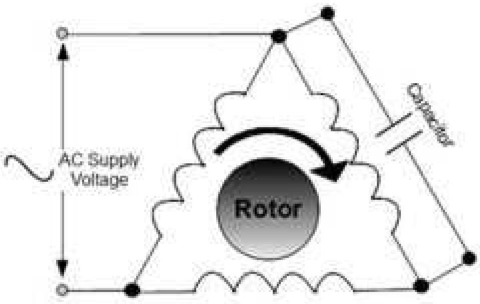


Now consider the lower drawing. The supply is feeding opposite ends of the buss bars; whilst this involves heavy current flowing in the wires from the supply to the buss bars, heavy cable is cheaper (and more reliable) than a repair. If cable volt drop really is a concern then Kelvin ("sense") leads can be run to the buss bar ends to nullify feeder cable volt drops, but I doubt if any amateur jobs - except perhaps legal limit full carrier service modes - would need such sophistication. Look at the volt drops in the lower drawing: they cancel each other along the length of the buss bars so each load or electrolytic absorbs or contributes exactly equal energy. Nett effect: you get much longer life from your electrolytics. Whilst it might not be possible to do this in your latest QRO solid state PA power supply, it's worth bearing in mind if you're doing a PCB copper layout.

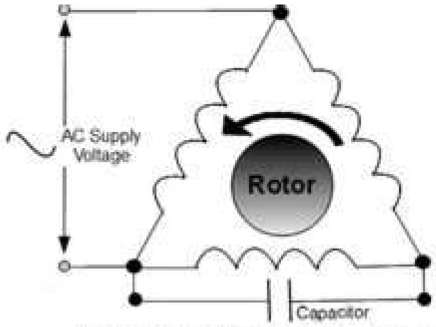
I won't labour the point too much, but in a bank of paralleled electrolytics, the one that will fail first, is the one that runs hottest - because that's the poor struggler who is working hardest to deliver the amps. If you have the luxury of an infra-red thermometer (a.k.a. "finger tip" at G6NGR) you can check this yourself whilst the electrolytics are running into a full load. You'll soon spot the future likely dud.

Running a three phase motor on single phase

A 3Φ motor can be successfully run on single phase if it can be wired in Delta - sometimes referred to as "Low Voltage" connection - and a suitable capacitor is added to phase shift the current in the phases as per the diagram below (from ijyam.blogspot.com with my thanks):



Forward Rotation of Delta Connected 3 phase AC Motor Supplied with Single Phase Voltage



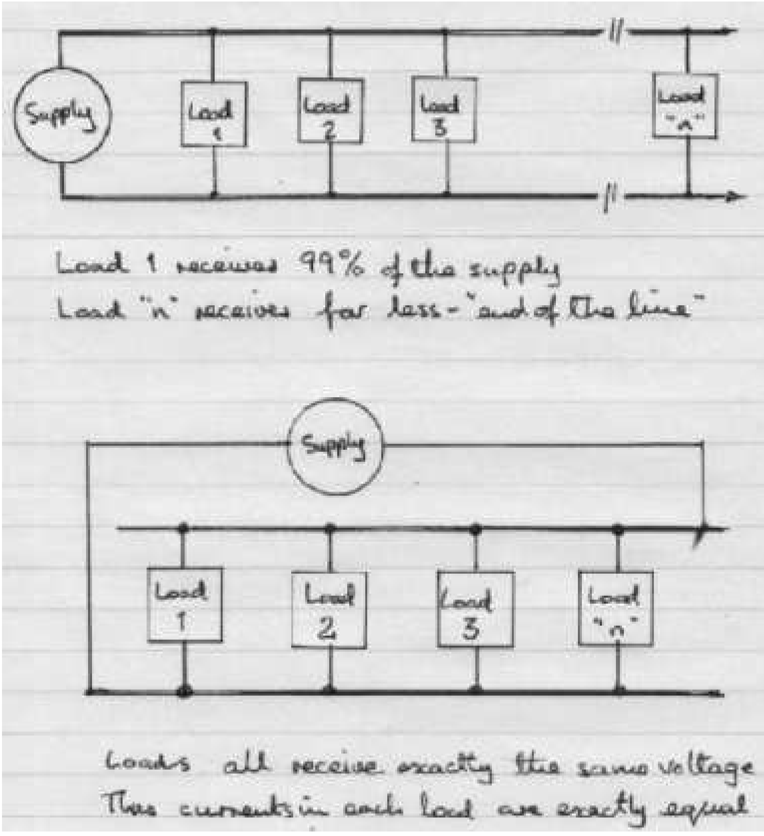
Reverse Rotation of Delta Connected 3 phase AC Motor Supplied with Single Phase Voltage

The capacitor is connected between one of the single phase wires to the third phase winding; if the motor runs the wrong way round, change the capacitor connection to the other single phase wire.

How big to make the capacitor? Reckon on roughly 75µF per kW of motor power, rated at at least 500 volts and specifically designed for motor applications. You'll need a few in parallel to get the capacity required. Don't be tempted to skimp: the capacitors have to carry fair amounts of reactive current, and have to be designed to do this for long periods without overheating. Small plastic capacitors just won't do, get those big oil and paper jobs that come in steel cases!

Amps and electrolytics

Need lots of µF's in parallel for a high current supply? Use the old electroplating shop trick of feeding buss bars from opposite ends - every capacitor then contributes equal current.



Manhattan Construction the easy way

This is a simple process, none of which involve spending any money (a G6NGR “must have”...).

Oh, alright, yes, I blew a single solitary spondulick in the ££shop for the Super Glue; but it was “officially” to repair a busted rubber “O” ring in our swivel tap in the kitchen, so I’m counting it as gratis.

1. Contact your local PCB manufacturer (web search, Yellow Pages, I have a choice of three in Rochdale; Oldham and Manchester have many more) and beg, cajole, wheedle the following:
2. Some scrap 0.1mm thick FR4 single or double side copper pcb laminate from the scrap bin - the stuff you can cut with scissors
3. Ditto 2mm thick scrap FR4 pieces - the stuff you can’t cut with scissors
4. On the way home, call in the ££shop and buy a tube of super glue
5. Once home, get the kitchen scissors from the drawer
6. Cut strips of the 0.1mm thick FR4 5mm wide (or whatever width you want your pads to be) with the kitchen scissors
7. Cut little squares or rectangles off this strip with the kitchen scissors
8. Cut the 2mm FR4 to size as a “baseboard” for your project with a hacksaw, sand the edges smooth and clean the copper with damp pan scrub, then dry it with a paper towel

9. Stick the little squares down with super glue in the pattern of the circuit, with power rails made from the initial 5mm wide strips

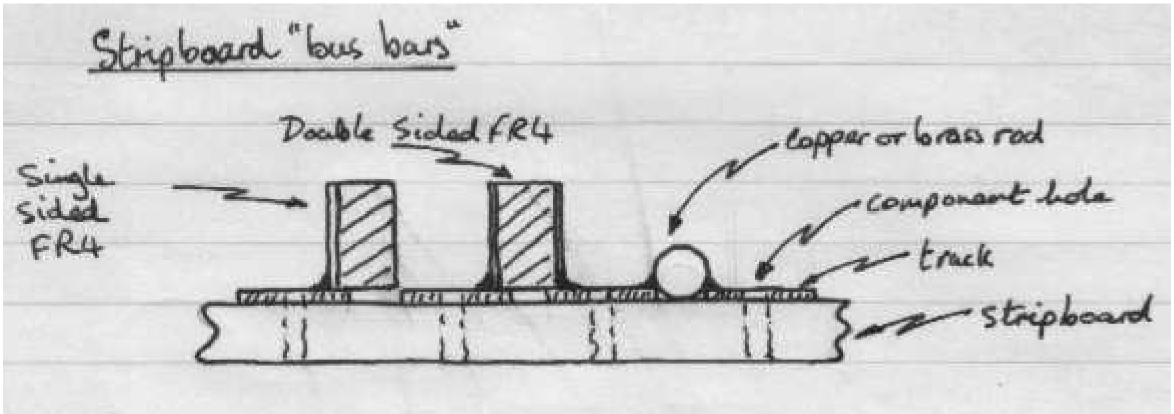
10. Solder up your circuit & test it. Job done...!

Total cost: £1.00 for super glue (and keep some ££'s for replacing kitchen scissors after her indoors sees you chopping laminate with her finest). Easy-peasy!

Stripboard ideas...

The biggest problem with stripboard ("Veroboard" in UK) is that you don't have low impedance power or ground plane "ampacity" for those demanding sections of your RF circuit or audio amplifier output stages. Since we're already in FR4 bashing territory, here's some tips.

Beef up stripboard supply rails with narrow offcut strips of FR4 pcb material soldered edge on to stripboard tracks, as shown below, left and centre. Single or double sided FR4 is fine, if the double sided strip (shown centre) is mounted between + and - supply rails, it offers easy decoupling capacitor possibilities that don't use up any stripboard holes. If you can get hold of some thick single strand copper wire, brazing or silver solder rods, the drawing on the right below will help. It uses two copper strips but is low profile and very neat.



The single sided FR4 sits on one edge of a copper strip; the double sided straddles two strips for plus and minus rails (and gives excellent mounting for 01.µF decouplers without using any stripboard holes); the rod sits in the insulating gap and solders to either side strip for a parallel pair.

If any "holes" get bunged up with solder during the previous operation, a deft touch with de-solder braid or a spring plunger sucker will clear them. The surface tension of the solder will maintain a thin bridge into the reinforcing FR4 copper you're adding. Cut component leads (you do save them in a little screw top jar, don't you?) can be used to support the FR4 too if needs be.

I'm not going to tell you how I found these tips; but it might have had something to do with taming a 100 watt stripboard audio (modulator) amplifier which thought it it was a power oscillator...!

Antenna Topics

Loopy Loops and all that...

https://w8ji.com/magnetic_receiving_loops.htm

W8JI's web pages are where the myths, superstitions and downright rubbish talked about Mag loops are stuffed where the sun don't shine by someone who really knows what he's talking about... and don't forget the idea proposed by one bright spark about the angle to tilt his loop to catch a wave coming down from the ionosphere - the wave comes down at any angle, polarisation, direction: just turn the loop to get best null of noise and highest desired signal. We live and learn!

Note too Chas. Wenzel's superb loop antennas / amplifiers at:
http://techlib.com/electronics/antennas.html

As Chas. shows, no real need for excessive technology unless you absolutely have to, so try much simpler and cheaper designs first! Occam and his Razor - "entities should not be multiplied without necessity" certainly helps stretch a tight (i.e. "zero less 10%") G6NGR budget!

Wave Traps (again)

Are very useful if you're (for instance) near a powerful broadcast transmitter which is drowning out your "wanted" witterings. Even the best receivers won't find fractions of a micro-volt right next to milli-volts of Wah-Wah-Boom-Boom signals from your local broadcaster. Give it a hand... use a wave trap to dump the unwanted (a common theme at G6NGR, as you'll have probably noticed) signals, and you'll soon see the improvement. In fact, a pre-selector can work wonders in many other ways too: it allows your £kilo-bucks black box techno-marvel gizmo to perform in a much "cleaner" environment, letting the real technology inside shine.

Mast Eye Bolts - think twice...

Eye bolts for antenna mast guy fixings are not often the best choice. Why? Because they need holes drilling through the mast that not only weaken the mast considerably, they allow the weather and consequent rot and corrosion to gain a foothold. Far better is a (preferably stainless steel) "U" bolt & saddle car exhaust clamp, as they inevitably have a portion of the U-bolt threaded ends available when clamped tight to fit (M6) tapped lifting eyes on - thus you get two lifting eyes at each clamp position for two guy ropes.

I gained this knowledge from repairing (for the umpteenth time) a roof mounted toxic gas discharge pipe for a semiconductor process; the existing pipe fractured regularly at an eye bolt hole. Even doubling the pipe's wall thickness didn't help; it just made the job heavier and more expensive.

I asked an aeronautics whiz (thanks, Simon) at a factory in North Manchester about the problem and he explained: "it's not just the pipe's brute strength. The whole mast will vibrate in the wind and has nodes of zero and maximum amplitude at various places: in an exposed roof top situation, it will sing like a harp, even though you may well not see or hear a thing - it could well be ultrasonic or infra-sonic. Guying will definitely help, but the weak points are the stress maxima around the eye bolt holes. You'll have no more bother if you use external clamp collars, and attach the guys to the clamp bolts. Use stainless steel thimbles in the guy rope eyes, in "figure eight" knotted loops and at your ground anchors where a clove hitch knot allows easy adjustment yet is reliable on load. You might also try attaching some thin sheet rubber or similar small flexible "flags" to the mast with UV proof cable ties to act as shock absorbers. They help damp out the vibration nodes".

And he was quite right. The only thing I added as extra insurance was bonding the clamps to the mast with bearing securing agent (thank you, Mr. Loctite) because I had some, but epoxy adhesive would be fine for most situations.

Thus the pipe is supported, without any drilling or other weakening, and you get free anchor points for the guys. Stainless exhaust saddle & U bolt clamps are available from our favourite auction web pages at fairly reasonable prices.

Common Mode Chokes?

This topic has been touched on many times; here's some real genuine antenna common sense from the man who knows:

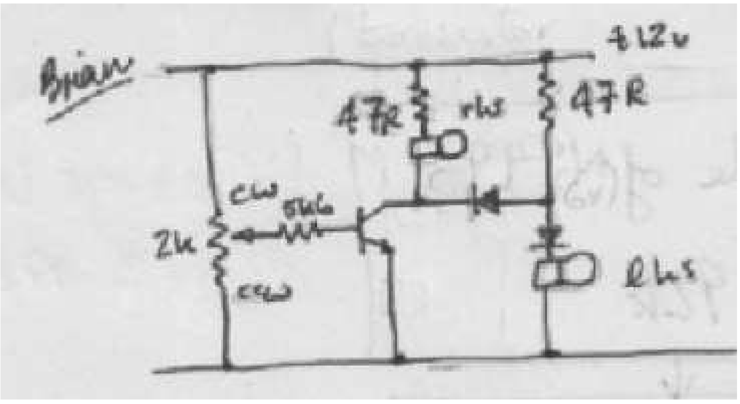
https://www.pa0nhc.nl/CommonModeChokes/indexE.htm

The use of looped counterpoises gives a useful reduction in noise: just as a "loop on the ground" antenna cancels common mode noise, then a "loop" counterpoise(s) has been proposed as doing the same. I haven't tried this, but it's a neat idea that has good reasoning behind it and might be a useful adjunct to common mode chokes and the like.

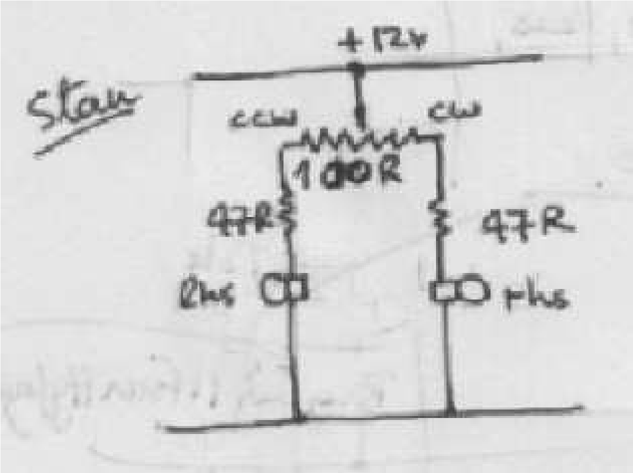
Finis 2020 and Welcome 2021!

Dial Lights...

Here are the circuits for the HP signal generator dial light, from Brian and Stan, as best I can recall them:



Brian built a sort of "OR" gate; as the control pot. rotated clock wise, the NPN transistor "robbed" more and more current from the 47R supplying the rhs lamp. The diode between the rhs and lhs lamp stopped both lamps being half lit when the pot. was fully counter clockwise, and the diode in series with the rhs lamp cancelled the forward volt drop of the other diode when the pot. was fully clockwise. You'll need to experiment with the base resistor (nominally 5k6 with a ZTX300 / BCW10 transistor); it will probably need to be a fair bit higher as you're asking the ZTX300 to perform in a "linear" fashion, not as a switch. 47K wouldn't surprise me!



Stan's circuit is self explanatory; the only comment is that the lamps were a bit dim at the halfway point on the pot. It took a bit of experimentation to get the right value pot., I recall it being 100R but my memory might be wonky!

Endpiece

All that remains for me to say now is I wish you all a very Merry Christmas and a Happy, peaceful New Year - as far as COVID-19 will allow - in this tumultuous World. Enjoy your amateur radio, remember we do this for enjoyment and self learning, so don't get too seriously involved - leave that to the professionals! But... try your ideas, experiment with circuits, **keep notes of everything** - including why and how it didn't work as well as the amazing results you never expected.

Don't decry historical research, we have in silicon technology more electronic capability today than our predecessors could dream of; though you can bet somebody, somewhere dreamt up your bright idea years ago, but didn't have the technology, opportunity or resources to fulfil it. You DO!

Keep asking "why" on every topic of amateur radio and the Universe you use it in, until you've found the definitive reason. More than anything else, whatever you build or try, keep it simple, robust, and fun: you learn by trying and try by learning.

If it's a nice day, unplug that soldering iron and go climb a mountain, or ponder on what an electron *really* is, but most of all, marvel at the wonders of Nature.

Good luck for 2021!

Peter Thornton, G6NGR

Hot Iron #111

Table of Contents

CQ-CQ-CQ

Software...

I have yet to come across anything (in my blatantly biased opinion) as ridiculous as the software "features" built into modern electronic equipment - be it amateur radio, photography, broadcast radio receivers, even fridges and freezers are now among the afflicted. Nobody, but nobody, likes sieving through stacked menus and selection tables, impossible in a rush: a control panel is far more pleasant with simple knobs to twiddle. Stacked menus, in the rush of the moment trying to capture that fleeting moment, that elusive Brocken Spectre of ephemeral fading voice, a dozen menus to navigate is exactly what you **don't** want, need or desire.

Not only is every electronic gizmo set up with umpteen menus and commands, there is no standard structure to the menus - so you have to learn a different system for every gadget you have. How does that help a customer? Answer: it doesn't!

Modern 'software' is verging on the ridiculous. Features you'd never use in a lifetime, added by some "disrupting" motivated irk (I suspect with nothing better to do) who thinks 'more is better, biggest is best': then promptly adds another abstruse function that only a "left handed non-smoking pole vaulting lemon squeezer" could possibly require - in his child-like determination to find yet another menu full of pointless adjustments that only serve to multiply confusion and irritation.

Mind you, that's not to say the knobs on the front of an AR88 didn't need dextrous hand movements to get (and keep) that contact - but get it they did, under the pressure of wartime too, in their original application. Having cut my teeth on electrical / electronic equipment featuring and using some of the most toxic substances this wonderful planet can create to make the twopenny transistors and diodes we happily use by the bucketful - as well as the hundreds of millions in a modern CPU chip - I can say that "simple is best"; robust construction and open, accessible chassis are the ONLY practical means of creating reliability with maintainability.

Many machines I worked on, either routine servicing or breakdown repairs, had computer controls, and mimic displays showing temperatures, set points and the like: one absolute I noted in my 50+ years of "active service" was that machines controlled by industrial PLC's (Programmable Logic Controllers) were more robust, reliable and faster to fix ("mean time to repair" is part of Production statistical process control) than the machines equipped with a PC running control software and interfacing to the real world via opto-isolators and miniature PCB mounted relays. The machines that ran, year in, year out, in the demanding semiconductor processes (I'm thinking of Vapour Phase Epitaxy, deep N layer Arsenic Diffusion Furnaces and Plasma Etch) had big open frame relays (with hefty contacts that could be cleaned up with a file); modular control units that could be interchanged in minutes; and simple interconnects with multipole "Mil-Spec" circular connectors that screwed together and had proper cable clamps - that would hold until the cables themselves parted.

The Test Hall was a mixture of discrete logic control, PLC's and Office PC's. The PC's were cheap, cheerful solutions; the high speed machinery used dedicated industrial PLC's running maths algorithms, but the real stars were the discrete logic controlled test stations. Utilising simple, fast logic - the "RISC" philosophy - these beasts might not have been easily adaptable to every device we made, but by jingo, would crunch a huge amount of throughput in a night shift. The only job in the morning was to empty the product bins to stop them overflowing! The sight of 25 million transistors in a bin is a nice way to start the working day!

The key feature of all this is SIMPLICITY, which gives reliable results. You're paying a hefty price for all the unused Bells and Whistles in modern amateur radio equipment. Oh, sure, it might have an edge on odd occasions - but, as Bruce Vaughan NR5Q comments in his book "Surviving Technology" - his Ultimate Regen receiver will receive at least 95% of the signals your mega-bucks commercial receiver can. We are Amateurs, after all, not professional listening stations, funded by Government money!

Occam's Razor is alive and well at GW6NGR; KISS technology is reliable, fixable, a pleasure to use. I would tactfully request that all manufacturers of electronic gear keep this in mind: the law of parsimony states that "entities should not be multiplied without necessity" in the design of their software. After all, how about thinking of your customer first, or is that a bit too "disruptive" for you?

Small is Beautiful?

E.F. Schumacher went to great pains to explain how technology has debased human creativity and more or less destroyed 'job satisfaction' in his book "Small is Beautiful". Technology diminishes the human appreciation of time well spent; it removes the human element to a great extent and offers convenient, but very limited, mental satisfaction to the user.

Think on this applied to your home constructed radio receiver. It might not have all the features a "bought in" receiver offers; it may well struggle to equal the capabilities, or the diversity of functions. But - and it's a huge 'but' - YOU made it. YOU put it together. YOU can modify it, improve it, try different approaches. It's YOURS, and belongs - in every way - to YOU, not some distant designer who's Muntzed the d*mn thing down to the lowest price, used midget components only a robot can manipulate, and needs a trained microbe that can solder to repair the blasted thing.

If you think surface mount components are a bit tricky, wait a few years hence until they are one tenth the size. Whatever you do, when using a "speck of dust" component, is don't sneeze! It gives an interesting view of the future when, to construct a simple circuit, a lab. standard microscope will be required; and how do the designers of ever shrinking components believe, will a less able, or less financially capable user, be able to work with them? Don't think that SPICE and similar software simulations will rescue you: software can't represent the real world surroundings of your circuit, and all the ill winds they might blow over your design!

Semiconductor manufacturers are looking at solder down dies, and even smaller programmable structures, so pcb manufacturers (that's you and me, in our amateur context) will need semiconductor assembly wire bonders to connect the components. If enough people want "through hole" parts, in sizes that humans can see, handle and rework, semiconductor manufacturers will make and sell them - IF you want 10 million next week, and every week thereafter. They do actively listen to customers and will fill a need if there's money to be made, but keep to mind it's a full production facility that has to be configured - and if the trend is towards smaller scale devices and more integrated construction technologies, the semiconductor manufacturers want their factory space for that, not "ancient technology" like through hole devices. There just isn't the profit in these old technologies with their lead frames, tin plating baths, testing via hard wired connection (not electron scanning) and money stuck in "Work in Progress"!

Take, for instance, the demise of the amateur's best friend, the RCA 40673 dual gate mosfet. It's relatively simple (as shown by Pete Juliano N6QW recently) to stack jfets in cascode to substitute a 40673.The only drawback is the vast spread of characteristics inherent in jfet's: you're almost certain to have to fiddle with the biasing to get the best from a jfet 40673 substitute.

That said, I sounded out a few contacts in the semiconductor industry and was pleasantly surprised to find there is a small manufacturer fitting SMT 3N211 dual gate mosfets on micro-pcb's as pin for pin compatible replacements for 40673 dual gate mosfets. Dual gate mosfets represent major simplification for radio amateurs, delivering excellent performance mixers and easy practicality. They disappeared primarily because semiconductor manufacturers didn't see enough demand for them in tin can through hole packages, which represent (in comparison with SMT devices) a much larger manufacturing cost. Any reasonably priced alternative would be a new opening for radio amateur constructors. I shall be following this up; and would welcome your comments. If the demand is there, I'll see if I can discover more information.

On a similar topic, one of the specialities of the old textile industry in my home county of Lancashire is the specialist manufacture of springs: used by the million in the textile machinery of yesteryear. Spring winding is an art identical to inductor stock manufacture: many varieties were once available to amateurs in years gone by, ("AirDux" for instance) but nowadays rarer than hen's teeth. I asked a leading Rochdale spring manufacturer about winding hard drawn copper or brass wire to make "standard" inductor stock: he thought it eminently "do-able" so long as the wire was of sufficient diameter and hardness. He suggested an internal diameter of 50mm, minimum, a wire diameter of 2.5mm - 3mm, in tight coiled lengths of 100mm. These could be easily manipulated by home constructors, cut, stretched, and supported using epoxy resin "bars" like the old AirDux style. If Hot Iron readers would comment I'd be very grateful - who knows, it might be a new chapter in amateur radio construction?

Bloggety Blog...

Ryan Flowers has asked me to mention his Blog at miscdotgeek.com so I have! Take a look, lots to see, and plenty of useful ideas too.

I had a very kind email from Tom McKee, K4ZAD; he asked if I could mention his pages. I will with pleasure!

http://www.radio.imradioha.org/DIY_Coil_Calculators.html

http://www.radio.imradioha.org/PC_Based_Test_Gear.htm

http://www.radio.imradioha.org/Manual_Sources.htm

These contributors are at the core of modern amateur radio construction and I think should receive the accolades they so richly deserve.

A brief note...

I'm now ensconced in my new home in West Wales, out on the Lleyn Peninsula. I'm surrounded by boxes, bales and bundles, and slowly getting back to civilised habitation. I don't have the facilities or easy access to materials (yet...) I enjoyed at my old house, so I apologise for the somewhat abbreviated Hot Iron presented here, and any typos you might spot. I have vast amounts of work to do on my house: getting the roof watertight and some form of heating, it's -2°C outside as I write! I will be up to speed hopefully within 9 - 12 months; much to do, trees to fell, walls to repair, drains to dig, not to mention the bills and final demands from my old address - all of which require attention. Please bear with me, normal service will be resumed as soon as possible!

Particular thanks go to the contributors who sent me articles for inclusion. It really is refreshing to hear from you constructors: no matter how simple or (apparently) old fashioned, every item for inclusion is valued and appreciated. More, please!

Rx Topics

The Audio Cube, by Alan Victor W4AMV

As most of you know, I favour a modular approach to radio equipment construction. It offers the opportunity to "cut and try" in a known environments and structure, so improvements (or otherwise) can be readily assessed. I had a very interesting email from Alan Victor, W4AMV, about his modular approach - and it ticked the "keep big signals away from the little 'uns" approach I like too. Alan has split, in old fashioned (i.e. proven) valve style, the audio output and power supply from the low level RF sections of his projects. I particularly like the twin op-amp filter of adjustable centre frequency and "Q" - it's a very neat circuit indeed. His article is below:

The AUDIO CUBE, Alan Victor, W4AMV

The AUDIO CUBE is an integrated assembly consisting of a high current power supply, audio power amplifier, active band pass filter and speaker. There is sufficient room in the chassis layout which is made up of left over bits and pieces of wood to add options. The filter targets narrow band pass applications for CW and has adjustable center frequency and Q. Their settings are independent and they do not interact, a nice feature. Filter details are discussed in Williams text [1] and simple equations are presented here. The filter structure is referenced in the literature as the Dual-Amplifier Bandpass or DABP structure for short. A single op-amp featuring dual amplifiers like the LM358 makes this filter an easy one to duplicate.

The goal of the assembly is to dedicate the audio processing chain in one package which could be used with any receiver on hand. The electrical assembly of the cards prompted the AUDIO CUBE name, as the final assembly takes on a 3-dimension cube form. The power supply card serves as the mother board and the audio filter and power amplifier cards are mounted vertically at right angles on the supply card. This makes a nice compact assembly, measuring 4x4x4 (10.2 cm) inches on a side. A picture of the electrical-mechanical assembly is shown in figure 1 while the finished front view of the housed unit is seen in figure 2.

Figure 1: Inside top down view of the AUDIO CUBE

The speaker enclosure houses a 3 ½ inch (8.9 cm) 4 ohm Infinity ™ speaker capable of 25 W rms power. The card nearest the speaker front panel is the filter card, to the left the audio power amplifier, a TDA2040 operating at 15 V. This amplifier is capable of 30 W audio output but limited to 5 W peak at 15 V supply. The amplifier heat sink is the center horizontal finned unit. The power supply card and main supply filter capacitor are just to the right of the amplifier heat sink. The line fuse is mounted on the left side wall. The power transformer is in the rear. The enclosure is made from ¾ inch (2 cm) thick MBF wood, quite dense and makes an excellent speaker housing. Because the front panel is thick, mechanical

Figure 2: Front view of the AUDIO CUBE.

The controls bottom are ON/OFF, filter bypass and external internal speaker switch while the top row provide control for filter Q, center frequency and volume.

mounting of control shafts is difficult. Hardware provided for mounting controls such as toggle switches and potentiometers will not work. You can counter sink the rear panel, cut out an area to mount a plate on the front or attach the controls from the rear with a mounting plate. This is the method I used and I fashioned a plate from some scrapes of PC board material. I thick this provides a cleaner look to the unit.

The enclosure outside dimensions are 8” x10” x11” (20 x 25.4 x 28 cm) inches and has a spacious bottom chassis area below for added circuits such as wider band filters if desired for SSB and AM audio enhancements. The DABP filter is capable of a wide range of Q and center frequency adjustments. The current design is set for approximately 400-to-1000 Hz center frequency with an ajustable Q of 3 to 50. Q values in excess of 100 are easily achieved as well as cascading multiple sections. The power supply is capable of high output load current without affecting audio distortion via power supply voltage clipping. The audio amplifier is built around a TDA2040, however discrete or other integrated circuit designs are quite capable. The main feature they should provide is low distortion and hum rejection. In operation, the AUDIO CUBE provides the enhanced Q multiplication audio effect of a narrow bandwidth filter. That chacteristic of low level hollow band limited noise power, reminiscent of high Q filters is apparent. However, there is no ringing. Schematics are shown in figures 3-through-5 and simulations provided by Spice are very helpful in finalizing the design. Shown are power supply, power amplifier and DABP schematics from Spice.

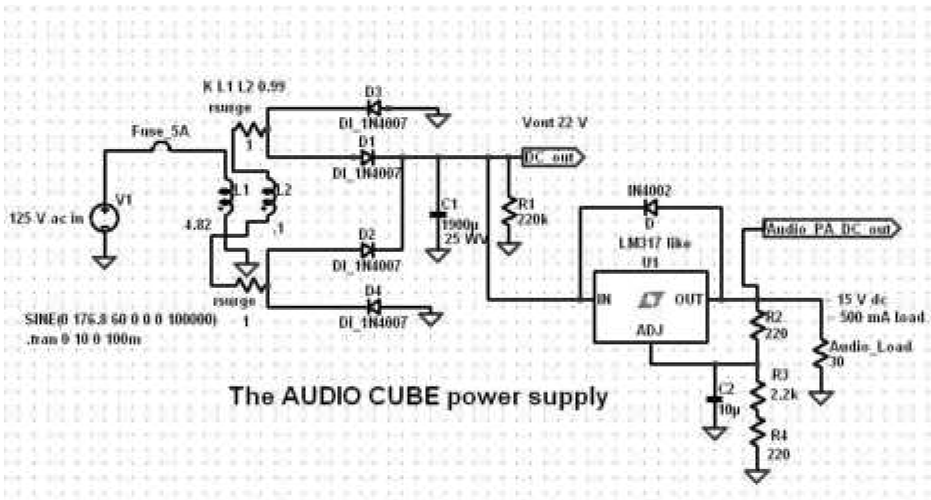


Figure 3: Power supply 15 V over 1 A capability

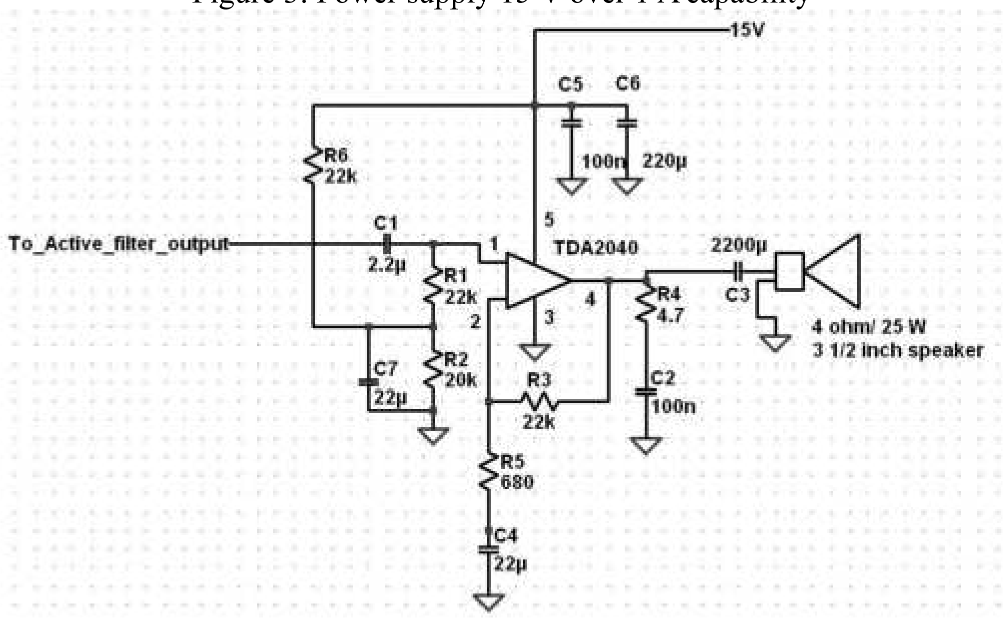


Figure 4: AUDIO CUBE Audio power amplifier, TDA2040

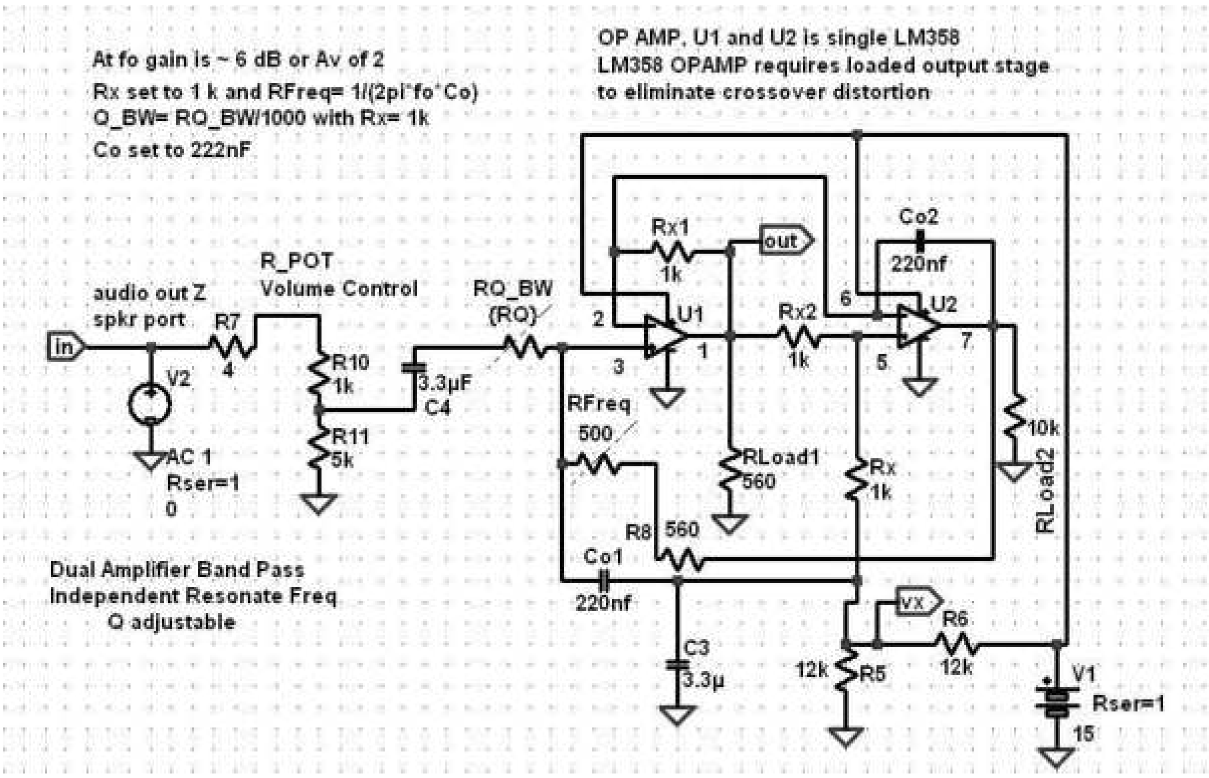


Figure 5: AUDIO CUBE DABP filter structure

The simulations for the filter response are collected herein and compare very well with bench test operation.

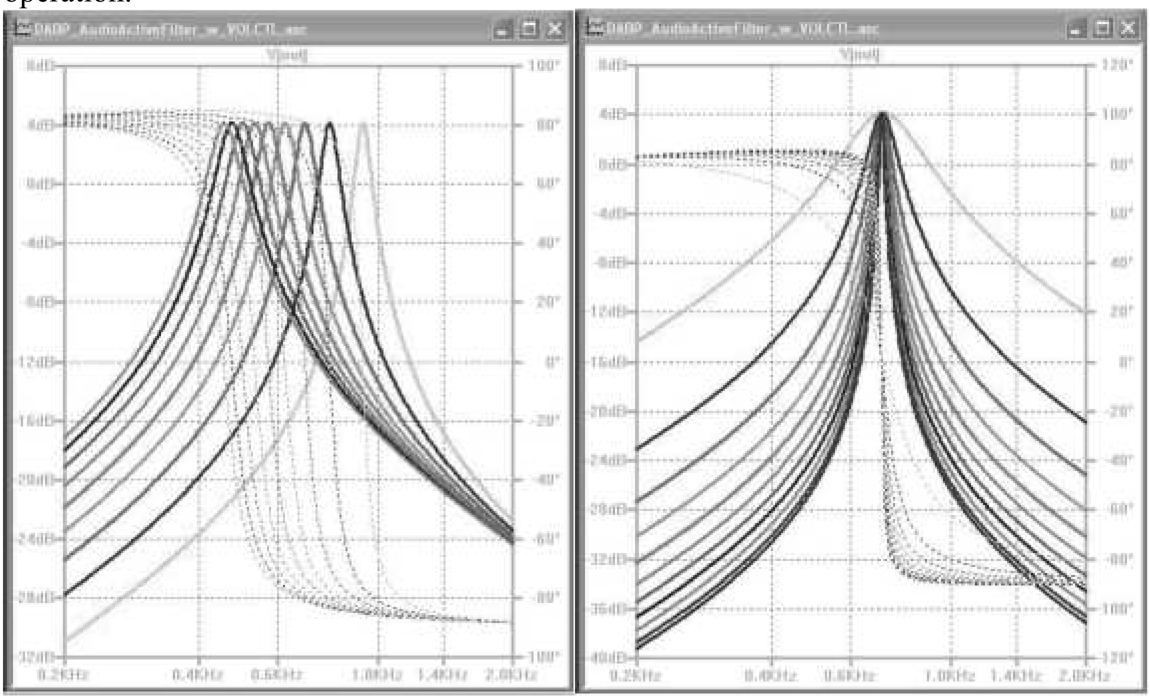


Figure 6: Filter center frequency sweeps and Q, bandwidth variation at 750 Hz.

DABP Design Equations:

Reference to the DABP schematic of figure 5, resistors Rx, Rx1 and Rx2 are conveniently selected to be the same value, all 1k. If (RFreq+R8)(Rx1) = R^2, the following design equations can be obtained:

(RFreq+R8) = $1/(2\pi * f_r C_{01})$ where f_r is the center frequency and again for convienience, the capacitors are chosen to be equal; $C_{01} = C_{02}$ = 220nF in my case.

The R8 value is selected so as to limit the min and max center frequency range.

And **RQ/Rx1 = Q** and with RQ varying up to 50 k and Rx1 set to 1k, Q max limit is 50.

This filter center frequency is variable from an approximate frequency of 1200 Hz down to 300 Hz if RFreq potentiometer varies from 0 to 2k ohm and $C_{o1,2}$ are 220nF.
Meanwhile the Q is adjustable to a maximum value of 50 with the RQ_BW potentiometer set to a maximum value of 50 k. This is implemented with a 10 turn helipot.
Note, if a single supply operation is desired, than the filter grounded nodal components, Rx and C_{o1}, must be returned to an AC bypassed node, schematic reference point Vx. At this node, half supply voltage is provided.

References: Arthur B. Williams, *Electronic Filter Design Handbook*, McGraw Hill, 1981, pp. 5-46,5-48.

An updated Spontaflex receiver
Can be viewed at:

https://www.transkommunikation.ch/dateien/schaltungen/diverse_schaltungen/radio_circuits/Spontaflex%20550khz-30MHZ%20Receiver.pdf

The designs of Sir Douglas Hall - regenerative and reflexed receivers - is the interesting topic outlined in: http://theradioboard.com/rb/viewtopic.php?t=7906

(with many thanks to "Radioboard").

These designs are perfectly capable of excellent results, not only on A.M., but SSB and CW by virtue of homodyne oscillation set by the regeneration control.

They are, in essence, frequency selective shunt feedback amplifiers, with RF feedback to create the regenerative function, and AF feedback (which uses RF and AF stages) to selectively amplify the audio. Only the vast difference between the RF and AF frequencies allows the signals to be simultaneously passed through each stage; however, if the RF was much lower then the two signals would need some very nimble "footwork" to separate the frequencies, nullifying any advantages - but reflexing a low bands regenerative receiver would make a very interesting and simple receiver for local and middle distance amateur communications.

A different approach to 2m FM?
(NOT a Super-regen, a superhet using ONE transistor!)

I was talking with an old friend who was waxing lyrical about the days of "Top Band and 2m A.M. nattering" and the ultra simple ways it could be done. Roger Lapthorn's (G3XBM) "6-Box", his version of the 2m cross town "Fred Box" of yesteryear, is a beautiful example of the art. Every radio rally or junk sale used to have a Top Band (and / or 2m) "talk in" service for out-of-town guests, and why not?

We have bands available, which allow different modes, so why not Top Band NBFM / Phase Modulation, for instance? I've always had it impressed on me by old established amateurs that to preserve amateur bands they need *using*; neglecting them is an open invitation to losing them. So long as we stick to our licence conditions, don't cause unnecessary interference, then off you go!

One transistor superhet? Take a look here:

https://www.google.com/search?q=Superheterodyne+receiver+with+one+transistor&newwindow=1&sa=X&rlz=1C1SQJL_roRO82

9RO829&biw=1280&bih=625&tbm=isch&source=iu&ictx=1&fir=fGv6UWzXKdfCOM%253A%252CgwXJCKeUoO1MdM%252C_&vet=1&usg=AI4_-kQbNjh4stya7KGAgrJIqGYCQ05NwQ&ved=2ahUKEwiP_c2a1NLhAhWKpYsKHSuwBzQQ9QEwA3oECAgQCA#imgrc=5NVF-7kbIbc4gM

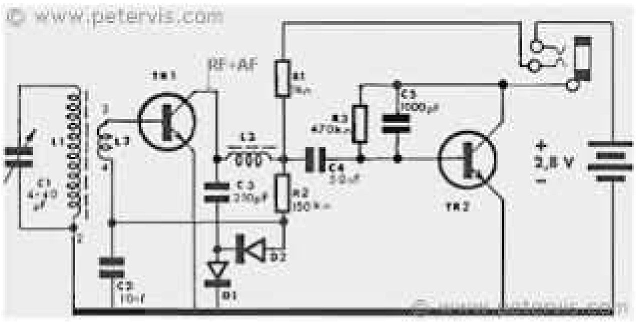
...all very interesting circuits - unfortunately no write up, but hey - experimenting with ONE transistor, what more do you want?

I admit trying to get a recalcitrant one transistor self oscillating squegging circuit running can be VERY frustrating, though. The FM receiver on this page struck me as being very simple; admitted, this is no “DX’er” but for local QRP fun, this has got to be worth an hour or two experimenting. Take a look at some of the other circuits too; some lovely little “dabbling” suggestions!

On this theme, take a look at:

https://www.petervis.com/Radios/Radios.html

...where you’ll find items like this:



Now ain’t that a cute little receiver for 160m, 80m or 40m A.M.?

Now an item from Rick Andersen, KE3IJ; a man from whom I have learned a great deal, and admire his simple and lucid approach. The idea of reflexing a receiver is a very useful way to get the most from a simple design. This would make a superb little Top Band natter box receiver; now if someone could design an efficient, small and light 160m portable antenna, that would be very just the job! To see what I mean... take a look at:

http://www.ke3ij.com/reflex.htm

I’d advise you to have a good trawl round Rick’s pages: good RF engineering on every one of ’em.

Tx Topics

Amplifier classes...
...apparently baffle some amateurs: so some simple notes to explain the “why and wherefore” are included.

A few facts, often missed, are in order here. A class A audio amplifier will give you the lowest distortion; but it will still distort. It is NOT a perfect amplifier! Gets very close, mind; but a properly designed class AB will be nearly as good you’ll never notice the difference.

Class B is where the output stage(s) have no standing current: the power devices switch on at each half cycle, but you get cross-over distortion - so allowing a sniff of standing current in the power devices helps eliminate distortion and is described as Class AB.

Class C is the well known RF technique: ensure you use high Q inductors in the output resonant circuits to get the best efficiency.

Class D is a pulse width modulation technique: very efficient, and low distortion; but it has the dreaded digital clock syndrome, where you have very high speed digital edges within and is just asking for trouble. The interference and edge issues are beatable, but the apparent ease and simplicity of the principle vanishes.

Below are some links and information:

Audio: https://sound-au.com/

A,B,C,D, and F => https://www.electronics-tutorials.ws/amplifier/amplifier-classes.html

E => https://people.physics.anu.edu.au/~dxt103/class-e/

E => http://www.wa0itp.com/class%20e%20design.html

(includes MOSFET characteristics in the spreadsheet)

Just fill in your requirements, power, supply volts, device, and the job's done.

Audio Topics

Analogue Switched capacitor filters

These little beasties promise superb results from one chip: varying the clock speed shifts the filter "pole/zero" characteristics, but - yes you guessed it - if it's got a clock then it's a source of digital noise. Another reason to split the RF bits and Audio / Power Supply methinks?

A typical example of this technology is the MAX291 family; I have no particular recommendation for Maxim, other makers devices are available, but I find the data sheets from Maxim are very easy to follow. The MAX291 offers an 8 pole filter network, configurable to Butterworth, Bessel and other filter characteristics: you pays your money and makes your choice.

But... and it's a big "but" - it needs some amateur experimentation here. Let's see one of these in an amateur receiver as a bandwidth defining speech processor for SSB transmitters. Anything with a digital clock is an uncomfortable passenger in an analogue system!

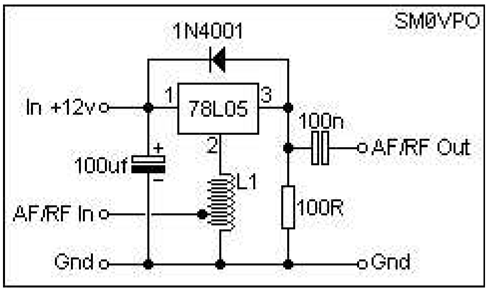
Power Supply Topics

The design of a power supply is usually relegated to the end of a project; it's normally thought of as a given - but this can land your in some real bother! A power supply must not just provide the amps and volts: it MUST be fast enough to cope with any sudden changes in load, either increasing or decreasing. Linear circuits, like op-amps, simple audio amplifiers and the like - rarely have sudden load changes, but if you have anything remotely "digital" you need to think carefully about your power supply and supply rail decoupling. It's all well and good having 0.1 µF disc ceramics scattered around; low series resistance electrolytics are a good idea too. These energy stores have to be refilled after any sudden load changes; and this is where amateur power supplies can fall down.

A technique called ‘step impulse testing’ is how designers check power supplies, as well as testing ampacity, voltage stability and regulation. The “gulp” power supply tester is the tool to use: this uses power mosfets to suddenly (in 10’s of nS!) apply a full load. The current rise characteristic is monitored to ensure the series impedance is low enough to eliminate resonances, formed in the series inductance and stray capacitance of the power supply’s internal wiring.

The moral of this tale: build your power supply as if you’re making an HF linear amplifier. Short, straight and wide printed circuit tracks, thick copper wire, far heavier than just the requirement to carry the amps without excessive volt drop. You have to get the energy out of the storage electrolytics and into the load with minimum time delay - and most im[portantly, without inductive resosnances, which cause over-voltage problems.

Of course, the regulator circuit must be fast, too: you’ll see some HF linear amplifiers that actually use a voltage regulator! Below is one design from Harry Lythall, SM0VPO:



I was responsible for maintaining an Ion Implanter in my previous life; this required a regulated power supply to heat the ion source filament: a 2.5mm diameter tungsten rod, 75mm long, to 1300°C. To get a little longer running life from the filament (it erodes due to sputtering and back electron bombardment) I adapted the power supply: the power supply eventually ran out of volts to drive the increased resistance of the filament when it got very thin. I couldn’t change the transformer or the physical structure of the power supply, so, I found some Schottky diode rectifier modules that were a one-to-one replacement for the PN junction power rectifiers. Schottky diodes have lower forward volts drop than a PN junction: changing to Schottky diodes not only got me 10% more filament life because of lower volt drops in the rectifiers, but cooler running which gave more reliable performance.

If you need reliable low voltage power rectification - consider Schottky rectifiers. They cost more or less the same as PN junction diodes, but give you far less rectifier volt drop.

Component Topics

Using DC bias to adjust toroid inductors

Following the interest I’ve received regarding magnetic amplifiers, I thought about L/C resonant circuits with DC bias applied to the toroid core forming the “L” component. I found some references that suggest this is indeed a practical and useful function, following the theory of magnetic amplifiers. The introduction of a DC bias component allows the inductance to be *reduced*; sorry, but I can’t find any way to *increase* the inductance by DC injection! The obvious thing to do is add a few turns more than the calculated number, and use DC bias to “back off” excess inductance. Obviously this can’t be taken too far; the core will saturate: the inductance - and “Q” - will rapidly diminish.

https://www.mag-inc.com/Media/Magnetics/File-Library/Product%20Literature/Ferrite%20Literature/cg-01.pdf?ext=.pdf and page 3 of https://www.vishay.com/docs/49782/49782.pdf indicates any core can be adjusted down on inductance by applying DC bias.

This idea of DC bias to shift the operating point along the magnetic B-H curve of the core material has, perhaps, a hidden caveat when you're building a simple 5 watt QRP transmitter that employs a 12 volt power supply. It's common practice to use a centre tapped bifilar output transformer to feed DC into the collector (or drain) of the power device and match the resultant ~12Ω collector (drain) load impedance - the power device biased to a nominal 1 amp current - to a 50Ω load. Keep to mind that the core you've used for the output transformer has to carry the 1 amp device current.

A.M. advocates will recognise this problem, it's traditionally overcome by adopting Heising Modulation. This (in essence) uses an RF choke to feed DC into the power device, and capacitor couple the bifilar output transformer to the collector (drain) side of the choke. Thus DC is eliminated from the matching transformer, at the expense of an RF choke that carries DC. The collector (drain) "Heising" choke doesn't need to be too large an inductance, though: otherwise you're asking for spurious / parasitic oscillation in the choke. Better to err a touch on the less inductance side than too much.

Sometimes, it's less costly...
To buy ready built assemblies for home construction. Take a look at:

https://www.ebay.co.uk/itm/10X-Pre-wired-Mini-Toggle-Switch-ON-OFF-Control-for-Car-Emergency-Lighting-B2Z/233692719260?hash=item36692be89c:g:6G0AAOSwa55cKbaV

I couldn't buy the bits to make these up for that price! What I don't know is the electrical specification; but for anything under 50v AC or 70v DC and an amp or two, they will be fine.

Construction Topics

Video training and demonstration
It can make life much easier if you are shown how to build something, either person to person or a video showing the how and why of the assembly. Some years ago I was involved in training Eastern European operators who had no grasp of English how to assemble pcb's; to surmount the language barrier, we video taped a skilled operator completing the assembly, carefully and slowly, illustrating the critical steps. If the trainee couldn't quite grasp the particular step, they could "rewind" the video and see the step repeated over and over - and in freeze frame too, so the exact detail could be studied. A video monitor set up over the benches meant that no language was required: the operators very quickly picked up the assembly procedure and production went at a very fair clip - the video scheme is still in use at the production plant and has being developed for many other tasks in the factory.

Stripping parts and wiring
Microwave ovens provide a host of useful "junk". The wiring - in all the m-waves I've dismantled - had radiation hardened PVC wiring ("poor man's PTFE") high temperature cables, Molex type connectors, HV capacitors with inbuilt bleed resistors, mains input filter modules, microswitches and HV diode(s), not to mention miniature lamp holders and those whopping HV transformers. All

these parts are grist to the mill for the home constructor: grab every scrap m-wave you can and strip it to the bone.

Scrap washing machines can be stripped too; they have yards of superb quality wiring inside, many wires terminated with ¼" Faston crimp push on connectors for easy assembly, and chunky mains filters capable of running many amps. They would cost a fortune to buy - so don't let these treasure troves escape your salvaging. Modern brushless drives also feature HV MOSFET power bridges, or BiCMOS power devices - ideal for HV jobs of all kinds. You'll not regret it!

Copper connecting straps

It's often far better to use broad copper straps, between hefty brass bolts with brass nuts and washers rather than a toggle or slide switch - especially if you're dealing with more than 5 watts. The simple combination of L & C in a 'L' tuner is one of radio's earliest and most reliable antenna tuners that can easily be reconfigured between series or parallel connection of the L and C elements, by using copper links and brass bolts. An L tuner, given enough turns on the coil and wide enough spaced variable capacitor will tune almost anything that conducts electricity to resonance and match almost any transmitter to a load.

Finding hefty copper strap, however, is not a easy or cheap task. Flattening copper water pipe is a possibility, but after a severe battering those pipe sections don't look pretty. "Pretty rough" is more like it! You might find copper sheet / strip in roofing suppliers; it's sometimes used for flashing strips and flat roo sheeting, as it can be soldered so readily.

A useful substitute for solid copper in this job is double sided 2oz. copper (or if you can get it, 4, 6 or even 8oz. copper) FR4 pcb material. I recall the Applications Laboratory design engineers scrounging from a sister factory some 6mm thick single sided FR4 material; this had 8oz. copper and was used to make stripline kW microwave equipment to test a proposed new range of high power FET's. The offcuts were voraciously grabbed by those in the know to make stable VHF super-regen receivers (radios were banned in the factory as being a "disruptive influence"). The 6mm FR4 was so rigid and stable, the receivers, despite being of the simplest designs, would hold a station rock steady for days on end without retuning (a lesson for regen. receiver designers: make it as rigid and solid as possible).

Of course, the HV capacitor is the "elephant in the room". Tuning high power RF systems into random antenna structures inevitably involves high voltages: Nikola Tesla strikes again. The Applications Lab. engineers had a sure favourite for fabricating high voltage capacitors: finned heatsinks. You can get these with wide fin spacings, they are easy to machine, drill and tap. Mesh a couple of these together on some simple mechanical sliders (nested aluminium angle sections make a good linear slider) and voila! You have a kV rated variable capacitor. If you're pushed for space (and money!), use just one heatsink, and assemble the other "plate" out of pieces of double sided FR4 material, stacked using spacers and brass studding. The main electrical connection to the FR4 "plates" should be a wide strap of FR4 material, soldered to each "plate"; I don't like the idea of relying just on the studding, especially 40m and above. All you have to do is set the heatsink up on a base and rig a simple mechanism to engage the "plates" together. Get a rough idea of the available capacitance by calculating 8.85 x (plate area) divided by (plate separation) = pF's, all dimensions in metres or sq. metres ($\varepsilon_o.\varepsilon_r.$ A/D in Farads)

Don’t be tempted to use insulation between the “plates” in a capacitor that’s carrying kW’s of RF. As my mentor Stan told me “for kW’s of RF, you can’t beat clean dry fresh air as an insulator. Cheap and plentiful... and it don’t catch fire with Tan δ (delta) losses”. There speaks the voice of experience!

VXO’s...
It’s not commonly known that the metal cover of a crystal, when used in a VXO application, should NOT be earthed - as is the usual practice for a fixed crystal oscillator. Why? Because removing as much stray capacitance around the crystal gives more “pull”. I can’t guarantee extra kHz, as it depends on the surrounding construction and the cut of the crystal, but it’s so simple it’s worth a try.

Another method of adjustment that might get you that bit further is to run the VXO from an adjustable voltage regulator; varying the supply will shift the frequency too. Often forgotten too is that an overtone crystal, run on it’s fundamental frequency, usually has much more “pullability” than a fundamental crystal.

Test Gear Topics

Febetrons & Marx Generators for RFI proofing
I once had the onerous task of maintaining laser marking machines that burned part numbers into plastic bodied transistors, by firing an IR laser via a text “mask” into the little beasties at a rate of 80 or so per minute. Ablated marking is very much more robust than printed ink marks, but... it had an “interesting” effect on the test equipment in the Test Hall nearby. The laser marker used a miniature Febetron to power the laser: most folk have never heard of Febetrons (or Marx Generators, from which they are derived) these being beasts of high energy research and the like - these devices can rip protons apart (if you build ‘em big enough - and inside a mountain). They use a triggered spark gap to initiate the main pulse: 25kV, 100 amps for ~10 nanoseconds.

A miniature version would be an ideal gadget to see if your designs can withstand RFI; before we tamed the Production beasts, we could draw fat 2” sparks to a screwdriver from the earth bonding braids! I’m not giving any designs or drawings for these devices: if you want to play “big boys electronics”, the kind of energies nuclear research indulges in, you’ll have to look them up yourself!

We ended up building a lined room around the machine, using 18swg aluminium sheets, pop rivet jointed, and 12” wide strips of aluminium from the machine’s copper earth bus bars - which ran all round the machine frame - to the screened walls; these connected to earth spikes spaced every foot sunk through the concrete floor into 12’ deep earth pits, connected with multiple 12” wide aluminium strips. That stopped the Test Hall adjacent from complaining about “odd” behaviour when running leakage tests; but when 500 amp SMPS’s in the nearby electro-plating shop blew up for no apparent reason, my mentor Stan thought it time to get the local electricity supply engineers involved. They set up distributed lightning arrestors and quench capacitors at appropriate points in the plant’s distribution system, which solved the problem! See:

http://www.electricstuff.co.uk/marxgen.htm & https://hibp.ecse.rpi.edu/~leij/febetron/febetron.html

Antenna Topics

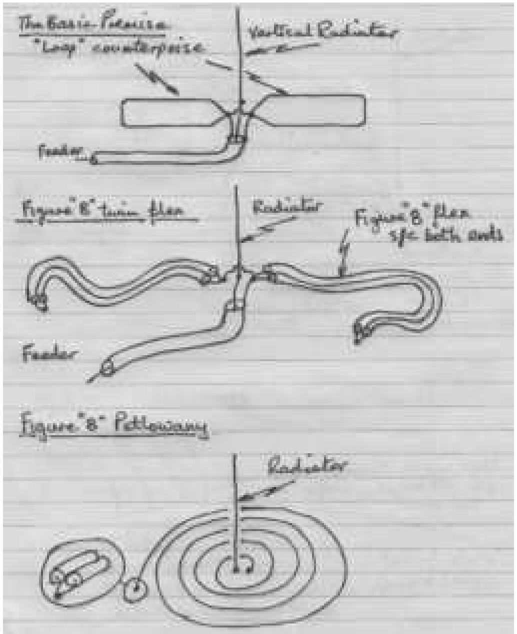
Home made HV Capacitors (again)

A home-brewed well engineered approach to high voltage capacitors can be seen at http://www.ta1lsx.com/high-voltage-diy-air-capacitor-for-magnetic-loop-antennas/, and I thank TA1LSX for his superb professional standard approach. Of course, the principle can be adapted to heatsink capacitors mentioned previously for use in hefty "L" section ATU's.

TA1LSX design is for his small transmitting loop, nicely engineered and functional.

Loop Counterpoises

I have been told of some rather novel counterpoise experiments that use short circuited loops of wire rather than single wires of λ/4 and the like set up beneath a vertical radiator element that on reception, outperform all expectations - on the lower bands, below 7MHz at any rate.



It has always seemed a bit of a oddity to me that we spend any amount of effort in the "radiating" bit of an antenna as it is suspended, cut, trimmed and generally laid out in a tight geometric form: yet the counterpoise, forming the return path to the transmitter, is any old bit of wire strewn about in any manner that will fit. Common savvy surely says the counterpoise should be aligned with the radiating element(s)?

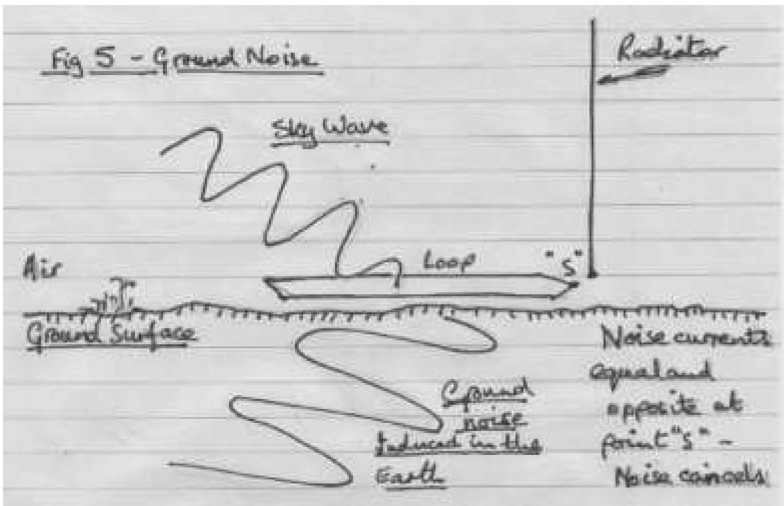
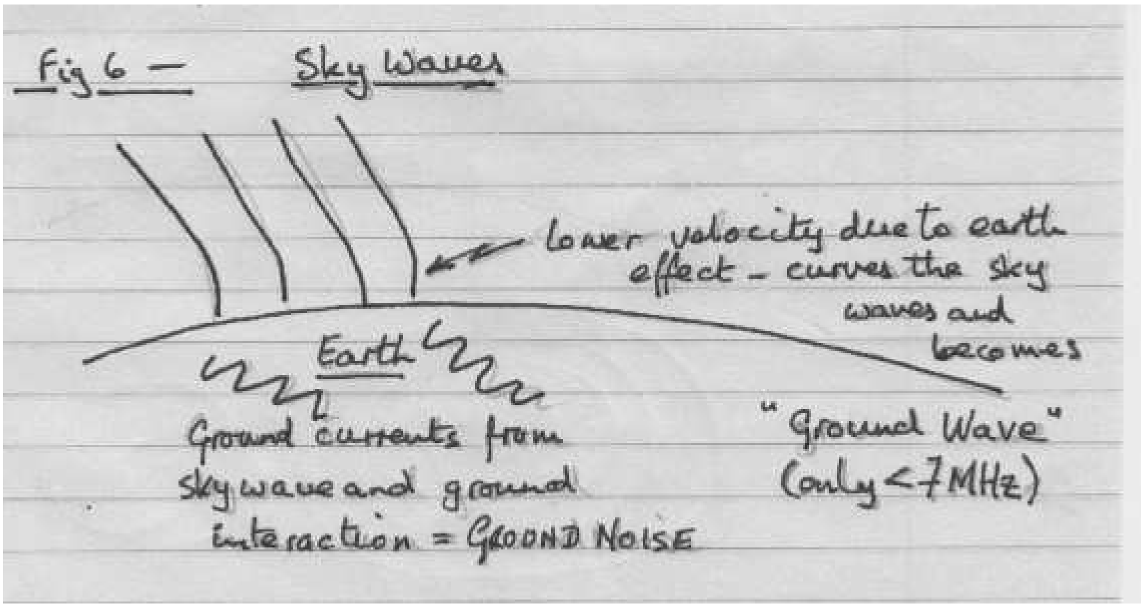


Fig 5 shows how sky wave "noise" - this includes ANY signals interfering with your desired signals of course - induce earth currents, which are capable of inducing noise currents in any conductor, including a counterpoise. To my way of thinking the fact that the loop counterpoise idea is specifically effective on low bands indicates to me that the effect we're looking for is LF: Fig 6 shows how the ground wave bends round the earth's curvature, thus is inducing strong earth currents over a larger area than, say, 30m and higher frequency signals which have a tighter "footprint" as they return to earth from the ionosphere.



The idea of a short circuited loop, the loop thus formed being no relation to $\lambda/4$, or any other fraction / multiple, being far lower noise, easier to match, etc., etc. seems to me to indicate that noise currents in each "half" of the loop, cancel at the "junction" ("S" in Fig 5), thus giving the better performance quoted. This immediately suggests to me a whole series of experiments: for instance, does it have to be a rounded / elliptical / circular loop, or will some twin core flex, shorted at the far end, do the same? Does the enclosed area of the loop have an effect, maximising the loop's area? Would a "Petlowany" spiral, with a radial short circuiting wire, work even better as it would be inductively self loading? Does the resonance of the loop play a part, or is it important it's non-resonant?

One thing I do know: the earth - and it's surface soils - carry hefty earth currents back to the sub-stations / distribution transformers from the noise filters now mandatory on SCR / Triac / mosfet bridge motor drives and power control mechanisms commonly used on washing machines and the like. And these earth current certainly can radiate: if you have RF current moving in a conductor, then you'll certainly make magnetic fields and those will in turn create electric fields around them. That's how your transmitting antenna works! Roger Lapthorn, G3XBM, has made effective transmitting antennas using an earth path for one "side" of a loop antenna. Thus, signals radiating up and out of the ground, encountering a counterpoise "short circuit loop" will induce signals equal and opposite in each half of the counterpoise: thus cancelling noise currents at the summing junction where the short circuit exists.

I shall be keeping an open mind on this matter and awaiting more results, especially those testing the limits and shapes of these counterpoise loops. That something - not fully understood nor maximised as yet - about "loops on the ground" antennas, proven successful in many cases on low bands (but where's the upper frequency limit?) are very similar to the short circuit loop counterpoise idea. If it only works on (say) 40m and under, is there a mechanism - akin perhaps to skin depth? - that is how these counterpoise loops work? What happens if the short circuit loop counterpoise is buried at a shallow / spade depth / yard below ground? In wet loam, sand, rocky sub-strata? Could low cost "Cat-5" twisted pair cables be used to form the loops or Petlowany spiral counterpoises? As ever, in the RF world, one idea spawns a hundred more questions!

One day I'll learn to just accept things at face value, stop questioning and attempting to understand the mechanism that's at work. Every time I ask a question to myself, another hundred take root, sprout and burst into full blown projects in my mind! Mind you, isn't that what amateur radio is really all about? If we look back to the giants of RF engineering, Terman, Jones, et al, this is what motivated them to simple yet far reaching conclusions. Jones especially espoused symmetrical circuits, antennas, and the like: he considered Nature to prefer balanced systems, electrical Yin and Yang, as his push-pull transmitters illustrate so well. Maybe it is best to keep to loops, balanced systems, symmetry at work?

Grounding, VDR's & Gas Tubes...

Thinking of earthing, ground currents and the like, here's a note from Frank Barnes, W4NPN, about grounding and other outdoor "aerial" bits-n-bobs in an article by Radio World (both of whom I thank muchly):
https://www.radioworld.com/columns-and-views/workbench/workbench-a-linemans-tips-to-ground-an-stl-pole?utm_source=SmartBrief&utm_medium=email&utm_campaign=0028F35E-226C-4B60-AC88-AB2831C8A639&utm_content=81D93CAF-3748-4527-AA52-AE635F78583D
All good practical stuff for the amateur antenna farmer!

Hot Iron #112

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CQ-CQ-CQ

Home Blues...

Ensconced in my new home in the mountains of West Wales, I now have a much better understanding of what my house here needs. Nobody sells a second hand Rolls Royce for Mini prices without good cause; now I know where my efforts (and money!) must go into my house in the near future.

For those who are familiar with roofing, I have two purlins with rotten ends, where previous owners have neglected basic and remedial roof maintenance and allowed water leaks from cracked lead flashing and slates to saturate the purlin ends in the supporting wall - consequently I either need to strip the entire roof to put new timbers in, or - and I think this is preferable - have the flashing, slates and flaunching repaired, then find a steel fabrication shop that can make me some 6 mm thick steel plate "U" sections, 2 metres long, to extend the existing purlins after chopping off the rotten ends, the steel to engage in the wall mortices and be through bolted into sound timber of the now (shortened) purlins.

There is a plus side to this: I have laid a floor in the loft, supported by new joists, for storage - and a dandy electronics bench will fit into the new space thus constructed. A bit draughty, mind; and quite a few existing tenants (with 8 legs...) will have to be evicted. I have nothing against spiders, mind you: but these are the size of wrens and don't run away when I prod them with a screwdriver blade! ardent wandering arachnid!

Correspondents write...

I am always very pleased to receive emails on any topic from Hot Iron readers, as I base items in each edition on the comments and ideas brought to light. The themes I have been asked about are most fascinating: they follow - loosely - common themes. Most are about receivers, how to make a 1μV capable, SSB / CW Dx receiver with one or two active devices that will run on simplest DC supplies, for a few ££'s.

The second topic is about antennas; how to make one that is invisible - a few metres long, typically - that will radiate 100 watts efficiently on any band between 135kHz and 50MHz at unity VSWR.

The third topic is winding inductors: quote: "I need 22μH, and I have a cardboard tube 2 inches diameter, how many turns of wire - and of what gauge - will I need, at what spacing?" is a typical (unanswerable!) request. Inductors, especially variable inductors for power RF, are rarer nowadays than hen's teeth: some do occasionally turn up on our favourite auction sites but alternative approaches are usually cheaper & more achievable. I consider the amateur who builds an antenna tuning device that eliminates the "roller coaster" to be a genius!

I strive to answer every request made to me via Hot Iron, but some, like the examples above, are just plain not possible. More to the point, surely, these questions illustrate a lack of electrical theory that studying for and passing the Radio Amateurs Examination is supposed to instil: how do licensed amateurs pass this examination, if they don't have basic electrical knowledge?

On basic safety grounds, if I'm asked to offer a design for a power supply that features voltages anywhere in it's construction above 50v AC rms or 70v DC then I have to refuse the request - I cannot encourage the unwary to use lethal voltages.

Amateurs who are unable to work confidently on anything running over 12 volts are (in my opinion) woefully lacking in education & confidence in their own abilities. Even on 12 volt DC supplies, a matching network with a decent loaded "Q" inductor running 100+ watts may well have RF voltages well over 500 volts swilling about; and an RF burn at these potentials is far worse than an AC or DC shock - RF arcs cause deep burns.

Hence this safety warning, which will be included in every edition of Hot Iron. I apologise to those who are entirely capable of complying with current safety requirements - but I must be sure those who don't are made aware that they are responsible for what they do, not me!

Circuits shown in Hot Iron may use potentially lethal voltages. It is your responsibility to ensure your own – and anybody else's – safety if you build or use equipment that employs hazardous voltages, currents or power. If in ANY doubt, you MUST get a competent person to check and approve the circuits, barriers and other provisions to avoid any injury and electric shock. You MUST comply with your local Electrical Regulations and Safety Regulations.

I cannot accept any liability for any damage or injury to you or any Third Party from any article or description in Hot Iron. It is your responsibility to ensure the safety and safe use of anything you build; I am not responsible for any errors or omissions in Hot Iron.

Unobtanium and Obsoletite

Many superb designs, both valve (tube) and solid state are from an age where components were of a different nature than those obtainable today. A couple of examples: the ubiquitous pie wound 2.5mH "RFC", and the darling of the mixer fraternity, the 40673 dual gate mosfet.

The 2.5mH RFC's were found by the hundreds in virtually every radio receiver or low power stages of transmitters, they were as cheap as chips and available from - well, anywhere that sold radio bits. Nowadays? You might find a few "NOS" ("new old stock"), or second hand of dubious parentage, but otherwise these chokes are as dinosaurs - gone from this earth.

Similarly the adored 40673 mosfet. You'll find "NOS" 40673's on auction sites, at serious money each - and one episode of rough handling (without static protection, typically) will have them shuffling off this mortal coil in a trice.

There are alternatives though, which breathe life into these old designs and make them a very viable proposition for the home constructor. I can't estimate the number of single tube receivers using a triode - pentode tube in various configurations, but where do you find, now the audiophools have hoovered up every available option, an ECL86? Or their kid brothers, the ECL84, '82 and '80? The RFC's are a different issue: in most instances they can be replaced by a resistor, but some designs will suffer with such substitutions. So how to proceed? Read this Hot Iron and see!

Tim's Topics

Transmit Receive changeover

It has been very busy these last few months - despite the Covid-19 virus – life on our farm has to carry on, which is why I missed a contribution to the last Hot Iron. I have several electronic projects on the go – in various stages of development. The most recent is the Queenie strong DC receiver for any band 20, 40 or 80m aimed at CW. It uses 4066 electronic switches for the product detector. Because that chip has a spare pair of switches, the RX has an optional simple add-on unit that gives single sideband CW reception by the phasing method. The matching transmitter is the Kingston which produces a nominal 5W on a 13.8v supply. To avoid chirp, this design triples from a low frequency VFO and then divides by 2 or 4 when 40 or 80m is desired; so it has coverage of the whole CW segment for whichever band is chosen and avoids the limitations of being 'rock bound'! The transmitter has full break-in TR changeover that often causes cause much design hassle to avoid nasty clicks or thumps that would be awful when using phones!

Aerial changeover using a relay is generally much easier even if the sequences and timing are somewhat slower. Clicks or thumps are usually caused by either or both of a) a change in internal supply line voltages or bias conditions when the key is closed/opened, or b) a transient of transmitted RF, or sudden change in bias voltages, that causes an audio filter to 'ring'. These effects occur as well as the need to prevent high levels of transmitter RF from damaging the RX front end! Using a relay to switch the aerial from the RX to the TX is seldom quick enough to hear the wanted station or other callers between morse characters, so modern rigs usually leave the aerial connected to the TX and have an electronic switch in series between aerial and RX input, sometimes also with another electronic switch across the RX input to reduce the transmitter attenuated RF applied to the RX even more!

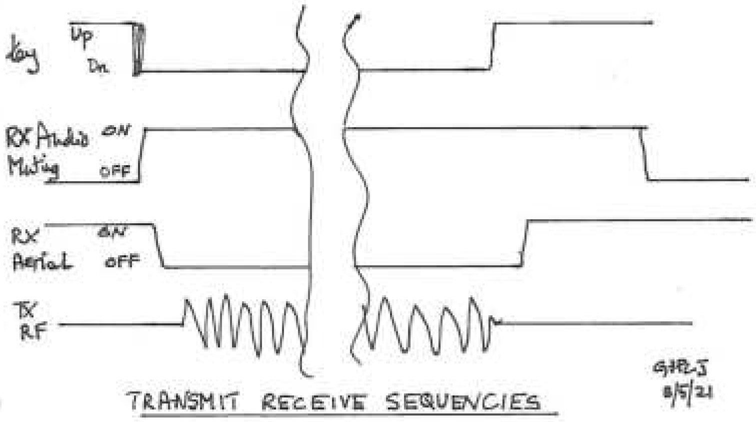
Avoiding changes in supply voltages is usually fairly simple using low power regulator ICs like the 78L05 series (for 5v up to 100 mA), or the 750L08 (for 8v up to 100 mA) for the bias controlling resistors or sensitive early stages in a RX. The 750 series are 'low drop-out' regulators so can be used for an 8v line with input down to near 8.5v! But they do need lots of decoupling to make their internal regulating control loop stable. The RX audio stages need to use op-amps and output power amps that are able to suppress/ignore the supply changes – eg TL072 and LM380. Following these principles usually avoids thumps due to bias changes. This leaves only the need for 'switches' of some sort for the signals. It is essential these 'switches' operate in a particular sequence. When the key is closed, the RX must first be muted very quickly (this is true for electronic TR and for relays), and then the RX aerial input disconnected before the transmitter RF is generated. After key up, the RF needs to stop quickly, reconnect the RX aerial and later unmute the RX when any filter or supply transients have settled out.

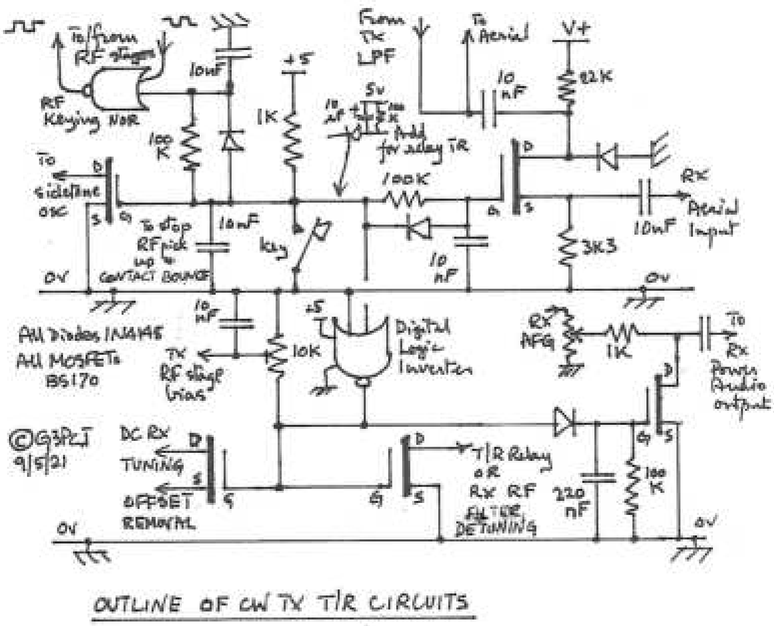
This sequence is key to avoiding or masking any unwanted noises – it is shown diagrammatically in the first part of the attached diagram. RX audio muting ought to occur within about 3 mS to be sure any transients due to relay currents are properly masked! The delay in activating the TX needs only to be long enough for the RX antenna switch to open – maybe 10 mS to allow for a relay but less for an electronic switch.

Removal of the RX muting usually needs to last much longer, either due to a relay operating or an audio filter settling after a burst of unwanted input signal. An audio muting on delay, or hold, of up to about 20 mS will often masks the worst effects while still being able to hear enough between fairly high speed morse key down periods.

It is not possible to give a simple universal circuit design to achieve these timings because of the interaction with the functional stages of the RX/TX. In my CW designs, the RF keying (or gating of the RF drive to the output stage) is done digitally in a CMOS digital NOR gate; for the series switch between aerial and RX input, I advocate a small MOSFET that can withstand the high voltages – the BS170s is cheap in quantity. I also use them for muting of the RX audio, and activation of the sidetone oscillator, when the key is down!

The inputs of digital NOR gates, and the control gate of the MOSFET, have a very high input impedance which allows simple CR circuits to be used to provide the proper sequence of actions to avoid the clicks and thumps. (The extra diodes control whether the long delay period occurs on the leading or trailing edge of the signal.) In some designs, it may be desirable to also 'shut down' the RX front end when RF is being generated; this can be done with another MOSFET that detunes the RF input bandpass filter by applying a short to the mid-tap of the resonant winding - the slight extra capacitance when it is off has a minimal effect on its tuning. The second part of the diagram shows a typical circuit which I hope is self-explanatory!
Tim Walford G3PCJ © May 9 2021





Rx Topics

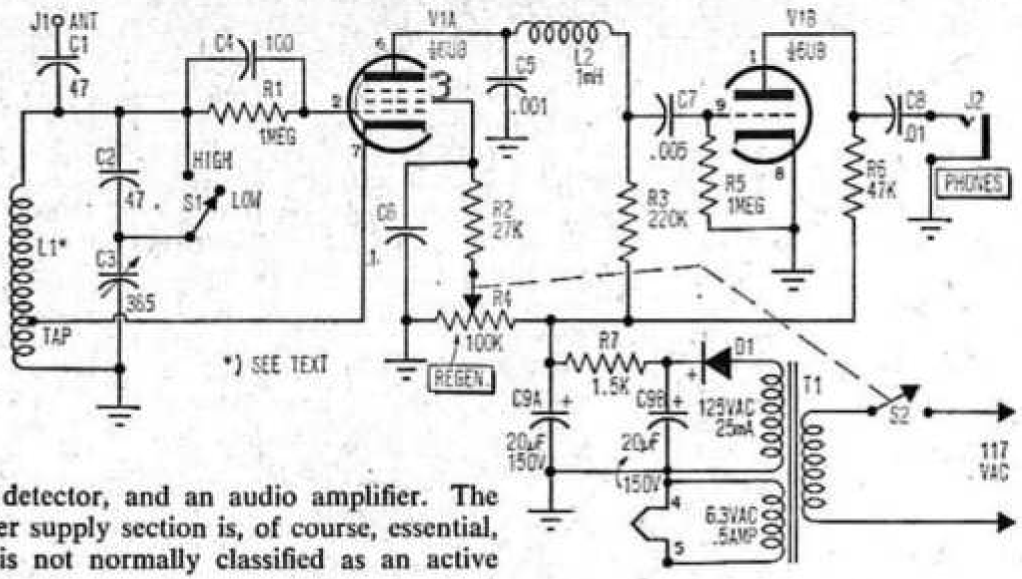
The ORIGINAL Neophyte receiver

In the next series of images is presented one of the most popular “generic” one valve receivers: the Neophyte. It is typical in every way; its components and construction are of its day and even though elderly, it can still put up a remarkably good performance if built robustly and operated by capable hands.

The original article reproduced is from “Electronics Hobbyist”, the year and edition I don’t know, but I give my grateful thanks to the original article author (again, unknown) and the publishers.

It fascinates me why these oh-so-simple designs have no parallel in the solid state era: I have thought about building these circuits with “solid state tetrodes” - Fetrons and their kin - but experience, both mine personally and others, show the valve circuits far outshine the solid state versions in both performance and simplicity. The only snags are as far as I can see, are the HV power supply and overall receiver size - but for most users, these genuine distractions are easily overcome for portable service as you’ll see later in this edition of Hot Iron.

Schematic of Neophyte I shows conventional regenerative detector circuit followed by a stage of audio. Note how band is changed simply by switching capacitor C2 in and out of tuning circuit.



tive detector, and an audio amplifier. The power supply section is, of course, essential, but is not normally classified as an active stage.

The circuits are traditional. A regenerative-type detector, although no longer in use in commercial equipment, still finds plenty of applications where budget-minded experimenters and space requirements are involved.

The detector, besides extracting the audio from the carrier signal, also provides a considerable amount of audio amplification. It would certainly take more than half of one tube to do this using other conventional circuits.

The amplified signal from the detector is coupled to the audio amplifier stage where its level is increased still further to operate a pair of standard high-impedance headphones with adequate volume.

Wherewithal. Starting at the antenna jack in the schematic, you will notice a 47-pF capacitor (C1) connected between it and the tuned circuit. This capacitor prevents antenna loading effects and results in smoother operation of the regenerative feedback circuit.

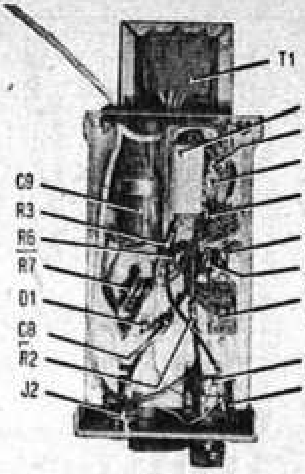
The tuned circuit consists of coil L1, tuning capacitor C3 and a fixed capacitor, C2. The single-pole-single-throw switch S1 shorts out C2 when closed and places C2 in series with the variable tuning capacitor C3 when it's open.

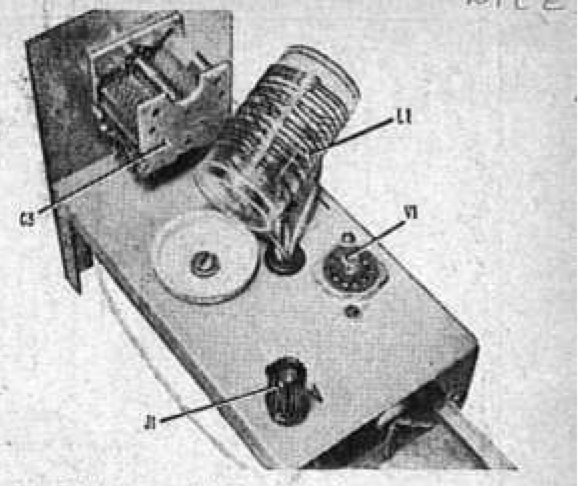
The closed position places more capacitance in the circuit and therefore tunes the receiver to a low frequency shortwave band. When the switch is open, total capacitance is less than 47 pF maximum (the value of

PARTS LIST

C1, C2—47-pF disc ceramic capacitor
C3—10 to 365- or 10 to 410-pF variable capacitor
C4—100-pF disc ceramic capacitor
C5—.001-uF disc ceramic capacitor
C6—0.1-uF capacitor
C7—.005-uF disc ceramic capacitor
C8—.01-uF disc ceramic capacitor
C9A, C9B—20-20-uF 150-VDC dual section electrolytic capacitor (Radio Shack 272-105 or equiv.)
D1—400-piv., 200-ma or better silicon rectifier diode (Radio Shack 276-1126 or equiv.)
J1—Insulated binding post (Radio Shack 274-736 or equiv.)
J2—Headphone jack (Radio Shack 274-293 or equiv.)
L1—Wound from #22 AWG enamel covered copper wire (see text)
L2—1-mH radio frequency choke
R1, R5—1,000,000-ohm, ½-watt resistor
R2—27,000-ohm, ½-watt resistor
R3—220,000-ohm, ½-watt resistor
R4—100,000-ohm linear taper potentiometer with s.p.s.t. switch S2
R6—47,000-ohm, ½-watt resistor
R7—1500-ohm, 1-watt resistor
S1—S.p.s.t. slide switch
S2—Mounted on R4
T1—Power transformer: 117-VAC pri., 125-VAC, 25-mA; 6.3-VAC, 0.3-A sec.
V1A, V1B—6U8A vacuum tube
1—5¼ x 3 x 2⅛-in. aluminum minibox Radio Shack 77-0683 or equiv.)
1—High impedance (2000-ohm or more) headphones
Misc.—9-pin tube socket, scrap aluminum for front panel, knobs, grommets, line cord and plug, terminal strips, screws and nuts, etc.

Built 8-16-93 NICE

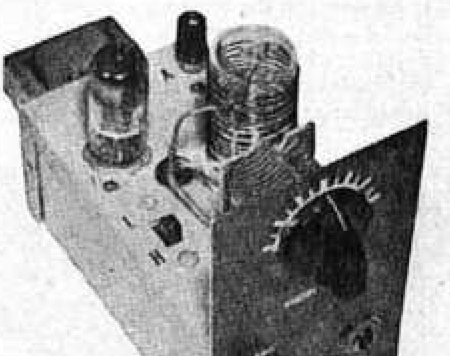




At left, parts arrangement in Neophyte is compact but uncluttered. Coil at right is wound on plastic pill bottle as shown.

C2) and this provides a second, higher frequency shortwave band. Using the specifications given for the coil and the capacitor values, Neophyte 1 covers from about 3 to 7 MHz on the low band, and from about 9 to 12 MHz on the high band. Other frequencies, higher or lower, may be covered by changing the value of C2 and the number of turns in L1. If you use variations, experimentation with the "tap" may be necessary.

Audio Extraction. As mentioned before, the first, or pentode section, of the dual section tube extracts the audio from the received signal and passes it to the triode audio amplifier stage. However, plenty of unwanted radio frequency signals also appear at the plate of the pentode section and they must be dispensed with for proper operation. The radio frequency choke L2 and bypass capacitor C5 are placed in the circuit for this purpose. The choke blocks or "chokes" higher frequencies, but allows lower audio frequencies to pass; conversely, the bypass capacitor blocks low frequencies and bypasses unwanted RF to ground. The result is a relatively clean audio signal appearing between the grid and cathode of the audio section for additional amplification.



Neophyte 1 will provide many hours of entertainment receiving the most active shortwave bands.

Regeneration. The current in the detector stage must flow through the lower portion of coil L1 and up to the cathode where it divides between the plate and the screen grid. The screen grid is connected to the positive (B+) supply through a limiting resistor and potentiometer R4. By changing the resistance of the pot, the screen voltage is varied and the tube current changes. The pot thereby varies the current through the tapped portion of the coil. The degree of current flow determines the amount of signal that is coupled to the upper portion of the coil which, in turn, determines the amount of feedback. The potentiometer is called a regeneration control, and it, as its name implies, controls the regeneration or feedback of the signal voltage.

Building Neophyte I. All parts mount on or in a 5¼ x 3 x 2⅛-in. aluminum minibox. A small piece of scrap aluminum measuring 3 x 4½-in. is used for the front panel. Follow the photos to locate mounting positions. *(Continued on page 104)*

Neophyte I

Continued from page 77

Start by cutting the large holes first, and finish up with all the small holes using the parts themselves for templates. The panel is secured to the box by the phone jack and regeneration control mounting hardware.

The power transformer T1 is mounted on the rear of the minibox. Two holes are made to pass the transformer leads inside the box for wiring. Make sure that all holes and mounting plans are such that the other half of the chassis box will fit in place without obstruction.

Cool Coil. A 1 x 2-in. long plastic pill vial is put to use as a coil form. The plastic cap of the vial serves as the coil form "socket" and is mounted on the chassis with a nut and bolt.

The coil consists of 17 turns of #22 AWG enamel-covered copper magnet wire. A tap is made 4 turns from the bottom or ground end of the coil.

The turns of the coil are spaced to cover approximately 1¼ inches. The #22 wire is stiff enough to be self-holding and cement is not needed. Minor frequency adjustments may be made later by adjusting the spacing between the turns.

Hookup wire brought through a grommet-protected hole in the minibox connects the coil to the proper circuit points. The band switch S1 is mounted on the top of the minibox, but a layout variation on the front panel will allow enough mounting space there.

When all components are wired in the circuit, make a careful check to insure that no short circuits exist and that there is proper clearance for the bottom of the chassis box.

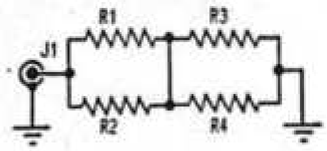
Fire It Up. Turn Neophyte 1 on and check that the tube lights. Then make sure nothing is smoking or overheating. Connect an antenna to the jack and advance the regeneration control to a point just before the set breaks into oscillation. Turn the band switch to the high band and tune for a station. Readjust the regeneration control for best reception. Receiving conditions will be best after dark so don't be discouraged if you turn the little Hertz-grabber on during daylight hours and don't find much action. Try various inside antenna lengths and use the best one. A high outside antenna will be best for long-distance reception. ■

Scrooge Special

Continued from page 70

PARTS LIST

J1—RF connector, single hole mounting, type SO-239SH (Lafayette 42H6907 or equiv.)
R1, R2, R3, R4—50-ohm, 100-watt, 1% non-inductive resistors (Corning Glass R-35* or equiv.)
1—5x4x3-in. aluminum chassis box (Lafayette 12H8389 or equiv.)
4—Rubber feet, ⅜-in. dia. (Lafayette 13H6035 or equiv.)
1—Equipment handle (Allied Radio 42E8078 or equiv.)
Misc.—Wire, solder, perforated aluminum, nuts, bolts, spray paint, insulated terminal lug, etc.
*Available from John Mesha, Jr. Surplus, 19 Allerton St., Lynn, Mass. 01904



Wire resistors together as shown in schematic, then install in chassis box.

ground lug, and the insulated terminal post as shown in the photo.

Finishing Up. Carefully note the physical placement of the load resistors R1 through R4. These resistors are supported by the connecting wires to connector J1 and the ground lug on one side of the case, and to the insulated terminal lug on the other side. The sole purpose of the insulated terminal lug is to support the load resistors, no other wires or components are connected to it.

To speed construction, first wire the load resistors together per the schematic. After

"I got tired of TVI"

"An Improved Neophyte"

From W9BRD, Dave Newkirk, in http://theradioboard.com/rb/viewtopic.php?t=9345

To W9BRD, and all concerned at radioboard.com, I give my very grateful thanks. The ideas and improvements presented are an object lesson in how to adopt, adapt and improve an already good design. That's the mark of a genuine radio artificer!

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"*I built one in about 1970 or so. It's just a simple 0-V-1, not too well understood by its author; it works well enough, as all simple regens do. But as with all simple regens, better performance awaits if you can break away from the circuit before you to some degree.*

So, some notes:

Band switch. The set's band switch isn't a band switch. All it does is put C in series with the tuning C. And all that really does is spread out part of the full coverage afforded by the tuning C on the "low" band, ever so slightly moving its upper limit slightly upward because of the C in series with the main tuning C's min C. So, like I said, it's not a band switch.

The AF stage needs cathode bias. Yes, it's a high-mu triode, but connecting the AF amp's cathode directly to common is benighted. If I remember right ~ ~ ~ use 2.7 kilohms, bypassed to common with a 10- to 25-uF electrolytic, positive toward the cathode.

Out with the RFC in the detector plate. A 47-kilohm resistor in series with the blocking C between the detector plate and AF amp grid will work as well, and only slightly tap the AF amp grid down on the detector output, like a turning down an AF GAIN pot just a bit and leaving it there. (0.001 uF for the detector plate bypass is a tad high for a pentode detector, as it will considerably roll off highs for those hoping to use the set for broadcast. Values that high generally come from those who don't grok the great difference in plate Z between triode and screen-grid detectors. I use 560 pF, and it works fine even at 1.7 MHz. All we're trying to do there is keep the RF level down at the AF grid; the RFC or series resistor toward the AF amp serves as the other part of that bypassing/decoupling function.) Maybe 220 kΩ for the detector plate load is a tad high. Nowadays I always use 150 kΩ for pentode-detector plate loads. (The plate circuit of a pentode detector is the equivalent of the plate circuit ofan RC-coupled AF voltage amplifier.)

Consider coupling the antenna to the detector cathode. Coupling the antenna to top of the detector tank is so 1930s wire-around-the-picture-molding-antenna-ish. Nowadays we generally use bigger, lower-Z antennas. (When I built mine, my dad suggested that I add a grounded-grid-triode input coupling tube (I used a 6C4), with the AC-coupled antenna input riding up and down on the wiper of the 1-kilohm pot that served as the g-g stage's cathode R. It worked fine with a low-Z antenna, and the pot allowed me to control the signal level presented to the detector to minimize pulling.

No, we do not use an interstage AF transformer between a screen-grid detector and the AF amp that follows it. That was for triode detectors, the plate Z of which suits using a 1:3 transformer. The plate Z of a pentode is on the order of hundreds of kilohms to a megohm, and no transformers are available with enough inductance to do 1:3 stepup based on that Z level.
~~~~~~

In the older days, a high-value AF choke (300 to 1080 H) was commonly used as the load for screen-grid detectors. Not only are such chokes pretty much Unobtainium nowadays, but they are unnecessary; an R between 120 k and 220 k works fine. Really.

If you haven't used (for CW communication) a high-C regen with its input level carefully adjusted to just overcome the detector's internal noise (for starters; more atten for stronger signals), you haven't heard how good a regen can sound on CW. Yes, that RC coupled input coupling tube is key; no need for an RFC-only load there, as we're out to add loss between the antenna and detector anyway. Regens work better on weaker input signals. Whatever regen circuit you use, keep the input level down as far as possible consistent with overcoming the detector's internal noise. Turning up regeneration to make the detector "oscillate harder" is not a substitute for input attenuation when one is using one's transmitting antenna for receiving with a regen.

Best regards,

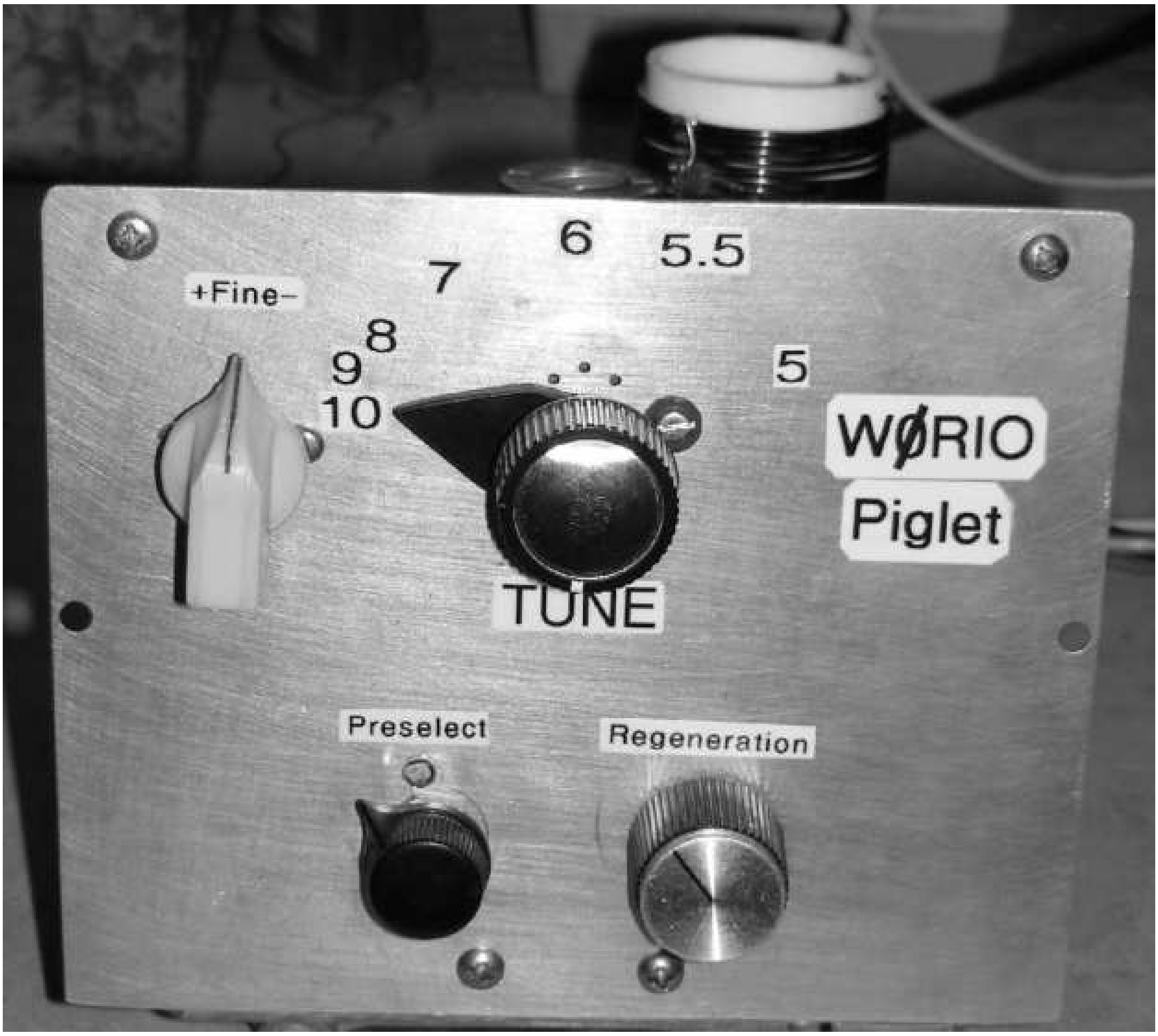
Dave W9BRD"

A "Modern approach"
The Piglet receiver, by Forrest Cook, W0RIO, at:
[http://www.solorb.com/elect/hamcirc/pigletregen/index.html]

...is an example of how the "accepted" format of a triode / pentode valve in a regenerative receiver as in the Neophyte above can be reversed; you lose the first stage audio amplification, but gain the (huge) advantage of isolating the antenna from the detector, by using the triode as an isolation stage. This RF stage could be made selective if needs be; say for a specific band A.M. / NBFM slots for instance. Yes, you do need some extra audio amplification, but, as Forrest does here, it gives you chance to add a "modular" audio amplifier to do the job, and deliver speaker level output. Note: 6U8A = ECF82 (more or less) in European nomenclature; with heaters 16v, 300mA.

"TV" type tubes - typically the 300mA types designed for series connected TV heater chains - are readily available as "NOS", simply because the Audiophools can't use them as they won't plug-n-play in their amplifiers. We, as constructors, can cock a snook to all that: need 19 volts for heaters? Pah! Nae bother, laddie, we have many means to create such heater supplies as we can design and build to our needs, we have all sorts of transformers to hand and don't forget the new kids on the block: halogen lamp transformers, available at very low prices (compared to conventional transformers) and are physically very small. Two of these, secondaries in series, will give plenty of volts for TV type valve heaters at very economical prices. And keep to mind simple diode / electrolytic voltage multipliers: not only can you derive heater volts with these, but you can get useful HT rails too: parallel multiplier designs can be made to run efficiently with modern silicon diodes as octuplers!

The W0RIO Piglet 6U8A Regenerative Receiver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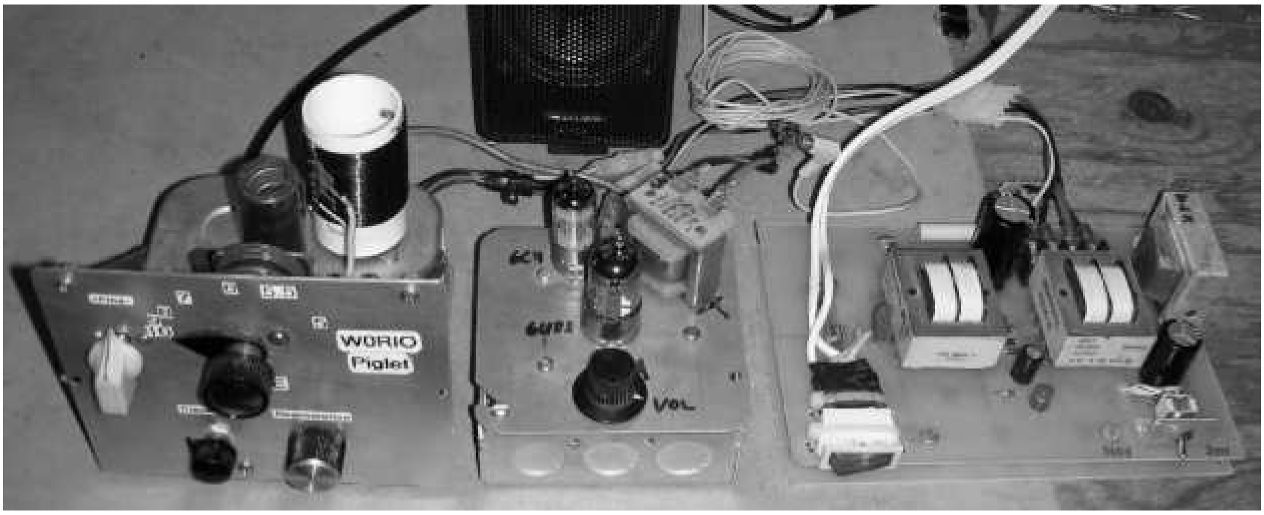
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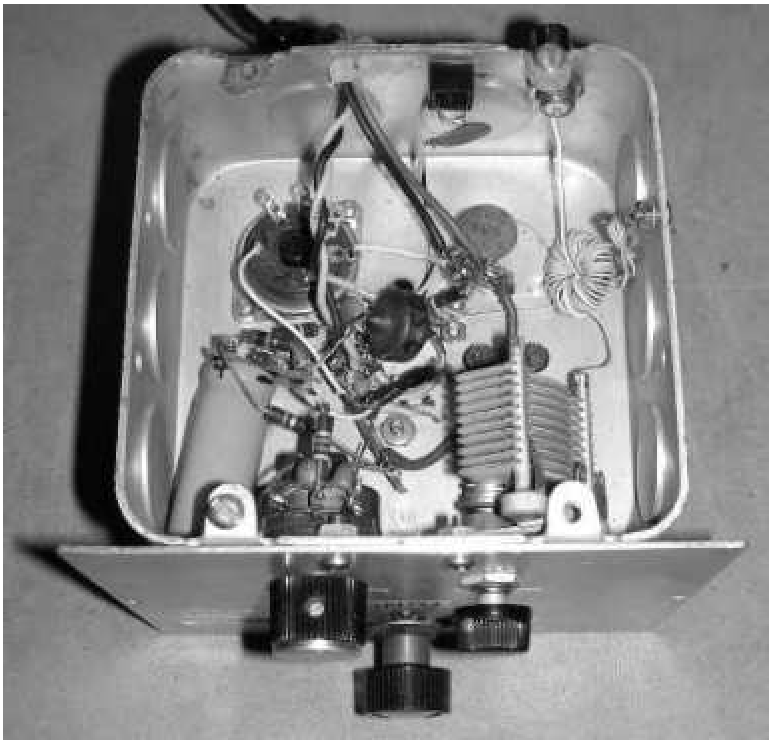
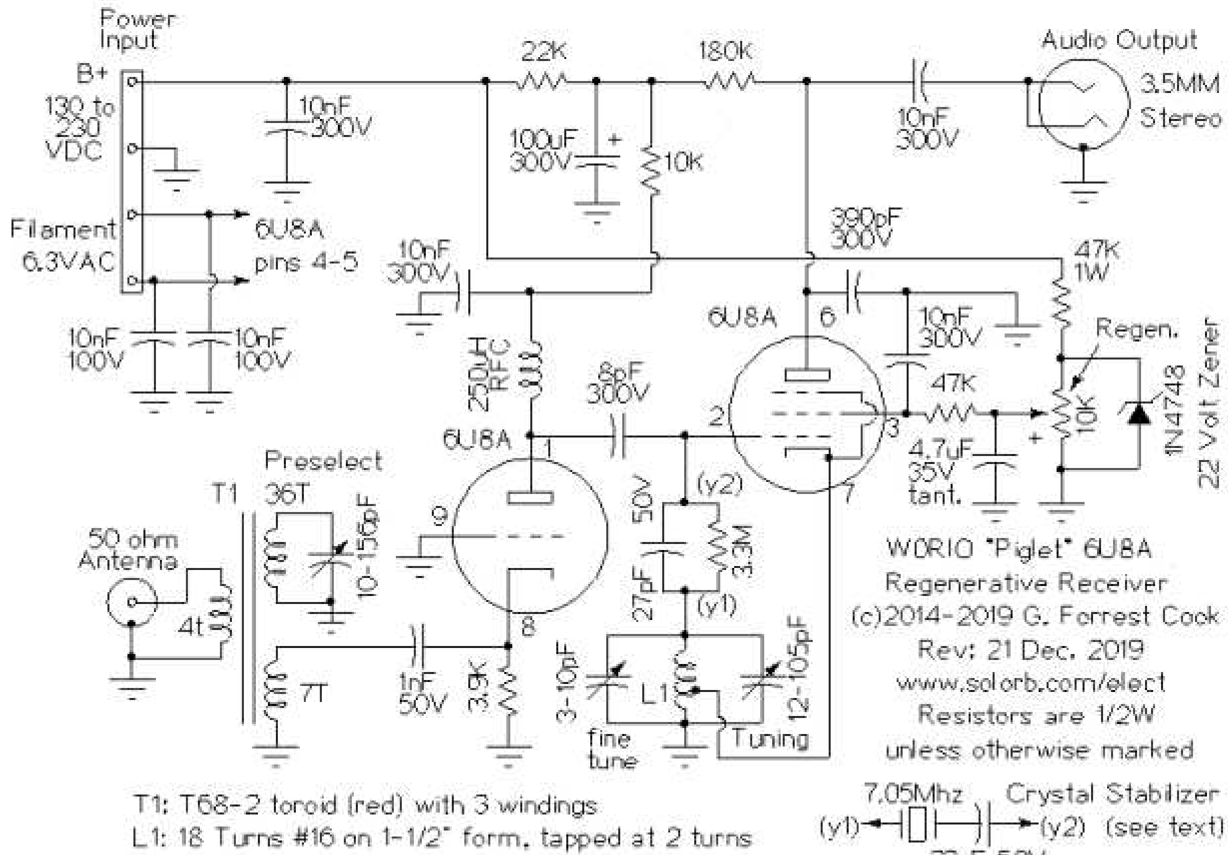




Introduction

This project is your author's first attempt at building a regenerative receiver, it has gone through several revisions. Thanks go to W9BRD, DF3DL and others for suggestions on how to improve the detector circuitry. The "Piglet" name comes from the squealing sounds that regenerative receivers can make when the regeneration control is adjusted. The receiver tunes from 5-10 MHz in the shortwave band and it can pick up foreign and domestic AM broadcast stations with ease. One of the design goals of the receiver was to be able to pick up both the 5Mhz and 10Mhz WWV time signals. When propagation conditions are good and the Piglet is connected to a good outdoor antenna, stations can be picked up across the entire tuning range of the receiver.

If the receiver is built with a narrow tuning range instead of the 5-10 MHz range, it can be used to receive SSB and CW radio signals in the 40 meter ham band. It could also be set up to cover just one shortwave broadcast segment. With a few minor coil adjustments, the receiver should also be able to work on the 80 and 30 meter ham bands.

Regens have always been very popular because they deliver a lot of performance from a small number of parts. Their disadvantages include being rather "tweaky" to adjust, de-tuning from wind on the antenna and a tendency to transmit RF from the receiving antenna while making tuning adjustments. This design fixes the second and third of those issues with a grounded-grid RF isolation amplifier.

The 6U8A tube includes a triode and a pentode in one 9 pin envelope. Most 6U8A regen designs use the pentode as the detector and the triode as an audio amp. This design uses the triode as a tuned grounded-grid RF amplifier ahead of the pentode detector section. This arrangement isolates the antenna from the detector stage and improves the front-end selectivity of the receiver. All of the audio amplfication is done outside of the Piglet.

The receiver can run on a wide span of B+ voltages, it works between 130VDC and 230VDC, allowing many power supply choices. I used my Power Supply for Vacuum Tube Experiments (set for either 160VDC or 260VDC) to power this project. When the supply is powering the Piglet and the V3 amp, the B+ loads down to either 130V or 230V. The higher supply voltages give the receiver more audio output and higher gain.

The supply is sufficient to power the Piglet and the Low Power 6U8A Vacuum Tube Audio Amp V3. If you don't want to build the outboard tube amplifier, a pair of stand-alone amplified computer speakers will also work.

Warning
This project involves the use of potentially lethal high voltages including 120 VAC and 160 VDC. The project should only be taken on by someone who has experience working with high voltage circuitry. The power supply should always be disconnected and the power supply capacitors should be discharged when working on the receiver.

Theory
A 10nF 200V bypass capacitor is wired across the B+ line and two 10nF bypass capacitors are wired to across filament pins, these parts bypass any extraneous RF that may be picked up on the power lines to ground.

The triode section of the 6U8A is wired in a tuned input grounded grid amplifier configuration. The 50 ohm antenna input is coupled via a 4 turn winding to the tuned input circuit's toroid coil. A 36 turn winding and a 10-156 pF variable capacitor form the resonant part of the tuned input circuit, it covers just beyond the 5-10 MHz tuning range of the detector. A 7 turn winding matches the input tuned circuit to the cathode of the grounded grid amplifier via a 1nF DC blocking capacitor. The 3.9K resistor sets the bias level of the grounded grid amplifier and the 250uH RF choke isolates the amplified RF input signal from the B+ supply. The 10K plate resistor and 10nF capacitor further isolates this stage from the detector circuitry.

The output of the RF amplifier is lightly coupled to the pentode detector stage via an 8pF capacitor. The detector's tuned circuit consists of a tapped solenoid coil in parallel with an 12-105pF tuning capacitor. The tap point on the L1 oscillator coil can be moved to change the behavior of the regeneration circuit. The tap at 6 turns can allow the circuit to oscillate at around 15Khz if the regeneration control is turned up, moving the tap down to 1 turn can reduce or eliminate this issue, but the gain is also reduced. Moving the tap to 2 turns provides a good compromise between sensitivity and stability.

A 3.3M grid leak resistor provides the grid bias and the 27pF capacitor couples the top of the tuning coil to the pentode's grid circuit. These values are not set in stone, but work well across the 5-10 MHz frequency range. The 27pF capacitor should be increased in value if the receiver is to be used at frequencies below 5MHz. The regeneration control provides a variable voltage to the 6U8A pentode's screen grid, it is used to keep the detector circuit at the point just at or slightly below the point of RF oscillation. The regeneration control's voltage is regulated by the 1N4748 22 Volt zener diode and filtered with a 4.7uF capacitor, this helps to stabilize the behavior of the circuit.

The plate circuit of the detector has the RF bypassed to ground via a 390pF capacitor. This capacitor also acts as an audio high-cut filter, the value can be adjusted for more or less treble. The audio output of the detector is fed to the output jack via a 10nF capacitor, where it is fed to a high-impedance audio amp.

The Regeneration circuit uses a 47K resistor and a 22V (or 24V) Zener diode to produce a regulated 22V supply. The 10K Regeneration potentiometer varies the pentode's screen grid voltage from 0-22V, which spans the region below and above the point of oscillation. The 4.7uF capacitor gives the Regeneration control a smoother response, the 47K resistor sets the screen current and the 10nF capacitor bypasses RF on the screen grid to ground.

Construction

The receiver was built into a 4-1/2"x4-1/2"x2" electrical utility box. An aluminum plate was mounted on the side of the box with some 6-32 screws to serve as the front panel. The 6U8A tube socket and the Octal coil form socket were installed into knockout holes on the top of the box. A solid box cover plate was used for the bottom of the box. Appropriate holes were drilled for the rest of the components. A number of multi-point terminal strips were installed inside the box and components were installed with the point-to-point wiring method. All RF wiring should be kept as short as possible.

The L1 mixer coil was wound onto a custom coil form. The form was made by gluing a section of plastic sink drain pipe to the base of an old octal tube. Small holes were drilled in the pipe to secure the ends of the wires. A matching octal tube socket was mounted to the chassis.

The L1 pluggable coil form was originally used with the intention of being able to use different coils for different bands. The circuit design changed during prototyping and the T1 tuned input circuit was added. Transformer T1 could also be bult as a pluggable coil if you want to be able to change bands. For single-band operation, L1 should be built without the plug and socket, this will help with the physical stability of the receiver.

In the first prototype version of the Piglet, the coil form was mounted too close to the 6U8A tube and undesired oscillations would occur with certain tubes. A grounded piece of printed circuit board material was added between the tube and the coil. A further modification of the receiver involved removing the circuit board shield and installing a metallic tube shield around the 6U8A.

Two copper braces were added to mechanically stabilize the front panel against the metal box. The brackets were made from 1/4" copper tubing, the ends were flattened in a vise and drilled to hold the mounting screws.

Parts Sources

A well-stocked junk box is the first place to start, your author scrounged most of the parts for this project from discarded electronics. The tuning capacitor came from an old radio and included a built-in gear-reduction drive. If you use a regular variable capacitor, a vernier dial is highly recommended. Tubes and sockets can be found at Antique Electrical Supply or on eBay. Home Depot, or any well-stocked hardware store will carry the electrical boxes and plumbing parts.

Use

Connect an antenna, power supply and audio amplifier or amplified computer speakers to the receiver. Be sure to ground the receiver chassis for safety and performance. A standard 40 meter ham radio dipole will work well with this receiver, a random longwire antenna will also be sufficient. Apply power to the receiver and let it warm up for a few minutes.

Adjust the Tuning control to a part of the band that you want to listen to. Set the Fine Tuning control to the center of its range. Adjust the Regeneration control until the receiver just starts to hiss. Adjust the Preselect control for the loudest signal, if the receiver starts to squeal, turn the Regen control down a bit. Adjust the Tuning control until you hear a station. Adjust the Fine Tuning control to zero in on the station. At the higher frequency end of the dial, the Fine Tuning control can be used to select individual stations across a small band segment.

All of the controls will interact with each other so it is a bit of an art form to get the receiver tuned to a station and peaked for the best signal. Once the controls are set correctly, the audio quality will be quite good. The Regeneration control will gradually need to be lowered as the Tuning control is changed to higher frequencies. If you tune to an active area on the shortwave band, multiple stations can be selected with just the Tuning control.

When the Regeneration control is adjusted too high, the 6U8A Pentode section has a tendency to break into oscillation at around 15Khz, not all regen circuits behave this way. Numerous changes were tried to eliminate this behavior, including removing the power and connections to the triode stage. Fortunately, this does not affect the receiver performance when it is adjusted correctly.

Circuit Variations

The initial design of this receiver covers 5-10 MHz, which includes several shortwave broadcast bands, the 40 meter ham radio band and the 5 and 10 MHz WWV time stations. With such a wide frequency range, the receiver tuning is very touchy, even with a vernier drive capacitor. If a narrower tuning range is desired, replace the tuning capacitor with a lower-capacitance part and add a fixed-value capacitor in parallel.

This design can be modified to receive frequencies from the AM broadcast band up to around 20 MHz by changing the resonant frequencies of the two tuned circuits.

The detector coil (L1) is already wound on a plug-in coil form. It would be relatively easy to construct other plug-in coils, just use a similar turns percentage (about 30% from the bottom) for locating the cathode tap. The extra pins on the coil socket could be used to connect the unused tuning capacitor sections for operation on lower frequencies. The preselector coil could also be built with a plug-in form, different types of toroid material and turn counts would be required for coverage of other frequency bands.

If the receiver is to be used to pick up ham radio signals, the tuning range should be reduced to cover a much smaller range, such as 6.9-7.4 MHz. This can be accomplished by replacing the tuning capacitor with a much smaller value variable capacitor and placing a fixed capacitor across the new tuning capacitor to set the range. It would be also be a good idea to use a gear reduction vernier dial on the tuning capacitor.

Crystal-Stabilizing the Piglet

An experimental crystal stabilizer was added to the regenerative feedback loop in an effort to stabilize the receiver over a narrow band of the radio spectrum. The results were quite impressive, when the receiver was tuned to near the crystal frequency it suddenly became more sensitive and also more stable. Morse code signals could be copied easily and could be listened to for many minutes without any significant drift.

A large FT-243 ham radio crystal with a nominal frequency of 7.05 MHz was used. With the crystal installed in the socket, the receiver can tune from about 7.03 to 7.05 MHz with the sensitivity dropping off on the edges of that range. When the tuning capacitor is adjusted so that the LC circuit resonates with the crystal, one can hear the crystal "pop in" to resonance and the received signals get much stronger. When the crystal is removed from the socket, the receiver goes back to its normal wide-band operation. For crystal-stabilized operation, the tuning capacitor configuration should be modified for single band operation (see above).

Other options for crystal stabilized tuning include adding a small coil in series with the crystal, using multiple crystals in parallel and using a ceramic resonator instead of a crystal. Ceramic resonators are known to have a wider pulling range than quartz crystals.

Hartley Regen receivers

The Hartley oscillator circuit, with the characteristic tapped inductor, is very common in regenerative receiver detectors: it offers a simple circuit that - from experience - wants to work even in rough, cobbled together formats. Sometimes though, if the gain stage, be it thermionic or solid state, has a bit too much gain, hfe or Gm, or perhaps you set the feedback tap a bit too “generous”, a shunt resistor in parallel with the feedback section of the winding will usually “soften” the beast, and yield a smoother slide into oscillatory autodyne mode for CW and SSB. So much so, the feedback function, rather than being solely applied to power volts or screen grids, can take the form of a pot. across the feedback section of the winding, so you have a “coarse” adjust on the screen grid, and a “fine” tweak pot in parallel across the feedback winding, making the adjustment far easier and repeatable whilst simultaneously softening the slide into oscillation.

I can't give any guaranteed values for the softening resistor, it's a "suck it and see" job - but you'll very soon find a value that delivers better performance.

A different approach to 2m FM? - Take 2!

I had a number of emails about FM on Top Band, for which I thank all correspondents very much! More like that is very encouraging: FM on Top Band is a revelation, for local - and not so local - communications. Some correspondents told me of being threatened by other amateurs that "they were breaking the law" or "you'll lose your licence because I'll report you" by operating NBFM (narrow band frequency modulation) on Top Band. What absolute bigoted nonsense!

The uncalled for obstinacy of these "policemen" amateurs - and this is the sad bit - is woefully wrong, by not having a grasp of their licence as laid down by OFCOM and publicly demonstrating lack of understanding of their license conditions.

A glimpse at the OFCOM (UK) licence does NOT state specific frequency allocations within the amateur bands. OFCOM state categorically what *modes* may be used by amateurs but neither offer (or apply) any band *plans*. They DO, however, suggest the RSGB voluntary plans be used; but give no compulsion, legal or otherwise.

I am fully in favour of band plans in each amateur frequency allocation, where you'll find an "All Modes" sector in each band and this is where NBFM could be used in full conformity with OFCOM and the voluntary RSGB band plans. The RSGB do a magnificent job in offering band plans that suit all current amateur modes - including NBFM in ANY band that has an "All Modes" sector. The steady carrier of FM sounds just like an unmodulated AM carrier, and will present a heterodyne whistle as the receiver tunes past the signal (assuming the BFO or Product Detector is running) - and if that's acceptable for AM then there is no valid argument against NBFM.

The demodulation of FM is beautifully simple nowadays: complete IC intermediate frequency strips on a chip are available; there are Phase Locked Loop demodulators, even the LM567 tone decoder can be used as an add-on FM demodulator, which removes the ratio detector and discriminator alignment issues. The LM567 PLL gives superb results: limiting and auto frequency control come for free along with the 20dB+ noise reduction advantage NBFM offers over AM.

For a real "lateral thinking" experience, consider Nat Bradley's (ZL3VN) discovery, who by introducing a pilot carrier from a local oscillator into the front end of a super regen receiver, demodulated NBFM perfectly by setting the pilot oscillator to exactly the quench frequency above or below the NBFM centre frequency.

This hints at some possibilities: make the pilot carrier oscillator variable, or - and this caught GW6NGR's attention - make the quench oscillator variable. Thus you could adjust the quench oscillator to "tune in" the receiver. This also hints at multiple channels being available on one carrier frequency, by running several different quench frequencies! There MUST be a snag somewhere with this!

A guide to successful Regen Receivers...

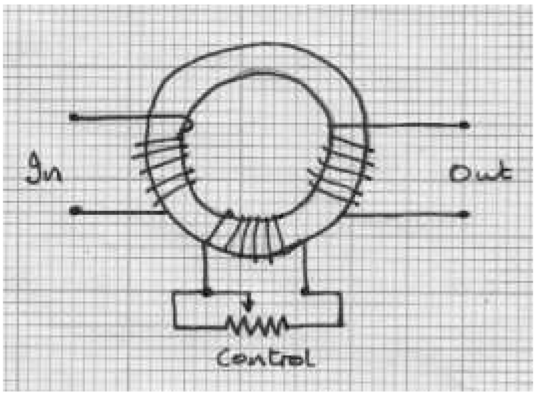
Once in a lifetime, an expert in regenerative receivers shows up. Dave Schmarder (N2DS) is one of these: his advice, designs and finished results are a credit to him and are a guide to all those interested in making a radio receiver that performs in the top notch category. You'll find all the relevant information you'll ever need for reference in his pages http://makearadio.com/; I was intending to give a sample below of his guide to making a high performance regen receiver; but after trying for a week, trawling through all his web pages and references to find an email address to write to and ask his permission - I found nothing to help. I don't want to upset Dave in any way and understand why he might want to be "unobtanium", so if anybody does have a contact email for Dave Schmarder I'd very much like to ask his permission to use his regen guide.

In the meantime I suggest you check his website out; he's an amateur - N2DS - so he knows the score with HF receivers. If you know his email, please forward it to me at equieng@gmail.com .

The Cachia Attenuator

Here's an input attenuator that can be made from junque parts, no critical bits. Basically, it's a transformer with a third "load" winding - the input winding creates flux in the core which is "robbed" by the control winding and rheostat, before coupling to the output turns.

Any ferrite ring will (probably) do; make two identical "signal" windings, and add a third "control" winding to connect to the rheostat. You will need to cut and try; as a start I usually try 3 x 10 turns, and a 100K - 1k (not *too* critical...!) carbon track potentiometer on VERY SHORT leads to the control winding. If you have a signal generator, you can try the attenuator by tuning your signal generator and receiver together, then inserting the Cachia attenuator in the line and check the effect. Not bad for a few junque parts! Make it up in a neat box when you've got the optimum performance with handy plugs and sockets for quick deployment.



Direct conversion receivers & SSB - the 4th. Method?

A novel approach to SSB - The 4th. method? See:

https://sites.google.com/site/vk3bhr/home/ssb-by-the-4th-method

I particularly like the blend of standard value phasing network with digital quadrature signal generation. Probably not the simplest method; but likely the easiest using commonly available (& therefore cheap...) parts: it's well worth a shot if you're an SSB aficionado!

Tx Topics

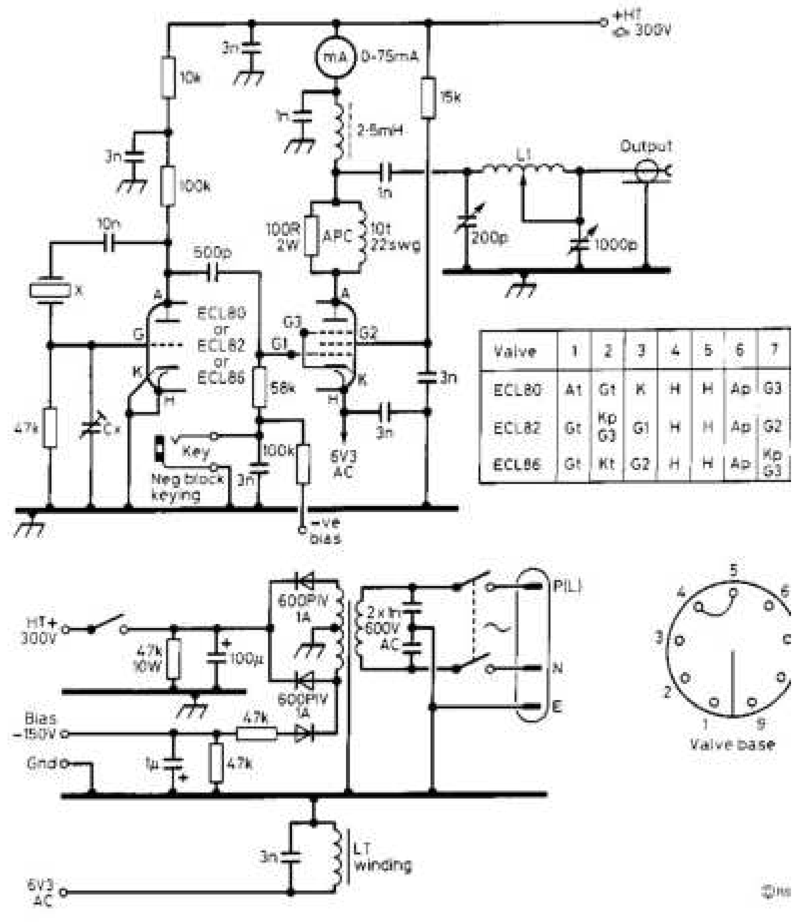
ECL 86 transmitter by G4VAM

How simple can it be? Bombproof, too! Knock this up with an el-cheapo PCL86 TV tube for a really nice home brew transmitter. The anode meter can be replaced with a filament lamp; 12v at 120mA would be about right, fitted with a “tune / run” shorting switch for those extra mW’s.

For the filament supply, 13.3v at 300 mA, use the 6.3v winding and a voltage doubler, then add a series ohm or two to get bang on. It’s not unknown for “enthusiastic” amateurs to push this valve to 13.5v on the heaters; and 350v (or more) on the anode. Just remember to back off a bit when the anode glows cherry red...!

A.M. enthusiasts could try “cathode modulation” for with a mosfet in the cathode to ground link: adjust the mosfet gate bias for 50% carrier output with key down and no audio applied to the mosfet gate. You’ll need some RFC’s and decoupling capacitors to keep the RF out the audio section.

The 14GW8 tube, perhaps more common than the PCL86 in the USA, and maybe cheaper too - is a direct substitute for the PCL86, but I’ve been told the pinout can be different so double check. You can usually spot the anode connections coming down through the base, and the filament leads - these in the “right” place should tell you if you’ve got a plug-n-play substitute.



Valve	1	2	3	4	5	6	7
ECL80	At	Gt	K	H	H	Ap	G3
ECL82	Gt	Kp G3	G1	H	H	Ap	G2
ECL86	Gt	Kt	G2	H	H	Ap	Kp G3

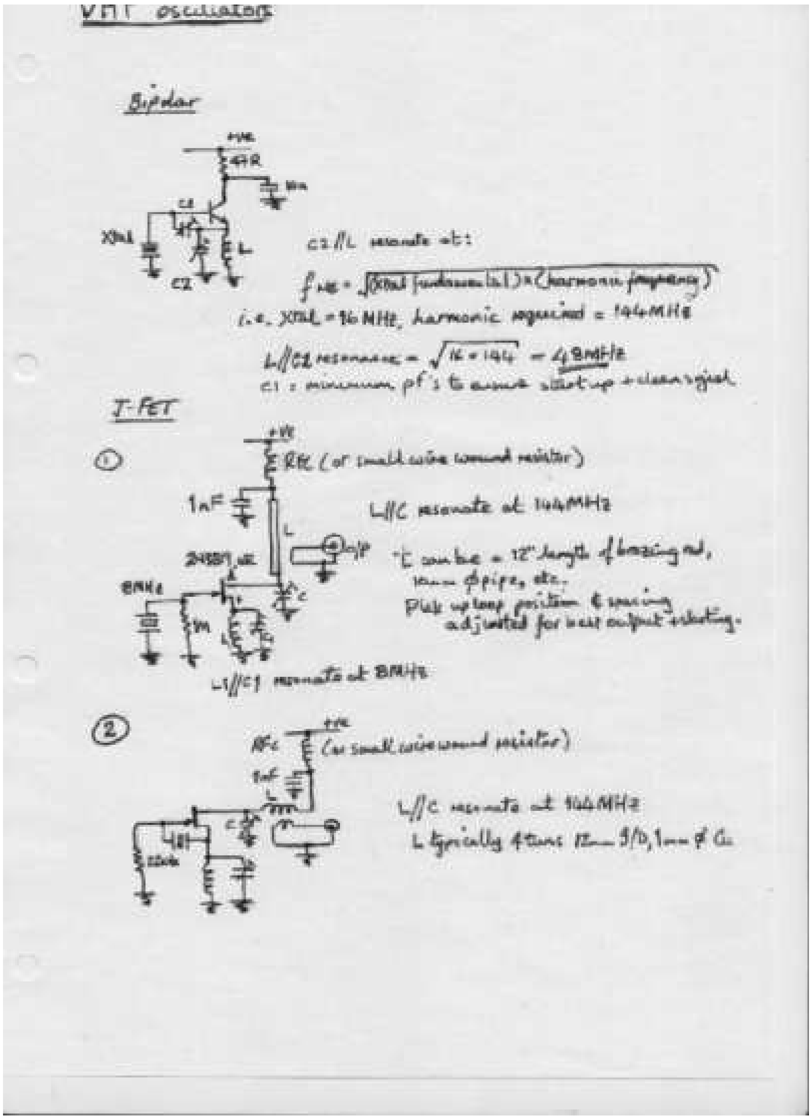
A QRPP 2m transmitter

It’s a very handy device to have around, if you’re into VHF: a local signal source to test your designs. I use a Trio Grid Dip Oscillator, but is afflicted by quite severe “driftitis”, a nasty feature of simple oscillators running at these frequencies - but for quick resonance checks and similar GDO jobs, quite adequate. So, 8 MHz crystal from the junque box, a crystal oscillator cobbled together, and lo! I had a stable, reliable signal source for Rx test. Pete Insley, who ran a radio and TV repair shop, put me onto these circuits, he used them as alignment aids for his VHF radio repairs by substituting crystal to hit 90MHz output. Of course you can substitute crystals and resonant elements for 4m or 6m bands, whatever you have to hand or prefer.

Below are a few VHF crystal oscillators, all of which use resonant harmonic multiplication and make dinky QRPP transmitters, when matched into a half decent Yagi antenna.

Tune the oscillator L & C for a dip in supply current, as per usual practice, you can detect output level with a simple Germanium diode probe - “tune for maximum smoke” as Stan used to tell me!

(Apologies for the reproduction quality; the original was a rather old piece of paper. Use “zoom in” to see in detail).



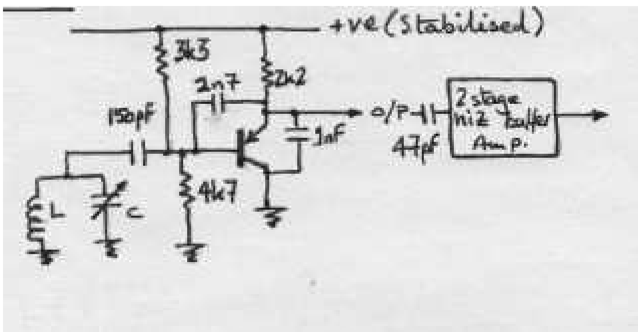
Oscillator Topics

The Synthetic Rock

I had a request for my "favourite" VFO circuit, meaning an L / C oscillator rather than a PLL / DDS, for 5MHz. For decent results you MUST use a good quality tuning capacitor(s), and a rock solid inductor wound on a decent former. These are not easy components to procure nowadays: a handy trick is to get a good example and design your VFO's to use an "outboard" tuning capacitor and inductor combination. The power supply is critical too: double stabilisation, via two monolithic regulator chips is a good way to go: initially to (say) 8 volts from +12v DC, then to 5v DC to feed the oscillator. The lower the voltage to the oscillator, the less the elements in the circuit heat up: running your oscillators on as low a voltage as you can is therefore a good idea. You might need a couple of buffer amplifiers to get the drive you need; but buffer amplifiers, if well away from the L / C, don't contribute to drift.

A diecast box for your superb L & C parts, with wide strips of pcb material to make the connecting jumpers inside (some oscillator circuits need parallel, some series, L / C combinations) is a good idea. Make the external interconnection a short length of screened cable, no longer than absolutely necessary; or make it a BNC socket on each and a "back-to-back" BNC adapter to connect them. The earthing of the L / C parts allows this and it makes for a very stable secure connection; as a series connected L / C oscillator doesn't care which component is earthed.

This circuit is a Seiler; it dates to 1963, and is the famed solid state "synthetic rock". It will, after a little warm up, hold zero beat with a crystal if reasonably steady temperatures are maintained - I've been tempted to try a Huff-n-Puff stabiliser on it, which would probably yield a good (low cost and easy!) substitute for a DDS / PLL, as it doesn't have the spurs and noise of digital controls.

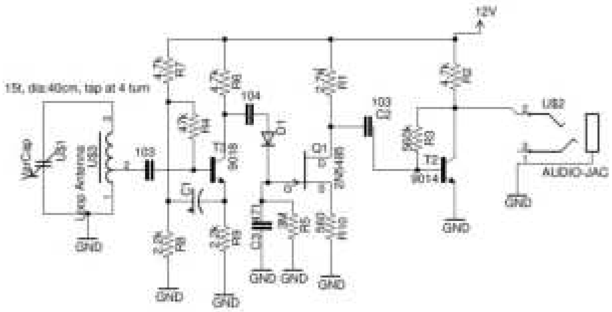


Purists will note the huge capacitances wrapped around the transistor: this is the key to good performance, as the any temperature shift in the transistor parameters and internal capacitances is swamped by the huge chunks of pF's wrapped around each terminal. Make the capacitors with NP0 dielectric, it's an idea to substitute the tuning capacitor(s) with a fixed NP0 capacitor, and note the drift after an hour - the fixed NP0 capacitor shows you the drift attributable to the inductor and the construction, so you can use a different ceramic dielectric capacitor to correct the drift. A useful reference is:

https://forum.digikey.com/t/understanding-ceramic-capacitor-temp-coefficients/727 .

The PNP design also allows earthing the collector, a great aid to stability and heat sinking, a heatsink on the transistor will help stability in most cases.

The 150pF base capacitor “unloads” the tuned circuit; another idea was active bootstrapping the base bias point - as in the circuit below, which is a simple bootstrapped TRF receiver, to illustrate bootstrapping an L / C resonant circuit:



(I don’t have the original reference for this circuit - if you recognise it please let me know).

The positive feedback via C1 creates >1Mohm input impedance, relieving the tuned circuit of virtually all loading, increasing the tuned circuit “Q” without using “traditional” regeneration. The bootstrap principle can be readily adapted to oscillators, amplifiers and any other application requiring high AC signal input impedances. For a more comprehensive reference about bootstrapping, see http://www.keith-snook.info/wireless-world-magazine/Wireless-World-1968/High%20Input-Impedance%20Amplifier%20Circuits.pdf .

Audio Topics

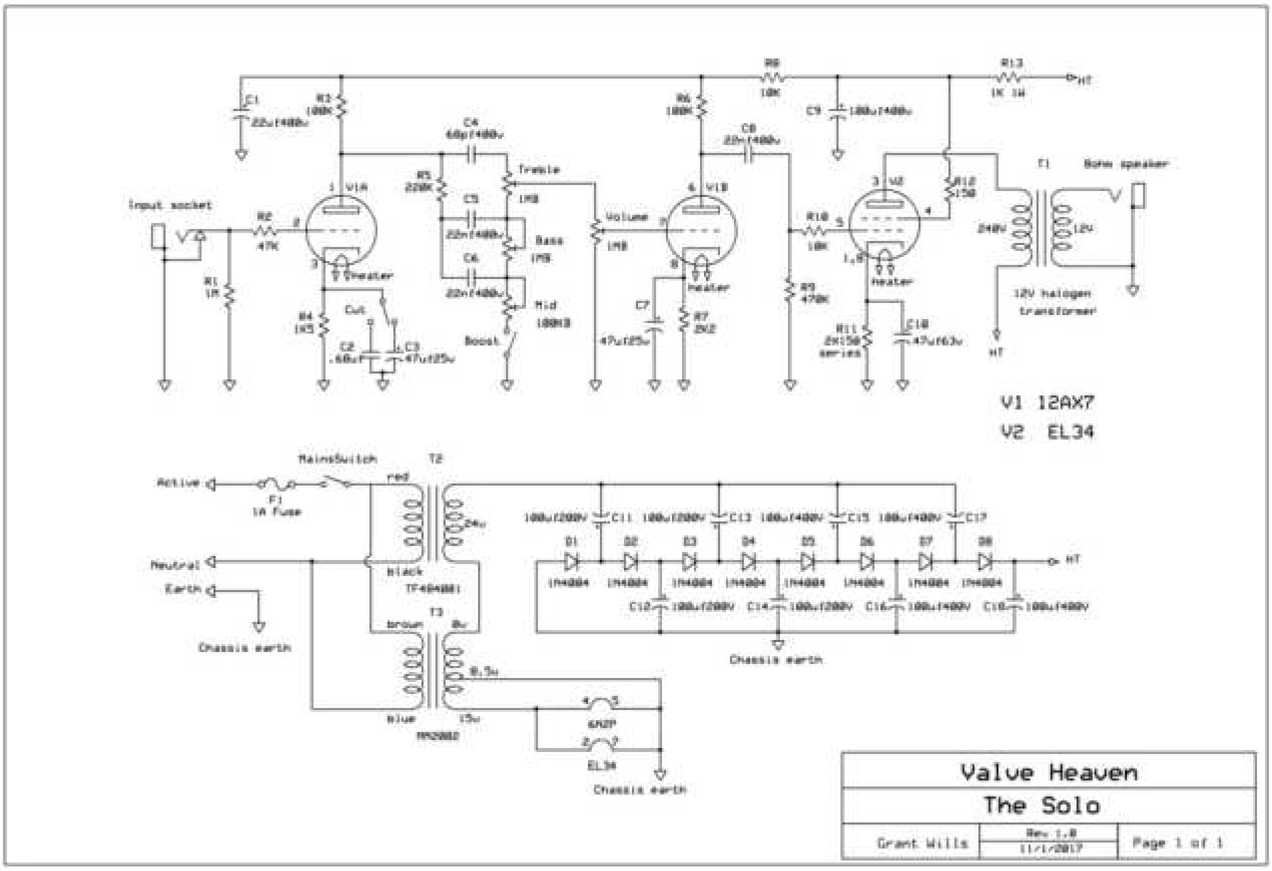
Valve Heaven

Working as I did in a factory with an applications lab that had several audio amplifier geniuses creating phonic sonic miracles it was guaranteed some audio appreciation rubbed off on me! One particular design was a 150 watt A.F. slave amplifier, based on a ZN424 gated op-amp. I would give a great deal to see that circuit again!

One major point though: to get really linear, low distortion amplifiers capable of driving cathode ray tube scan coils - a more or less identical job to driving loudspeakers - you need a complex circuit, and, in some instances, matched pairs or quads - whereas older hands who had been brought up with “Williamson” valve amplifiers loved the valve circuit simplicity (derived primarily from canny output transformer screen grid taps) generally disliked the feedback and bootstrapping in silicon designs.

The arguments for and against solid state vs. thermionic amplifiers still rages today: neither will win, it’s so subjective. But experience points toward the inherent simplicity of tube designs, delivering reliable watts of “good-to-the-ear” audio. The commercial music industry like tubed amplifiers: there’s a damn good reason for that, and it’s not nostalgia!

In hunting around for active, practical designs for “TV” type tubes with “odd” heater voltages - thus still obtainable at penny prices (well, nearly...) as “NOS” - I came across Grant’s web pages [https://valveheaven.com] and lo! There was the answer to my prayers: take a look, read slowly and absorb the wisdom. You won’t be disappointed! Below is Grant’s design of a simple 10 watt valve amplifier, using common tubes.



Take a look at that power supply: I've not seen a parallel voltage octupler circuit driving real mA's for many a year. Note that the diodes are rated at comparatively low voltages; the electrolytics step up in voltage rating, unlike the diodes, as in the usual "series" connected multipliers. Note too the heater voltages - Grant is a lover of TV tubes and halogen lamp transformers. He uses, in some instances, these low cost transformers as valve output transformers, the turns ratio of roughly 20 to 1 (240v in, ~12v out) giving an impedance ratio of 400 to 1 - an 8 ohms load = 3k2 in the anode, far cheaper and vastly more available than many other "audio transformer" solutions.

He's not over driving the heaters using an 8.5 volt tapping: the wiring combined with transformer regulation means he gets 6.3v delivered right at the valve base terminals.

Would you like to check out those junk box tubes you have never used? Try Grant's Tube Tester, so simple, so straightforward. Take a look at:

http://www.valveheaven.com/2015/03/an-inexpensive-easy-to-build-diy-valvetube-tester/

A different "TV tubes" amplifier is at: https://valveheaven.com/2019/11/another-tv-special-amp/ which illustrates a simple "doubler and dropper" set up to get the heater voltages spot on.

Power Supply Topics

The "ideal" HV power supply & some Notes on Safety Earthing

From: https://www.angelfire.com/electronic/funwithtubes/Com_Rcvr-E.html I read what follows; & I agree entirely!

Safety Grounding.

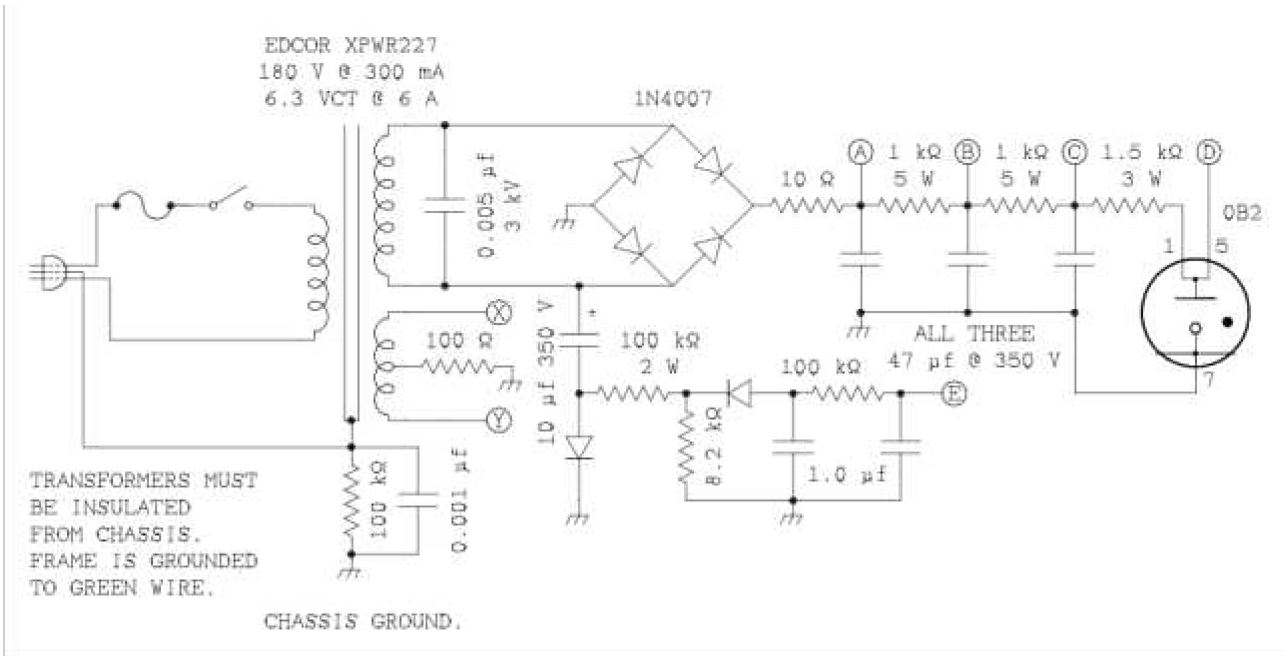
Electrical safety has been taken to the extreme of forcing new construction to use spark detecting circuit breakers that will be tripped by a sparking thermostat in a hair dryer or an electric drill with a sparking commutator. I have to advise you to be safe so you can't say I didn't warn you! A ham station is one of the safest things around because it is connected to an antenna earth / ground that in most cases is better than the one the power company put in when the house was built; however that's not enough for some safety fanatics. Here is my advice and it's up to you to take it or leave it.

Insulate the power transformer from the chassis and connect it to the third wire ground which is usually a green wire in power cords with molded plugs or a green screw in a plug you attach to the cord yourself. If a fault develops in the power transformer the fault current will go back to the power ground as intended. The power on/off switch should be similarly isolated from chassis and connected to the power safety ground. No metal that is part of the switch should be located where the operator can come in contact with it.

"*The secondary is connected to the chassis which is the common return for the rest of the receiver. Just in case the receiver is operated away from the ham station ground there is a resistor capacitor parallel combination connected from the power safety ground to the chassis.*

The reason the two grounds are not connected together is 60 Hz hum. When an independent ground is connected to the power ground, such as the TV cable or a ham station, relatively large current flows because there is a small potential difference between the two grounds. Although the voltage is small, so is the impedance so the current is relatively large. This will induce hum into everything including your transmitted signal. If your station happens to be located right next to the main electrical panel you may want to try using the power ground as your station ground. This may or may not work. Be prepared to sink your own ground if it does not."

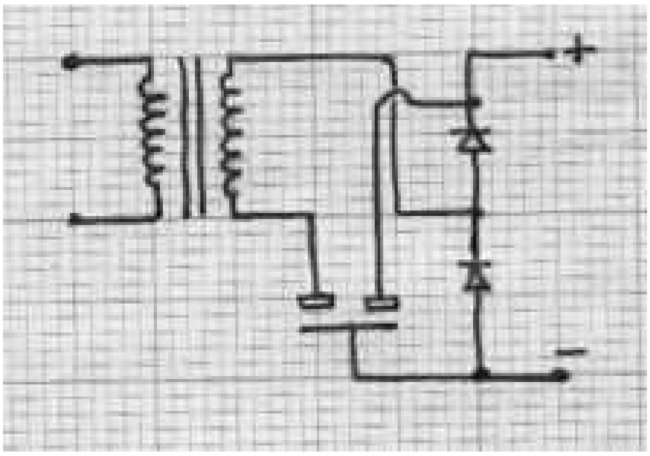
He shows the following diagram to illustrate:



The Dinky Doubler

Years ago double or twin electrolytics in one canister were common: you got reservoir and smoothing capacitors all in one, with a common negative terminal (the metal case). The addition of a choke or low ohms power resistor between the two positive terminals gave you a complete power supply in very small space for tube electronics. Nowadays these are rarely seen; but the circuit is still of interest as it's so simple and effective, and the insulating sleeves on HV electrolytics are well capable of service in this application. Below is a full voltage doubler using a twin common -ve electrolytic.

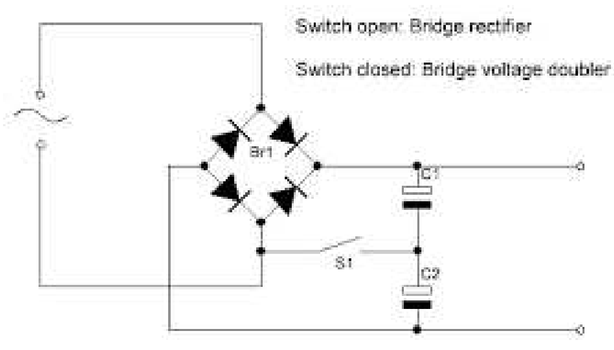
It's also a note to those of us who service tube gear of any sort: those old boys certainly knew their onions when it came to economical and elegant design, something seemingly forgotten in this day and age where the ease of bunging in another dozen or two active devices renders modern designers somewhat lacking in the wonderful (read "reliable") simplicity of economical design!



QRP or QRO?

Here's a wonderfully simple design, that's adaptable to either tube or solid state jobs: it's a voltage doubler with TWO massive advantages. It uses a cheap and readily available bridge rectifier and it can provide either "QRP" output volts or... for QRO operators who want all the RF watts they can get (think RTTY and the like), a doubled output - at the flick of a switch. Neat, eh? Using a common 120v to 230v transformer - or back-to-back halogen lamp transformers to get 230v AC, this circuit gives ~ 310v or ~ 620v.

Might be usefully used for the PCL86 transmitter, for instance, if fed with 110v AC?



My thanks to the author of this diagram - not given on the image. Please let me know if it's yours and I'll credit you in the next edition.

Component Topics

Home made RF chokes

RFC's can be made cheaply and easily by adopting, adapting and improving other technologies - in this instance, sewing machines! Nowadays the once common 2.5mH RFC's are rare, if not "Unobtanium" - so here's a good substitute.

To make your own RFC's, you need a few items, as well as the enamelled copper wire for the winding. First, from our favourite auction house, you need "Universal Sewing Bobbins": typically https://www.ebay.co.uk/itm/262670781164?hash=item3d28660aec:g:afwAAOSwZmdgeEHi . Then, by watching your local rummage sales, junk shops and such like, procure a small hand drill, as per:

To mount the drill, you'll need a small vice - the suction based type is good - and this holds the hand drill by gripping the body beneath the large pinion wheel, thus putting the drill in a horizontal position. Some M4 steel bolts, 30mm long or more, with some M4 washers and an M4 wing nut for easy mounting of the sewing machine plastic bobbins in the chuck of the hand drill are used to grip and turn the bobbins.

The spool of enamelled copper wire is held on a bit of dowel (or even a pencil!) fitted vertically into an offcut of timber, weighted down or clamped to a table top; the friction to tension the wire as it's wound is created by packing some kitchen tissue packed into the centre of the wire spool to bind gently on the vertical dowel. Mount the sewing machine bobbin on the 4mm diameter bolt, and lock into the drill chuck. Mount the spool of wire and friction dowel roughly in line with the bobbin in the drill chuck and clamp or weight it to maintain its position.

Now it's time to wind the choke. Feed some wire through a convenient hole in the sewing machine bobbin; they are usually moulded in. Feed through the hole roughly 100mm of enamelled copper wire and secure with super glue or hot melt glue.

Start rotating the hand drill handle, guiding the wire with the free hand; the friction on the wire spool sets the tension and is maintained as long as you keep a little pressure on the drill handle. Fill the inner diameter of the sewing machine bobbin evenly until you reach the opposite cheek; a touch of super glue secures. Now, and this is an important point, bring the now secured wire back across the first layer of turns to the start cheek, in just one turn - this minimises the capacitance between the layers - and secure with super glue. Wind the second layer, exactly above the first layer, and return to the start end cheek once again when the second layer is complete. Fill the bobbin keeping the windings neat and tidy, always returning to the start end cheek after every each complete layer and using super glue to keep the windings secure. Keep a tally of the completed layers for reference.

For the low bands, say below 20m, fill the bobbin, keeping pressure on the end cheeks to a minimum. For the higher frequencies, you'll need fewer layers: at 10m probably a single layer will do fine. Check the inductance thus created with a home made Maxwell bridge, or direct reading instrument. My first attempt was ~ 2.0mH with 38 swg enamelled copper wire and a full-ish bobbin, with soft iron pins packed into the core of the inductor, measured on my home made bridge. Bear in mind too, the bobbin can be anchored with a screw through the centre hole very easily.

The layers of windings tally can be used to scale up or down your inductors; the multiplication ratio makes the winding job a doddle. Always remember to keep some friction pressure on the wire spool; some people use springs and cotton pads, weights on top of the spool - in fact anything to stop the wire spool spinning freely and preventing the wire from springing off the spool and unravelling. I've even used spring clothes pegs, a lump of rock off the beach with a hole drilled in - you name it, it will probably work.

Low Ohms "resistors"?

Need an ohm or two for a filament dropper? Use a length of wire, neatly coiled up for the job. Got a bit of ribbon cable? Join alternate ends to form a series chain, and you've got a yard or two of thin wire in a neat package that's low inductance too, should the job need that.

Fault Finding without a Schematic: COLD TESTING

WARNING: **On an unknown pcb or circuit you must exercise due caution at all times: all mains power MUST be removed and an "Earth Hook" fitted to short incoming mains terminal(s) to Earth; capacitors must be discharged via a 240 volt 10 watt lamp in series with a 3k9 / 10 watt resistor on INSULATED clip leads (which has saved my life more than once - if the lamp doesn't dim after a few moments consider that terminal as continuously LIVE). ALWAYS cold test as far as possible before testing powered up. This applies to ANY supply voltage or system.**

Ask the user...

When faced with a "dud", find out as much as possible what happened at the last attempt to run the circuit / system. Typically "it was running fine, but then made a funny noise and then nothing", "it wouldn't switch on", "it's not run for a year or two (for which read 20 or more!)".

All these (and a hundred more, all of similar features) point towards a fault based on different prognoses, as below.

Description given	Probable fault symptom
Running then stopped	Sudden failure: something's blown or died the death.
Won't start up but was running OK yesterdayS	Start up surge and / or start resistor(s) blown; no mains fuse, on/off switch jammed / welded off,

Description given	Probable fault symptom
	look for mechanical problems, broken wire(s) inside sheaths, unplugged loose plugs / sockets.
Not run for a while	Electrolytics! Or vermin, damp rot, physical damage, perished insulation, resistors open circuit, relays jammed, connectors rotted, wires snapped... plus all the above.

Fault categories (1) & (2) call for immediate physical inspection; fault category (3), get ready for a long slog! All this assumes that some daft Herbert hasn't been in and radically altered the original (functioning!) design. I often wonder what these bumblers are trying to achieve: they make changes and alterations without any notes, get deep into a non-functioning mire, then go on chopping and changing until eventually wrecking the whole thing.

The only hope here is a rebuild (possibly from archive libraries or other on-line sources to original circuit and components (or substitutes that are very close to original) then repair the mechanical mayhem these clowns have created. As you might gather, I've been in this situation before - and the wreaker of all this havoc usually denies all responsibility, even though he bought it from new and nobody else has ever been in there.

Don't always believe the symptoms of failure you're told: "oh, it just won't start..." can really mean "I've been in there and randomly changed everything I could find, then plugged it in but it blew the mains and internal fuses so I tried 13 amp plug top fuses instead of 2 amp and then tried 30 amp car fuses...". Yes, it's happened to me when taking on a repair for an (erstwhile) friend.

First Moves

Open all the covers to physically inspect the circuit / system. Look for components with burns, damage or fractures. Simply replacing a burnt out component (including fuses!) is pointless: the original died for a reason, and you must resolve this before replacement. Look too for lead wires fractured right next to the component or just above the pcb; resistors burnt; capacitors swollen or distorted; tracks blown out; pcb scorched; wire insulation melted or burned. Use all your senses: gently tug and stress test connection wires, components, plugs and sockets, IC's in sockets (always a favourite candidate for "weird" faults); trapped or crushed wires / coax. You can sometimes smell "burn out" faults, see the leakage of electrolyte from electrolytic capacitors bulging cases, discoloured pins or nearby pcb tracks on connectors.

Cold Testing common semiconductors

Cold Testing means, in most instances, looking for short circuits with your multimeter. Not just low resistances, this means dead shorts, and you might need to take into account your meter's test lead resistances if the instrument can't compensate for these.

Test every semiconductor device with your multimeter set on "OHMS / Diode Test" (or, if you're using an analogue meter, the readings with a known good diode). Note many analogue meters REVERSE the probe polarity on OHMS test, black becoming "+ve" and RED "-ve". Checking your meter's reading on a known good diode proves the polarity of the test probes and gives a "good" reading for you to refer to during fault finding.

I keep a set of known good semiconductor devices to check my instruments at the start of each shift, and after break time - it's not unknown for your "mates" to "borrow" the battery from your multimeter whilst you're away from your bench!

Check each transistor / diode for short circuits, from every pin to every other. Next identify the diodes that make bipolar transistors / jfet's / mosfet's - but be aware that not all mosfets have diodes from Source to Drain; nor are all mosfets N channel with the protection diode cathode connected to Drain: P Channel mosfets reverse this.

Any bipolar transistor will test as two back-to-back diodes on OHMS test, the BASE terminal being the centre connection of two diodes. For NPN, base terminal is +ve probe, diode reading with -ve probe to the other two pins. For PNP reverse this: base = -ve, collector & emitter = diode.

For a jfet, you can find the gate similarly, using one probe to drain or source, the other probe to gate = diode. Note that drain to source will read some (high-ish) resistance, unlike bipolar transistors.

Many power mosfets show a diode from Drain to Source; but small signal mosfets (2N7000, &c.) don't always have this diode: it depends on the manufacturing technologies used. A sneaky test for mosfet functioning is to clip your meter on "OHMS" +ve probe to drain and -ve probe to source, then touch the gate terminal with a graphite pencil tip. Usually the mosfet turns "on", giving a low OHMS reading on the meter. You might need to reverse your meter probes for this to work, it depends on the mosfet polarity, P or N channel. +ve probe to Drain = N channel; -ve probe to Drain = P channel.

Cold Testing Passive Components

Resistors...

...Are where you look for open circuits: a resistor should have some electrical path through them! Check each resistor for a reading on your multimeter when set on OHMS. Resistors can go high with age: this often used to be carbon composition types on screen grid feeds, but nowadays, even quality metal oxide resistors suffer from old age. Any resistor (usually) above a few k-ohms is suspect - why this is, I don't know - but 47k and up are good candidates for going high or open. When testing any resistor in circuit, you should read something equal or lower than the rated value as there must be circuitry around it in parallel! Try reversing your test probes; this might give you a better indication, as it's common for a diode to be fitted reverse polarity in the power supply to catch any inductive backwash which can cause odd readings.

Note too that mains input filters often contain high value resistors to bleed the capacitors down in high power filters. These bleed resistors, failed open circuit, can leave hefty µF capacitors charged up to mains peak volts and capable of giving a very nasty "bite". Your 10 Watt lamp in series with a 3k9 power resistor should be used every time a filter is suspected to discharge all pins to each other, then leave shorting croc clip lead shorting the capacitor terminals together.

On systems where you can't be alongside the mains power source switch, lock out the switch (if possible) and put an "earth hook" onto the live incoming terminal of the equipment. This is a hook, lug or similar fits onto the live incoming termination; the other end is fastened to a solid Earth terminal. Any attempt to power up the circuit immediately blows the upstream fuse, protecting the fault finder from a dangerous situation.

Capacitors...
Of all electronic components, the most likely candidate for old age infirmity is the electrolytic capacitor! You'll fix many electronic faults by simply changing all the electrolytics, lock stock and barrel. If you're a purist, remove every electrolytic and test its ESR with a suitable instrument (an AC OHMS meter in effect). Several circuits have featured in Hot Iron and simple bench test gizmos are available if you're wanting to take up electronic fault finding for professional reasons.

Capacitors in mains AC service - filters and the like - are specially rated for continuous AC mains service. DON'T substitute any other, it's dangerous and false economy. Class X and Y are the ones to go for: https://www.allaboutcircuits.com/technical-articles/safety-capacitor-class-x-and-class-y-capacitors/ has an excellent description and pictures. Basically, Class X are for Line to Line; Class Y are for Line to Neutral. They make superb RF coupling capacitors: just watch the DC levels and voltage ratings, you might need to put a few in series to stand off the volts when used as kV anode couplings.

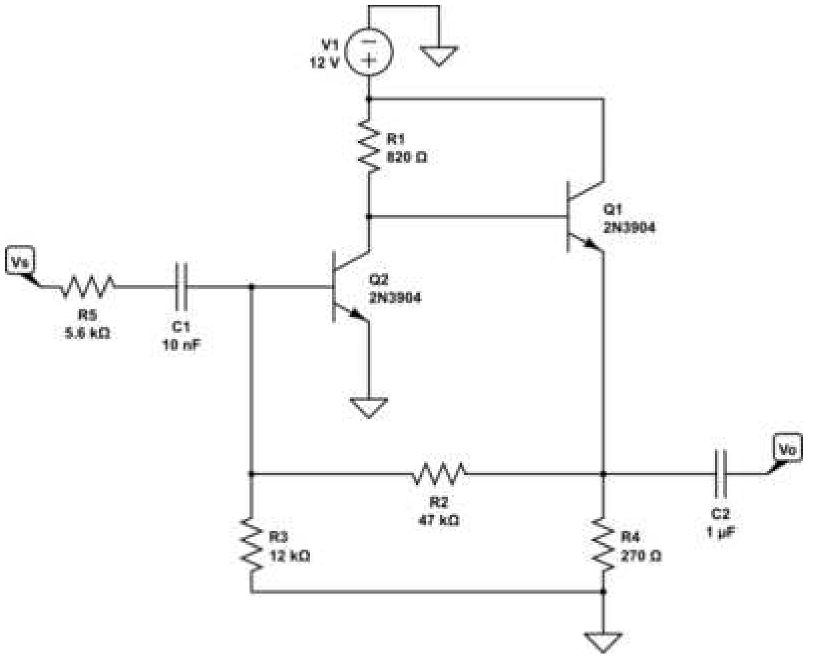
Smaller film capacitors, used all through RF applications, are pretty tough; failures will generally show as two bits of wire with an exploded mess in the middle. What some amateurs forget is the peak RF volts add to the standing DC bias: under high VSWR conditions blown capacitors can indicate an intermittent antenna, dodgy counterpoise or earth mat connection.

Relays
These are often used for Rx / Tx switch-over duty - and if you're a break-in CW operator you're going to need a good supply of spare relays! In basic terms anything that has bearings and contacts will wear out at exactly the wrong moment. Bearings wear; contacts burn. Anything that moves or is subject to mechanical movement like connectors and sockets are other likely candidates for going open circuit when the power is running flat out. Why this should be I don't know: but do it, it does, so be ready! Think “MMS” - “Micro Mechanical Systems” are a million times more unreliable than a hefty diode electronic switch.

Hot testing - measure the volts at every node

Locate the power supply tracks from the smoothing capacitors or voltage regulators on the pcb: these are usually bellwethers to guide you into the circuit. “Common” rails can soon be found with OHMS tests; usually they are the NEGATIVE supply connection - but NOT always. POSITIVE supply tracks can be found from voltage regulator output pin “cold ohms” test to tracks.

Consider the circuit below:



Here is a quick analysis to illustrate fault finding. We don't have a circuit diagram, but we can see the wider common ground tracks on the PCB so it's a good guess that's the point for our negative probe of our multimeter. Similarly, we know the +ve. supply from "cold ohms" testing from regulator chip output pins to various heavy tracks on the circuit board. Watch for components in the common lead of three terminal regulators: often used for auxiliary functions and "jacking up" the output volts.

Let's look at transistor Q2 using a voltmeter (an analogue multimeter for preference). We don't know (or can't find) any information about the transistor; we don't know if it's a jfet, bipolar, or mosfet. It has 3 pins.

Q2 Pin	Voltage to common / gnd.	Probable terminal
1	0.55v.	Base
2	5.5v.	Collector
3	0.0v.	Emitter

It's a good guess the transistor is an NPN bipolar from these results: we know from "cold test ohms" it read as two diodes and an "o/c" across the diode cathode ends. If it was depletion jfet, you would have picked up ONE diode, the gate - and an equal (high-ish) resistance reading either way between the other two terminals, probably the drain and source, which are (usually) interchangeable.

In circuit, volts "on", a j-fet is identified by the source being more +ve than the gate (n channel, the most common type). We can use similar logic on Q1: the chart would look like below.

Q1 Pin	Voltage to common / gnd.	Probable terminal
1	4.9v.	Emitter
2	12.0v	Collector
3	5.5v.	Base

If you look at pin 3 and pin 1 voltages above, you'll spot a silicon diode forward volt drop: the dead give-away. One terminal is at supply rail, or nearly so, and one terminal is at identical voltage to the previous test result chart: they are indeed directly connected, as found by a "cold ohms" test to double check.

You can now, with the aid of the charts, "cold ohms" checks, and physical layout, sketch the circuit and thus see it's function: it's at two stage buffer amplifier, with voltage gain (Av) of 47k divided by12k = 3.92

A "logical" approach
You will see in many fault finding guides the term "...using a logical approach...". The authors rarely, if ever, tell you what that is! At Hot Iron, we take a far more practical viewpoint: below is a technique taught to me by Stan, my mentor all those years ago, when I was a green as grass and hadn't seen the millions of circuit failures Stan had. I was faced with a Cathode Ray Tube scan coil test unit, used in testing radar cathode ray tubes. It generated ramp currents that were applied to the X and Y deflection coils, to create a spiral sweeping the electron spot from the dead centre to the outer periphery, then back to the centre during flyback blanking and off again on its perpetual (or not so perpetual, as it had ceased to function!) journey round and round.

I'd "cold ohms" checked, and found a dud output transistor, short circuit, every terminal to every other. I had the chart below from Stan's guidance:

Reading between every terminal	Probable cause
Dead Short between all terminals	Over-voltage or reverse polarity "punch through" of the internal junctions.
Open Circuit between all terminals	Over-current blown the bond wires.
Ohms between all terminals, tested both directions	Long term overload has melted the silicon die.

A Logical Approach: Artificially duplicate the problem
So, what had blown the transistor? Where had the short circuit come from? Probably - from the chart - over-voltage. Stan came, out as ever, with a golden phrase that still echoes from all those years ago: "what would you have to do to make this circuit create these voltages?". Or, "what voltages would I see if the transistor was collector to emitter short? (or open?)" In this instance, I needed to find where a high or reverse polarity voltage could have come from.

This is the trick Stan taught me: at each stage in a circuit, how would you (mentally!) artificially duplicate the fault conditions you see? Stan gave these examples: "if you find a collector at a very low voltage above ground, you could duplicate that fault with a short, collector to ground, yes? Or driving permanent base current? If the collector was at full rail volts, you could duplicate that fault by open circuiting the collector bond wire inside the transistor? Or shorting the collector load out? Or open circuiting the base bias?”

I saw the point he was making. How could you make this circuit create the situation you’re seeing with some artificial means - because those are the probable cause(s) of the fault you’re seeing, and now you know what and where to test.

I knew over-voltage was the likely cause; the load was inductive (scan coils round a CRT) so where was the backwash (Lenz’s law) back emf protection? A quick search showed, on cold OHMS, a open circuit diode - soldered to the scan coil binding post terminals inside the test gear - the anode connected to the collector, the cathode to the HV positive rail, in reverse parallel with the scan coil on test. Stan reckoned it had been fitted to cope with possible open circuits in the coil wires, and fitted right on the binding posts to stop transients entering the test gear. The diode was quickly replaced; a new drive transistor fitted and a scan coil connected and tested OK. I did notice one of the binding posts slipped round a little as I tightened up the securing nuts...

Ask ‘Why?’ five times...
Stan wasn’t happy. The cause of the O/C diode was not an electrical fault: on close inspection, one binding post had lost its locating key, and was move slightly when the operator tightened up the binding post. The original backwash diode, fitted directly to the binding post terminals, had sheared a “leg”, and this was the source of the open circuit and consequent damaged transistor.

Stan recommended I replace the binding post and apply hefty dose of epoxy resin as double indemnity: then he played a simple but effective master stroke. “Critical components like this diode should always have some redundancy both electrically and mechanically. These binding posts get a right heave-ho hundreds of times a week, every time a coil goes on test. Fit the new diode on flying leads, if the binding post locating key fails again, the diode won’t be damaged”. I made up a pair of flying leads by winding wire round my screwdriver blade to make a simple “spring”, and re-fitted the diode with heat shrink to cover the diode lead wires and solder joints.

“Always consider the cause of the fault, and keep backtracking to find the root cause. You might have to ask ‘why?’ five times as you backtrack to get the real source of trouble! Don’t just bung another component in - it will fail again sooner or later”.

Thank you, Stan: the radar scan coil test gear flew like a bird for years, no more problems.

Construction Topics

Lighting - spot lamps vs flood lights
Modern LED bench lights are a godsend in some cases. Years ago we had halogen lamp spotlights (as used on microscopes and the like) for close bench work; the modern single, ultra-bright LED type, on a long flexible chrome “bendy stalk” is a modern alternative that can throw a bright light just where you want it, stays cools so you don’t burn your fingers, and can get right in to see awkward spots. They do have a problem, though, just as the old halogen lights did: they cast very intense shadows, the brightness of the illuminated spot swamping any peripheral view, and causing some quite severe eye strain, especially in those who wear glasses.

An easy solution is to also use an old fashioned bench (or machine tool) incandescent work light, set a bit higher up; it's more red biased tungsten filament illumination dispels deep shadows and allows much longer on the bench without consequent eye strain. A 40 watt incandescent lamp is perfectly adequate for most purposes, but do keep to mind the shades run HOT! Try by all means an LED equivalent: they run cool and give very even illumination.

Test Gear Topics

Why Moving coil meters aren't dead

My "go to" instrument for most purposes is my elderly AVO Model 7 - it dates from 1947 - and is about as robust as they come, with diecast casing and screw clamp binding post terminals. It's been overloaded, dropped, suffered years of abuse, yet still does the job superbly. As most battle hardened electrical / electronic engineers know, those digits a'dancing on a digital meter just don't reflect reality; they lead to a false sense of accuracy and are generally hopeless at finding peaks or minima in tuning circuits. Yes, digital meters only lightly load, agreed, but I'd bank on my old AVO in the rough and tumble of industrial grade kV's, MHz, and kA's.

To that effect, you might like to read the following: it makes my old heart sing to see this sort of thing. See what you think!

https://hackaday.com/2017/11/08/why-you-shouldnt-quite-forget-the-moving-coil-multimeter/

Antenna Topics

Active Antenna co-ax outer noise

If you consider the modern home with its plethora of switching power supplies, digital noise generators and TV electronics all spewing out broadband RF, any adjacent - and not so adjacent - conductor will intercept the radiated hash, and this includes the outside of the OUTER screen of co-ax: your prized antenna lead-in. For those of us with limited "real estate" to assemble our antennas often turn to active receiving antennas, and these, though excellent, can be badly disturbed with the onslaught of noise from household appliance power supplies and the like. This, on the outer of the co-ax coupling line to the receiver, walks into the active antenna amplifier via earth / common power supply lines and apparently "grounded" enclosures.

This is a job for those chunky ferrite tubes, or similar, to catch those outer screen interference currents. Consider too, for a quick fix, wrapping your active antenna downlead around a ferrite rod - or even a taped together bunch of iron nails. This will give you a quick means of checking if outer screen currents are really the problem with your "noisy" antenna.

Put the ferrite or iron chokes very close to the antenna amplifier module if you can; this can be a bit of a problem in some installations - so try several smaller chokes along the downlead. It is, as always, a very good idea to use a "braid-breaker" transformer or link coupling into a pre-selector tuned circuit, to reject as much unwanted mush entering your receiver as possible. A simple LC tuned circuit, followed by a high input impedance unity gain buffer (or even below unity gain, creating an active attenuator) a-la bootstrapping as shown earlier in this edition of Hot Iron should be of benefit.

You won't do any harm using those big ferrite sleeve cores on any coa-ax antenna lead: current on the outside of the screen are trouble, whatever the cause - so if a ferrite sleeve on the outer makes a difference, you need to investigate further!

Impedance Matching made easy

From Tom McKee K4ZAD I have the following, and as a lover of simplicity, I admire his obvious choice and design!

"*An Antenna Impedance Matching Tale* *Tom K4ZAD*

A neighbor recently got re-licensed after being off the air for almost 60 years. He wanted to use CW as he did as a teenager via a 20 Meter 5 W QRP rig. Our neighborhood's antenna restrictions prohibited an outdoor antenna so he installed a 20 M dipole in his attic and trimmed it to resonance at 14.08 MHz. Unfortunately, and possibly due to nearby wiring and heating/AC gear, its impedance was 84 Ohms, almost pure resistance with some inconsequential C, as measured through a Balun at the antenna. Not really a terrible match.

But, unhappy with the mismatch to his 50 Ohm coax feed line and the line match to the rig, and not wanting to use an ATU just for single-band CW operation, he talked with me about what else might be done to get a more-perfect match. We discussed the, "quarter-waves transform and half-waves repeat," phenomenon and he tried a couple of short random lengths of coax added to the feed-line but neither alone, or both in series, made the match at the rig satisfactory. Besides, I knew that the problem was best corrected at the antenna.

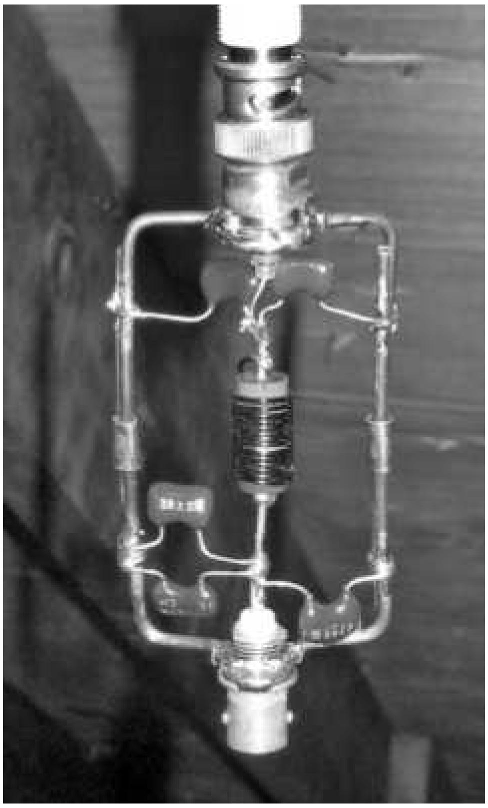
A quarter-wave length of 72 Ohm coax installed at the antenna could transform the impedance to 60 Ohms. That was a bulky solution needing a velocity-factor correction and only partially correcting the problem. Then I remembered the simple, three-element, Pi-network, lumped-constant equivalents of quarter-wave coax-line transformers that I occasionally used years ago in my work with General Electric's (USA) mobile-radio business. Five Watts wouldn't stress one of those. I could build a 67 Ohm one and it would transform the 84 Ohms to 50 Ohms. Digging through some old notes produced the design equations.

The input and output capacitors: $C = 1/(2 \pi f Z)$ The series inductor: $L = Z/(2 \pi f)$

Where Z is the desired transformer impedance in Ohms, C is in Farads, L is in Henrys and f is in Hertz.

Putting 67 Ohms and 14.08 MHz into the equations yielded 169 microFarads for the 2 capacitors and 0.758 microHenrys for the series inductor. The capacitor value was achieved by paralleling capacitors from my mica capacitor box and the inductor was custom wound on a 6.8 MegaOhm resistor.

The resulting network is shown in the photo. With the network installed at the antenna the impedance there, and at the rig, was now 50 Ohms resistive with some inconsequential L. He is pleased that his antenna is now optimally (SWR 1:1.1) matched, and is happily making North American and European contacts with his QRP rig".



How simple and straightforward is that? An excellent solution!

------------------------------------X-----------------------------------

Hot Iron 112 Peter Thornton June 1st 2021
equieng@gmail.com

HOT IRON #113

End August / Start September 2021

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CQ-CQ-CQ

Questions which crop up time & time again...

I have had questions recently about “coil dope” for securing turns of a coil, and proofing against moisture. A lot of the questions were about the “dope” coating lowering the “Q” of the coil; a few concerned making the coil assembly rigid to withstand mechanical vibration, electrical properties or other environmental influences.

Those of us of a “mature” age will recall “Q-Dope” coil coating - a liquid form of polystyrene - and was (is?) produced by General Cement in the USA. See: https://forums.qrz.com/index.php?threads/home-made-q-dope-or-transformer-varnish.267610/, where the comment by WA7PRC sums this up. None of the amateur (or professional) electronic supply houses I approached in the UK had Q-Dope: they only had “impregnation” varnish, which isn’t for this job - it’s for motor windings & the like where coils **don’t** have to maintain (near as possible) a constant inductance or high “Q”. This doesn’t mean they don’t exist in the UK; I just couldn’t find them!

I’ve seen industrial RF coils where every turn was secured to the former by multiple carefully tied silk or cotton threads; some with flat clamp bars, or moulded covers to secure every turn. The whole point was that the coil had to be of stable construction, be that inductance or mechanically, to withstand vibration & environmental factors. The application of epoxy resin as a coating is frowned upon by some as it’s thought the inter-turn capacitance will be increased by the ε_r of the resin, thus lowering Q. This may well be so; I’ve never had chance (or need!) to test this hypothesis. Others have tried varnishes of various types, mostly meant for wood finishing, sometimes thinned or straight out the tin. They are designed for *wood* finishing, not the electrical stress which amateur coils might be asked to cope with & have a remarkable propensity for flaking, discolouring or possibly catching fire when used on non-wooden (coil) substrates.

The whole point of the coating - if for turn securing, environmental resistance & lowest additional capacitance in an amateur context - is that it must be thin in both initial viscosity and final thickness, yet mechanically & environmentally capable when dried thoroughly. You’re looking for a coating of just a few microns thick: make it yourself from Acetone (nail varnish remover) into which clean polystyrene packing has been dissolved. Thinly coat the the coil to aid evaporation of the acetone solvent to leave a clear, micron thin coating that will withstand electrical, mechanical and environmental stress, the same as the venerated “Q-Dope” of yesteryear.

Annealing Toroid Cores

There are questions about making stable inductors with toroid cores and enamel insulated copper wire: I open or close the turns once I’m within spitting distance of the desired value and leave it at that. Some amateurs, though, recommend annealing the wound toroid “to reduce the mechanical stresses and stabilise the inductor”. Knowing that toroid cores, ferrite or iron powder, are manufactured using very high temperatures and are coated with high temperature coatings to withstand 200°C or more & annealing copper involves quenching copper heated to 800°C or more in water (the exact opposite to iron or steel, oddly) any so-called “annealing” in an amateur context must be - well - inapplicable!

I decided to put this topic to bed once and for all. Those wonderful people at Amidon, World leading toroid inductor manufacturers, gave me this reply about annealing toroid cores - with or without windings - below:

"*Dear Peter,*
You are correct: annealing will not have much effect on a core in most situations, but it can have an effect, both positive or negative, depending on the situation. An anneal at 200C may work on select materials, normally those that are coated where it may release stress of the coated cores so long as it does not ruin the coating, it is a dangerous slope with time and temp on Epoxy and Parylene to relieve the coating stress vs. damaging the coating and core. Also, on cores with a high Curie temp, the anneal is likely to not do anything at all to the core. Ferrite and iron powder cores are fired at much higher temps than 200 so it really is not doing anything 99% of the time.

Best Regards
Amidon."

For those amateurs who are in the remaining 1% of the time, please carry on annealing: that's your choice. I'll follow Amidon's advice, thank you!

Radio amateur examinations (1)

Here's another point that crops up time and time again: how do some licensed amateurs achieve a Radio Amateur Examination "pass" when they have (in some instances, blatant) lack of knowledge about RF technology, even in it's most basic form? Whilst I appreciate that tube ("valve" in the UK) technology might not be as relevant to modern amateurs as solid state, the immediate lack of RF knowledge some licensed amateurs display is staggering.

I have noted this before and had some remarkable emails from trainers and tutors about RAE candidates, which clearly illustrate how radio amateurs are rapidly becoming appliance operators, with zero (or at best, very little) interest in building their own equipment. Yes, I have heard many of the (partially) viable reasons why aspiring amateur operators should have no technical knowledge whatsoever: just as in photography or any other "appliance users" cases, the operator need know absolutely nothing about the technology and it's implementation behind his pastime.

This however leaves the aspiring "amateur" radio hobbyist in a conundrum: how does operating even the best technology teach anything about radio? yes, propagation is a fascinating study - but is only one part of one percent of the vast range amateur radio encompasses! Since all else has been catered for in this appliance operator's "station", all he has left is a conversation with distant others; which the wonders of email has resolved almost, if not completely for conversing with anybody else on the planet, and in complete (ahem...) privacy too. Why spend thousands of £'s or $'s for technology to do what a half decent refurbished computer can do, and not as well?

No: the future of amateur radio - if it is to survive, which I think it will as most "appliance operators" soon lose interest in futile blethering - is in construction, design, development and exploratory technology. The route to such things, if not already instilled from years working with electronics - is kits. Many kit providers are available for every aspect of amateur radio desired, be it transmitters, receivers, local oscillators, keyers, and all the rest. The kit builder is guided through the technology, he / she builds a carefully tested and tried design: this is indeed a magnificent stepping stone to designing his own circuits by following the kit designer's logic. It is well worth studying the kit's circuit diagram and working out just what every component contributes to the whole, it is the passport to designing your own circuits or adapting an existing circuit to a different purpose. Hark my following words well, though, those who would alter a working, functional design: change only one thing at a time, make copious notes of what you've done so you can always return to the original state of affairs. Ignore this and wander aimlessly in a wilderness!

Radio amateur examinations (2) - Safety Issues

From an old friend of mine...

"*Hi Peter,*

Thanks a lot for the latest hot edition, and I fully agree with your comments about people working on high voltages. When I was teaching RAE and later, Foundation, Intermediate and Advanced courses, I nearly always found that most beginners thought that putting a bigger fuse in was in some way making things better because bigger must always be better, and I always tried to explain to them why the opposite is true. I personally think they should teach such basic info in schools, as I'm sure it would greatly reduce the number of house fires and electrocutions."

And here's an interesting slant from another reader...

"*Good afternoon Peter,*
Reading this month's Hot Iron I note your comments about passing the amateur exams with little or no electrical knowledge and how are they passed. Firstly let me say that I am / was a qualified assessor, I became one because of the way I was taught, or lack of teaching, by the assessor who taught me. I did very few of the practical tasks and I know of others who didn't do an awful lot. The assessor said people didn't care about learning only about getting a pass! Indeed, I know of 1 M0 who didn't do any studying for the advanced exam, guessed the questions he didn't know and scraped a pass.

On my courses, 100% pass rate, everyone did the practical exercises, made antennas and circuits, some have gone onto building kit. What has surprised me about amateur radio is how few people actually build or repair kit, I tried to get a construction class going when I was a club committee member but there was very little interest, club wouldn't buy any basic kit like soldering irons but happily spent money on the club contest and special event station. In the end I left and training ground to a halt.

So no, I'm not surprised at the lack of electrical knowledge or even basic knowledge of setting up and operating a station from my experience. It's easy to buy a black box, hook it up to a pc, buy an antenna and go digital, and there's always the next better than ever transceiver on the horizon according to the marketing people so why bother building?"

I know for sure, from the emails I receive and requests for information, that the bulk of amateur radio operators are appliance users. I feel very sorry for them; they are missing > 99% of what amateur radio is about (in my opinion). Radio technology is a lifelong learning curve, something new every day, week and year that opens up new horizons - if you're willing to explore mentally how you can make something elegant, functional and useful.

For those who can't be bothered to think, wanting Plug-N-Play instant - but short term - gratification, then go ahead: buy the latest £2000 + transceiver, the latest FireRod Super Signal

Grabber antenna, the latest 128-bit computer to interface. It's your money, your lack of imagination, shortage of knowledge and ultimate dissatisfaction.

What does frighten me is the lack of fundamental education. The "dumbing down" of vast swathes of society is showing all the more, with Elf-N-Safety being the new Stasi Secret Police, with more intrusion into our privacy via State legislative interference into our private lives.

The reason I like building bits of radio gear is not to natter endlessly about whatever the latest pressure marketed lump of technology can magically (or cannot, more like) deliver: that route is Quixotic, merely tilting at distant windmills with no ultimate ability to knock 'em over.

No, I build bits of gear to have a quick call to whoever is listening to be sure my idea works, then I'm off and away on my next project, having learned from my previous construction successes (and failings). "Continuous improvement" I believe it's called?

Tim's Topics

Tim has told me about his latest kit receiver, and his notes are below, verbatim:

The Bratton Regenerative Receiver

I wanted a RX to go with a new small AM TX (using MOSFET gate modulation) called the Bradney. Conventional AM RXs tend to be superhets but they would be too complex for this TX so I reverted to the much older concept of a regenerative RX. The key functional block in a Regen is an 'amplifying stage with feedback' operating at the reception radio frequency using a tuned filter circuit, whose gain is controllable so that it can either just not quite oscillate, or is actually oscillating at low level, depending on the type of signal to be copied. At this critical point the selectivity (or Q) of the tuned circuit is very much increased resulting in much better rejection of unwanted nearby signals and increased gain/sensitivity for signals on the nose of the tuned circuit. Provided this filter stage feeds an amplitude detector it can be used to copy amplitude modulated signals, or with the tuned stage just oscillating to provide a local oscillator signal, it can also copy CW or SSB. Hence the Regen RX circuit, which is relatively simple, is a very useful and versatile functional block well suited to simple AM RXs in particular.Over the years I have tried many arrangements of Regens and undoubtedly it pays to separate the gain-controlled oscillator stage from the detector stage. The oscillator stage can be prone to overload by strong signals which, on CW can lead to a rough sounding beat note as the oscillator is pulled from the slightly offset value to try and agree with the incoming frequency. The cure is to have an RF gain control to reduce such high amplitude signals, and then provide more audio gain. Using Junction FETs in the RF stages makes the circuit design much easier! The circuit shows 2N5459s for TR1-3 but 2N3819s (with different pin out) can also be used. The RX has a grounded gate RF amp with the important tuned circuit as its drain load. This approach avoids more complex inductors needing a low impedance winding for the aerial input, and also reduces radiation by the RX when the oscillator is working for CW. This particular RX is for 80 or 160m, hence the relatively high values for the inductance L1 (38 uH, tapped at just below half way) and tuning capacitors C5-7 (all 150 pF, with C5 omitted for 80m) but it can be easily adapted for other bands. The 65 &/or 150 pF sections of C1 connect to any one of points X, Y or Z for the tuning range desired. The source resistor of TR1 is the RF gain control – as a pot (short leads) or preset - aerial to the slider. The tuned circuit is coupled lightly to the oscillator stage TR2 - another JFET, arranged in the Hartley configuration with gain control by some extra variable positive DC bias to the FET source from the Regen potentiometer. An increasing positive source voltage, cuts off the JFET so reducing its gain. The third JFET TR3 is an infinite impedance amplitude detector which is also lightly coupled to the RF amp tuned circuit; the R and C values at its source have a compromise time constant to hold the peak positive RF voltage between RF cycles, while following the audio modulation peaks and troughs without affecting the audio bandwidth. (I also tried a JFET buffer stage feeding a full wave diode amplitude detector but it was no better than the simple infinite impedance detector.)

The remaining stages consist of a pair of small BS170 MOSFETs in an audio amplifier TR4 (gain about x10), followed by a buffer TR5, with DC feedback to control the DC bias point of both stages, feeding the logarithmic AF gain control. The amplifier drain load R11 has two capacitors C14/15 which can be connected in series for phone bandwidths, or in parallel with a lower bandwidth for CW. Finally, there is an LM380 audio power stage IC2 which has a fixed voltage gain of x50; it can drive phones or a small LS. A stabilised supply is preferred for the early stages, hence the use of a low drop out regulator for IC1 to enable operation on down to 9v if required.

The performance of this RX has far exceeded my sensitivity expectation! A few feet of wire produces band noise which I initially thought must be something hooting unintentionally - but I cannot find anything amiss & our noise levels are low! The photo shows the prototype which was subject to various detector experiments and eventual simplification – hence the spare holes if you look carefully! Over the years, I have done quite a lot of experiments to see if I could make a Regen stage sufficiently frequency stable when going from just not oscillating (for AM) to oscillating hard so it could drive a transmitter for single knob transceiver tuning; but it was all too tender and not likely to be repeatable even with a frequency converter stage to avoid chirp or pulling from RF feedback from the higher power output circuits!

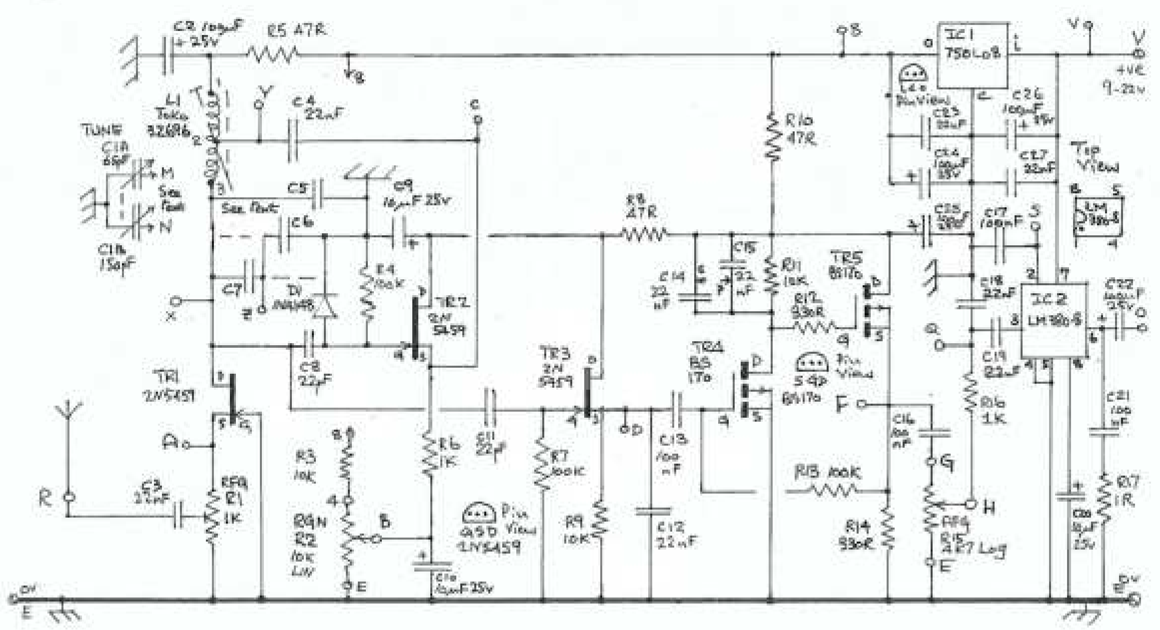


FIG3: CIRCUIT OF BRATTON RX

My grateful thanks to Tim for his notes and drawing, and we wish him every success!

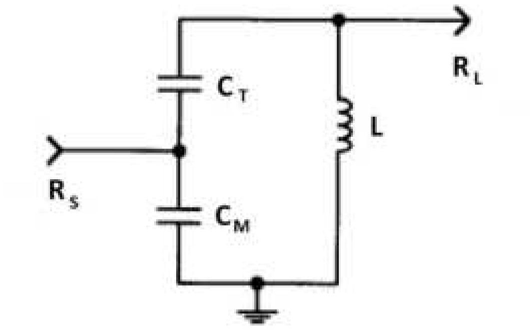
Receivers

The Underutilized Capacity Tap from Tom, K4ZAD

The Franklin Receiver article in Hot Iron # 105 states, "You'll have noticed an anomaly in the Franklin diagram (*Fig. 3.8*): the 10nF capacitor to ground below the tuning capacitor VC1 effectively shunts the antenna signal to ground."

However, the Fig. 3.8 input circuit that the receiver designer chose is logical when viewed as a "Capacity Tap," connection of the antenna. When viewed this way the 10 nF capacitor is a component of the turned circuit and is the means transforming the antenna's low impedance up to something much higher and better matched to the TR1 gate.

Assuming reasonable L/C ratios and inductor Qs, here's a formula for computing the approximate capacity tap transformation ratio where the source is a low impedance (R_S) and the load (R_L) is a much-higher impedance and C_T, the tuning capacitor, is in series with C_M a much-larger capacity-tap capacitor.



$$R_L \approx R_S(1+(C_M/C_T))^2$$

In the Franklin receiver circuit of Fig, 3.8 in Hot Iron # 105: VC1 is C_T in the above formula and C2 is C_M. Using 175 pF as a mid-range value for C_T and 10 nF (10000 pF) for C_M gives 10000/175 or 57 for this ratio. Adding the 1 and squaring yields 3364 as the total transformation ratio. So, if we assume a 200 Ohm antenna load (R_S) it will be transformed to 673K Ohms (R_L), a light load on the gate of TR1. It's similar to a light load provided by a small antenna input capacitor connected to the top of VC1/L1. The same 200 Ohm R_S and a C_T of 365pF yields a 156K Ohm R_L.

When designing a tuned circuit for mass production it's worthwhile to determine the proper placement of a tap on the inductor because, in production, inductor taps cost little and they help reduce the parts count. However, when design time and small-lot construction time are more important, a capacity tap is often a better alternative. The simple formula make it easy for Hot Iron enthusiasts to use capacity taps. I have found them quite useful especially when I needed to match to on-hand, but untapped or unsuitably-tapped inductors.

You can read more than you probably want to know about capacity taps here:

https://analog.intgckts.com/impedance-matching/tapped-capacitor-matching/
https://www.qsl.net/va3iul/Impedance_Matching/Impedance_Matching.pdf

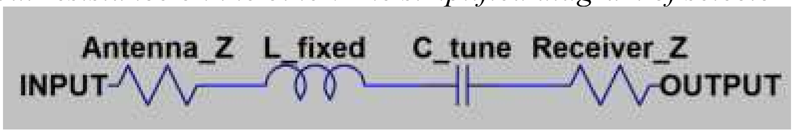
{*Thanks Tom: much appreciated...! GW6NGR*}

Pre-selectors...

A very welcome article about simple circuits with very significant purpose...a simple RF preselector for HF, by Alan Victor, W4 AMV:

"A tunable RF filter for HF is an excellent way to improve sensitivity and reduce distortion. The preselector, selector, is applicable to modern SDR receivers as well older boat anchors. The unit I constructed is used on an old National HRO radio and is quite flexible in its design.

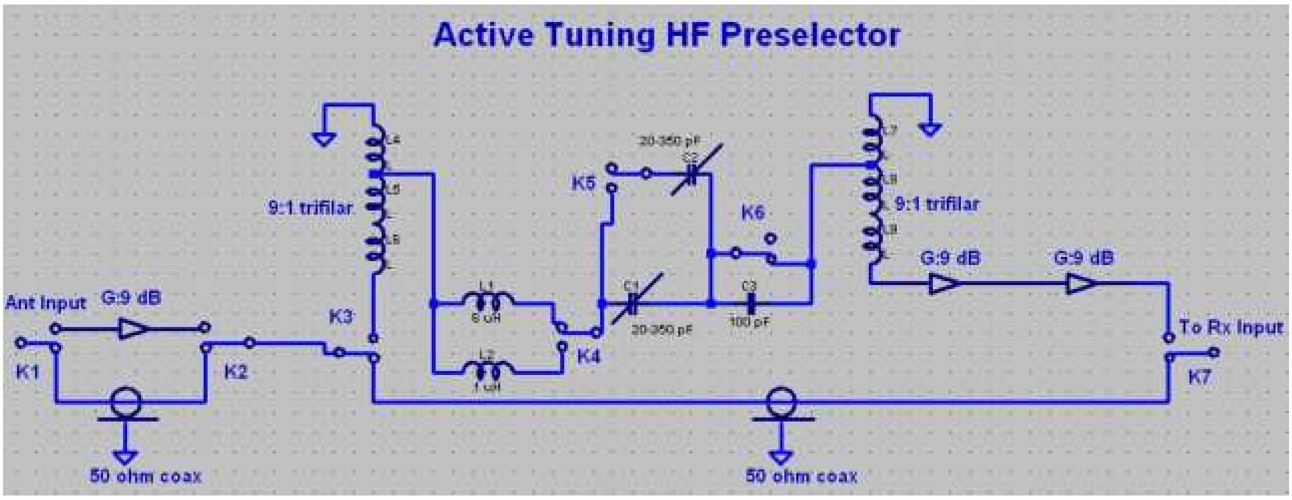
A series tuned circuit is used. Unlike a parallel tuned circuit, the resonant frequency is independent of the resistance used. A portion of the R values are set by the antenna Z on one side of the selector and the receiver input resistance on the other. The simplified diagram of selector is shown below.



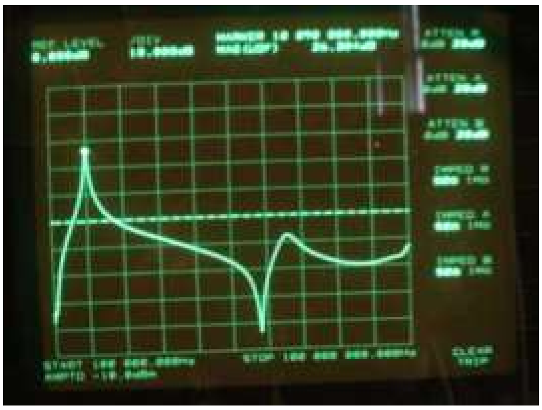
The bandwidth of the selector is controlled by the total series R and this is reduced to a value that can control the bandwidth of the selector. Wideband transformers like a 4:1, 9:1 to 16:1 are easy to build and are placed at the input and output of the selector. At the antenna port, the Z value is reduced and at the output port, the same transformer is used to step the Z back up to match the receiver input. The selector bandwidth (BW) is controlled by the selector Q and this Q is given by

$$Q\_s=2*\pi*fo*L\_fixed/(Rz\_ant+Rz\_rx)$$

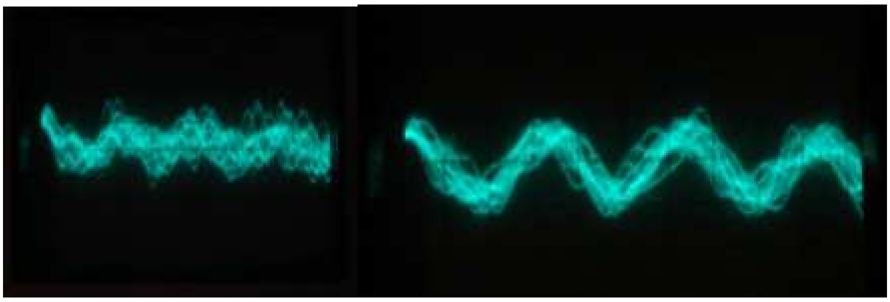
Where fo is the desired center frequency and Rz_ant and Rz_rx are the transformed Z values of the antenna and the receiver. For example, assuming the antenna and receiver are both 50 ohms and a 9:1 transformer pair are used, then these values are each 12.5 ohms. The value of C_tune controls the center frequency. Using a selection of L_fixed and C_tune, it is quite easy to cover the entire HF frequency range. A schematic of such an arrangement is shown below:



The selector loss is quite small if a high Q inductor is used and the addition of low noise amplifiers will further improve its utility. The amplifiers may be placed before or after the selector depending on your operating conditions and local strong signal environments. The improvement in selectivity and sensitivity is clearly visible in the figures shown below. The sensitivity on a boat anchor receiver with 0.25 uV input with selector OFF and then ON. The selector passband response centred near 10 MHz.



The selector frequency response



The selector signal to noise at 0.25uV RF input… OFF to ON"

Many thanks Alan: much appreciated!

In days gone by...

...it used to be *de rigour* that an aspiring radio amateur, before even considering the RAE (the UK radio amateur's examination) would build a simple HF band(s) receiver - to listen to the fascinating world of short wave broadcasts as well as amateurs in his locality and - hopefully - further afield, even inter-continental. A soldering iron was soon fabricated from scrap brass rod offcut filed down to a point from the local machine shop mounted on a ¼" welding rod plus wooden file handle, to be heated over a gas cooker's small burner on low simmer. Tinner's solder (60/40 tin - lead) scrounged from a local sheet metal shop - after learning the hard way that plumber's solder was NOT suitable! - made for easy soldering. Simple chassis made from ply and covered with earthed (flattened) tin cans, and a a couple of brass screws and washers for antenna connection, a scrap ¼" jack socket from an old "radiogram" made the 'phones connection. To power the receiver, batteries initially, common and cheaply available in those days, but soon gave way to a simple mains transformer / rectifier PSU in a plywood box, which gave better regulation - fed power via "choc" (terminal) block, as a "polarised" connector (blank hole with a bit of wooden skewer as a key).

To hear an amateur signal from "across the pond" USA was a true accolade; an signal from the antipodes was a real gem, to be discussed for days over lunch in the works canteen and QSL card eagerly awaited. The construction of this "window on the World" entailed checking various DC voltages and currents; a 1mA moving coil meter plus a bundle of resistors - series multipliers for voltage measurement, shunt resistors for current, easily calculated values by simple maths, made the construction and testing possible. Some rotary switches made a multimeter , some used sockets for each range.

The receiver opened the door to much, much, more: a switched crystal controlled multivibrator gushed harmonics - a frequency marker was soon built, with 100kHz / 1MHz crystals from a scrapped machine - made for accurate calibration of the receiver tuning dial. A home made "grid dipper" was now feasible, as the receiver could pick up the dipper, allowing dipper calibration. The dipper made resonating antennas and tuned circuits easy: what's more the dipper, turned down to just below oscillation, made an effective wave meter.

The aspiring amateur could now consider building a transmitter: the dipper ensured harmonics and spurious outputs were detected then eliminated, and was tuned to the right spot. The RF coils - home made from scrap “Twin & Earth” mains cables, carefully stripped, wound onto whatever cardboard tubes were available - resonated with shunt capacitor and dipper.

Designs studied, parts scrounged, borrowed, begged, and construction underway, each stage tested with a simple diode RF probe feeding the now well used DC voltmeter, currents and voltages noted for future reference in fault finding.

All this cost literally pennies, from scrap materials, imagination and determination, and was the finest teacher an aspiring radio amateur could wish for. Thorough grounding in all the aspects of electronics by practice, the actual construction of a working amateur station from ground up (literally! So that’s where that 6’ length of ½” copper water pipe went...!) gave far more satisfaction than any bought toy, a lifetime of discovery and development, experimenting and new ideas.

To me, that’s what amateur radio is all about: try it and see for yourself. You don’t need industrial electronics tools, equipment or mountains of cash: it’s all out there waiting to be adopted, adapted, and improved. Use what you can to the best of your ability and give it a try! It can be done, within the regulations, without causing interference or straying out of the bands, without budget planning or constant reference to a specification. Amateur Radio is a HOBBY, not a profession: it is a PASTIME, not an occupation.

Building and running an amateur radio station from ground up is a lifelong affair; if you want to sample this approach, try a building a receiver kit. Once the kit is finished and tested, put it into a case and fit, to the best of your ability, a tuning dial and control pots with scales. Make the case (10 - 12mm ply is good) and line it with aluminium foil (earthed) to prevent “hand effects” and paint the outside of the (empty!) case a decent black crackle finish. It will become a thing of value far beyond anything you could buy, believe me.

Modular!

Well, bless my soul! Somebody has grasped the mettle and put together a “modular receiver”, see:

https://oz1bxm.blogspot.com/2021/05/dc-receiver-01-100-mhz.html

Purists will note the lack of audio filtering and the use of an LM386 isn’t perhaps the best choice for low noise and audio quality but plenty of other options are available, have a hunt around in our favourite online auction house(s) for a plethora of choices: but avoid class D amplifiers - life’s difficult enough in the amateur constructor’s world, don’t compound the difficulties with a switch mode audio amplifier! (Note... look up the LM3886, it’s on my list for a superb bench amplifier and looks like it will make a cracking good amplitude modulator too.)

Pseudo Stereo and the frustrated CW man

Years ago, it was a neat trick to “stereofy” a mono audio signal be using filters of various sorts to create false left and right channels. It was rumoured at the time a certain Sergeant Pepper had this technique impressed upon him to widen and intensify the stereo effect: be that as it may, it is a very useful technique for the CW man, in his constant battle to dig out those tiny signals from the fading, drift and other ionospheric nasties that abound around very weak signals. Step into the breach, pseudo stereo, where the signal can be split into two "channels" - so listening in the headphones, as one side's signal fades, the other side picks up: and the human brain is very alert to spacial sounds.

The ideas for pseudo stereo were manifold, but the two techniques that will probably be useful for the CW man are high / low pass filtering and time delay channel splitting.

Here's a circuit or two from makingcircuits.com, which illustrates the filter method and signal inversion technique to create pseudo stereo -

https://makingcircuits.com/blog/simple-stereo-simulator-circuits/

As the signal drifts slightly, the apparent "position" of the sound from stereo headphones inside the listener's head appears to shift to one side; adjusting the receiver's RIT incremental tuning can be tweaked to centre the sound again, enhancing readability, or biased to the listener's preferred ear which might be more sensitive. Here's another option:

http://zpostbox.ru/how_to_create_stereo_from_mono_signal.html

And finally a simple option using one chip:

https://www.aaroncake.net/circuits/stereosynth.asp

Another technique is to apply a frequency sensitive delay to one pseudo "channel" - a technique originally developed by R.A. Penfold in 1994 - which can be seen at:

https://theramsgatehovercraft.com/2013/05/11/mono-to-stereo-effect/

These techniques can be usefully used as bit slicers too, for the basic frequency shift keying detection so beloved by our RTTY colleagues from days gone by; are there still some RTTY enthusiasts out there in this digital world?

Oscillator Topics

DDS / PLL thoughts...

Well, it's finally happened: I'm falling to bits. Yes, bits and bytes - after all these years of doing battle with recalcitrant machine code, EPROM's, and gawd knows how many LS-TTL and C-MOS chips that have been dispatched to their sandy silicon sepulchres in a sniff of smoke, I've decided to go digital. I'm gathering the bits to build my first Si5351 VFO, covering 10kHz to 225MHz, controlled by an Arduino Nano control board, as advised by Pete Juliano, as noted below.

This doesn't mean that I have eschewed "analogue" VFO; no, it's horses for courses: if I need a signal source that I can rely on being bang on frequency, nowadays, it's got to be digital: if I want a BFO running somewhere around 470kHz then it's an analogue job every time.

The fact I've chosen, for this experiment, an Arduino Nano controller doesn't mean I've discarded alternative controllers: for instance, VK5TM, Terry Mowles - a no-nonsense, zero "B-S" man if ever there was one - has some superb PIC chip designs, see:

https://www.vk5tm.com/homebrew/xtal_sub/xtal_sub.php and ZL2PD, Andrew Woodfield, whilst embracing the Arduino Nano in his design at: https://www.zl2pd.com/9bandModularVFO.html

his “Sugacube” oscillator is a triumph in miniaturisation, see:

https://www.zl2pd.com/sugarcube_VFO.html Now isn’t that the most cute bit of kit?

Below is a concise and accurate synopsis of the digital revolution in RF VFO’s by Pete Juliano, N6QW:

Hi Peter,

Just some info for your article.

1. *I started with the PIC and long ago abandoned same. EI9GQ was instrumental in my getting my feet wet with the PIC but alas working in assembly language is not my cup of tea. I want to build hardware not become a software engineer.*
2. *The Arduino is far more intuitive and has a larger support base with tutorials etc. One of the best introductions to the Arduino is from the genius behind the that device. Massimo Banzi has written a small book that steps you through simple projects that can be built upon into more complex circuits.*
3. *Now a huge factor with the Arduino – portability of the code. Once you have code set for an oscillator it can literally be like a set of woman’s panty hose – one size fits all. I simply reuse the same basic code set for any project –what may change is the display type or maybe a few more switch inputs. There are literally thousands of pieces of downloadable code for the Arduino*
4. *Another factor is transposition between various Arduinos. I can write a program that can be used on an Uno, R3 a Nano or Pro-Mini and the only difference is when you load the code you must tell the programmer – which one are you loading.*

For a general one size fits all article– I would place a pox on anything other than the Arduino.”

Installing Arduino programming suite on an Ubuntu Linux machine (I don’t like Windoze and can’t afford anything Mac) gave me some issues: after thrutching about with infuriating error messages that bore no relevance to the real problem, I found https://www.chippiko.com/2021/05/install-arduino-linux.html that did the trick.

Test Equipment, Servicing & Maintenance

Analogue Signature Analysis - finding faults with no circuit diagram

You use what is basically a curve tracer: it plots the V/I characteristic of each voltage node in a circuit. If the “good” V/I characteristics of every voltage node are logged, it’s very simple to go through the nodes of a “faulty” circuit to find where the trouble lies. You don’t have to be too specific; a slight deviation from the logged result is perfectly acceptable. A real fault - often showing as short or open - will be readily detected. Of course, the old hands at the fault finding game will tell of using a multimeter on ohms to do a similar job: ohms test every pin on every IC and log the “forward” and “reverse” resistances registered on the multimeter. The power rails too can yield to resistance checks: the supply rails should never be dead short or open circuit.

Any short or open pin is readily found - but, from experience, it’s a tedious procedure. The big plus is, of course, you can find a dud component without a circuit diagram.

The tracker is capable of showing both forward and reverse characteristics of every node in one test: thus cutting the search by half. If a short is indicated, a quick check on the pcb can show a deliberate connection to common, 0v.

A neat circuit for an amateur curve tracer / signature analyser using commonly available parts is:

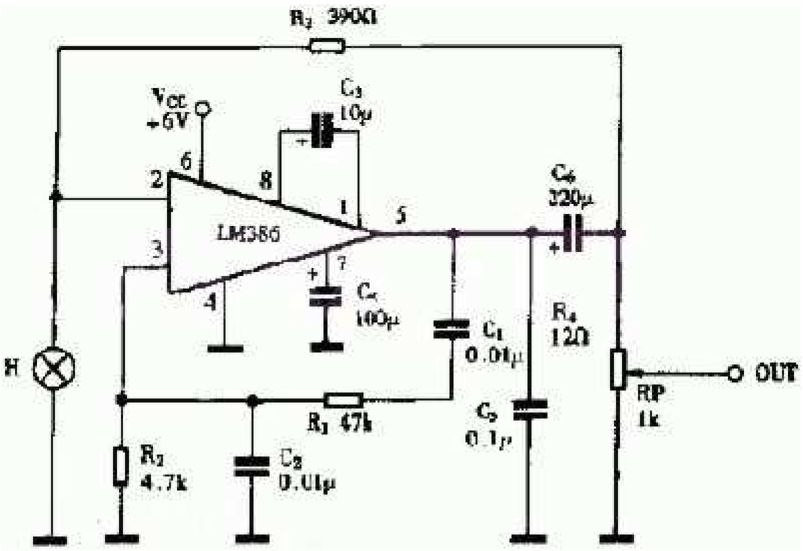
https://www.qsl.net/kd7rem/octopus.html

and I can thoroughly recommend it. It has been mentioned previously in Hot Iron; I’d like to present here (not presented in the previous text if I remember right...?) some rather different approaches to Octopus testing I saw promoted recently. You can use ANY two voltage nodes as test points. You don’t have to put one test probe on the common or 0v. rail: it’s possible to use other voltage nodes for signature analysis, as are individual components like capacitors and transformer windings. You don’t have to use 50Hz from the mains, either: build a power oscillator for 1, 10, 30 kHz or whatever that gives good results. A 100pF capacitor on 50 Hz won’t give a signature that’s too readable, but try 20 - 50kHz and you’ll see the signature ellipse clear as a bell.

For a useful power oscillator to drive the Octopus for HF measurements, see:

https://www.apogeeweb.net/circuitry/lm386-oscillator-circuit.html

...and look down the page for the sine wave oscillator (copy below):



The arbitrary filament lamp (“H”) is usually a show stopper, but from experience an old Xmas tree bulb - or in fact any other filament lamp you can lay your hands on - or even a pair of back-to-back equal value zeners (3v3 or 4v7) plus a 1k series resistor. A bit of cut and try will get the job done.

This is not a common application for the LM 386! I wonder if somebody will put together a QRP VLF transmitter with one?

ESR of electrolytics - AGAIN
http://www.conradhoffman.com/capchecktut.htm makes the very valid point often ignored by those amateurs looking to repair a switch mode power supply: the original designer specified a particular electrolytic because it had ESR, temperature, ripple current and value / tolerance that suited his requirements. In making a repair, you need to meet - or better - his specifications for the power supply to continue giving good and reliable service. One value very rarely quoted, but very important to the SMPS designer is the inductance of an electrolytic: remember these beasties are put together by winding aluminium foil electrodes very tightly, the perfect recipe for creating inductance. Not a problem on 50 / 60 Hz; but the 30kHz - 200kHz often found in miniature SMPS's might find that tiny and cheap replacement 'lytic too inductive to be suitable.

The best bet: replace with an exact duplicate of the original; and thoroughly clean out and test the cooling "fins-n-fans" to assure proper cooling - 'lytics don't like hot, Mum!

Measuring RF voltages
Chas. Wenzel's biased diode RF volt meter circuit at: http://techlib.com/electronics/detect.htm will do the job with simple circuitry and yields far more accurate results on low level signals - the differential circuit is especially useful for fault finding: for single point tests, ground one probe. This is a much better solution than the usual shunt diode type for low RF voltages.

Or, if you want to push the boat out, Roy Lewallen's (W7EL) circuit can be seen at:

https://www.robkalmeijer.nl/techniek/electronica/radiotechniek/hambladen/qst/1990/02/page19/index.html (thank you, Rob), will keep you on the straight and narrow.

Heathkit diagrams, circuits, service information
For those who are repairing one of these marvellous bits of kit, useful information and servicing notes can be found at:

Can be found at: https://www.vintage-radio.info/heathkit/

On the topic just discussed, for those of you who have faith in a 1, 10 or 20k-ohm per volt analogue test meter (AVO rules, OK?) Heathkit produced an RF probe kit specifically designed for lower impedance readouts or oscilloscopes: see below -
https://archive.org/details/Heathkit337CDemodulatorProbemanual/page/n1/mode/2up

If you study the circuit diagram, identify the 27k shunt resistor and remove it for useful readings on a 10 or 20 k-ohm per volt analogue multimeter.

One point I will make, however, is that whilst the probe and analogue multimeter might not be as sensitive or capable of very low RF voltage indication, it *will* suffice for most tuning up or peaking in amateur construction. The current manic desire for accuracy and more digits in a digital multimeter is utterly pointless, as absolute measurements are rarely required in amateur construction. What you DO need are comparative readings: whether or not the circuit is peaked up or tuned for best output - where a digital multimeter presents no advantage. The few µA's drawn by a 10 or 20k-ohm per volt multimeter can be useful as it shows the stage can deliver some RF current, and what's more, the peak is far more readily seen on an analogue meter.

The table below illustrates some typical measurements:

Meter Ohms per Volt	Meter range (FSD*)	Loading Resistance	Current drawn at FSD*
1k	100 volts DC	100k-ohm	1mA
10k	500 volts DC	5M-ohm	0.1mA
20k	10 volts DC	200k-ohm	0.05mA
10M digital	1000 volts DC	10M-ohm	0.1mA

*FSD = Full Scale Deflection on the meter

From Ohm's Law: I = V/R thus "20k-ohm per volt" represents 50µA, 10k per volt represents 100µA, 1k-ohm per volt represents 1mA, and so on, *quo rata*.

The 20 k-ohm per volt will read closer to a 10M-ohm digital multimeter the higher the voltage scale selected; the loading resistance increases as the range setting is increased but the pointer is deflected proportionally less. Loading resistance = (Ohms per volt) x (meter scale selected)

The digital meter is usually 10M-ohm input resistance. On HV circuits an analogue meter on high volts ranges offers very similar light loading to a 10M digital multimeter! Note too that a voltage node can read as expected on a digital meter even fed via a high resistance joint as the input resistance is so high. Don't be fooled: once current is being drawn, the output sags - always test a power supply on load.

For example, let's consider a dry joint in a power supply output. The dry joint has a resistance of 10k-ohms; the nominal PSU output voltage is 500 volts. A digital multimeter, of input resistance 10M-ohms, will read (500v) x 10M/(10M + 10k) = 499.5v. You'd be happy to say your power supply was running fine? Near enough to 500 volts? Now let's try our home brewed 1k-ohm per volt multimeter and see the result. The meter will have a resistance of 500 x 1k = 500k-ohms. Applied to our "dry jointed" PSU, the meter will read 500v x 500k / 500k +10k = 490.2v. It's 10 volts light!

That would certainly be enough to prompt a further check at GW6NGR; so out comes my "universal" load bank: a string of 40 watt 230v light bulbs in series, 3 of which on 500 volts are about 1k-ohm each (filaments, when not run on full volts, will be lower resistance) across the PSU.

Let's calculate the output voltage: our load resistance is 3k-ohm in parallel with the 500k-ohm of the analogue meter = 2.9821 k-ohms. The resistance of the dry joint is 10k-ohms so the total circuit resistance = 10k-ohm + 2.9821k-ohm = 12.9821k-ohms; the current flowing is 500v / 12.9832k-ohm = 38.51mA. Thus the terminal voltage is 38.51mA x 2.9821k-ohms = 114.85v.

The table below summarises the results, spot the "uh-oh" line!

Nominal output = 500 volts DC

Meter	Output Volts	Load resistance	Comments
Home made 1k / volt	490v	500k-ohms	This PSU is probably faulty!
Digital 10M	499.5v	10M	This PSU is probably OK! <<<!!!
1k / volt or digital	114.8v	3K lamp load	This PSU is definitely faulty!

The moral is that whatever meter you use to check a power supply, check unloaded volts first, then compare with loaded: the difference should be well within the regulation specification of the PSU.

If you take meter loading into account, and use comparative readings, an analogue meter can be just as useful as a digital multimeter as it can indicate trends far better and is invaluable for "peaking up" a circuit.

Filament lamps, now obsolete and thus somewhat rare: are a very useful and adaptable bit of RF shack test gear. Go and buy some now and keep them for future shack use!

If used as a bridge detector, an analogue multimeter becomes an **infinite impedance** device. Read up on bridge measurements, it will be useful in the long run, believe me!

Kit suppliers

This is from the Long Island CW Club, Radio Kit Guide Updated from Neil W2NDG list at: http://radiokitguide.com...and my very grateful thanks to Neil for the effort in compiling and updating this list for all us kit watchers.

Reverse Polarity protection

Whilst semiconductors are generally low power, efficient devices, the machinery to manufacture them is decidedly not! It takes many hundreds of kWh's to make the most basic devices; and a breakdown represents a catastrophic loss of money as the machines following the breakdown stand idle waiting for silicon to work on. Thus reliability is paramount - machines frequently use many layers of protection, such as phase rotation detectors, automatic re-connect fusing, reverse polarity protection and the like.

The last item might seem somewhat trivial; but think instead of what happens if another machine in the plant, it's transformers consuming hundreds of kW's, blows a fuse. The inductive transients are BIG, and walk straight past most VDR's and the like as they are fast, big energy transients, not the 2µS & 10µS classic simulations of lightning strikes. Thus the reverse polarity protection has to cope with some really heavy currents, fast (nS) rise times and long decay times of many kJ's energy.

It's wise to see what automotive electronics designers are up to: they seek reliability and economy at every turn and semiconductor manufacturers are definitely switched on to this, as that's exactly what they want users of their products to enjoy. I found this in my notes:

https://www.infineon.com/dgdl/Reverse-Batery-Protection-Rev2.pdf?fileId=db3a304412b407950112b41887722615

from Infineon Semi, where this topic of reverse protection is discussed.

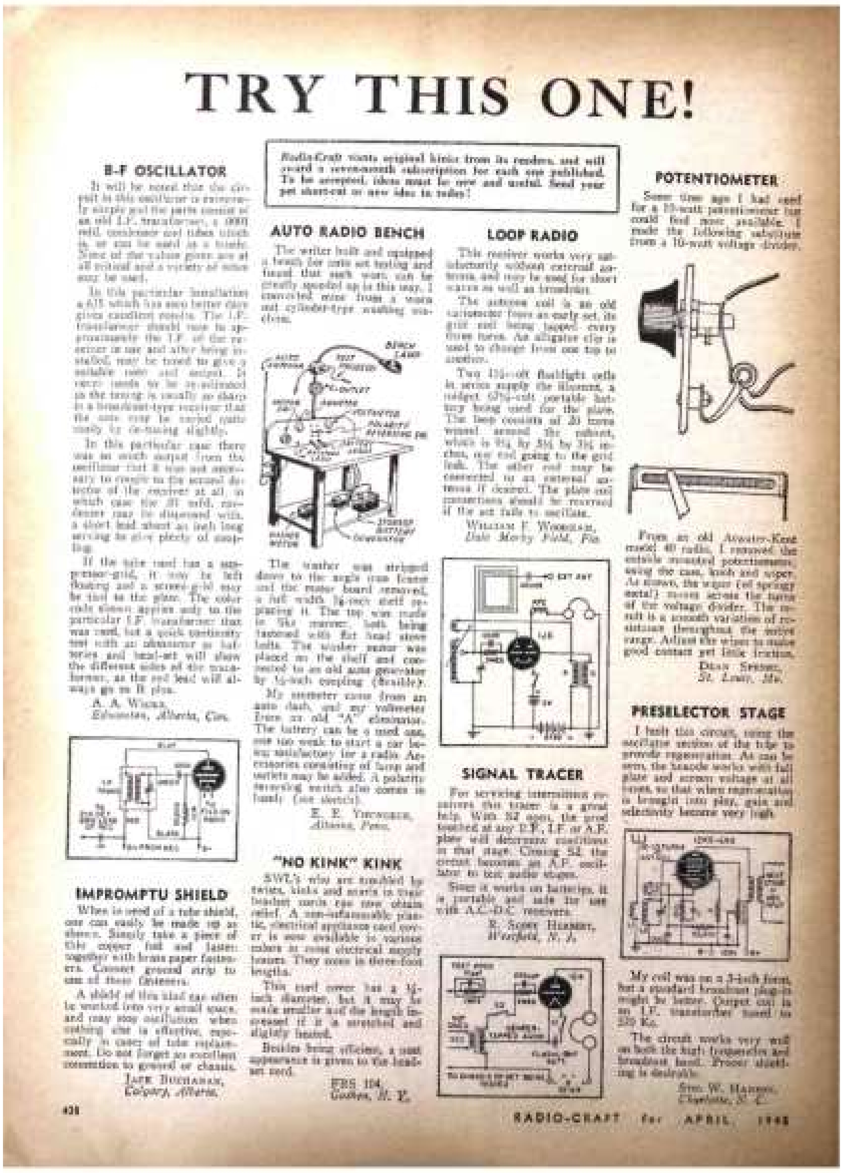
I will add only one additional comment: the most reliable, regularly used HV power supply in the Wafer Fabrication plant I last worked in has several layers of reverse polarity protection, and the one that never failed was a high current mercury vapour switch, that could switch in less than 10nS a current of 100 amps. P-Channel mosfets abounded in the electronics and the 3 phase line conditioner was the size of a small car and considerably heavier; but the mercury vapour switch did it's job and we only ever needed routine cleaning and interlock tests for maintenance.

Well designed protection pays every time!

Old ideas...

Here's a page that caught my eye from 1945, the signal tracer / injector with just ONE active component - if you don't want to use a hearing aid "pencil" tube, a jfet (with added 3k9 bypassed with a 0.1 µF in the source lead for DC biasing) would likely substitute nicely, with a 500 + 500 ohm centre tapped transistor interstage transformer for the feedback. It's a complement to those old boys back them how they squeezed every drop of performance out of one tube!

Take a look at the bench set-up too: those old boys knew how to make the most with the least, that's for sure. Something we all could learn from, rather than discarding or throwing more and more silicon into a design. (Hint, use a bit of "zoom in" for a clearer view. Ed.)



Construction notes

Wire Nuts

There is considerable misunderstanding about electrical safety in the UK, especially among the "non-technical" radio amateur cohort, that it is somehow "illegal" to use Wire Nut connectors according to UK "IEE Regs".

We all carry a duty of care; if someone is hurt because of your negligence, be it from loose slates falling, a wobbly fence or exploding power supply electrolytics, it is this injury that forms the basis of claim the injured party can bring in the Civil Court. Broadly speaking - and I'm no lawyer - it's not a Criminal but a Civil matter. There are NO "electrical police", NO list of "illegal" components that must not be used: whatever you do, beyond the socket of any domestic electrical installation, it's down to you to make the area safe for anybody who could be hurt by what you've built.

This "illegal" misunderstanding dates back to the 1930's, when ceramic wire nuts ("Screwits") were used in the UK. They had a nasty habit of cracking, break in half and were the cause of a few 'shocking' incidents.

Now let's move on: in the USA, the ceramic Wire Nuts were replaced by the steel spring insert in a plastic cap type - these were the forerunners of wire wrap technology so common and reliably used in all aspects of electronics and electrical power interconnections nowadays. They are used literally everywhere in the USA and Australia for house and other general wiring: they are cheap, reliable, safe, secure, far easier to use and smaller than the screw type "choc-bloc" so common in the UK. I have several boxes of Wire Nuts, and to be fully "IEE Regs" compliant they should be installed under a secure cover, just as a choc-bloc should.

Wire Nuts contain a tapered spiral hardened steel spring, they are used by stripping the wire ends to expose the copper conductors which are twisted lightly together in a clockwise manner. The Wire Nut is placed over the exposed copper ends and screwed (clockwise, right hand thread) up until the outer insulation has one or two full twists visible. Because of the internal tapered shape of the steel spring, the copper of the conductors being joined is forced together intimately; the spring material is square section so the corners dig into the copper making a metal-to-metal cold weld. The copper conductors, being in close intimate connection for their entire stripped length, make the best possible copper-to-copper joint locked into place by the tapered spring then insulated and supported by the wire nut cap. They form the finest wire connection possible: copper to copper, no intermediate joints.

The outer insulation twists provide a visible "tight enough" indication, and a small degree of strain relief. Moreover, you can common many wires in a Wire Nut, by choosing the appropriate size. You can't over-tighten Wire Nuts: hand tight is perfect - try fitting or undoing choc-bloc connectors up a swaying ladder with a heavy antenna wire to contend with and you'll soon see the advantages of Wire Nuts! One hand holding the ladder; one hand holding the choc-bloc; one hand holding (each) antenna wire; one hand holding the screwdriver.... you see the problem!

For fixing antenna wires and similar outdoor electrical joints, mount the Wire Nuts closed end upwards and they will withstand weather as they naturally shed water and even with wind blown water ingress, mounting the Wire Nuts open end down naturally drains water away, preventing shorts. You can find more information here:

https://www.heamar.co.uk/ideal-wire-nuts/41572-ideal-30-074-wing-nut-box-of-100-783250300747.html

Antennas

An updated Mini-Whip
https://www.pa3fwm.nl/projects/miniwhip/ has designed a nice derivative of the original PA0RDT idea. I'll refer you to the original (Copyright reasons) rather than going into detail here.

I'd be tempted to try a BS170 mosfet as the Hi-Z input element but the gate / source capacitance might be bit on the high side. Another approach - for those who like building things to see what happens, rather than spending hours and hours with data sheets and theory - is to bung in a 2N3819 j-fet driving a BD136 (high Ft medium power video amplifier) PNP transistor (or equivalent, see: BD132, BD136G, BD138, BD138G, BD140, BD140G, BD166, BD168, BD170, BD176, BD178, BD180, BD180G, BD188, BD190, BD227, BD229, BD231, BD234, BD234G, BD236, BD236G, BD238, BD238G, BD376, BD380, BD786, BD788, BD788G, BD790, MJE235, MJE252, MJE711, MJE712) (my grateful thanks to https://www.el-component.com for the equivalents list). If you build one of these, or an "alternative device" version, please let me know how it performs, and I'll publish your circuit in Hot Iron (sorry, no money, just everlasting fame and fortune..!).

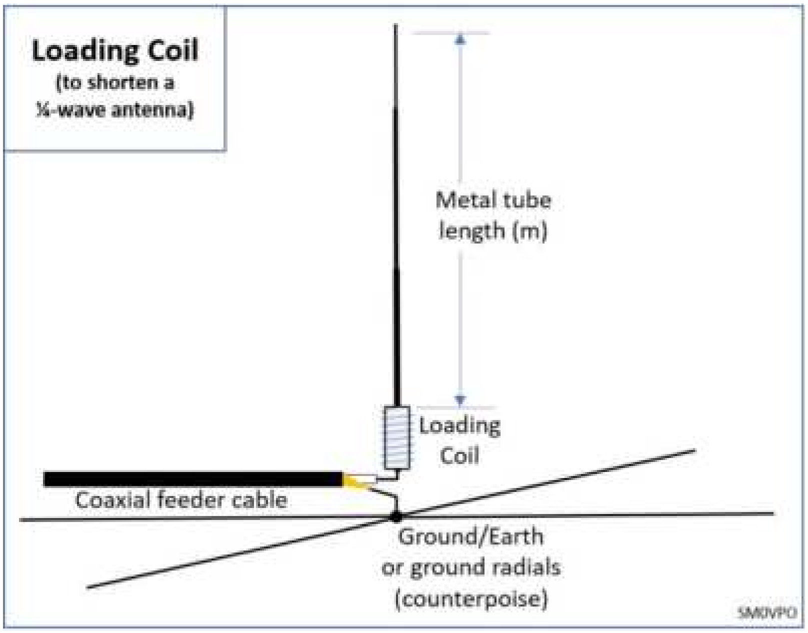
From Harry Lythall, SM0VPO...
A welcome note from that magnificent RF guru, Harry Lythall, SM0VPO:

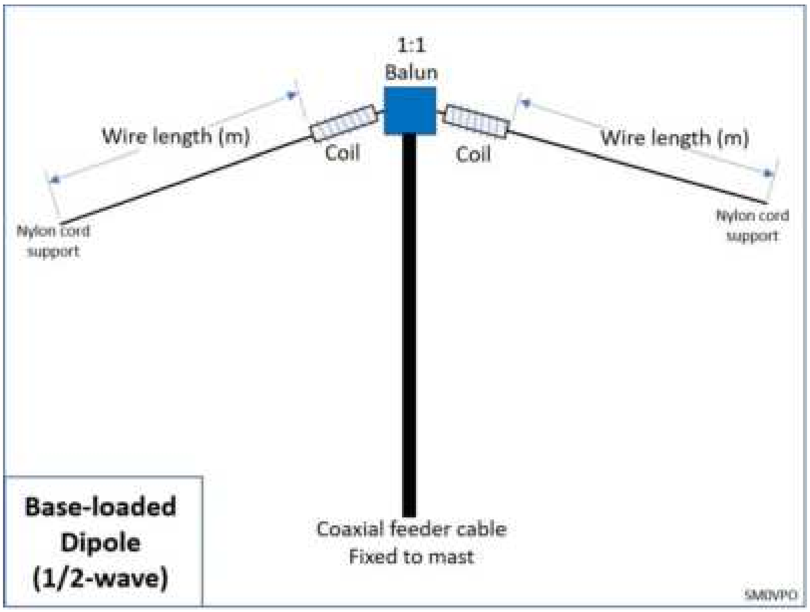
"Hello Peter,

I found this month's Hot Iron 112 really interesting, but my eyes zoomed into the paragraph on page 3:

"Correspondents write...
The third topic is winding inductors: quote: "I need 22µH, and I have a cardboard tube 2 inches diameter, how many turns of wire - and of what gauge - will I need, at what spacing?" is a typical (unanswerable!) request."

No it is NOT at all unanswerable. I recently moved into a house with a miniscule garden in a community where any visible structure is frowned upon. I was told that I may be able to get away with some installation, providing it had a low visual profile.
Short vertical antennas require some form of correction, ie. a base loading coil. Shortening a dipole is exactly the same problem as the ground-plane, but using two coils that are located out of reach. The ends of the dipole may be accessible for trimming.





There is a formula published in QST September 1974 for calculating coils, but it is a bit big and cumbersome (http://85.226.187.247/). Not only that but the dimensions are in inches and feet.

$$L_{\mu H} = \frac{10^6}{68\pi^2 f^2}\left\{\frac{\left[\ln\frac{24\left(\frac{234}{f}-B\right)}{D}-1\right]\left[\left(1-\frac{fB}{234}\right)^2-1\right]}{\frac{234}{f}-B} - \frac{\left[\ln\frac{24\left(\frac{A}{2}-B\right)}{D}-1\right]\left[\left(\frac{\frac{fA}{2}-fB}{234}\right)^2-1\right]}{\frac{A}{2}-B}\right\}$$

So I wrote the article http://85.226.187.247/ and re-wrote the formula in script so that there is an online calculator "Calculator for Base Loading Coil Inductance". I also modified it to remove centre-loading options (to simplify it) and to use metres and millimetres. Using this formula you can calculate the inductance required to make a short antenna resonant at any HF band frequency, without an ATU (I do not believe in them).

Immediately after the inductance calculator is a coil-turns calculator that gives the number of turns of wire for a single-layer coil.

$$N^2 = \frac{L(9r + 10l)}{r^2}$$

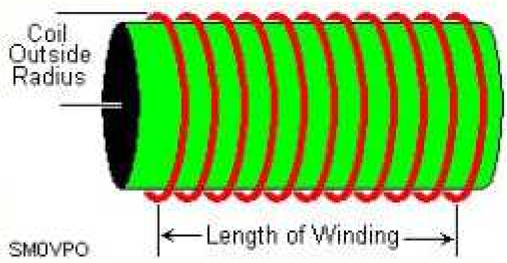
That calculator also answers the question given in Hot Iron112, and you do not need to take off your shoes and socks to use your toes to count. The only thing is you need to guess the coil length for close spacing, calculate, then re-enter the value and re-calculate.

Calculator for Base Loading Coil Inductance

[Enter] Frequency 14.175 MHz (max 7 digits)	[Enter] Wire length 3 metres
[Enter] Wire Diameter 8 mm (non-zero)	[Result] 2.9660918172185635 µH
Inductance calculator	Show µH

Calculator for Single Layer Coil

Formula: $N^2 = \frac{L(9r + 10l)}{r^2}$



[Enter] Inductance (µH) [L] 2.9660918172185635	[Enter] Length of Winding [l] 8.8
[Enter] Coil Outside Radius [r] 10.8	**All sizes in millimeters**
Turns required [N] [Result] 10.93719334100439	Show Turns

As an example let us take a vertical ground-plane antenna, but I only have a 3m aluminium pole, painted and decorated to look like a fishing rod in a garden umbrella stand. I want it to resonate on 14.175MHz. Enter the parameters 14.175Mhz, (average) diameter is 8mm, the result is 2.9661µH.

Using a 20mm diameter plastic water pipe and 0.8mm diameter magnet wire, you need 11 turns of wire, close spaced.

If your readers want just the formulas on their desktop then they can copy/paste from the HTML document (below) into a new notepad.exe file and save it as: `EasyNameYouWillNotForget.html` on your desktop. As regards copyright, just be sure to copy it correctly or it will not work :-). Your readers are welcome to copy and use the code in their own homepages.

I used these calculators to build a complete multiband dipole from 7MHz to 29MHz (including 27MHz!!) and no ATU is needed for any band. The only point to remember is that a shortened antenna with a coil has a higher Q-factor, which makes the bandwidth a little narrower.

If you want constructional ideas for a hidden vertical GP antenna then how about a high metal bird-table (2m high because you have cats), with a 1m stainless-steel "birdy-flagpole" for our feathered friends, just to extend it a bit. An interesting legal point is that the UK height restrictions do not apply to bird tables. I used to have a 20m high bird table when I lived in Grunty Fen. The planning officer who came was most upset when I told him it was a bird table and the antennas were anchored below the actual table, on a secondary basis, on an existing structure. He admitted there was nothing he could do.

Ok Peter, I hope that this answers the question about winding coils, and some additional information about calculating coils for shortening antennas, without the use of a lossy ATU. If you want to use this information then you are most welcome to share it.

Very best regards from Harold "Harry" Lythall - SM0VPO
harry.lythall@sm0vpo.com

Harry's routine is listed below: I apologise if my "cutting & pasting" has disrupted the formatting: you may need to adjust appropriately - aaarghh!

```
<html>
<body bgcolor=#FFFFF8>
<head><title>Extract From Small Space HF Antennas by Harry Lythall
(www.sm0vpo.com)</title></
```

```
<p><center><h2>Calculator for Base Loading Coil Inductance</h2>
<p><p><form name="coil">
<table border cellpadding=5 bgcolor="#5FFFFF">
<tr>
    <td>[Enter] Frequency <input name="f" size=8> MHz <span
style="font-size:10px">(max 7 digits)</span></td>
    <td>[Enter] Wire length <input name="l" size=6> metres</td>
</tr>
<tr>
    <td>[Enter] Wire Diameter <input name="d" size=7> mm <span
style="font-size:10px">(non-
    <td>[Result] <input name="uH" size=22> µH</td>
</tr>
<tr>
    <td>Inductance calculator</td><td><input type="button"
value="Show µH"
onClick=coil.uH.value=(
</tr></table></form></p></p>

<p><center><h2>Calculator for Coil Turns</h2>
<p><center><p><form name="slayer">
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    <td>[Enter] Inductance (µH) [L]<br><input name="uH"
size=20></td>
    <td>[Enter] Length of Winding [l]<br><input name="len"
size=20></td>
</tr>
<tr>
    <td>[Enter] Coil Outside Radius [r]<br><input name="rad"
size=20></td>
    <td><center><strong>All sizes in
millimeters</strong></center><
</tr>

<tr>
<td>Turns required [N]<br>
    [Result] <input name="tur" size=20></td>

<td valign="bottom" halign="right">
    <input type="button" value="Show Turns"
    onClick="slayer.tur.value=
    (slayer.uH.value-0)*
    ((9*(slayer.rad.value-0)/25.
    (10*(slayer.len.value-0)/25.
    /(((slayer.rad.value-0)/25.4)
    *((slayer.rad.value-0)/25.4))
</tr>
```

```
</table></form></center></p></
</body></html>
```

From Gerald Stancey, G3MCK

FILE GW6NG

Matching an indoor dipole

Gerald Stancey G3MCK

I was interested to read in Hot Iron 112 Tom's (K4ZAD) solution to his friend's problem as I have had this problem but took another route. On any feeder that is operating with a SWR there are points where the resistive component of the impedance is the same as the impedance of the line. A Smith Chart, figure 1, shows that when a 50 ohm line is terminated in a resistive load of 84 ohms at 0.106 wavelengths from the load the impedance is 50 ohms resistive in series with a capacitive reactance of 25 ohms which, at 14 MHz, is equivalent to 0.28 micro Henries. Inserting a coil of that inductance into the line at that point will ensure that the rest of the line operates at unity SWR. The author has successfully done this with both 30m and 20m indoor dipoles. The only equipment needed was a SWR meter, Smith Chart and a tape measure.

Having got the theory out of the way let us look at some practical details; do you need to achieve unity SWR? You will reduce the line loss but for the short lengths of line that you are likely to be using this is trivial so it can be ignored. However your rig may be unhappy and may even self destruct. This is serious so read the manual and see what is the maximum safe SWR. Let us assume that it is 1.5, in other words you don't have to achieve unity SWR. The author always terminates his coax in the roof space with a coaxial plug so that he can play with what antenna takes his fancy. This means that the easiest way to establish the desired point on the feeder is to extend it by 0.106 wavelengths rather than cut into the existing coax. At 14 MHz using normal 50 ohm line this equals (300 x 0.66 x 0.106 x 39.6)/ 14 metres which 59 inches, the velocity factor of the coax being taken as 0.66. To be on the safe side make it a bit longer, say 66", as it is easier to reduce the length rather than extend it.

Now to find the size of the inductance. The author likes to make coils where the diameter is the same as the length and uses the following formula:

Inductance in micro Henries = (diameter x n^2)/58 where n is the number of turns and the diameter is measured in inches.

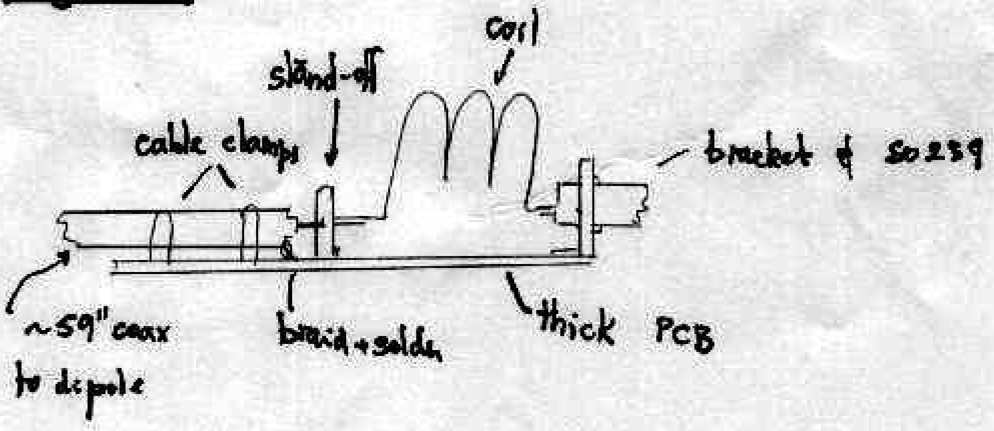
For a 1¼" diameter coil this formula gives 3.23 turns and if the coil is made self supporting then making it three turns and squeezing it a bit will yield the desired value. If you

{Please forgive the image quality; my scanner isn't the best...!}

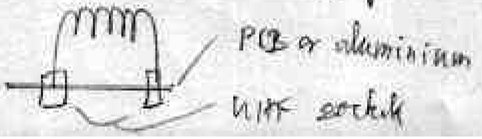
can't get an acceptable SWR then reduce the length of the coax a little and adjust the coil again. The author first made the coil from 22 swg wire as this is easy to distort and when its final, ugly, shape was found he made a nice copy from 16 swg wire. A variation in inductance of about 2:1 can be achieved by varying the length by +/- 50%. Figure 2 shows the layout that the author used. Unity SWR depends solely on how much time you want to spend.

Another way of dealing with this problem is stub matching and this is adequately dealt with in the standard hand books. If you have access to an antenna analyser this looks to be very easy. I only write about things that I have done, if you do it then please write it up and tell us all if it is as easy as it appears.

Figure 2



Peter, apologies for a very poor sketch. Another method is:-



please use either.

I particularly like the use of SO239 “UHF” sockets as insulating stand-offs: probably a far better function for them than as a “UHF” connector!

A last word...

My apologies for a somewhat abrupt |edition of Hot Iron; my computer went dool-alley during an upgrade, leaving me with a teletype screen and not much else. It has taken many hours of head scratching to recover my Hot Iron files, when the PC you rely on goes PHUTTT! you don’t have too many options open! Thank goodness I run Ubuntu Linux, the help available - even to working via a TTY-1 screen in stark black and white with rudimentary commands and my lack of in-depth Linux - got me recovered, and you see the result above.

I couldn’t have done this on any other O/S; I can thoroughly recommend Ubuntu Linux to anybody looking for an easy-to-fix O/S with masses of on-line free help.

Thank you Ubuntu!

Hot Iron #114

End November / start December 2021

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CQ-CQ-CQ

My beginnings…

The whole issue to my mind revolves around the simple human response: once the novelty of a new toy, the commercial transceiver, let's say - has faded, just as a Christmas present ends up languishing in a cupboard in the New Year when the novelty has faded. These thoughts prompted me to think back to my first steps in amateur radio; not particularly the technical issues or construction, but *why* I found it interesting and the *route* I took which still inspires me to this day, many years down the line.

The fascination then was to listen to radio stations from far distant lands; household radios could, with luck receive stations from Europe (Luxembourg on 208 metres for instance) or Eire when holidaying on the West coast of Wales: hearing stations further afield was a fascination. Inspired at work too by the combination of repetitive tasks and that radios were banned in my workplace, I asked my mentor, Stan, how I might assemble a "covert" receiver with components to hand or scrounged.

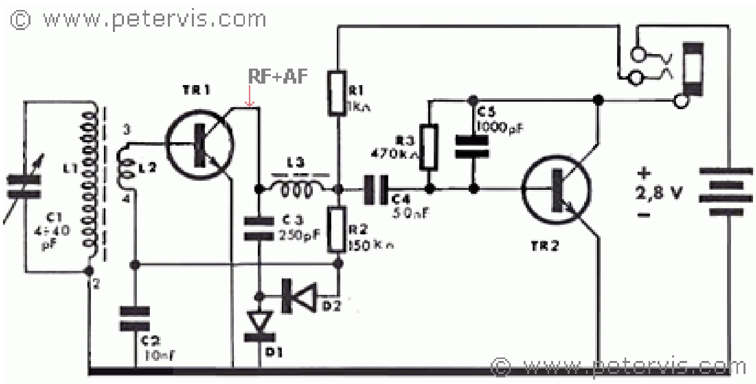
Stan reckoned I should build a super-regen receiver (he drew out a simple one transistor circuit for me) and a 50mW audio amplifier so I could listen to the VHF stations then available, using some crystal earphones, with their lead making a VHF antenna. This probably explains my love for super-regens, as the circuit worked first time and VHF stations from 80 to 150 MHz stormed in at ear-cracking volume. I did note some odd bits of conversations way up towards 150MHz, which Stan explained were probably amateurs on 2m using A.M. phone - again, this is probably why I have a fascination for A.M., it being the simplest phone technique an amateur can use and readily received on simple receivers.

My interest in radio, both receiving and transmitting, advanced, but the trials and tribulations of life meant amateur radio had to take a back seat for some years: but I never lost the bug, it had bitten me deep and hard. I built many super-regen receivers for many frequencies; much experimenting with super-regen RF amplification, separate detection, a superhet using an RF "converter" to feed a fixed frequency super-regen detector stage and many more bits and pieces. To this day I'm fascinated by the super-regen and it's foibles. Clive Sinclair's designs appeared about this period, his "Micro FM" VHF pulse count receiver was rapidly duplicated in silicon to compare with my VHF Super-Regen using transistors to hand and reworked biasing. It worked OK; it was vastly more complex than a Super-regen, but was more selective and stable across the VHF broadcast band.

After a fair amount of bending Stan's ear, built a silicon version of Sinclair's "MicroMatic" two transistor reflexed A.M. Broadcast band, which proved suprisingly good. Stan helped me bend the MicroMatic onto "Top Band", where I heard - especially in early evenings at work on the back shift, "2 / 10" - a host of amateurs running A.M. on 160 metres.

No need nor desire for Japanese technology; just a thorough learning curve which instilled a respect for those who knew the technology of radio and used it in home built gear day in, day out as commercial gear was nigh on impossible on my wages of those days.

Thanks to https://www.petervis.com/Radios/sinclair-micromatic-pocket-radio/sinclair-micromatic-pocket-radio.html for the following schematic, and Peter gives a thorough write up of the circuit.



This simple technology works fine; building it gives an immense satisfaction that no commercial gear can ever bring - then, now or in the future - as we humans only appreciate something that we have put effort into and created ourselves, and this is what makes true amateur radio.

Subscribers…

Hot Iron relies on input from subscribers; and thank you to all who email me comments, ideas and suggestions. It's good to know that the spirit of amateur radio is still alive, albeit in the small proportion of amateurs who aren't satisfied or content with being "machine operators". Commercial radio gear is truly excellent in terms of performance and price: it's as near as you'll get to a *professional* communications system your money can get. That, in my opinion, is the very crux of the fading support for "amateur" radio.

So it's with great thanks I receive your notes and emails - the more the merrier! From subscribers, I have definitive results about coil dope and Q; some great ideas about crystal oscillators; a lovely circuit for a signal injector / tracer; a kaliatron (transistorised) grid dipper which illustrates how you can use **any** oscillator with a simple add on metering stage to resonate antennas, coils, etc.; winding toroids without ferrites for ultimate "buildability" All using standard technology that can be built on a kitchen table (suitably covered of course…!) but oh so useful and inspiring. That's the best of amateur radio: it gets your grey cells, neurons and synapses a'firing on all cylinders!

Below is an article which chimes very much with my opinions and I sincerely hope he writes more along these lines!

From Lindsay Pearson...

"Our esteemed Editor has, for reasons unclear, (Hah! If only you knew… Ed.) *asked me to pen (or type) a few words as a contribution to this excellent journal. I must confess, with some embarrassment, I have only just discovered it, and you can blame the G-QRP Club for the introduction.*

A brief introduction. You can probably tell that I am on the wrong side of 70, having been let loose on the Amateur bands in the early 1960s with all-home-brew radio. Those with a strong disposition can try searching my call-sign on Google and find I won a competition for the smallest mobile transceiver – fitted to a pair of roller-skates. I have drifted in and out of Amateur Radio over the years, an early introduction to Top Band AM in the Bristol area, a flurry of activity when my wife, a Guide Leader, suggested a "Thinking Day on the Air" station (many thanks to Ipswich Radio Club), then finding the G-QRP Club and a few trips to Yeovil, another gap, and now back to radio, trying to get my CW up to "head copy" (yet to be achieved, but via the inestimable G4FON method, Ray now sadly a Silent Key).

I have been a professional Electronics Engineer for over 40 years, and this has coloured my hands-on approach to Amateur Radio. I found myself wondering why I was messing about with scraps of PCB, random components and making something that looked like a rat's nest. So I have been over to the Dark Side, with commercial radios for a few months, and now treading back to construction, with a kit from QRP Labs. Who knows what may follow?

I now look at Amateur Radio and wonder what went wrong. OK, we are a diverse group, but I see the tendrils of microprocessors feeling their way into everything, surface-mount components pushing hand-manageable components into the long grass, and don't get me started on software and computers. How is a youngster expected to learn about radio?

When someone asks me what is the point of Amateur Radio, holding up their mobile phone and saying "I can chat to my pal in Australia with this", my answer is "So can I, but I don't need several hundred million pounds worth of kit owned by someone else to do so".

I note, with sadness, that a "Foundation Licence" holder cannot build a transmitter and operate it legally – but then I have looked at the multiple-choice exam papers and see that actually knowing how a transmitter works is not required.

Several years ago, I taught some youngsters through to getting their "Novice" licence – we built simple circuits and generally messed around with electronics, as well as the theory necessary to get them through the exam. But very few stayed with the hobby for more than a few months.

Back to "what is the point?" Quite simple. Some of us like to make something, understand how it works, get it working again when something goes "pop". Oh, I miss the days of minor explosions as an over-voltaged electrolytic turns the room into one of those snow-storm toy globes, though I'll pass on again seeing the plume of blue smoke rising from my arm as it touched the top-cap of a 6146 running at 400 volts…

The same applies to any hobby. You can buy anything you can make, far cheaper if you cost your time at commercial rates. But that misses the point, you enjoy the "making".

Which is why "Hot Iron" exists, and long may it do so!"
(I sincerely hope we hear much more from Lindsay, this is exactly what Hot Iron is all about! Ed.)

From Radio History…

I often like to browse through old copies of radio magazines, my favourite (at the moment!) is QST. I find it very stimulating to see how the exact self-same problems encountered nowadays were tackled yesteryears! Take a look, let your imagination wander, and check out any article that catches your eye. See:

https://www.rfcafe.com/references/qst/vintage-qst-articles.htm

https://worldradiohistory.com/QST.htm

where you'll find just about everything you might ever need or want to know about Amateur Radio!

There is a library of Technical magazines in the commercial and amateur radio field: a truly monumental reference of most of the history of radio in print. See:

https://worldradiohistory.com/

I give you fair warning, make sure you've plenty of time in hand when you dip in there – you'll be in there for days!

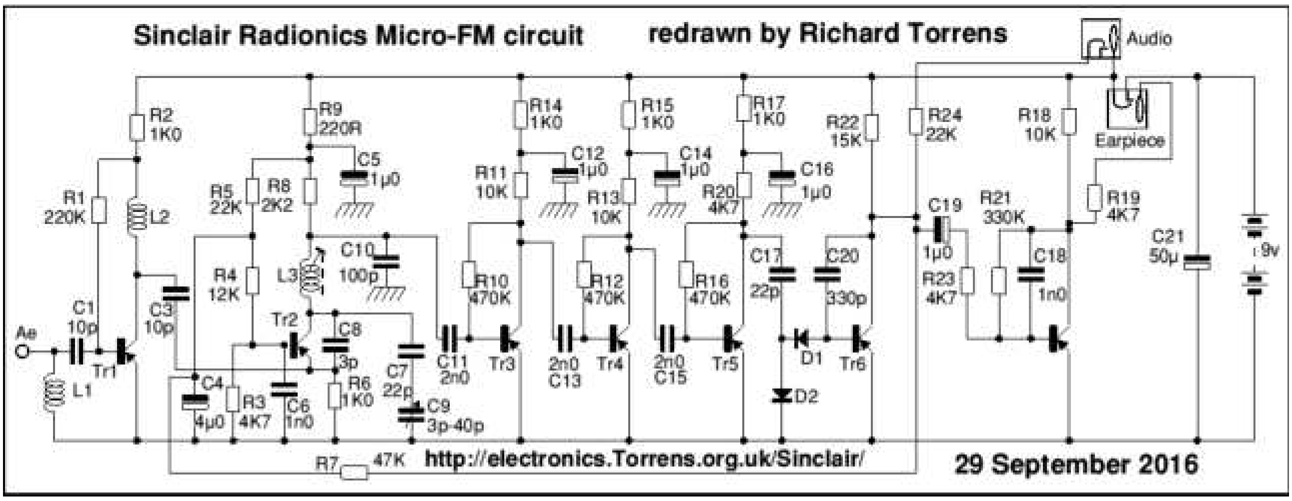
Receiver Topics

Sir Clive Sinclair

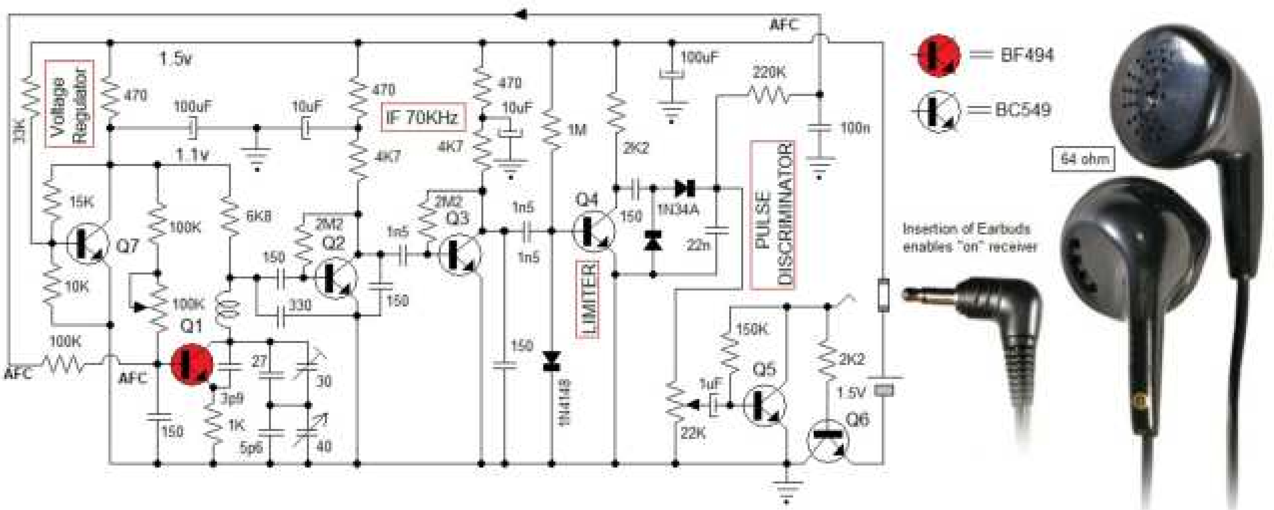
With great thanks to Richard Torrens, who worked with Sir Clive and has produced the most complete history of his time with Clive Sinclair. See:

http://diy.torrens.org/Sinclair/index.html

For your delectation, below are two circuits: the first is the original schematic of the "Micro FM" VHF receiver, and second is a modern version both of which use the Armstrong "Pulse Counting" FM demodulation system.



This is the “ modern” schematic, from http://www.vk6fh.com/vk6fh/pulsecountrcvr2.htm :



You can see the genealogy of the design; Sinclair took it from valve technology and solid stated it in germanium devices; VK6FH put it in silicon. Now, dear reader, spot the antenna in the silicon version above! It’s not noted, and I can see several candidates, but would really like to know.

IF thoughts…

The IF strip of a receiver is where the bulk of the gain can be concentrated, as well as the selectivity. But keep to mind, several other signal handling features can be built in too - purely because the signal waveform distortion introduced at IF frequencies is more or less (give or take…) absent after post IF demodulation.

The AGC can be derived from the IF output; the DC AGC signal an analogue of the signal magnitude. This AGC signal is used to alter the bias of one or more stages of the IF strip, the consequent distortion of an amplifier stage rendered irrelevant as demodulation doesn’t (usually…) cause any problems. For simpler receivers, a crafty trick to limit the gain - and thus effectively put a “ceiling” on the signal amplitude available - by allowing an IF stage to clip, either saturating fully “on” on positive signal input peaks, or the output hitting positive rail voltage as the stage shuts off on negative signal peaks - or both! Once a transistor has hit saturation or is fully off, then no matter how much more the signal wants to go, it physically can’t. That gives a very definite clamping of the amplitude the IF strip can feed to the demodulation stage(s) - the audio recovered is (almost…) free from any distortion. Sinclair used this approach in his germanium Micro FM IF strip I'm told.

IF strips can be made with conventional IF transformers, with tuned windings to give the bandpass characteristic desired. Indeed, double conversion receivers with multiple IF strips can be made incredibly selective: a 10.7 MHz first IF driving a 80kHz second IF can deliver astonishing performance, so much so audio frequencies can be clipped as the combined bandwidths of an 80kHz IF can easily be just a few hundred Hz; ideal for CW, but horrible for SSB or AM speech!

It should be kept in mind that other selective methods are available: crystal filters are superb, easy, cheap (if home made!) by using the very cheap PAL-TV colour sub-carrier frequency crystals and the like, set up in ladder filters.

One option is rarely seen nowadays: the RC band pass filter, set up for (say) 40kHz, set in chains with a buffer amplifier stage every other stage can prove useful: being cascaded *single order* filters, they do not "ring" - a defect seen in "conventional" IF strips under impulse noise attack. But you pay for this: the output is delayed, by a significant (but constant) amount of time - these filters are sequential low pass / high pass networks and the low pass elements slow things down!

I first saw the passive filter IF principle in a Rohde & Schwarz AC nano-voltmeter way back in the 70's, whilst categorising pulse driven Gallium Arsenide laser diodes. The instrument was remarkably robust coping with industrial scenario RF electrical noise; our other instruments had to be run in our cramped double walled Faraday cage to achieve similar performance.

As a brief introduction, try the filter design gizmo below where you can plug in any frequency and see how the components change:

http://www.learningaboutelectronics.com/Articles/Bandpass-filter-calculator.php#answer1

Plug in frequency values a kHz or two apart, as a start. For an IF of 145kHz, bandwidth 2kHz, you get C1 = 100nF, R1 = 11 ohms, C2 = 1nF, R2 = 1091 ohms.

Similarly, for and IF of 42kHz, bandwidth 200Hz (for the CW man, set at 41.9kHz and 42.1kHz) you get:

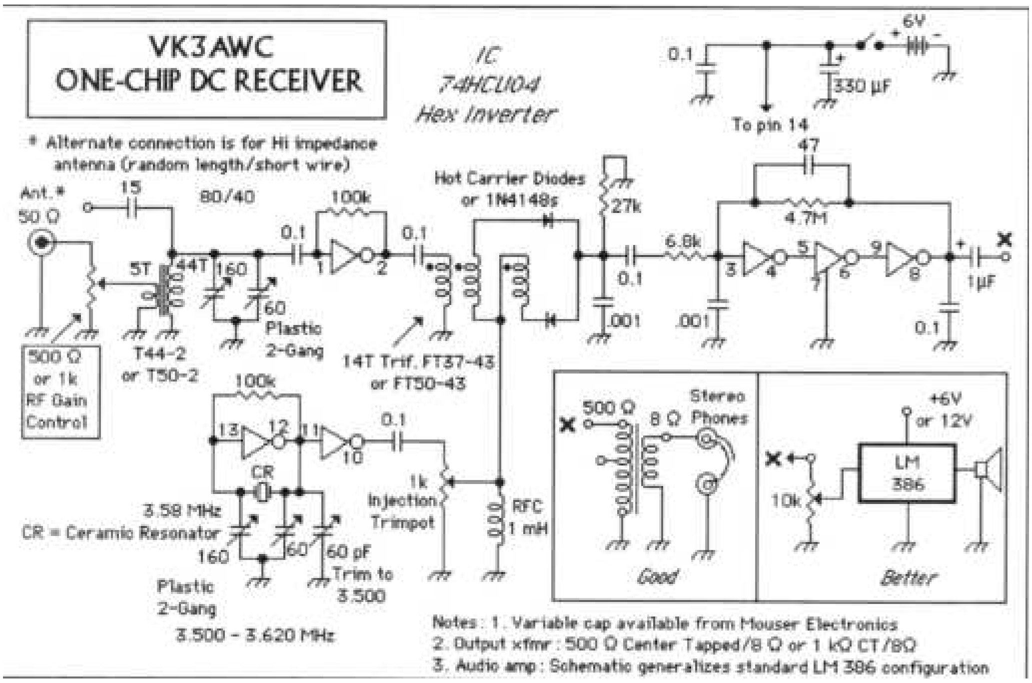
C1 = 100nF, R1 = 38 ohms, C2 = 1nF, R2 = 3782 ohms

The capacitors are easy 1% poly values; the resistors are 2% metal oxides and close to standard ranges. A slight tweak to frequency values will get you to standard values near as makes no difference and who cares what the *exact* IF frequency is?

One thing is important: the resistor and capacitor values need to be matched in every section of a cascaded IF strip, but I'm sure you can find an IF frequency that facilitates "easy" component values - the whole beauty of this approach is you can select any IF that suits you.

A Single Chip complete receiver

From that amazing Antipodean, Bill Currie, VK3AWC…

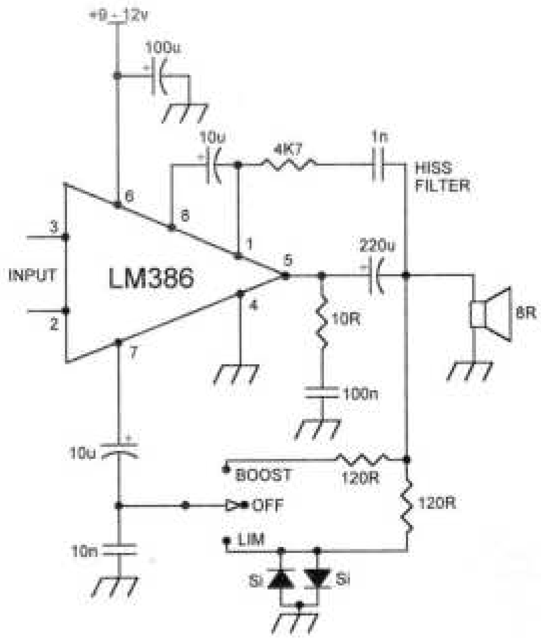


Here at Hot Iron, we reckon simple, easy, low cost home made radio is the way to enjoy Amateur Radio; taking that stance allows even the hardest up, impoverished amateur can get on the air and have a lot of fun whilst learning from doing - surely the very best way to learn. Bill Currie's design above exemplifies everything that Hot Iron stands for! Thanks Bill, much appreciated.

Audio topics

The LM386 - again...

That old workhorse beloved by most (ahem…) the LM386 can be adapted with a few external components to deliver functions and performance not initially designed in the chip. I have a suspicion this little adaptation was by Bill Currie, VK3AWC:

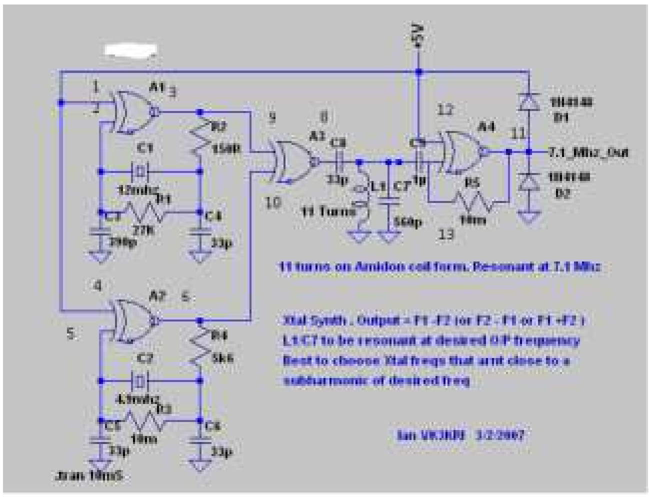


This circuit is so simple, yet delivers so much from a minimum of components. Beautiful! Should the circuit oscillate on “Boost”, then increase the 120R “boost” resistor up a tad; try 150R or 180R.

Oscillators

A novel crystal oscillator, John Kirk, VK4TJ…

“The Silence Is Deafening...



Back in Hot Iron #109, Peter threw down the gauntlet for a “single active device / dual (or more) crystal oscillator” circuit, and describe their adventures with it.

Anyone...anyone....Bueller? Who knew? The ever-efficient Kostas, SV3ORA, had actually solved this riddle 5 years before Peter even posed it! http://qrp.gr/multiosc/index.htm

I declined to dip my toes in those waters. It had a whiff of “Well, it worked for me!” about it. In my “metal years” (silver in my hair, gold in my teeth, and lead in my arse), “Starts every time” begins to influence my choice of not just vehicles, but oscillators as well.

Having said that, I think we could reasonably expect the sum & difference products from said crystals to appear in the output, an absolute boon if Alibaba's 40 million thieves failed to come up with a suitable rock (See Hot Iron #110) for your latest madcap invention. Clearly, playing off the 150-odd frequencies available against each other results in a MUCH higher probability that something can be made to work.

Scanning the web on a completely unrelated quest, I tripped over Ian, VK3KRI's “XTAL Synth Using 74HC86”: http://www.smoke.com.au/~ic/ham/xtal_synth.html
He has kindly allowed us to reproduce the schematic here. Ian may know it as a synthesizer, but “crystalplexer” was the term more in vogue back in the days of 23-channel AM CB, and certain Ed Clegg early 2 mtr FM transceivers. A quick check online revealed that the 74HC86 currently retails for something like 10 cents USD, or 2.5 cents per gate, so I thought “damn the expense!”, and blew the kid's inheritance on one. I'm not sure why Ian ended up with radically different component values in the two oscillators - mine ended up with 1K series resistors, 1 meg parallel resistors, and 47 pF phase shifters fore and aft, and cheerfully took on all comers from 1.8 MHz to 20 MHz.

In playing with my new “crystalplexer”, I was very surprised to see that both input frequencies are totally suppressed in the output! 'Tis the nature of exclusive OR gates thusly wired, apparently. No doubt this will make life considerably easier for experimenters trying to tidy up the output with primitive test gear or low-parts-count output filters. Of course, it also means that this little circuit will not take pride of place over my universal test oscillator, as my junk box does occasionally come up with exactly the right (single) crystal.

OK, so I failed to “meet the brief” of one active device/two (or more) output frequencies, but managed to trip over a pretty useful addition to the shack, no? So how does it play in the real world? Calculating sum and difference products in my head was rapidly giving me a brain hurt, so I spent a few minutes trying to be oh-so-clever with Excel's “Goal Seek” function, trying to persuade it to ease my aching cranium by doing the mind-numbing repetitive calculations required to nut out a specific frequency. As usual, I was making it harder than it needed to be. Another name for “sum and difference products” is “intermods”. Huh? Yep. For my sins, I was heavily involved for decades with VK Intruder Watch, and used to use a great little freebee program called PRFIntermod: http://www3.telus.net/PassiveRF/
to try to keep VOA honest when they tried dumb-arse stunts like feeding two (or more!) transmitters into a single antenna, then wondering why we observed little replicas of their propaganda right across 20 mtrs. Don't try this at home, kids! I digress...

To give this a real-world feel, I grabbed a comment off GQRP's reflector bemoaning the lack of really good 5332 kHz rocks for 60 mtrs. I bunged in pretty much the entire 1 to 20 MHz Alibaba stash, and straight away, a handful of good prospects leaped out! Luck, or good management? Only further road trials will let us know. I'm really looking forward to trying VK3KRI's circuit on a couple of “box of rocks” type HF commercial band SSB transceivers that were gifted to me. At the current price of custom-ground crystals, these have clearly passed their “sell by” date, but, with a bit of “pick a rock - any rock” sleight of hand, particularly if I can get some VXO happening, they might just find a place on our 80, 40 and 30 mtr bands. As an added bonus, they are, of course, loaded with critically-coupled bandpass tuned circuits to meet commercial specs, so are highly unlikely to let anything slip through that would not withstand close scrutiny by the spectrum police.”

~~~~~~~~~~~~~~~~~~~~~~~X~~~~~~~~~~~~~~~~~~~~~~~

Great stuff, John! I wonder what would happen if we added another crystal and X-OR’ed all three outputs? Or, dare I say it… “N” crystals feeding an N.X-OR tree?

Here’s similar approach from that fount of simple but effective circuitry, Chas. Wenzel:
~~~~~~~~~~~~~~~~~~~~~~~

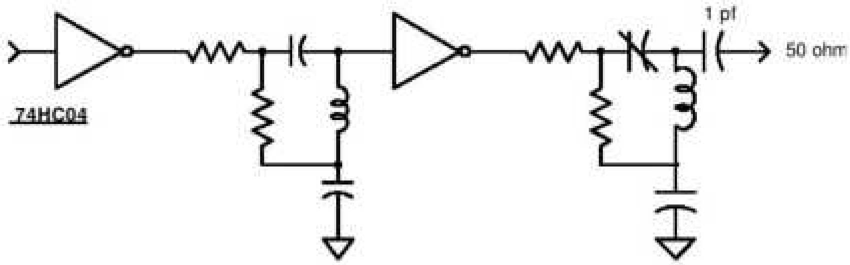


Figure 2: 6 MHz to 30 MHz multiplier with sinewave output.

Note that the output network is tuned to the same frequency as the multiplier network unless two stages of multiplication are desired. The second gate may be left out if a low-level sinewave is adequate.

The frequency synthesizer depicted in fig. 3 illustrates how flip-flops can be used to divide and multiply simultaneously to achieve fractional multiplication factors.

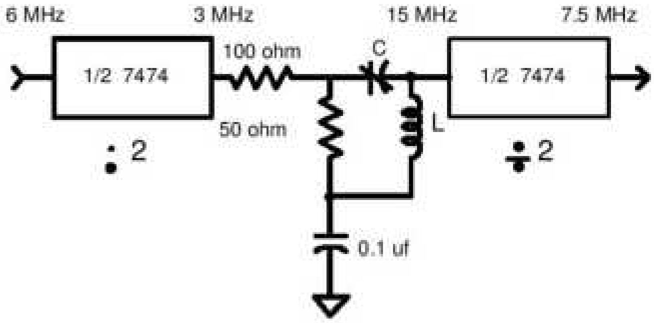


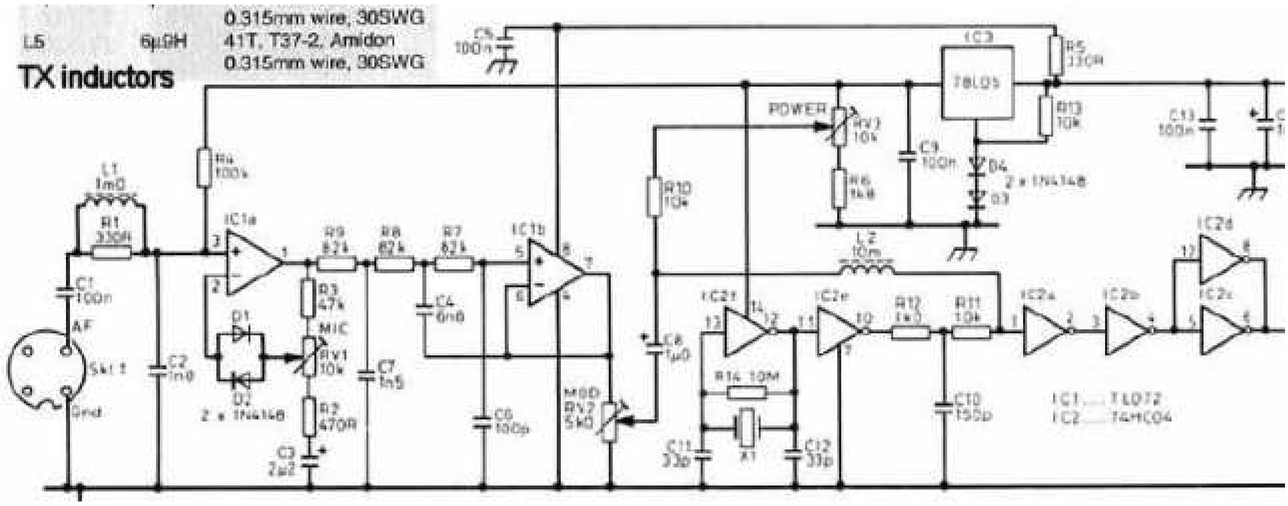
Figure 3 : 6 MHz to 7.5 MHz multiplier

This synthesizer uses a single 7474 flip-flop to convert a 6 MHz input to 7.5 MHz (a multiplication factor of 1.25). The 6 MHz square wave from a clock oscillator is divided by one of the flip-flops and applied to a network similar to fig. 1. The fifth harmonic of 3 MHz (15 MHz) is divided by the second flip-flop to produce 7.5 MHz.

Fig. 4 shows a gated-output multiplier using two nand gates. Network values are selected as before. Gated multipliers are useful when a high on-off ratio at the output frequency is desired since stopping the multiplication process essentially eliminates the frequency. For the best performance choose non-inverting gates since the output will be connected to ground through a very low impedance when the multiplier is off reducing the opportunity for harmonics from other stages to find their way into the output tank via the power buss.

Transmitters

A.M. with C-MOS hex inverter



The diagram is part of a D/F Tx/Rx schematic that illustrates how a logic gate can generate Pulse Width A.M.

Observe dual op-amp Ic1 a and b form a microphone amplifier and clipper, basic speech processing. Note too L1 and C2 stray RF stoppers - excellent RF practice. The processed speech is passed through C8, where a bias voltage is added from the “Power” control pot, and thence via L2 into the input of gate IC2a, the pulse width modulator.

IC2f is the crystal oscillator, in a standard circuit, which ensures the crystal “sees” the correct loading capacitances - in this case C11 (33pF) and C12 (33pF). The oscillator output is buffered by IC2e; R11 and 12 with C10 eliminate harmonics and load IC2e output so as to produce a “clean” RF carrier to the modulator summing junction.

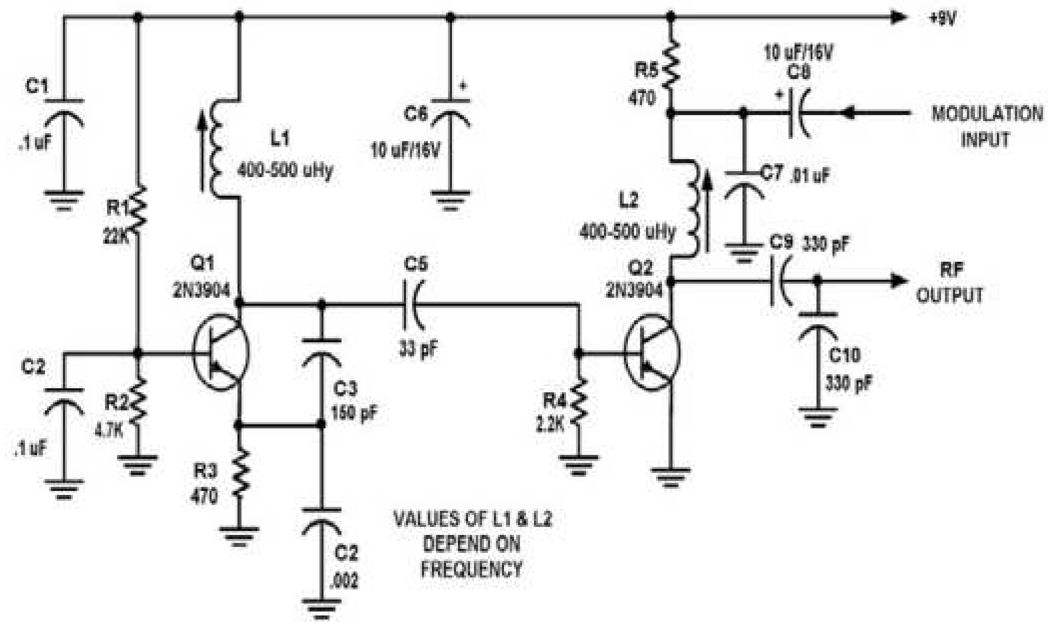
Consider the RF cycles appearing at the input of IC2a, compared to the audio from IC1b: assuming a 3kHz upper frequency from IC2b, a 2 pole active low pass filter, then in one cycle of audio many thousands of RF cycles appear. The audio, compared to the carrier RF, appears like a slow ramp so the point at which the input pin of gate IC2a reaches it’s switching point - the voltage that forces the output of IC2a from a “0” to “1” (and vice versa) - sets the width of the RF pulses appearing at IC2a’s output. Thus the *average RF power*, appearing at the output of IC2a, varies in proportion with the audio signal: i.e. pulse width modulated A.M.

The other gates of IC2, namely IC2b,c,d are gate drivers, feeding a power mosfet class C “final” (not shown, but a standard circuit). A low pass filter follows the mosfet final in usual practice, set for the band of operation.

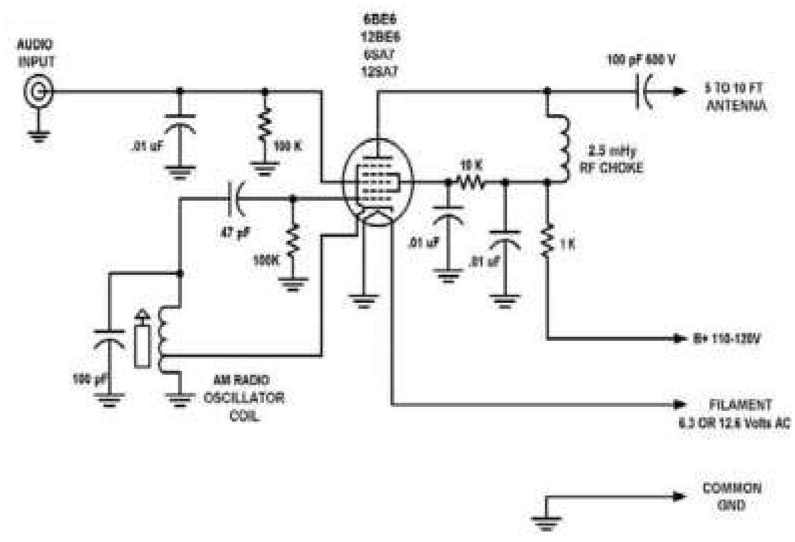
Simple A.M. transmitters

Ideal for test purposes and QRPP operation if adapted to crystal control, from: “Build your own low-power transmitters : projects for the electronics experimenter / Rudolf F. Graf, William Sheets” (copy and paste in your favourite search engine).

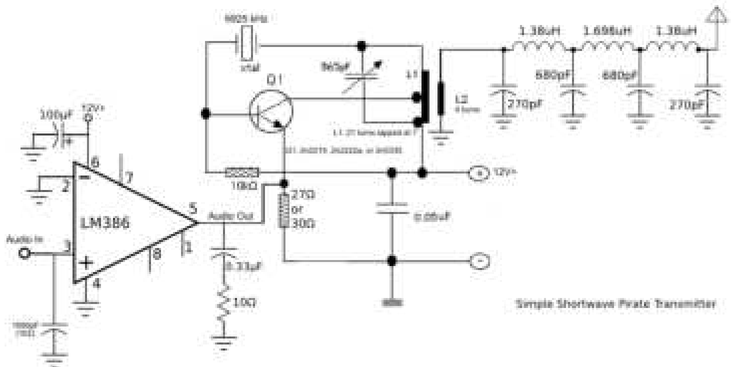
The two circuits below illustrate just how easy A.M. phone is to generate:



In both circuits the audio input should be sufficient to give 10 - 90% modulation; **don't overdrive!!**



The diagram above shows a Hartley VFO, a crystal can be substituted for "rock solid" stability.



I wonder how many "pirates" tried this circuit (the Michigan Mighty Mite) on A.M. without an RF choke between the LM386 output and Q1 emitter, and to pin 3 of the LM 386? Hah!

Power Supplies

Low voltage AC for transformer test

In trying to identify an unknown transformer it's not a good idea to bung it on the mains and see what happens. That's a recipe for blown fuses, windings or worse!

What the canny amateur might try is a known good transformer to feed low voltage AC into unknown transformer winding(s), then measure the resulting voltages on the other winding(s), and thus deduce the turns (hence voltage) ratio linking the winding(s). Note that this is done without any loads connected and the test transformer's primary safely fed via a "dim lamp" current limiter.

First identify the winding(s) start and finish wires using a multimeter on resistance and label the pairs identified carefully. Centre taps are equal resistance to "ends", measure carefully and (on suspected centre tapped windings) check for "end-to-end" resistance being exactly the sum of two!

You can usually make a guess as to the high voltage winding(s), either primary or secondary, they are usually of thinner wire, and might have extra sleeving insulation; whereas the low voltage secondary(s) will be thicker wire (usually). This test method works best on low voltage transformers if you drive a secondary, because the voltages on the other windings will (usually) be more representative.

Let's suppose you're feeding 15 volts AC into an unknown secondary on an unknown transformer, and read the following AC voltages on the windings identified previously by DC resistance test:

Winding (1) = 15.0 volts (test input drive voltage)

Winding (2) = 278 volts

Winding (3) = 7.7 volts

This indicates winding (2) is *probably* a 230v primary; and that 15 volts driving the secondary is higher than the rated voltage of the winding, by a factor of 278 / 230 = 1.2; the 15 volt drive is 1.2 times the "proper" voltage for that secondary. The winding we're driving with 15 volts is probably designed to be 15 / 1.2 = <u>12.5 volts.</u> (Note that test results for one winding *should hold valid* for all other windings).

We have now identified a 230 volt primary, and a 12 volt secondary, so let's measure the other secondary volts: we see an output of ~7.7 volts so the "proper" voltage is probably 7.7 / 1.2 = 6.41 volts. This seems very much like a 6.0 volt winding, so we now know both secondaries: we have a 12.5 volt and 6.0 volt windings, and a 230 volt primary by the looks of it.

One thing to keep in mind is that transformer designers always specify an output voltage at a certain current to take in account the winding resistances, the "regulation" of the transformer. Because we are driving this transformer "backwards", i.e. driving a secondary, we're pushing against regulation: the windings are yielding slightly high voltages than those specified by the designer.

The next step is to apply mains to the primary as identified above, vis a dim lamp, if all is good, then drive with full mains and load the secondaries one at a time. By varying the load resistance you'll find the current the transformer is designed for: it's when the windings are delivering the expected voltages, in our case, 12.5 volts and 6.0 volts AC, *under load*. Let your transformer drive a load for an hour or two, checking the core and winding temperature every few minutes. The transformer may well run warm, but not “cooking”, indicating the usable VA rating of the transformer.

Batteries, Chargers, and the curse of SMPS’s

Nowadays, battery powered drills are great: no more hours with a wheel brace drilling holes - the battery drill has “revolutionised” (groan….Ed.) home bashing of metal chassis for our latest projects. But - those battery packs are certainly expensive! So we keep them charged, take care not to overcharge them by using an “intelligent” charger… and that’s when trouble can rear it’s ever-present head if you’re not aware of how these things run.

The charger is a power supply designed to monitor the battery under charge, so that it doesn’t push the amps in too fast; these batteries have to be spoon fed their charge *just so*, until the charger sees the voltage and current are within the “charged” specification. To protect the charger and battery pack the current is monitored: it has to be within certain limits or the charger says “not today, Josephine” and shuts itself down. Not that the charger will indicate any of this to you: it just stops, and sits there waiting for you to remove the load drawing too many amps (some form of “foldback” limiting lock out I suspect).

This is a common scenario with SMPS’s (Switch Mode Power Supplies). These are emotional little beggars: if they aren’t connected to a load they expect, they get sulky, and disappear into their own little inner Nirvana and refuse to play any more until all power is removed and a fresh start made. This is the result of shutdown on over-current: typically, the load has sucked out too many amps all in one go and the poor little darling has spat out it’s dummy until you unplug / de-energise the damn thing and start again. However, this can be the case in a battery charger if the SMPS does not deliver enough amps: it shuts down if the volts and amps don’t suit it, it assumes a foetal position until you shut off the juice and start again.

Now, let’s step one pace further: your pal Joe / Josephine calls you and says “my 12 volt shack power supply has died, you got any ideas?” Now you, having been tipped off, know that if the load isn’t just so, the little darling SMPS could, if the mood takes it, up and away with itself into the electronic dark lands, with ne’er a whisper in a buzzer or glint in a LED to tell you that it’s upset and sulking in a corner.

The answer is a trip to your local car spares shop, for some 12 volt 21 watt lamps, used on countless vehicles as brake lights, to make a dummy load. You’ll need a few 10 - 25 ohm power resistors too. I’ll assume you’ve soldered some flying leads and croc clips (or any other easy connection means) to the auto lamps and resistors for easy connections.

First test:

Connect lamp to suspect SMPS and power up. Does the lamp light? Yes = probably good SMPS, it’s managed to drive the inrush current into the load, as the cold filament(s) have a very low resistance. Add more lamps in parallel to the ampacity of the power supply, repeating the start up at every added lamp.

When load lamps fail to light light, it doesn’t necessarily mean the SMPS is faulty: it’s sensed the high current demand of cold filament lamps and shut down. So…

Second test: repeat the above with the 25 / 33 ohm 25 watt resistors as load. Does the load energise (they will get warm…ouch!!) Yes = good power supply, resistors don't have the cold inrush current lamps exhibit.

Failure to drive a load with high inrush current (like the lamps) can indicate the output electrolytic(s) of the SMPS are failing: they do a lot of the heavy lifting in an SMPS, and often give up the ghost first, the "fail to start" on high amps fault being a fair guide to that problem. If this is the case, replace ALL electrolytic capacitor(s) inside your SMPS with IDENTICAL spec. parts (this is important, don't skimp or the SMPS will fail again), as if one electrolytic has shuffled off his / her mortal coil, the others won't be far behind - and now you know why it's important to keep the air louvres clear and clean on an SMPS!

Faults and breakdowns in SMPS's fall roughly into the following sections, common faults first, rare occurrences last:

Output electrolytic: gone high ESR, loss of µF's, leaky (look for swollen cannister!)

Input bridge rectifier: o/c or s/c diodes due to mains transients; ohms check each bridge diode.

Surge suppressors blown: look for exploded VDR's and polypropylene capacitors near mains input. Probably an over-voltage surge; lightning strike, etc.: replace blown bits & clean the PCB!

Input electrolytic: as per output electrolytic above; beware! This can be charged to rectified mains voltages, 330v., so check with a meter before touching!

Start-up resistor o/c: This is a high value resistor from the rectified mains input side to the control chip, to cold start the system which, once running, powers itself from it's own output. 2M2 to 470K are typical, err on high side if unknown, "cut and try" until the SMPS starts up reliably.

Edge connectors: unplug daughter pcb's and reseat; if this doesn't work, then *gently* cleaning the PCB edge connector pads with a soft pencil eraser or similar, never anything abrasive but emphasise *gently;* that gold is thin! Ensure pcb's are fully seated and secured in place.

Control chip faulty: usually bomb proof; look for cracked package or pins shorted with detritus.

Power MOSFET's: look for exploded packages, dead shorts drain to source and / or gate. Gate shorts mean the driver chip's probably shot too.

Schottky diodes: chunky rectifiers found near the power MOSFETs, they rectify the low voltage DC output(s); look for leaky reverse or high forward resistance on ohms check. Remember Schottky diodes have ~ ½ the "ohms" reading of a PN junction; for multimeters showing forward volts, a Schottky will read ~ 300mV, a PN junction ~ 560mV. Sometimes high speed PN diodes are used here, any replacements must be identical to originals, don't substitute!

Blown output tracks on PCB: repair blown tracks with enamelled copper wire, but ALWAYS ohms check for shorts inside the SMPS and load before powering up!

"Hidden" fuses o/c: these look for all the World like surface mount resistors which, of course, they are - of zero ohms value! Test by jumpering a fuse of equal value (take a guess if no markings) soldered across the suspect fuse before replacing, but investigate load compatibility too.

Test equipment & Fault Finding

Kaliatron grid dipper

The Grid Dipper is a very useful bit of kit for any amateur bench: here at GW6NGR it's a permanent resident on the bench, and many a time I've thanked the powers that be for it's assistance. It really is a multi-function bit of kit: as well as finding resonances in tuned circuits, it's a signal source, a fault tracer / demodulator and a general all round useful bit of kit.

A "must have" for a GDO is an oscillator that's robust in output terms: it must drive a significant signal into a circuit under test without crashing the oscillator.

For those who like this sort of thing, the locus of the gain / phase plot of a good GDO oscillator well and truly encloses the -1 &180° point, known as the Nyquist Criterion for oscillation. In general terms, if the gain round the loop is >1, and the phase gives positive feedback then the circuit will hoot. The popular circuit is the Kaliatron oscillator of valve fame; it resists "pulling" by an external tuned circuit better than most other topologies - again, because the oscillator is very "rugged".

The whole article from Homemade-Circuits is at:

https://www.homemade-circuits.com/grid-dip-meter-circuit/

Built with some decent high Ft transistors, and decent diodes (germanium OA81 or similar are good) this little gizmo will help you check your tuned circuits right up to many hundreds of MHz. Calibrate each coil and a simple paper chart beneath the tuning knob with the aid of a receiver; don't look for dead accuracy but "near enough" will suffice for most jobs.

A useful write up about using the GDO can be found at:

https://worldradiohistory.com/BOOKSHELF-ARH/Servicing/How-to-use-Grid-Dip-Oscillators-Rufus-P-Turner-1960.pdf

One easy substitute for a GDO is an oscillator, be it a Signal Generator, a stand alone synthesizer local oscillator, or whatever you have to hand, with a diode RF probe measuring the output. The Sig. Gen. is connected to a test coil and held near the tuned circuit under test. As the frequency of the output is varied, and the tuned circuit resonates, the diode RF voltmeter will show a distinct "twitch" - if it's a parallel tank circuit, the RF volts will kick UP at resonance; a series tank will slump the RF volts DOWN, because parallel tanks show high resistance and series tanks show low resistance at resonance. These alter the loading on the sig. gen. output, and consequently the reading on the RF probe voltmeter.

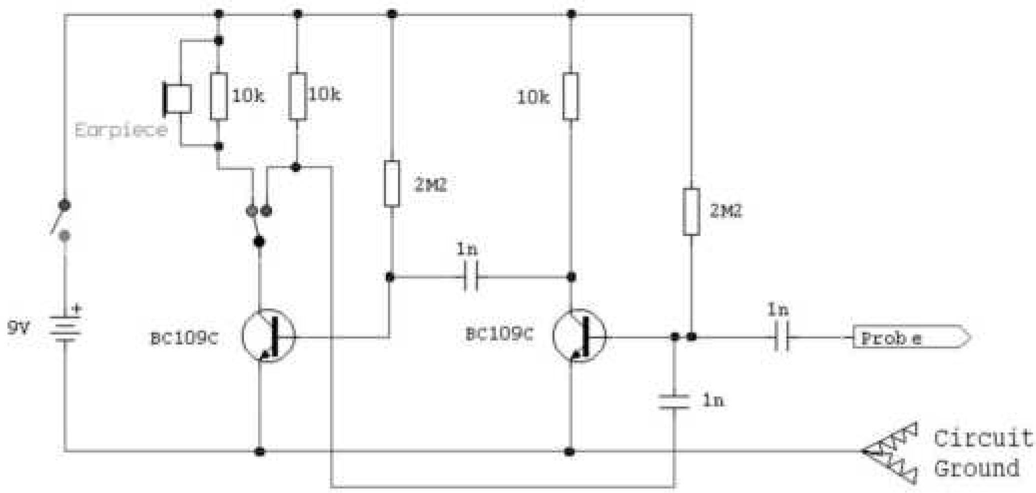
You'll find some superb GDO designs on our old friend Harry Lythall's SM0VPO pages, see:

http://sm0vpo.altervista.org/use/gdo2.htm

I personally prefer single section tuning capacitors, as in the Kaliatron oscillator, but that's just me being stingy!

Signal tracer / injector

This design is ubiquitous: I've seen this diagram on many web pages, it's a two stage audio amplifier for detecting signals that can be switched into an astable multi-vibrator, thus becoming a signal injector. Here at Hot Iron we like circuits that can do two (or more!) jobs for the price of one. We assume the “earpiece” is the very high impedance crystal variety; if you only have low impedance “ear bud” types a small output transformer, 10k to 16 ohm transformer with a series resistor to make a total of 10k (DC) in the left hand transistor collector would be a good idea.



The Growler and Star Point disconnect

How to find shorted turns in a coil or transformer? We all rely on transformers and motors, not always an amateur radio topic, but always useful to know: that bargain HV transformer or rotator motor might be fit for years of service or a doorstop, and you can spot the duds if you know what to look for.

Shorted turns, buried deep within a transformer winding, leakage to the frame from frayed insulation, or a shorted turn in a motor armature coil are all faults I’ve seen: some for no apparent reason, some from lightning impulses, or earth faults caused by 400kV pylon collapse a few miles away, by over-volts from inadvertent opening of star point earths (or in the USA, split leg earths); all are likely problems that can cause severe damage to windings without you knowing anything other than a blown fuse. If you know what to look for you can help protect your “hard earned” in some instances, try the following.

Test for shorts to frame / earth; look for discoloured or obvious signs of heat; always start up an unknown or “bargain” transformer or motor via a “dull lamp” test set-up and / or a low voltage transformer. This will preserve your fuses and sanity, as any decent transformer will need only a touch of AC to magnetise the core with no secondary load connected. Similarly any motor will need only a sniff of AC amps with no mechanical load connected.

Let’s look at a transformer first. Leaks to frame / core earth can be found by an insulation tester – easy, Tiger, go gently with a 500 volt Megger, as the peak volts of a 220v AC supply is 315 volts and the winding might not be insulated beyond that value - a 500 volt Megger might actually ***create*** a short in a sound transformer, by breaking down the inner winding insulation: go easy! A series 1M-ohm in one test lead will reduce the chance of damage. The shorted turn fault is trickier to find, but the Growler principle can help; see:

http://dictionary.sensagent.com/Growler%20(electrical%20device)/en-en/

When a transformer is energised via a dul lamp, a shorted turn represents a significant load and the dull lamp will be brightly lit. This isn't a 100% certain test for a shorted turn; other faults like a primary to secondary short or a shorted start-to-finish winding in either primary or secondary will cause this. One thing is for certain though, a shorted turn will set up a very strong magnetic field.. Thus a thin magnetic probe (a thin steel feeler gauge for instance, try 0.004" or 0.1mm) run all over the outer cover of a winding with no load connected should, if no shorted turns are present, pick up very little field when run over the winding outer cover.

A shorted turn will create another field from fault current so at certain spots whilst searching over the winding cover, anomalies will be felt (or heard!) in the probe. It will begin to buzz or "growl" as the flux set up by the shorted turn bucks against the flux the rest of the winding has created (Lenz's law). This shorted turn flux isn't always obvious; it takes a few tries to spot the anomalies and obviously a small (i.e. less than 20VA transformer) is difficult to probe and diagnose this way.

An alternative method is pulse testing, where you clobber the winding with impulse volts and observe the ringing of the winding inductance with it's intrinsic (or added for test) capacitance. A good winding rings like a bell for a good few cycles after the pulse; a shorted turn winding shows a much shorter ringing transient, the shorted turn absorbing the magnetomotive force in the core. This web page will explain:

https://www.voltech.com/support/technical-articles/detecting-shorted-windings/

The "stress test" they call up is in fact the "dull lamp" test alluded to earlier; you are using a series lamp to limit the input as a good transformer will only need a sniff of AC to energise the core to full flux. Only when a secondary (a shorted turn ***in any winding*** on the core represents an unwanted secondary) "absorbs" flux does the primary current rise. See:

https://static1.squarespace.com/static/575eb8279f7266835098dee0/t/5761b65ed210b8df02c13ec7/1466021471651/coil-a-winding-testing-handbook.pdf

https://www.voltech.com/support/technical-articles/detecting-shorted-windings/

https://www.themagnetoguys.co.uk/using-the-growler

I find myself digging into my experiences for a possible sideways take on the job in hand. I was reminded of doing measurements on Gallium Phosphide wafers, to calculate various properties of the wafer - like carrier concentration, doping profiles and the like by passing the wafer through a powerful magnetic field, using "Hall Effect" millivolt shifts which could be interpreted to give the data required. I've used Hall Effect sensors to detect magnetic fields in designing fail-safe solenoid valve systems, where just putting the volts onto the solenoid coil wasn't enough - we had to know the valve coil had actually magnetised the valve stem, the Hall sensor detected the magnetic field of the energised valve.

Thus, thinking about shorted turns test and the Growler reference above, a Hall Effect sensor could be used to pick up the intense magnetic field a shorted turn creates: by holding the sensor a distance away from the coil assembly (or bobbin of a transformer, for instance) you could distinguish the "fault" field from the steady state field from the core magnetising current on no load.

We can go much further with Hall Effect devices: for instance an over-current situation can be detected, *without any connection or disturbance of the wire carrying the current*. Ideal for High voltage systems, or other EHT situations; or where electrical isolation is required for any reason. Unfortunately for radio amateurs, Hall Effect sensors can't respond to more than a kHz or two, so make no easy "sniffer" or power monitor for a transmitter - but I'm sure you'll find plenty to stimulate the imagination, see:

https://www.digikey.co.uk/en/product-highlight/m/melexis/mlx90392-3d-magnetometer?dclid=CIitvMjV2_MCFddDHQkdaSoK5w (other suppliers are available).

Components & Circuitry

Nylon washer toroids

Farhan, the BITX guru, winds toroids on plastic washers, grommets, tap washers - indeed anything BUT ferrite cores! Why? Because in some parts of the World, Amidon (other makes are available...) iron dust or ferrite ring cores toroids are as rare as Hen's teeth, that's why!

The results using a non-magnetic former (μ = 1) are just as useful as winding on a higher permeability core: the magnetic flux is more or less totally contained within the toroid winding and the distributed capacitance across the winding is reduced as compared to a solenoid. A useful reference to this method is: https://groups.io/g/BITX20/topic/4104526?p=,,,20,0,0,0::,,,0,0,0,4104526

Of course, it helps if you know what inductance you'll get for your turns, so here's a formula and auto calculator that will do just that for you (remember to use μ = 1 in these calculations)

http://hyperphysics.phy-astr.gsu.edu/hbase/magnetic/indtor.html

Just plug in your values, press [return] on your keyboard to input the value, shuffle the decimal point a few places and you'll find (for example) a 2cm toroid, wound with 20 turns, each turn of 5mm diameter will give you an inductance of ~ 0.314 μH. Just plug in the values from your winding and the job's a good 'un.

A big bag of plastic / nylon washers from my local hardware store cost me £1.49 for 100 nylon washers, 20mm outer diameter, 12mm hole, 2mm thick, ideal for a good few designs - what's not to like?

Of course, a magnetic core of some sort will require fewer turns for a given inductance - but for my VHF experiments, plastic washers and a bit of cut and try will do me nicely, thank you!

Constant Current sources

These little beasts turn up in almost every op-amp, NiCad battery chargers and the like: they are the opposite to a constant voltage source (also more commonly known as a power supply!). Constant current sources can be very useful in bench test and repair scenarios as well as in testing prototypes, and if implemented as one of their cousins, the "current limiting" circuit. A very useful function is in a linear scale ohm meter where constant current results in a far easier to read meter scale; it will aid fault finding those really tricky intermittent bad connections - commonly those push on ("Faston") connectors crimps, etc., of a spade fitting into a twin furled brass "socket".

Applications include automatic semiconductor test gear, very high gain amplifier stages (they are often found inside op-amps), instrumentation and laser diode modulation circuits (now I bet that's got your attention!), extremely high audio / RF gain stages utilising only one transistor. Yes, constant current circuits crop up in many circumstances; if you recognise the function, you'll see the principle at work in many varied and useful amateur radio scenarios.

There are a couple of unfamiliar terms used in the "constant current" World - the most important being the "**compliance**" of a constant current source - and the "**equivalent source resistance**". To understand these terms, the basic principle of a constant current source needs to be (briefly!) analysed, and the circuit below will illustrate these points. It comprises a (theoretical…) 1kV voltage in series with a high resistance, feeding a variable resistance load. For this illustration, let's consider a 1kV supply with series resistor 1 of Meg-ohm.

[kV supply via a 1meg resistor sketch here; and add the double circle symbol]

If the output terminals are shorted, (i.e. R_{load} = 0 ohms) the current in the load = 1mA.

If the load connected is now 1 k-ohm, the current through it will be = 0.9999999mA.

If the load connected is now 10k-ohm, the current through it will be = 0.999000mA.

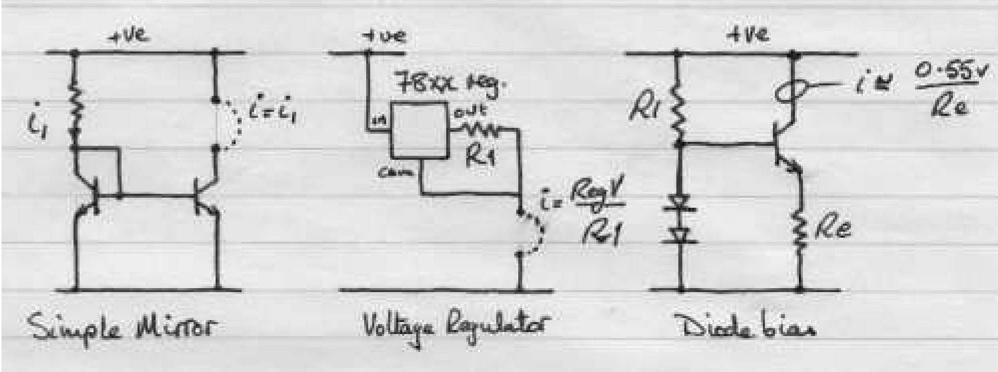
If the load connected is now 100k-ohm, the current through it will be = 0.990099mA.

And so on, and so on. The current is, for all intents and purposes, constant at just a tad under 1mA., ***no matter what load resistance*** is connected.

We can now define the two criteria mentioned above for a practical constant current source - the "compliance" is the maximum voltage available to drive the load, i.e. 1kV. The "equivalent source resistance" is 1M-ohm, and it's this value which defines the current regulation available.

For the best constant current source, you need an infinitely high voltage source, feeding an infinitely high series resistance: these components are not readily available from suppliers (for obvious reasons!). What we have to do to implement a "quality" constant current source is apply a dose of active components - usually bipolar transistors and diodes - to implement the function. If you're building very high precision current sources for test and calibration purposes, you might choose an esoteric op-amp, precision voltage reference IC's and precision resistors to get the range and accuracy you need.

The simplest circuits are the diode biased bipolar transistor brethren. They can be implemented very easily in both NPN and PNP versions, depending on how you want to connect the load: supply +ve connected (NPN) or supply ground connected (PNP).

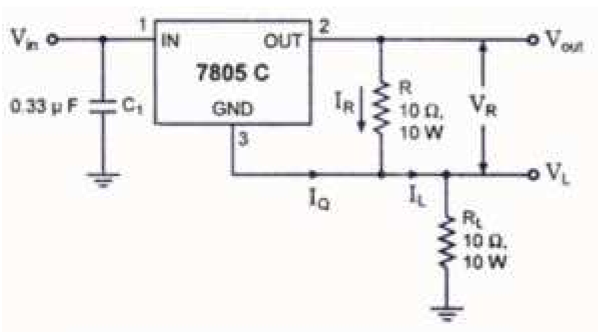


A similar (but subtly different) circuit is the “Simple Mirror” - in this, a transistor is directly controlled by another, which is “diode connected”, the subtle difference is that both transistors are fabricated right next to each other on a silicon chip so are both subject to identical temperatures and operating conditions, guaranteeing tracking and matching to a very high degree. You’ll see many of these in the inner workings of quality op-amps specifically for this tracking and matching capability.

This Diode Bias design relies on the biasing in one transistor (usually the diode connected device) driving the second (open collector) device: and this makes an ideal laser, Infra-Red or visible LED modulator feasible. Simply add a few millivolts of audio (or digital pulses) to the standing DC bias in the diode connected device and the mirror will slave the signal in the open collector device - this can be an LED or similar, NO limiting resistor required, but watch the dissipation in the LED driver! You can very usefully use plastic tab power devices in this role, you can bolt them together for good thermal tracking, and they’ll certainly do the business for you - but watch the bias stability in the diode connected device; the Vbe of this transistor will drop at 2mV per °C. Think of it as you would biasing an RF power bipolar amplifier, and you’ll not go far wrong.

A useful device too for power constant current sources is the Voltage Regulator design, the 7805 type and it’s many variations works remarkably well, and I use them for high current ohms tester designs, for PCB track evaluation, solder joint quality, crimp connector testing and any other ohms test jobs that needs amps, and plenty of ’em.

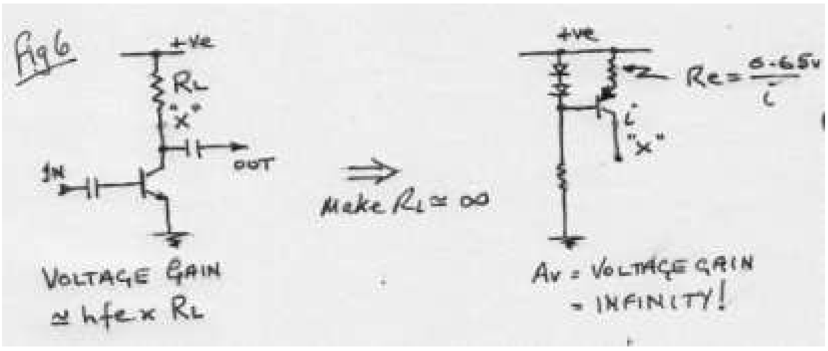
The circuit is very simple in it’s operation: the 7805 strives to create 5 volts difference between the “output” pin (labelled 2) and the “common” terminal (labelled 3). If we connect a load between the “common” and ground, a constant current, set by the resistor from “output” to “common”, flows to ground from the “common” terminal.



The 7805 as a 0.5 A Current Source

By fitting a “wrap around” booster PNP transistor, the 7805 applies precision regulation to the output voltage up to as many amps as you require; the PNP wrap around booster can handle the amps, and leave the 7805 to keep it’s cool and regulate the load voltage. Assuming the output current setting resistor is hefty enough to cope with the amps, you get a very low cost constant current source with superb regulation; modulation can be applied in the common terminal too, but I prefer the current mirror for that job, it’s a simpler method. The regulator won’t allow too much adjustment by jacking the common pin; push it too far and you’ll lose all hope of linearity and you’ll possibly kick the regulator into instability. But - here’s a thought - you could drive audio at a suitable level into the common pin to amplitude modulate the output voltage (and hence current). I’ve not tried this, so can’t comment on frequency response, linearity and the like, so if any readers have gone down this route to generate A.M., then I’d very much like to know!

Of course, nothing in this Universe comes *cheap ’n easy*! The compliance of the 7805 current source is reduced by the drop out voltage of the 7805 chip. It’s going to take at least 6 or 7 volts (depending on the 7805 regulator you choose) across the regulator to maintain stable running; you could try a low drop out 3.3 volt regulator, driving a 3.3 ohm resistor for a 1 amp super stable current source. Using a wrap around, you can easily extend this to 10 or more amps, but again, watch the linearity. Voltage regulators aren’t often used as audio amps, but maybe our old friend Harry Lythall SM0VPO can help, as he’s used them in various amplifier configurations.



One use - and this one really caught my attention when I first saw it - is the “infinite gain” amplifier shown above in Fig. 6, using one ordinary audio transistor as the amplifier device. The constant current circuit feeds current into the collector (at point “X” above) of the gain stage; gain ~Hfe x R_L. If R_L approaches infinity ohms, gain = infinity!

This circuit’s a good ‘un, used many times in power amplifiers and op-amps. I saw it in the ZN424 op-amp applications booklet from Ferranti Semiconductors (oh, how I wish I could get another copy of that booklet...), which illustrated a 150 watt gated audio amplifier using this gain stage; this also taught me that infinite gain = oscillation every time! Care has to be taken to stabilise the beast by rolling off the high frequency gain (a capacitor between collector and base of the NPN, 22pF - 470pF is typical) and hefty decoupling of the power supplies, or the infinite resistance ability of the current source will readily become obvious: infinite gain = full output with no input!

It works like this: the AC signal gain of a common emitter amplifier is (approximately) collector current divided by the base current, multiplied by the load resistor in the collector. If this load resistor is replaced by a constant current source, you’ll recall the equivalent series resistance of a constant current source is not just high, it’s nigh on infinite, so the AC signal gain is approaching infinite too. But… it is possible to stabilise the beast, note the collector to base capacitor in the gain stage rolling off the HF gain. You'll need to experiment here to get the beast under control before you allow it to modulate a signal, or you'll be looking at some mighty wide bandwidths in an optical comms system.

Sticky Pads and Manhattan construction

Hot melt glue slivers, cut with a craft knife from a stick, slipped beneath the "pad" to be fixed make the job of placement, removal and / or remodelling a doddle. A touch longer than usual on the pad with a hot iron and the pad lifts off clean as a whistle; any remnants are easily cleaned with a fine tipped screwdriver used as a scraper once everything has gone cold.

This trick also keeps more in line with Health and Safety issues: the nasty niff from some overheated super-glue formulations isn't at all pleasant, and may well be toxic (iso-cyano-acrylates if I recall right).

For the over enthusiastic amateur, pushing the "final" a bit too hard, the scheme also provides some protection if designed with disconnection in mind: the pad removes itself with the excess heat and can be arranged to open the critical part of the circuit.

Croc clips and test leads

An old dodge which vastly extends the working life of croc clip test leads is to run the wire through the longitudinal split clamp / entry section (which, incidentally, is often a perfect fit for 4mm test plugs, allowing the use of double plug ended 4mm test leads) for a lifetime (almost a lifetime; mine made up this way are still reliable in regular use after 50+ years) of reliable test clipping.

The job's a lot easier if you do the soldering first, then open up the clamp section to allow looping the wire two times before carefully closing with pliers. With modern "fat" silicone leads it takes a bit of juggling to get two turns on and clamped up, but the key seems to be the clamping of not just the insulation but the core too, locked by the double loop.

Antennas

Mobile bobtails, the VK3YE way

VK3YE has demonstrated a dinky mobile Bobtail curtain - and his modifications thereof, which he shows to be a real performer. I have heard of the Bobtail before; I've seen it used on low VHF too, but it's a bit big for anything below 20m though for those with enough space can be useful down to 30m if you really try. Peter gives his summation in a neat video, well worth watching (as is all of Peter's output!), see:

https://www.youtube.com/watch?v=1cnc14VW8Ro

WQ1GV gives this analysis of the Bobtail without any deep maths, with known solid RF practice and illustrates how the directivity can best be be utilised. See:
https://www.simplehamradioantennas.com/2019/09/bobtail-curtain-antenna.html

The Bobtail isn't a new antenna; it dates way back to the early 20th. Century if not earlier, and is a proven winner far outpacing a dipole for instance. You don't need any fancy or demanding earth mats or grounding; it's fairly easy to match and delivers. Just the job for portable, if you can get your hands on cheap fishing poles for support and can build a simple “L” tuner ATU to drive the centre “leg”. The outer leg insulators can usefully be polypropylene rope or cord, but make sure it’s clean and dry if you’re driving more than a few watts into the beast or the resonant Q factor voltage multiplication will sizzle the insulators!

An ATU for all seasons

There have been literally hundreds of ATU (antenna tuner units) over the years; I spotted this design (QST, November, 1941) as it is a “plug-n-play” design and readily adaptable to single band or whatever particularly suits your needs. The basic principle remains the same: if your antenna is short (the usual case for lower HF bands) for the wavelength, you add inductance. If it’s long (typically 15m band and higher) you add capacitance to ensure the reactive part of the antenna impedance is resonated out. All that then remains is the impedance matching of the transmitter output to the antenna; and that’s where a lot of designs fail. This design uses the link coupling to adapt the impedance match to the output device(s) be they valves of solid state: where “plate current” is discussed, substitute “collector” or “drain”, and observe the use of simple current indication (i.e. filament lamps) and RF volts (neon bulb with earthed plate nearby for capacitive coupling).

“L” networks will match impedances as well as reactive loads; but you’re better to get the impedances somewhere near matched so as not to compromise the “Q” of the L Network.

• *For the Junior Constructor —*

An Antenna Tuner for the Beginner

A Low-Power Coupler and How to Use It

Antennas fed by tuned lines have long been popular with old hands at the game as well as beginners. The use of transmission lines permits the antenna to be placed in the most favorable position available without regard to the location of the transmitter. While the line may be either tuned or untuned, the tuned line is more tolerant in adjustment and is, therefore, more easily handled by the beginner.

While it is possible to connect a tuned line directly to the tank coil, this practice is not recommended, because not only is it impossible to segregate the tuning of the transmitter output tank and that of the antenna system, but also direct coupling provides an excellent means of introducing undesired harmonic frequencies in the antenna system. For these reasons, it is advisable to provide a separate circuit for tuning the antenna system

This tank circuit may be coupled to the transmitter output tank circuit by placing the two coils in inductive relation to each other. Coupling may be adjusted by changing the distance between the two coils. Another method of coupling the two circuits, more popular in recent years, is one in which the two circuits are coupled with a low-impedance line or "link" between the two. This permits mounting the antenna tuner at a distance from the transmitter, if desirable, and allows the antenna coil to be fixed in position, the coupling being adjusted by altering the number

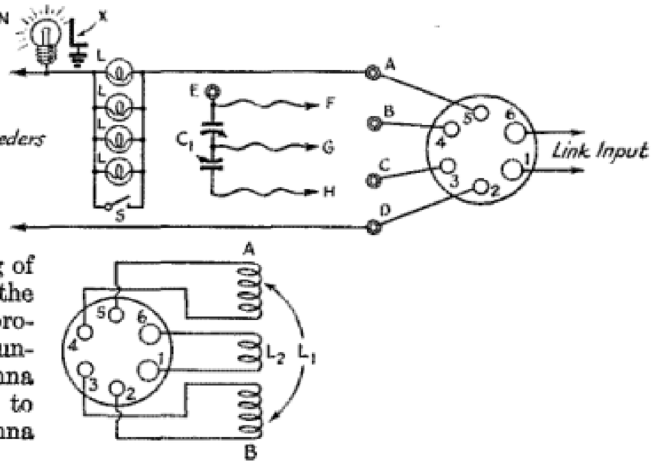


Fig. 1—Circuit diagram of the low-power antenna tuner.

Section A shows the connections to the coil socket. C_1 has a capacity of 140 μμfd. per section (Hammarlund MCD-140). L is a 250-ma. dial light, No. 46. N is a ¼-watt neon bulb. X is a grounded piece of metal to form a capacity for igniting the neon bulb. S is a switch or clip for short-circuiting the lamps after tuning.

B shows the connections to the 6 pins of the coil form. L_1, whose approximate dimensions are given below, is wound in two sections on the form, with the link winding, L_2, in between.

L_1 — 1.75 Mc. — 20 turns No. 22 enam., ¾-in. long each section, ½-in. space between sections, 40 turns total.

3.5 Mc. — 11 turns No. 20 enam., ¾-in. long each section, ½-in. between sections, 22 turns total.

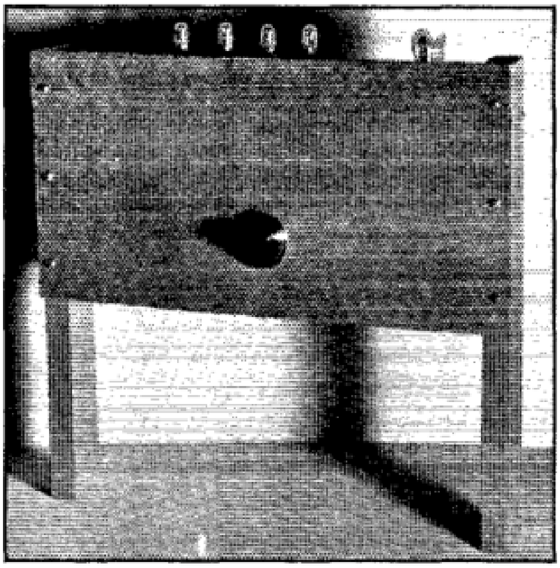
7 Mc. — 6 turns No. 20 enam., ¾-in. long each section, ½-in. space between sections, 12 turns total.

14 Mc. — 3 turns No. 20 enam., ½-in. long each section, ¼-in. space between sections, 6 turns total.

Number of turns for the link winding, L_2, will vary from 2 to 6 or 8 turns, depending upon coupling required for proper loading. Coils are wound on Hammarlund 6-prong, 1½-in. diameter forms.

of turns in the link coil at each end of the line. Providing the power-output level does not change greatly, the same antenna tuner may be used with several different transmitters without rebuilding it.

Such an antenna tuner is shown in the photographs and the circuit diagram is shown in Fig. 1. In the form shown, it may be mounted on the operating table within easy reach and view of the operator. It consists essentially of a plug-in coil and tuning condenser with a system of clips by



The low-power antenna tuner is built up in panel form to mount on the operating table within reach of the operator. The indicator lamps are visible from the front.

which several different combinations of inductance and capacity may be selected to suit requirements. Since meters to indicate r.f. current in the feeders are expensive, cheap dial lamps and a neon bulb serve as indicators of optimum antenna-circuit adjustment.

Construction

The two uprights and the strip supporting the indicating lamps are pieces of "one-by-two" stock. The uprights are each 13 inches long, while the cross-strip is 12 inches long, although these dimensions may be changed to suit the constructor. The shelf for the condenser and coil is made of a piece of crate wood 4½ inches wide. The panel may be made from a scrap of plywood 7 inches high and the whole thing may be given a couple coats of shellac or paint to suit the taste.

The dial lamps are soldered to a pair of parallel wires supported at each end on small stand-off insulators. The bottom of the neon bulb is soldered to a short piece of wire between a third pair of standoffs. The piece of grounded metal next to the neon bulb is about 1¾ inches square. This provides a capacity to ground to enable the neon bulb to operate without touching the hand to it.

The socket for the plug-in coil is mounted on the shelf with spacers and woodscrews. The shield between the two sections of the variable condenser is removed to allow mounting with a screw through the hole to the shelf. The shaft of the condenser is cut off and an insulating coupling inserted between the shaft and the control knob. The contacts for shifting connections consist of machine screws set in a small strip of bakelite.

Antenna and Feeder Dimensions

In order to avoid possible difficulties in tuning and coupling, both antenna and feeders should be cut within reasonably-close limits dependent upon the frequency at which the transmitter is operating. Charts are shown from which both proper antenna length and feeder length may be determined for any frequency. To determine the length of the antenna, place a point on the horizontal scale at the desired frequency. Now

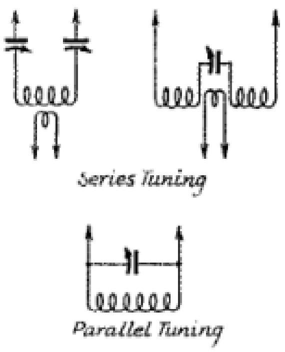
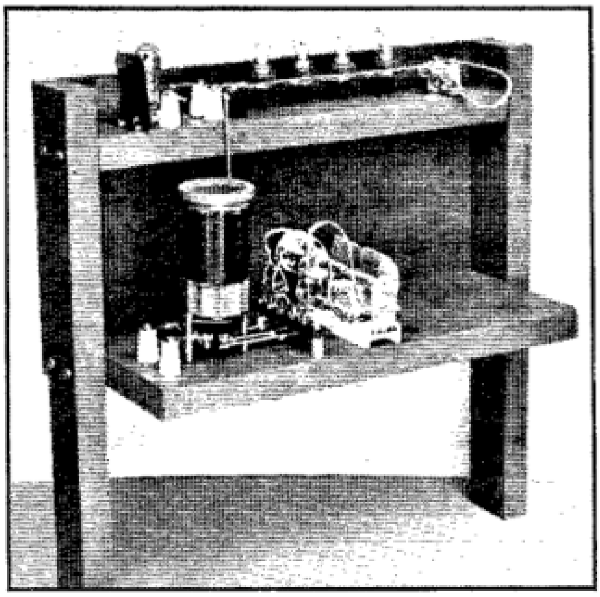


Fig. 2 — **Circuits for series and parallel tuning. Separate series condensers may be used in the feeders or a single condenser may be used at the center of the coil to maintain balance.**



Rear view of the low-power antenna tuner.

run the point vertically until it hits the solid diagonal line. Then run the point horizontally to the left to the vertical scale which will show the proper length of antenna. With a center-fed antenna, the length given is the sum of the lengths of the two halves of the antenna.

To determine the length of feeders to use with this antenna, start out as before, but run vertically to the dotted diagonal line and, thence horizontally, to the right to the vertical scale indicating feeder lengths. Choice of feeder lengths for the same frequency is given so that some selection is possible in choosing a length which will cover the distance between antenna and transmitter. The lengths used should not vary more than 25 per cent of the length given in the *first* feeder-length column of each chart. If a 125-foot antenna with 187.5-foot feeders are chosen, both should be within 25 per cent of 62.5 feet (3.5-Mc. Chart), the length given in the first column. Be sure to include any length of feeder which must be run inside the station to reach the coupler terminals.

End Feed or Center Feed

Tuned feeders are normally used either at the center of the antenna or at one end. Center feed is preferable whenever possible, since a balanced line is automatically maintained, regardless of antenna length. With the end-fed or Zepp system, a complete balance is never possible and the situation becomes worse as the length of the antenna varies from the exact proper length for the frequency in use. If the antenna is operated at a harmonic, different patterns of directivity will be obtained with end feed and center feed.[1]

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[1] Don Mix, "Antennas for Domestic Work," *QST*, Sept., 1941.

Charts showing correct antenna and feeder lengths for antennas fed by tuned lines for frequencies in the 1.75-, 3.5-, 7- and 14-Mc. bands.

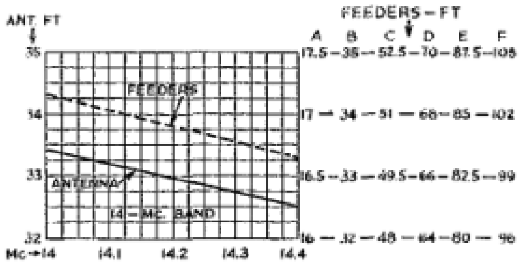


Chart for 14-Mc. band. With end feed, use series tuning for A, C and E; parallel for B, D and F. With center feed, use series tuning for B, D and F; parallel for A, C and E.

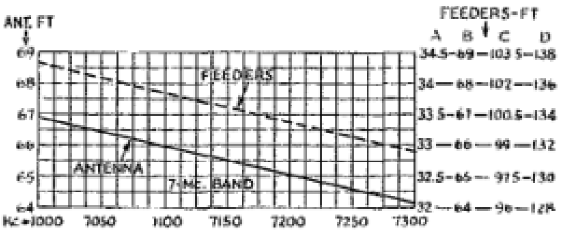


Chart for 7-Mc. band. With end feed, use series tuning for A and C; parallel for B and D. With center feed, use series tuning for B and D; parallel for A and B.

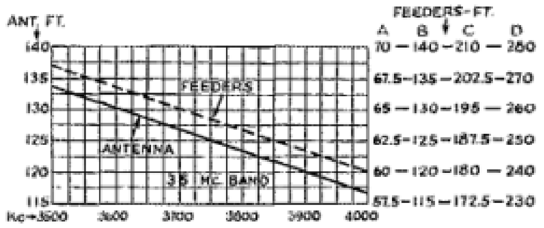


Chart for 3.5-Mc. band. With end feed, use series tuning for A and C; parallel for B and D. With center feed, use series tuning for B and D; parallel for A and C.

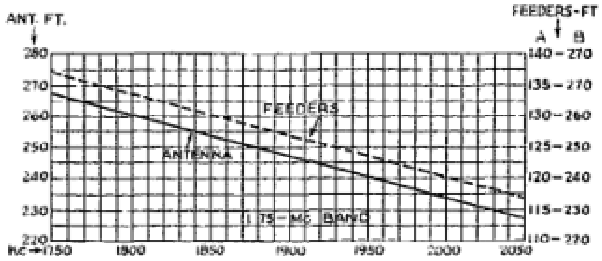


Chart for 1.75-Mc. band. With end feed, use series tuning for A; parallel for B. With center feed, use parallel tuning for A; series for B.

Series and Parallel Tuning

With feeders of certain lengths the antenna-tuner tank circuit must be connected in series with the feeders, while for other lengths it must be connected in parallel, as shown in Fig. 2, to resonate. Feeder balance will be maintained with series tuning by the use of separate condensers, one in each feeder, set to equal capacities or by a single condenser at the center of the coil. For any given length of feeder, the proper use of series or parallel tuning will depend upon whether the antenna is end fed or center fed. The correct system to use with feeders of any chosen length is indicated above the feeder-length columns to the right of each chart.

The antenna tuner shown in the pictures is arranged so that either series or parallel tuning may be used at will by shifting the position of the clips marked *F*, *G* and *H* in the diagram. *A*, *B*, *C* and *D* represent the four machine-screw contacts in the strip near the coil, while *E* represents a contact on the rear stator of the condenser. When *F* is connected to *A*, *H* to *D* and *B* to *C*, the two sections of C_1 in series are connected across L_1, forming a low-capacity parallel-tuned circuit. When *H* is connected to *E* and *G* to *D*, other connections remaining the same, a high-capacity parallel circuit is formed. For series tuning, *H* is connected to *E*, *F* to *B* and *G* to *C*. A low-capacity series-tuned circuit is formed by connecting *F* to *B* and *H* to *C*. The high-capacity circuits will be used at the lower frequencies, while the low-capacity connections will be found useful at the higher frequencies. Approximate coil dimensions for parallel tuning for each band are given under the diagram. Slight alterations in specific instances may be required. Where series tuning is required, the coil for the next-higher frequency band will usually be satisfactory.

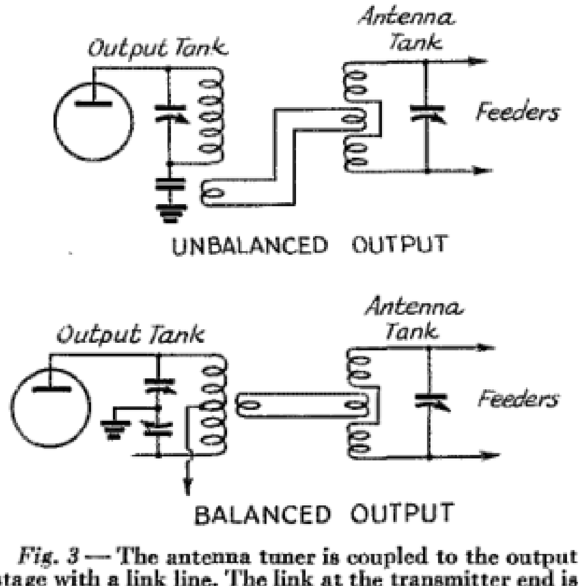


Fig. 3 — The antenna tuner is coupled to the output stage with a link line. The link at the transmitter end is coupled to one end of the coil if the output circuit is unbalanced or to the center if a balanced circuit is used.

Tuning

The antenna tuner and the output tank circuit should be coupled by a link line as illustrated in Fig. 3. This line may consist of a pair of closely-spaced parallel wires. When the tank circuit of the output stage is unbalanced, the link at that end

(*Continued on page 68*)

U. S. Antarctic Service

(Continued from page 17)

on the air in contact with KC4USA. Charlie has the greatest number of contacts (followed closely only by "Skunk" Scrivener, W3EXI).

Why the special test and observation skeds with W1FH? Well, I'll tell you — that's where Mama was. You see, in 1934 we were unable to work Boston on 20 meters from Little America. In 1940, 'twas no trouble at all.

Thanks a lot for the kind assistance rendered by you and your staff in handling our amateur business.

— *Clay W. Bailey*
Communications,
U. S. Antarctic Service

An Antenna Tuner

(Continued from page 20)

should be coupled to the end of the tank coil opposite to that to which the plate is connected. With balanced-output circuits, the link winding should be placed at the center of the tank coil. The link at the antenna tuner will always be placed at the center of the coil.

The tuning procedure with series tuning is as follows: With C_1 at minimum capacity, couple the antenna coil, L_1, loosely to the transmitter output tank circuit, by using a single link turn at each end of the line, and observe the plate current. Then increase C_1 until a setting is reached which gives maximum plate current, indicating that the antenna system is in resonance with the transmitting frequency. Readjust the plate tank condenser to minimum plate current. This is necessary because tuning the antenna circuit will have some effect upon the tuning of the plate tank. The new minimum plate current will be higher than with the antenna system detuned, but should still be well below the rated value for the tube or tubes. Increase the coupling between the two circuits by adding link turns, one at a time at each end, each time retuning both antenna tuner and output tank until the minimum plate current is equal to the rated plate current for the output tube or tubes. Always use the degree of coupling which will just bring the plate current of the output stage to rated value when the antenna circuit is tuned through resonance.

With parallel tuning, the procedure is similar. When the correct degree of coupling has been attained, the simplest procedure is to tune the output tank to resonance with the antenna circuit well detuned and then swing the antenna tuning up to resonance. This procedure will cause the least detuning of the output stage, although the tuning of the latter should always be checked as the final adjustment.

R. F. Indicators

Feeder current, as indicated by the lamps, is useful for tuning purposes only and will not give an indication of the actual power output. When series tuning is used, the lamps should glow more brightly as the antenna is tuned to resonance and the coupling is increased. Tuning should be started with all four lamps in the sockets. If no indication is obtained with the antenna tuned, the bulbs should be unscrewed, one at a time, until an indication is obtained. If a single lamp shows sufficient brightness to be in danger of burning out, another should be inserted in the circuit. Greatest output will be obtained with the lamp or lamps glowing most brightly. When the antenna tuning is complete, the lamps should be short-circuited with a clip to eliminate the power consumed by them.

With parallel tuning, the lamps will seldom be of great value, since they are then near a point on the feeders of maximum voltage and minimum current. In this case, the neon bulb will probably be a more useful indicator. With the antenna circuit tuned to resonance as indicated by the plate current, the grounded metal piece *X* should be bent toward the neon bulb until it ignites. The bulb will glow most brightly when the transmitter is delivering the greatest output. The distance between the neon bulb and the metal piece should be adjusted for best indication.

Harmonic Operation of Antennas

Any of the antenna dimensions given in the charts will be satisfactory if the antenna is operated at harmonics of the frequency for which it is cut. Parallel tuning will always be used for harmonic operation. A tank coil suitable for the harmonic frequency should, of course, be employed when operating at the harmonic.

—*D. H. M.*

What the League Is Doing

(Continued from page 21)

numerous W7 amateurs, considering that Section 2.91 gave them that authority. As it is reported to us, some of the amateurs operated at addresses other than the licensed ones, including the moving of their portable equipment to Army locations contrary to Order No. 73. The Seattle R. I. started citing amateurs and finally descended upon the scene with fire in his eye but, after going into a huddle which showed that all concerned had acted in good faith because of the language of 2.91, the citations were squashed.

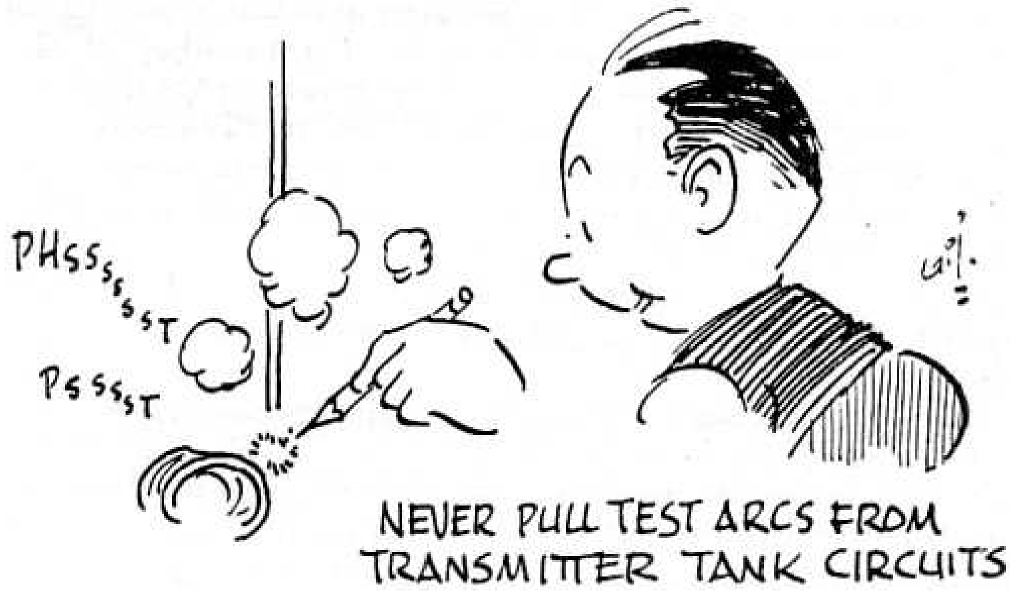
The matter has now become the subject of an understanding between the War Department and FCC. It is henceforth to be understood by all concerned that before Army field commanders can secure the participation of amateurs in Army communication systems, they must get the approval of the War Department at Washington and, at the latter's request, the issuance to the amateur by FCC of special temporary authority.

Strays

October *Harper's* has a grand article on "Our Radio Amateurs," by Carl Dreher and Zeh Bouck. Good publicity for us with the general public, you'll enjoy it yourself.

Elf-n-Safety Dept.

Pencil RF detectors...



Hot Iron # 115

End February / Start March 2022

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CQ-CQ-CQ

Frank Barnes W4NPN.net has recently shown some weird pages… but the index Frank compiled shows perfectly at:

https://www.w4npn.net/w4npns-hot-iron-directory/

...and Frank's Hot Iron back issue files are at:

https://www.w4npn.net/hot-iron-directory/

...where you can select the issues of Hot Iron for download, and the "standard" files and lists of various electrical / electronic data that I used in my working life.

I hope Frank is OK, and he's able to keep up his amazing archiving job with Hot Iron. Frank asked me some time ago if he could do this; it takes a massive load off me for which I am forever in his debt. Compiling, writing, drawing and issuing Hot Iron takes a lot of time, but I do it as when I was a "green" apprentice, my mentor Stan spent hours talking me through the intricacies of electrical and electronic Test Gear design and Maintenance; if I can pass on a few percent of his wisdom then I'll feel I've achieved something worthwhile.

STOP PRESS! 26th. February:
Frank has returned, and has resumed "normal service", thank goodness!

HF interference and LED lamps

A s if the radio amateur's life wasn't hard enough, some cheap LED light bulbs create one holy hell of electromagnetic mush. I never thought I'd wish for the return of tungsten filament lamps, but at least they didn't radiate S9+40 of random mush! The moral is don't buy cheapest; look for EEC or (IF you can find any) "made in the UK" for at least some limit of radiated electromagnetic noise.

The choke between Earth and Chassis

If you look inside electrical equipment, washing machines being where I first saw one, you see a chunky toroid that is connected between the earth of the supply cable and the chassis of the equipment. I could see no rhyme nor reason for this component: my working life philosophy of "bonding" the chassis of all equipment would effectively short this inductor out, so it was time to talk to Stan (my mentor) and see if this was indeed the case. "I reckon it's a noise stopper: either to stop earth line noise getting *IN* or motor control noise getting *OUT*" quoth he, and I've never discovered which - if not both.

If we are making our own radio gear, then it is beholden on us to make it SAFE. In all fairness, you, the builder, might be the only (current) user and be aware of any "issues" you've chosen to ignore but… memory fades, and others may be present when you aren't. All this comes to light with the increasing use of "IT" gear in amateur RF applications: many of these equipments are fed by mains input filter sockets containing delta connected capacitors and a line choke in the earth connection, as well as common mode Line and Neutral chokes. My advice is to **bond any exposed metal that can become live under fault conditions** - be this for DC, 50/60Hz. And… considering "wall wart" power supplies - how do you know, beyond any shadow of doubt, that they can cope with a high DC or RF back voltage impressed on the output, with AC mains on the input?

I was always taught to deal with interference, earthing, leakage and similar matters on an individual basis - fix the fault, don't just fudge the consequences!

You can find a historical reference here:

https://www2.ttheiet.org/forums/forum/messageview.cfm?catid=5&threadid=1794

Morse decoders and all that…

I've seen it said that using Morse decoders - or encoders - is "not in the spirit of amateur radio". I consider this twaddle; indeed, Samuel Morse himself tried very hard to de-skill the telegrapher's job as far as he could, and I very much doubt he'd refuse modern silicon IT equipment if he had had it in his day.

The telegraphers of his day, after a few weeks of hearing the receiving equipment's relays clattering, discovered they could interpret the noise as code, much to Samuel Morse's frustration - he wanted his system to be private and secure with the receiver operators merely handing the customer a printed message, without the operator knowing it's contents. The operators began decoding intuitively and writing the interpreted code down directly; this proved far quicker and more economical than the primitive printing technology so became the accepted *modus operandi*.

Think too of those who cannot use a hand key or hear sufficiently - for whatever reasons - are they to be disallowed on the airwaves with CW? As far as I'm concerned, if an amateur stays within the regulations governing amateur operation, I don't care if he uses a bent nail or a mainframe computer to send and receive signals, be they CW, AM, FM, or anything in between. Indeed it is very much "in the spirit of amateur radio" for technology to be tried, explored, and used to advance the hobby - thus we progress and amateur radio is enhanced.

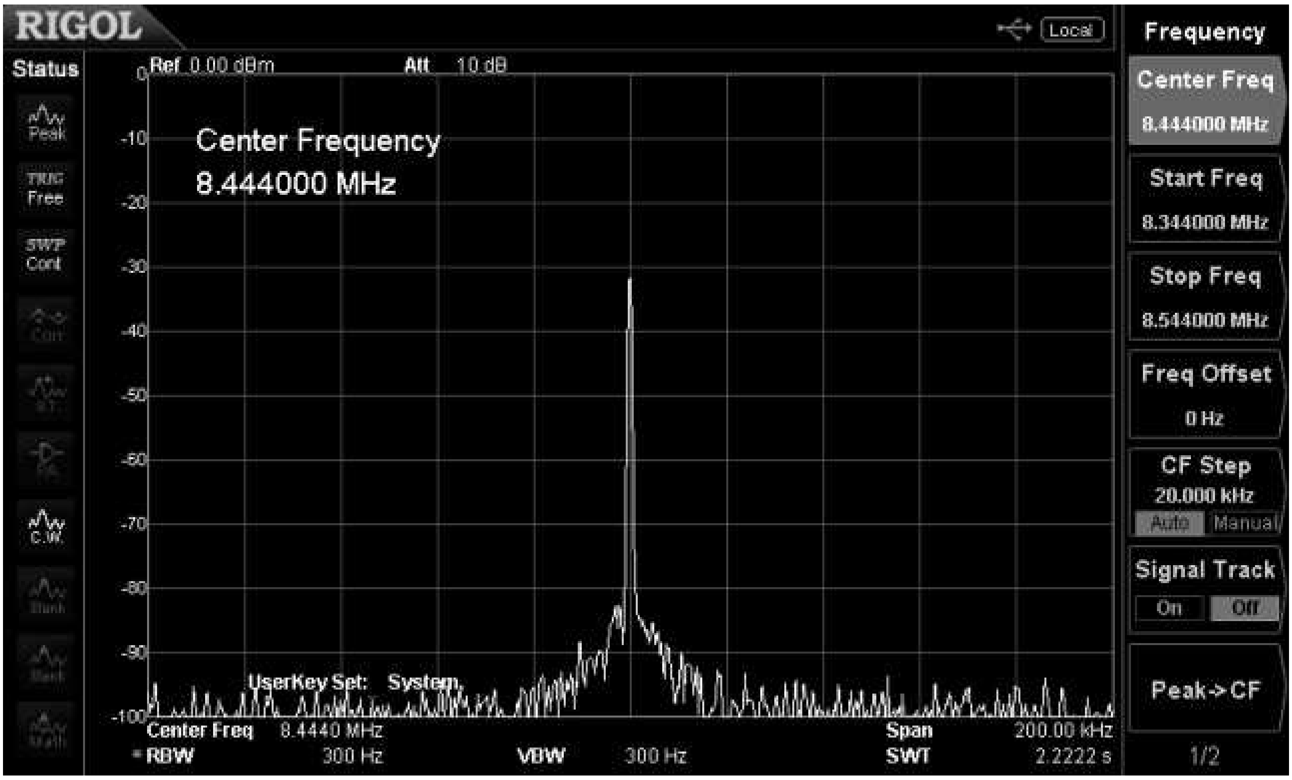
Transmitters

Si5351 Oscillators…

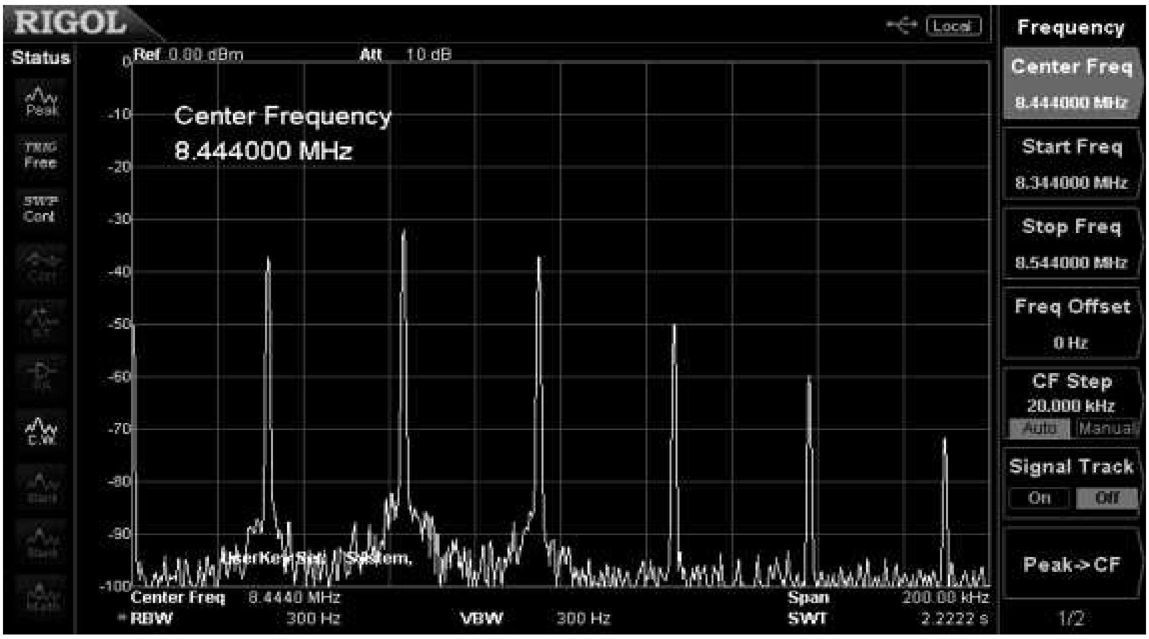
From Dave Benson, K1SWL, and very much appreciated in light of the current problems in acquiring the Si Labs Si5351 chips...

"I've been using the Silicon Labs Si5351 frequency generator IC in my homebrew project over the past 3-4 years. For those not familiar with it, it's a tiny 10-pin IC with two Phase-locked loops inside it. A single PLL can be used to output two separate signals divided down to any frequency from 8 kHz to 125 MHz. Unlike a 'wide-range VFO' IC of a few years ago, these outputs are clean enough to use in our transceivers. I'm using two separate outputs to furnish the receiver Local Oscillator and the transmitter output frequency for a superhet CW rig. Only one of the two outputs is active at a time. On transmit, the receiver LO is turned off, so there's no big signal appearing at the receiver output. There's a learning curve involved in using this device, since it's controlled over a serial interface. It's not an insurmountable barrier, though. I'm commanding the IC from the Arduino 'C' environment, and library code examples are available for it.

Anyway- the Si5351 IC recently became unobtainable after a fire at the foundry facility. I had taken to using an Adafruit Si5351 module measuring only 0.7 x 1.2 inches and was surprised that they could continue to supply the modules.
The bigger surprise- they'd begun using a 'reverse-engineered' (read: pirated) version of the IC with a flaw. The first figure shows what the output should look like on a spectrum analyser.



The second figure shows what I received. I embedded one of the Adafruit modules in an 80M rig. I was surprised to find the output off by 30-some kHz on a frequency counter. It's normally within a few hundred Hz even without calibration. I was further surprised to copy an HF aviation weather service from outside the amateur band. Additionally, any given amateur signal could be copied every 32 kHz. As if this weren't bad enough, I conducted a brief QSO and was doubtlessly transmitting outside the band.



My discussions with the Adafruit support engineers got me nowhere. I talked to three different engineers over several weeks. I don't think any of them knew what my spectrum analyzer plots meant. They did finally concede defeat and sent me several replacement modules. Those were also bad.

I'm grateful to an RF engineer who weighed in on my forum topic with an explanation for the behaviour. In reverse-engineering a new version of the IC, the 'Spread-Spectrum' feature was 'ON' by default rather than off. The 'fix' was anticlimactic- I added a snippet of code to my firmware."

```
------------------------------
Wire.beginTransmission(0x60); //turn off spread spectrum
   Wire.write(149);
   Wire.write(0x00);
   Wire.endTransmission();
------------------------------
```

Many, many thanks to Dave for this contribution: this is the heart of amateur radio – not just the technology, but the free sharing of information, either as the written word or "on the air".

Rugged MOSFET's

Technology, as ever, rolls relentlessly on: silicon devices in very "trying" or "must not break" applications are giving way to alternative technologies, and amateurs not wishing to be forever replacing "finals" in their transmitters would do well to read up on silicon carbide power devices. These promise to be a positive step forward in the "withstand anything" capabilities so beloved by thermionic devotees in transmitter finals, so well worth a look. Check:

https://www.wolfspeed.com/products/power/sic-mosfets?gclid=Cj0KCQiA09eQBhCxARIsAAYRiylbuFNfe2zxCQEPC3bAv0BfiGVwrbCTJOIpU-4cHWG-L6nJi06iBEEaAleqEALw_wcB

Receivers

Rush Boxes et al…

There are very few users of the super-regen on the amateur bands, the method is virtually unknown and even if it is known, it is shunned as it has such a bad reputation. Well, you should know that the super-regen is alive and well and used in literally millions of applications world wide, in commercial and industrial applications like security RF service, RF remote controls, low cost telemetry and a million and one other uses.

Here's why you shouldn't be frightened of using a super-regen:

1. It's just another version of a regenerative receiver, yes, the sort you wouldn't think twice about building;
2. It will NOT spew out huge amounts of interference if you use a simple RF amplifier;
3. It is simple, sensitive and reliable;
4. It can be made very selective if used with a crystal filter i.e. as part of a superhet style design;
5. They are good fun to use, easy to get going, very forgiving, (in semiconductor form) and are very capable;
6. Can be a major part of a simple VHF / QRP transceiver packed into in a very small portable unit;

7. Can open up the whole world of VHF for pennies.

Having said that, below is a cracking good design for a 6m receiver that can readily be adapted to 10m, 2m, 4m, etc. from Bob Liesen WB0POQ:-

"Nice to get your post. I have been playing with "rush" boxes for quite some time. Here is one I have been playing with of late. The audio reflex is an idea I borrowed from some simple BC designs. It seems to increase the AF output a bit and extends the freq response somewhat.

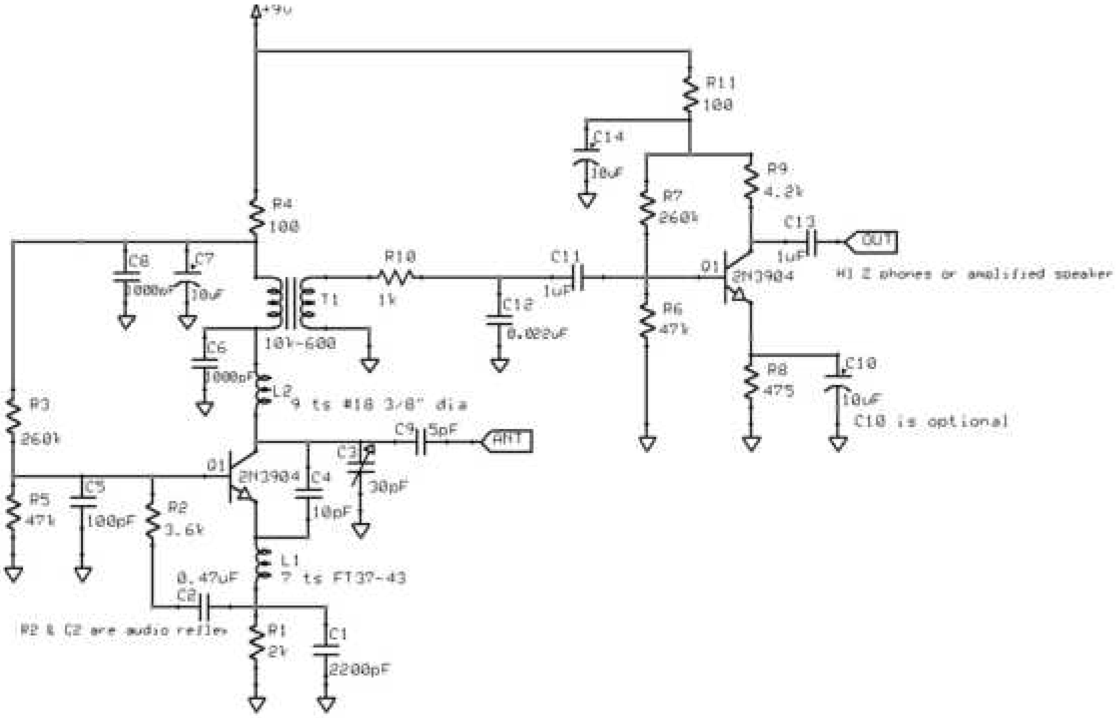
Most of my designs use BJTs, but I have done a few JFET designs as well. Someday I want to try a dual gate MOSFET, but my experience suggests that a high enough Ft, along with low noise are the presiding factors in these things.

One interesting note on JFET designs….I don't know if you have access to the QST magazine archive, but in the Aug 1968 issue, Doug DeMaw built one called the "Connecticut Bond Box". I'll be darned if I could get the detector to work. I suspect the schematic may be in error, and it should be a grounded gate design, but the author usually presents pristine designs plus in those days, QST contained very few errors in their schematics. (Anybody got a "Bond Box"schematic I could analyse for Hot Iron? Please email it to me! Ed.)

Here is an interesting thing that happened to me a while back when working on one. I was using my work Metcal soldering station. At one point in testing I was changing some component values, and the circuit stopped working. No audio output, not even the no signal hiss.
I juiced the generator up to 1mV output…..nada….dead.
At this kind of turn, I typically go back to the last working values, which I did……….nada…………dead as an 807 with an open filament.
I worked on this for an afternoon. I was about to reach for the ball-peen hammer, but turned the solder station off first. The circuit came alive! Turn the Metcal back on….dead…
Metcals use RF to heat the tip and having the iron near the circuit was somehow killing the regeneration.

Crazy.........
Bob

Bob's VHF Super-Regen

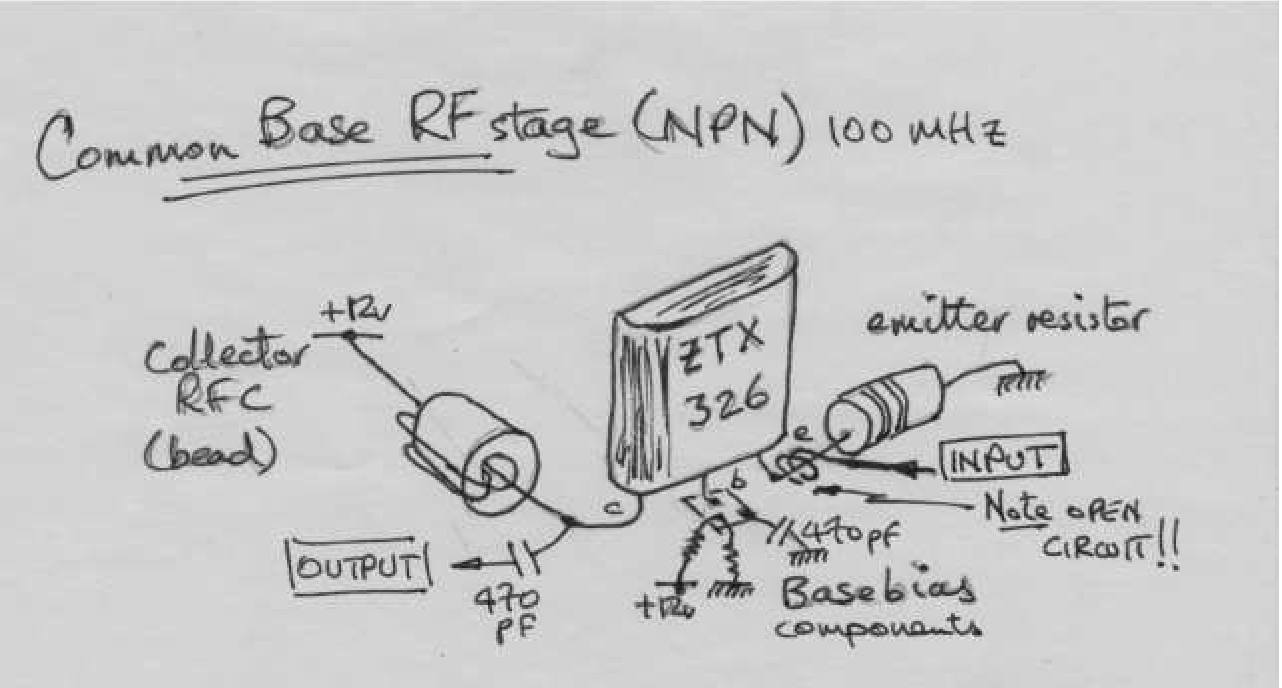


This is a design I've used myself; it's a real performer - the circuit warrants a few notes. First, note capacitor C5 in the base connection. This is used to shunt RF to ground; but it allows audio from R2 + C2 to pass into the base, giving a useful boost to the audio output. This is reflexing and was well known in the early days of solid state devices: every device had to work hard for it's living. I prefer a "gimmick" antenna input capacitor in place of C9, usually a wire close alongside or one turn round)one of C4's leads (doesn't matter which, try either and see which is best!).

C4 is the Colpitts feedback capacitor (it's a common base Colpitts oscillator) and with C3 form the tuning section with L2. The crafty amongst us (ahemm…) will use a screw type piston trimmer here, as you get lovely fine tuning and repeatability.

Other than that, the circuit is a standard: the dead give-away for a super-regen is the choke in the emitter (L1). This choke is in no way critical; grab a ferrite bead and bung some turns on, and the beast fires up a treat. It would be nice to experiment with different inductances / formers but the thing just goes with a sniff of inductance, I've run this common base design up to 1300 MHz with no bother using a BF180 or similar UHF device - recall that in common base the frequency capability of a transistor is vastly more than running in common emitter (virtually no Miller effect).

I like a grounded base un-tuned pre-amp (below) to feed the antenna signal into the super-regen, this prevents the super-regen from splattering noise across the band, but for local QRPpp ops it's a bit of overkill. Be careful when wrapping the input wire round the emitter lead; the open end can short to ground, so tuck it out the way. The ZTX 326 is in no way critical - it's just my favourite VHF transistor, try anything you have to hand.



Now note the transformer in the super-regen's collector. It serves several purposes: it's an output impedance "shifter" to match the collector circuit; it's also an RF choke, which is necessary to maintain oscillation at VHF frequencies. You might note though that audio is also present at the lower end of the emitter choke, as is the quench frequency - if passed out to an audio amplifier via a two stage low pass filter (simple R/C is fine, set for top cut at 5kHz or so - just make sure you use a high value of series resistor, 22k or more, which mandates a high input impedance audio stage like a jfet) the results are nearly as good as the collector transformer design Bob uses. If you go for the emitter audio output, remember to put an RFC in the collector to replace the choke effect of the audio transformer. You don't need much inductance: just bung a good few turns on a ferrite bead, on any old bit of ferrite or core, or even round an iron nail. It will most likely work fine!

Diode Mixers and the Cube Law

Viktor Polyakov's design for harmonic mixers and the cubic law – is this design (or any other…) better with matched Ge diodes for a closer approximation of the cubic response?

It would make an interesting experiment to compare, say, a Polyakov mixer made with (1) 1N4148 diodes; (2) HP5300 Schottky diodes; (3) OA81 Ge diodes (cheaper and more easily obtained than 1N34's) that have been roughly matched by the "ohm-meter" method. Test for linearity with varying input signals.

Maybe someone has already done this? I have searched but to no avail; however, if Viktor Polyakov thinks it best to approximate a cube law response, I'm certainly not going to argue!

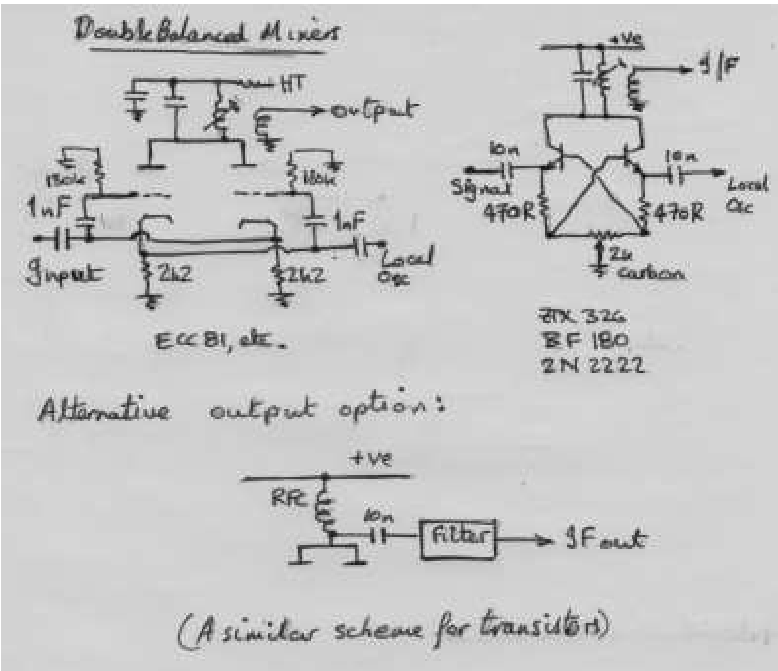
On the subject of mixers…

Transformer-less Double Balanced Mixers

Packaged or home made, diode ring Double Balanced Mixers (DBM's) whilst usually a good choice have several issues: they need "Hemi-V8" local oscillator power to slam the diodes in and out of conduction; they have transformer which, unless wound very carefully (as in production manufactured windings, for instance), will include an imbalance that can't be adjusted out; they need 50 ohms on every port, from DC to daylight; they feature significant losses that require gain stages (and the consequent noise and overloading distortions) to make up.

DBM's were derived from valve / tube circuits, which proved good candidates for commercial radio gear: if memory serves me, Eddystone Radio used them in Marine service "Trawler band" MF transmitter and receivers. The circuits featured a balance adjustment which meant a ship's "sparks" could tweak the balance control a touch to give basic receivers a bit of carrier, or an unmodulated carrier for CW.

For amateur applications, the circuits below bear a distinct similarity to the innards of such mixers as the SA602 / 612, or the MC1496. These devices are much more developed than these earlier circuits, but for simple home made radio jobs the forerunners are usually adequate and feature some big advantages. (1) They need *no transformers*; (2) they are somewhat tolerant of mismatched ports; (3) they have decent gain with low noise (it tends to cancel due to the balance - if you're lucky). They would make a simple direct conversion receiver possible with very low component counts for mobile gear, too. I must admit that discrete semiconductors are my choice over IC's as you can repair the circuit with a (near) substitute in the event of disaster - try that with a blown IC, without one to hand! Anybody got any "unusual" balanced mixer schematics, please let me know.



Specs of modern receivers

Modern mass-produced solid state receivers are (probably) tested in a production facility, lab gear providing the signals, measurements and power. What are considered excellent figures are given in specifications, and, yes, no doubt under those “lab” conditions, are probably met. Now let’s switch to the typical amateur station...

The antenna(s) feeding the receiver can easily deliver 10mV of RF; a quoted rejection ratio of 60 dB (considered a respectable figure) for IF breakthrough is not adequate (dB = 20 $\log_{10}$ [Av] where Av = the gain or attenuation) then 60dB represents 10µV of signal! Such strong signal interference in the amateur station isn’t at all uncommon: really powerful broadcast stations, D/F systems and the like *even though non local* can be present such powerful signals.

The more astute will have noticed I quoted “solid state” above; and for good reason. Whilst valve / tube technology is more demanding in terms of size, power and the like, vacuum devices just do it better. The CW DX man, hunting that tiny fraction of a µV signal, really needs to be looking at 120 dB of rejection; if possible, 130 - 140dB is required. Modern gear quote 50, 60 or exceptionally, 80dB of rejection of spurious signals is not really that good: there might be other local amateurs in close proximity pushing hundreds of mV’s into his receiver input. 140 dB or more is his only hope if he’s to work faint CW DX.

This isn’t a modern scenario: in 73 Magazine, December 1967, E. Conklin, K6KA brought this to light. He quoted 10,000 amateurs in California all within ground wave distance from each other! This brings to mind a special receiver designed for the Royal Navy by GEC (UK). It had proven rejection of 130dB+; synthesizer tuning of a 1600kHz IF design, with two low gain RF stages using 12AU7 double triode cascode connected followed by a 12AT7 twin triode balanced push-pull mixer (similar to that presented in this issue) very carefully constructed and shielded. Superb though solid state might be, it struggles to match this level of performance, even nowadays.

It is to be pointed out though, figures like this rely on engineering to a level not normally available to the amateur; nor at an amateur price. The points to be made - often neglected in amateur construction - placing a really effective (auto controlled AGC with adjustable time characteristics) attenuator at the input: silicon diodes are superb in this role; as is purity of the local oscillator; shielding; balanced circuitry wherever possible; vacuum tube (or possibly FET's) in the signal path; low ripple power supplies; adequately decoupled circuits at every stage; build for good dynamic range (again, vacuum devices can score here).

All this points to hybrid designs being a definite step forward for amateurs wanting the best performance at practical costs and complexity.

Regenerative receivers: some questions

I have had some emails about regenerative receivers and how they relate to the more unknown corners of design I've mentioned previously in Hot Iron. Home constructors still find excitement in hearing a signal on their home made receiver and want more about how to improve their circuits.

It won't do any harm to discuss the different regenerative receiver "morphologies": there are roughly three to consider, each with it's own pros and cons.

(1) Manually controlled regenerative receiver

This design features a control to adjust the amount of feedback; advanced too far, the circuit will oscillate. It is the general idea that the circuit will be "stimulated" by the incoming carrier and lock onto the carrier, thus we have the "autodyne", "synchrodyne" and "homodyne" circuits which demodulate A.M. signals and reject others present at the input by the Q factor of the oscillator circuit and the low pass nature of the audio amplifier following the detector / oscillator stage.

These designs need a feedback, tuning and volume controls as a minimum.

(2) Automatic feedback regenerative receivers

These are the circuits above, with a diode rectifier circuit sensing the condition of the oscillator section - if the oscillator is in fact oscillating, the diodes rectify the oscillations, producing a DC voltage which is used to limit or "back off" the bias to the oscillator, thus automatically holding the circuit just on the point of oscillation, or (depending on bias) only just oscillating. This is done by tweaking the bias point of the oscillator to ensure slight oscillation or hold the circuit right on the point of oscillation.

There have been a couple of these "auto regen" circuits in Hot iron; Viktor Polyakov and other Russian designers have come up with ingenious means of applying auto feedback control. These designs don't need a "regen" control; just tuning and volume; they might have a switch to allow CW to be demodulated by biasing the circuit just into oscillation; or A.M. by holding the circuit just before the point of oscillation.

(3) Super-regenerative receivers

Imagine, if you will, a regenerative receiver as described in (1) above, but with an "electronic" motor turning the feedback control up and down so the circuit bursts into oscillation thousands of times a second. This means the receiver goes through the maximum gain point of the circuit repeatedly - at a rate well above human hearing. You would hear the incoming signals amplified and demodulated to the absolute maximum capability of the circuit.

Super-regens need a tuning control, and (because of the immense gain available) a squelch gate if you don't want ear shattering white noise when the signal shuts off.

You can see the virtue of each design: manual control is the simplest, auto control is a fascinating area, not fully explored on HF as far as I know; super-regens have their devotees (me included!) and are an amazing way to get onto VHF, UHF, microwave bands very easily and simply.

A magnificent article about regenerative receivers, homodyne, synchrodyne, autodyne *et al* can be seen at:
https://www.thevalvepage.com/radtech/synchro/section1/section1.htm

Auto control regens have featured in Hot Iron previously; for those who like experimenting, the following is a cracking good circuit:

https://www.cool386.com/arc/arc.html

And Viktor Polyakov's adapted by S. Kovalenko

"*This is the tuned radio frequency receiver for short wave (25 meter band, 11.7...12.1 MHz). It was created as experimental design for further experiments with the autodyne synchronous receiver (see Polyakov V. T. Autodyne synchronous regenerative receiver. - Radio, 1994, N 3, page. 10.). The circuit diagram is shown in Figure 1.*

The first RF stage is a regenerative Q multiplier circuit with fast automatic regeneration control.

The input resonant tank composed of the loop antenna WA1 and capacitors C6 (the trimmer capacitor), C7 (the variable capacitor), C8 and C9. The resonant tank circuit has very high quality factor Q within the working band (11.7...12.1 MHz), so the effective height of the loop antenna can be up to several tens of meters. An antenna with this parameters can receive very weak signals. The sensitivity of this shortwave receiver is limited by the noise of the transistor VT1, so it would be better to use in the first stage a low-noise RF transistor.

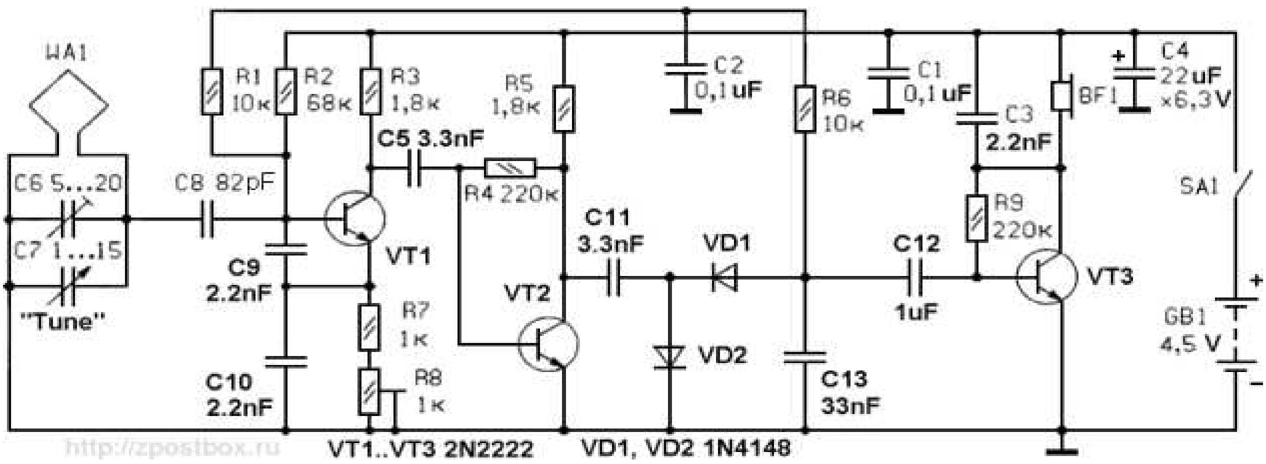


Figure 1. The circuit schematic of the regenerative shortwave receiver with automatic regeneration control.
C6 - 5..20pF, trimmer capacitor; C7 - 1..15pF, variable capacitor; C8 - 82pF;
Transistors VT1-VT3 - 2N2222; h_{FE} *min = 50, transition frequency ft = 250 MHz.*

The automatic regeneration control circuit includes the second stage of HF amplifier (the transistor VT2) and the diode based detector (C11, VD1, VD2 ,C13). The resistors R1, R2 and R6 provide a bias current for diodes VD1, VD2 and for the transistor VT1. From the output of the detector the DC signal corrects the regeneration of the regenerative stage, the AC component of signal goes through the capacitor C12 to the one-stage audio amplifier based on the transistor VT3. The headphones BF1 is the load of this audio amplifier. The resistance of the headphones is about 1600...3200 ohms. The output power of the audio amplifier is about 1 milliwatt.

The resistor R4 provides a feedback biasing for the transistor VT2, and the resistor R9 does the same for the transistor VT3. Match the resistor R4 to get the voltage across the collector of the transistor VT2 equals to half of the supply voltage.

The coil of the loop antenna WA1 is frameless with a diameter of 200 mm, it consists of 2 turns of copper wire 1.5 mm (AWG 15), the step of the winding is 10 mm. To make the loop antenna rigid, we can fix the turns with each other with pieces of dielectric material. The antenna can be made out of a ferrite rod, but it would work much worse.

The variable capacitor C7 can be used with larger capacitance, for example, 4...200 pF, but it requires a small ceramic capacitor 15..25 pF connected in series with C7. A varicap can be used for tuning, but it will reduce the quality factor Q of the resonant tank circuit, and the varicap will require an additional voltage source of 15..25 V.

Setup the regenerative stage on the edge of oscillation by matching value of the capacitor C10 and by adjusting the trimming potentiometer R8. This potentiometer should be high quality, else its noise will interfere with the receiver. If you haven't a high quality potentiometer, you can replace it with a resistor (match its value). Use the trimmer capacitor C6 to adjust the frequency band of the receiver.

The consumption current of this regenerative receiver is about 3 mA, so with a battery 3R12 the receiver will work for 1000 hours.

There are two shortages in this regenerative receiver - the tuning of the regenerative stage is depends on the supply voltage, and if there is a massive object in vicinity of the loop antenna, its quality factor goes down.

The reception quality of this radio receiver is better than a superheterodyne radio receiver because of the narrow band, the directional properties of the loop antenna, and total absence of an image frequency interference. But this advantages are useless when there is a powerful radio signal in the working frequency range.

S. Kovalenko"

An modified version of this receiver is:

http://www.antentop.org/016html/016_p85.htm

You'll find another idea for auto control on page 79 of:

https://worldradiohistory.com/Archive-Poptronics/50s/59/Pop-1959-04.pdf

I don't know how effective these are, I've never tried them!

Power Supplies

An alternative approach to smoothing

I once had to build some gear into an existing 19 inch rack in a Faraday shielded dark room, used for photodiode testing. I had the transformer, a magnificent toroidal design from our own CRT scan coil section - toroids being a very uncommon transformer in the 1960's - and a chunky bridge rectifier, built from discrete stud diodes; but the issue was the smoothing.

The transformer delivered only just enough volts to run the silicon diode bridge at the current required, and because of existing rack space whatever I used for smoothing had to be as small as I could make it. I experimented with many µF's of electrolytics, but unfortunately the output regulation was inadequate and the inrush current way too high; on no load the voltage floated too high. A three terminal regulator was no solution: I didn't have one, they were not to easily obtained in the 1960's, and what's more, I didn't have the voltage headroom for such luxuries!

A quick chat with mentor Stan paid dividends: he pointed me towards the "black hole", our dusty, dark, cellar store - for a 250mH toroidal inductor, from a stock that had been ordered for electroplating duty, nominally 10 amps, just what I needed. "But, surely, 250mH isn't anywhere near big enough inductance" I asked in my innocence?."It'll be fine, put a 10 µF electrolytic in parallel with it, positive terminal towards the bridge positive output" quoth Stan… I was staggered: I'd never seen a smoothing choke with an electrolytic in parallel in a power supply.

"Simple", says Stan: "that L and C are resonant at about 100Hz; with a good quality electrolytic for decent Q it'll smooth more than enough. Check it out on the bench first, as electrolytics can have wide value tolerances, look for the electrolytic that gives lowest ripple into a dummy load then fit it into the rack module - it'll just go in with luck". "But surely" says I, "the electrolytic won't tolerate reverse bias in a resonant circuit?" "The electrolytic will never see any reverse bias, look at the circuit. It works by exchanging energy with the inductor as a tank circuit filter. It rejects the 100 Hz ripple, but DC passes with ne'er a blemish".

As ever, Stan was on the money: good smoothing, decent regulation, in a much smaller volume than I'd ever expected. Job Done!

P.S. Yes, the resonant smoothing did work… for a couple of months. The electrolytics in those halcyon days were not as nowadays; they "dried up" quickly in "ampy" jobs; that's why when refurbishing any vintage gear, the first job is to replace the electrolytics - keeping the cans and connectors so you can put modern capacitors inside to preserve the aesthetics of the job.

Rectifier Diodes in parallel

Current sharing is the problem: one diode of the paralleled devices will hog the current. This makes this component heat up - and the forward volt drop of a silicon junction falls at 2 mV per ^{o}C so the "hogging" device attracts even more current, leaving the parallel devices doing little if anything.

The answer? Add a low resistance in series with each diode (incidentally, this is how RF power transistors work: they are multiple paralleled devices, with resistors in each emitter to force current sharing), typically 0.1 ohm to 1 ohm. The diodes will share the current equally.

The maths behind this is to estimate of the slope resistance (almost never quoted, so you'll need a curve tracer) and add an equal amount of external resistance. This (after a lot of abstruse maths - if you don't believe me, try it) results in the minimal loss for effective current sharing.

Components

Electrolytic capacitor "reforming"

Though I can't honestly recommend "boiling up" old electrolytics like this, it's a technique I saw years ago that crops up every now and then; the vintage radio and TV restorers love this sort of thing, so here's the gist of the job.

The most important component in these reforming devices is a strong, stout wooden box. You need this to contain the electrolytic being "reformed" - they have a nasty habit of going BOOM! when you least expect it, and the box keeps the shrapnel down. Seriously, exploding electrolytics are bl**dy dangerous!

We ran devices like this with the electrolytic on the end of a long, long run of two core cable, the cover box being in the factory yard well away from anybody. 4700μF charged up to 500 (or more) volts is a potential bomb if all the stored energy is released in one sudden burst. Don't take chances!

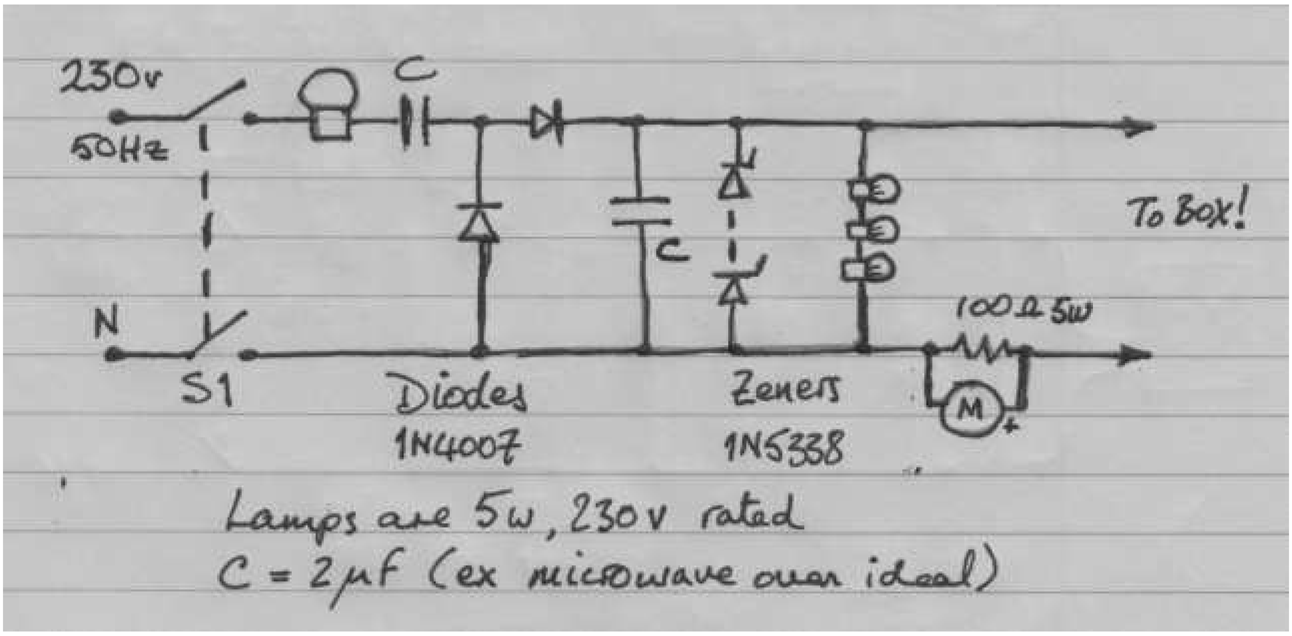
Right, if you choose to build and run a device like this, be it on your own head: they are very simple but rely on mains power to generate high voltages, so must be fed as per your local electrical regulations i.e. via double pole isolation switches with appropriate contact gaps (or use an isolating transformer…? Ed.); and fit bleed resistors that are self indicating. An open circuit wire wound resistor doesn't tell you if it's gone open circuit - so I advocate using 5 watt filament lamps, as used in cooker hoods, rated 5 watts 230 volts working. They represent roughly 10.5kΩ each, and the filament glow tells you they are functional.

The circuit uses a Greinacher voltage doubler - an ideal job for salvaged microwave oven 2uF / 2kV capacitors? - fed via a current limiting lamp to double up to roughly 600 volts, a string of 5 watt HV zeners (1N5338 type, 100 volts and 50 volts typically) clamp the output to the appropriate rating of the electrolytic being "reformed". You could jumper unwanted zeners rather than removing them, to make life easier? In parallel with the zener string are three 5 watt 230 volt lamps in series: these bleed the "reformed" electrolytic and indicate via filament glow that they are functional.

The 100Ω resistor in the return lead to neutral is for current sensing: 1 volt across 100Ω representing 10mA. In practice, the meter indicating the current is set to 10 volts DC full scale, connected up with insulated leads and clips and is NOT TOUCHED during the "reforming" process. The electrolytic to be "reformed" is connected up with robust secure connections, noting polarity (!!!), and the power very briefly applied - if no disaster, then apply the power for a couple of seconds, noting the current reading. It will be a good few mA's to start with; but as the plates "reform" the current will gradually reduce - ideally to a low value of mA's.

If you see a steady (and usually rapid…!) rise in the current - shut off the power! That electrolytic is destined for pastures new… i.e. in the BIN, not your current refurbish project!

"Don't expect miracles" is good advice. "Reformed" electrolytics are usually OK for a while; but they have a habit of failing after a period of running, probably the internal losses evaporate what's left of the electrolyte - the result is typically a loss of μF's with a corresponding rise in mains buzz or audio fading, if not a complete breakdown and the corresponding smoke followed by major clean-up. But - if it restores a beloved vintage bit of kit, with all original parts, then all's well with the World. Good Luck!



Note: two silicon diodes in series, connected in parallel with the current sense resistor, cathode of the series pair to the +ve. end of the meter, is a good idea to stop the meter movement getting zapped. A digital multimeter may be more robust, but a dead short electrolytic will zap a digital multimeter meter just as effectively as a mechanical movement meter - Ed.

Switch cleaner & Lubricant

A neat dodge that can really help clear those noisy pots, notchy rotary switches, bad contacts and the like… buy a small bottle of "white spirit" (turpentine substitute or white kerosene) and drop into the bottle a scant half teaspoon of petroleum jelly ("Vaseline") and replace the cap.

Now, shake, baby, shake! Mix the petroleum jelly in completely, then apply **very sparingly** with a cotton bud or cocktail stick to the offending gizmo. Work the mechanism a good few times back and forth and the job's a good 'un! Keep the fluid firmly capped until needed on the back of your bench.

Fault Finding when a meter won't help

I was called out at some god-forsaken hour of the night to see a fault the night shift had: the 3 phase transformer's soft-start resistors, made up of 1kW firebars, glowed a healthy red hot on power up of a high voltage power supply, rated at 15 kV, 3 Amp DC on a ETE back face aluminium evaporator running a 270^{o} magnetic wrap-around electron gun source. My first test was to disconnect the primary of the 50kVA HV transformer: now the firebars stayed cool, so nothing odd on the 415 volt 3 phase side of things. Reconnect the primary, disconnect the secondaries and try again - yes, the fault was there again, even on no secondary load.

Obviously the fault is in the transformer, so disconnect the ends of the delta connected primaries and ohms test each winding, making sure the primaries were all genuinely isolated, to avoid parallel paths disrupting the measurements.

OK; all three primary winding showed equal DC resistances, so out with the 500 volt Megger and test for primary shorts to earth. Nothing! All primaries - and the terminal boards, wiring and anything else that could somehow affect the primaries - all tested clear.

Now I had real problems. No doubt there was a fault inside this transformer: no spare (50kVA transformers are big, expensive, and heavy!) for an swap out, but nothing, absolutely nothing could be found in error with the instruments - or equipment - we had.

By now, dawn had broken, the day shift coming in, and found yours truly in front of a cup of tea, desperately trying to figure out a way I could positively, without any doubt, condemn this transformer and ask the plant manager to buy another transformer without my proving beyond a shadow of doubt that the transformer was faulty. I knew the answer and it's unprintable here!

Enter Rob P., an epitaxy process engineer and the conversation rounded to my problem. "Oh, you need that article I saw in TV Servicing last month, about finding shorted turns in windings", quoth Rob P. Intrigued I asked Rob P. to draw it out on paper, and thus enlightened asked Mike P. the Technician, to drag out a 1 kV DC HV supply from the Ion Implanter spares.

I made a changeover switch from some copper bus bars, brass bolts and a bit of Tufnol for a base and handle, and dragged the completed assemblage round to the transformer. The circuit was simple: an 8uF oil & paper capacitor to the switch moving blade; one fixed pole to the charging HV supply with a series current limit resistor, the other pole to a winding on the suspect transformer, all the negative returns commoned to the negative of the power supply.

Thus the switch, in one position, charged the capacitor up; in the other position, the capacitor charge was dumped into the primary of the suspect transformer. I tried it on a known good single phase transformer Mike P. had "procured" (doesn't pay to ask Technicians too many questions…!), and yes, the primary on the good transformer (secondary open circuit) rang like a bell on the 'scope.

Now try the evaporator transformer primary: not even a full cycle! The other primaries looked similar under test, but since they are all magnetically connected, one dud primary would affect the others. It was a "gotcha" moment; Rob P. went off to his Gemini Epitaxy reactors with a big smile, Mike P. gave me a knowing wink, and I prepared my £15k purchase request for the big man to choke on when he came in at 'executive' start time, 9.00 a.m. (ish).

The replacement 3 phase transformer was delivered next day, the evaporator up and running a treat and still is as far as I know; when the day shift operator came back on shift after his 4 days off, I asked him to describe any odd things he'd seen before the original transformer blew. "Err, yes, a full charge of aluminium blew out the crucible when de-gassing; went with a right thump, I can tell you - took ages to clean the chamber and crucible".

Well, that sorted it all out: and I knew for sure what blew the transformer. The sudden burst of aluminium vapour in the vacuum chamber was a dead short across the transformer secondary, the corresponding primary surge current melted the winding wire enamel and voila, shorted turn(s). They are usually in the dead centre of a winding - that's where it's hottest and the enamel melts.

Now you know how to find a transformer shorted turn, a fault no multimeter can ever diagnose. Happy Hunting!

Audio Topics

Forrest Cook's Code Practice Oscillator – sounds NICE!

Once again, Forrest brings the golden tones of valve audio to the shack: how come valves do the job with that added touch of gentility and etiquette so sadly lacking in some transistor audio projects?

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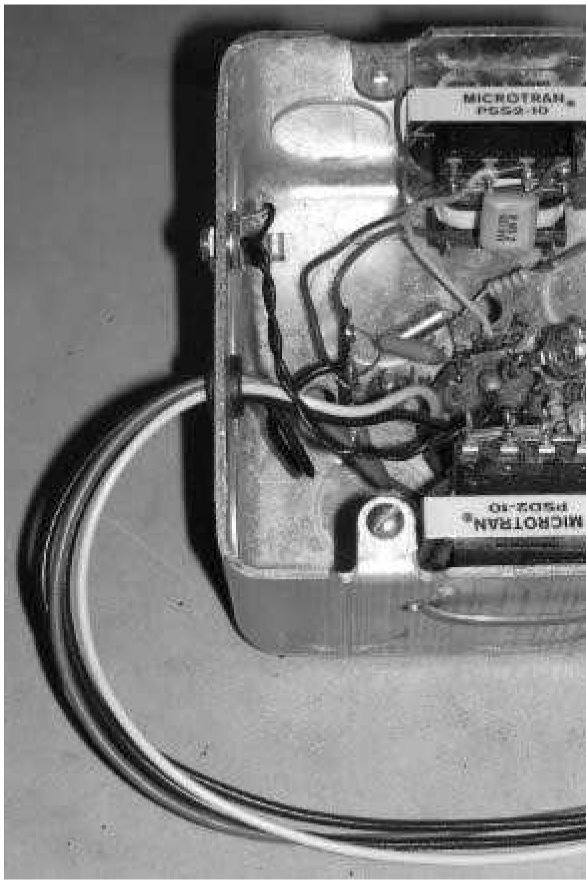
I thought you might be interested in a project I did a few years ago, it's a one-tube code practice oscillator that is built around several modern split-bobbin transformers. It's a relatively simple project and is easy on the ears. Details are here:

http://www.solorb.com/elect/ha

[*I've reproduced part of Forrest's article below, follow the link above for the "full trip"... Ed.*]

The W0RIO 6U8A Code Practice Oscillator

(C) 2015, G. Forrest Cook, W0RIO (formerly WB0RIO)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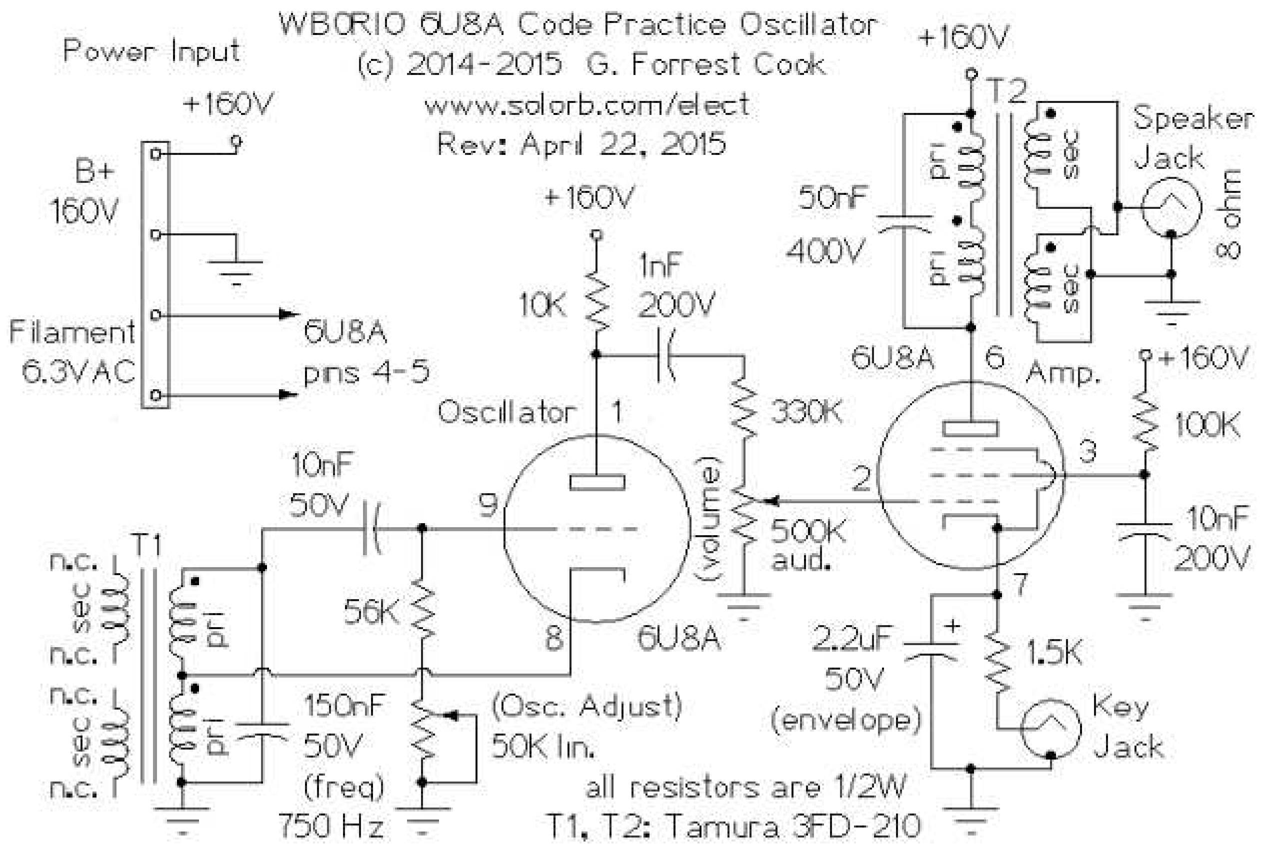


Introduction

This circuit uses a 6U8A triode/pentode tube as the heart of a code practice oscillator (CPO). It is simple enough to be built by a beginner and would be a good introductory project for those who want to experiment with vacuum tubes.

The circuit produces a hi-fi sinusoidal output with a wave-shaped envelope for minimal key clicks. These features reduce operator fatigue and make the CPO easy to listen to for extended periods. For contrast, see my solid-state Smooth Tone Clickless CW Sidetone Generator project.

The circuit is designed to work as a stand-alone unit. The design is modular and it would be fairly easy to adapt it to most tube transmitters as a side tone oscillator.

This simple Power Supply for Vacuum Tube Experiments (set for 160VDC) provides power for the code practice oscillator.

Warning

This project involves the use of potentially lethal high voltages including 120 VAC and 160 VDC. The project should only be taken on by someone who has experience working with high voltage circuitry. The power supply should always be disconnected and the power supply capacitors should be discharged when working on the code practice oscillator. The circuit's chassis should always be connected to the AC power ground when operating.

[*An EF82 or similar will substitute nicely for the 6U8A; and the transformers are any dual 110 volt primary / 3, 5 or 6 volt dual secondary rated 1 – 2 VA… Ed.*)

Test Gear

Meter multipliers – and practical options

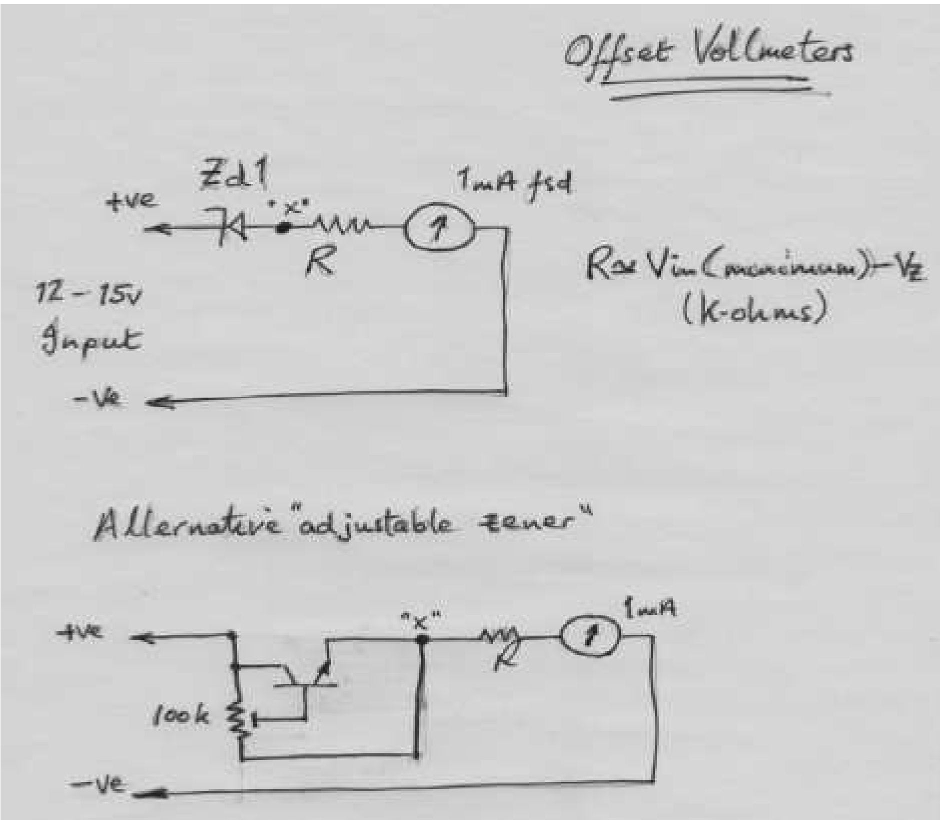
In many cases, amateurs inevitable discover the old fashioned moving coil meters are a far better option than digital instruments; true both have their places in the RF world, but I far prefer watching that meter needle indicate a peak than some dancing digits or LED’s!

One area that a moving coil meter far outweighs a digital is in low power field operations, “SOTA” and the like - because a moving coil meter needs no battery, a device of the Devil which uncannily will die just at that crucial moment!

One place moving coil meters can score is the instant recognition the needle position gives: it’s like looking at the fingers on a clock, the image is all you need to tell you the time. I bet you have a clock face image in your mind when you look at a digital time readout, yes?

Any which way, here’s a trick I learned when using battery power in extreme low noise measurements: it’s offset voltmeters to indicate battery charge. Think of a sealed lead acid battery, full charged, it’s at 14.2 volts or so: flat at around 12 volts or so. The volts under 12 are irrelevant; I wanted to see 12 to 15 volts, spread right across the meter scale.

Easy-peasy; use an offset circuit, to feed a nought to three volts meter! A 12 volt zener did the job, a 3k resistor made up from 3 x 1k metal oxides. I didn’t, however, have a 12 volt zener: Stan reckoned a “Vbe multiplier” circuit would do the trick for me: thus the job was done with trimmer pot, an NPN transistor and a few minutes juggling. Job done! Full scale = full charge, flat = zero scale, at a glimpse. That did the trick in the Faraday shield darkroom; the tiniest light to see the meter was enough, no LED digits and stray light.

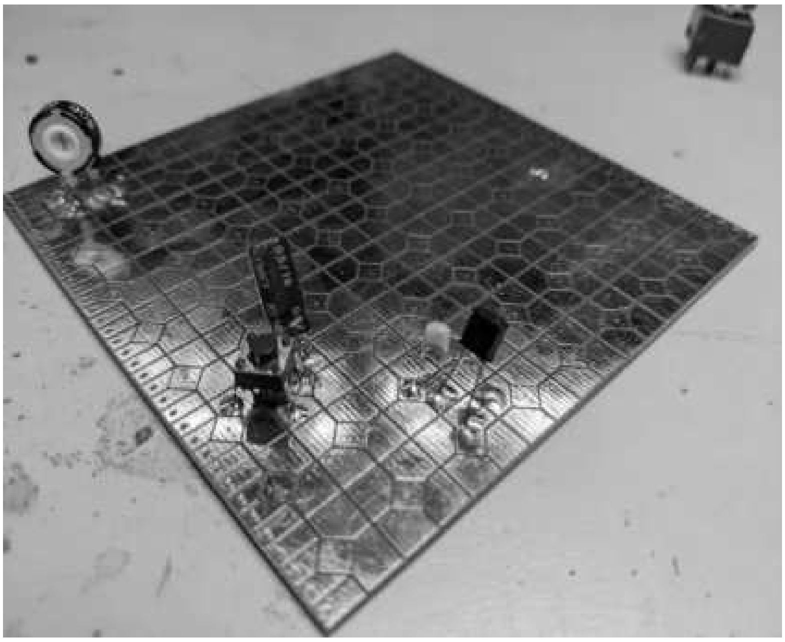


A new take on RF prototype boards

Tom McKee brought this to my attention, many thanks, Tom!

https://miscdotgeek.com/a-new-prototyping-pcb-for-qrp-homebrew-radio/

Here's a glimpse from the website, but personally I like wide "buss" rails - especially grounds - so I'd use strips of pcb material mounted above the "islands" at right angles, anchored by small bits of wire to appropriate pads: this design would be good for close implementation of circuits, as the ground busses so installed could form shields around sensitive circuit areas.



A few thoughts about Grid Dip testing…

When an amateur gets a grid dip meter, he's well on the way to constructing successful circuits, using his own designs or bits and pieces culled from existing designs. At first glimpse, the Grid Dip Oscillator is a wonderful bit of kit - and so it is - if you keep in mind some basic operating methods. Grid Dip Oscillators have been mentioned previously, but to answer a few question I've had, I've found three main issues.

Question: "*I can't seem to get a dip with this toroid inductor and a parallel capacitor?*"

Toroid circuits s are notoriously tricky to "dip": you can't easily get good magnetic coupling into the circuit as the toroid keeps the flux inside the material. The good point is this, though: very "loose" coupling is a good idea when chasing resonances! The Toroid "problem" can easily be resolved with a simple "link" coupling, a turn of wire through the toroid, brought out and the bare copper ends of the loop twisted together. The GDO coil is brought close to the coupling link and adjusted for a "dip" then progressively moved away from the link. The resonance indication becomes sharper and sharper, thus giving a good indication of resonance.

Make sure too the capacitor you've used to test the resonance is a reasonable value: keep to mind that at resonance, $X_C = X_L$; 300 ohms at f_0 (resonance) is a good start… you could try to resonate

100pF with 1 Henry of inductance (fo = ~ 50kHz) but I doubt very much you'd get a clear resonance with these components, representing a reactance over 31k ohms!

Question: "*I get dip indications at many frequencies, which is the "real" one?*"

The coil of the GDO emits RF (albeit at very low power) into anything around the coil; this can be over quite some distance (as seen in Q.1, above). Thus anything that can absorb energy from the coil - screening cans, chassis plates, wiring, and so on - but these "stray" dips are nothing like as deep or broad as the fundamental resonance. Look for the real "show stopper" dip, then withdraw the GDO coil away, as described above. This should show a very strong dip even at a distance, indicating the fundamental resonance.

Question: "*I get dips on related frequencies, like 2 x, 3 x, and so on?*"

You are seeing the harmonics of the complex circuit you've created by injecting RF into a circuit by bringing a GDO coil in close proximity to a resonant circuit. The trick is to look for the lowest frequency dip that is deepest.

Imagine in your minds eye what's happening here, you have two resonant circuits in close proximity; one is the circuit under test, the other is inside the GDO. As the frequency of the energy exciting these double tuned circuits become close, the coil under test influences the GDO oscillator resonance, and vice versa: only at the true resonant point do the two oscillators exchange maximum energy between them. This is what creates the fundamental and harmonic dips!

Resonant circuits can't resonate below their fundamental; harmonics - whether the GDO oscillator or the resonant circuit under test - "ring like a bell" on any integer multiple of the fundamental, be it 1 x, 2 x, 3 x, and so on. The higher the harmonic, the shallower the dip, is fundamental physics but be aware that it depends on the magnetic properties of the coil and core - so you might not see any solid dip beyond the third harmonic. If the GDO waveform is a clean sine waver, that is; if it's squared off for instance, the third harmonic might show nearly as deep a dip as the fundamental but the frequency always gives the game away.

Antennas too can be dipped via a link loop, and the same as above applies. The dips can be as deep or incredibly tight (often seen when dipping an antenna with high Q loading coils employed). The resonances will be easily apparent too for those building multiple (harmonically related) dipoles for instance.

Happy Grid Dipping!

DC Analysis

You can rapidly decipher a non-functioning circuit by checking a few DC voltages around the circuit, and, as I was vigorously taught, check the power supplies first! Some circuit diagrams will include "normal" DC voltages at various points, and a very big "thank you" to the designers who took the time to do so. Most faults will quickly show awry DC conditions; you know, for instance, that (assuming a simple common emitter NPN amplifier stage) the collector should be a reasonably high +ve voltage; but certainly not at full +ve rail volts. Similarly, the emitter should be a low voltage, and indeed might well be at ground potential. The base should be somewhat higher than the emitter, by the base-emitter voltage, ~ 0.55v.

You should keep in mind however that some circuits can radically change when an input signal is present, or when an oscillator (for instance) is oscillating: the DC conditions change quite dramatically. In these cases, it's a good idea to disable the input - short it to ground, via a 0.1 uF if a DC bias exists on the input - or unplug the coil or crystal to stop the AC conditions swamping the DC you're looking for. Make sure that doing this doesn't cause any disasters afore you do it! If a fault exists, disabling the input can force damaging circumstances in the circuit, so check first on (if possible…) lower supply voltage / current. A series resistor or our old friend, a filament lamp, can be a help here.

One additional test you can do is to check that a transistor can actually switch; the voltages you have seen might be feedback from another source. I often use this trick as a quick check, but be careful: you will be forcing the transistor to switch and this may not be a good idea! Check as best you can the circuit to see if forcing the transistor to turn off is harmless.

Those of you with valve / tube experience will probably know the effect of touching a metal screwdriver blade to the grid terminal; you inject a fair bit of hum and noise. Shorting base to emitter is similar and can indicate faults.

You'll be monitoring the collector voltage to ground, ideally with a clip to leave your hands free, and deftly touch a (insulated handle!) screwdriver blade tip to both base and emitter, shorting them together. This forces the transistor to turn off, thus the collector voltage (assuming the collector load isn't open circuit…?) will rise to the rail voltage, thus proving that the transistor will actually switch.

You can check long tail pairs this way by monitoring the collector and the "long tail" link; you'll see a swing in the voltage. By shorting with the aforementioned screwdriver pin 2 to pin 3 of a "741" op-amp (or any op-amp with the same pin out) you can force the output to "balanced" condition, or, if the op-amp is an audio amplifier, hear a significant change in output. Be aware though, this can throw some circuits into oscillation, so be brief and be careful!

This trick works on both NPN and PNP bipolar transistors, enhancement mosfets (gate to source in common source connection), IGBT's and the like, but BE CAREFUL. You're forcing what is effectively a fault on the circuit, so be sure you've got your dull lamp current limiter or similar in the power feed, just in case.

Antennas

A "universal" HF antenna that needs no special earthing

From Pete Millis, M3KXZ who writes...

Hi Peter,

The antenna I currently use is a home brewed version of the Bushcomm Mil-1.

This is fed with a 9:1 unun with one side going to a 16m long wire, with a load or termination resistor and a further 8m of wire beyond that. The other side of the unun goes to a 4m long wire which is grounded. The 9:1 unun and the load or termination resistor provide a good match to 50 Ohm coax right from 160m to 10m with SWR ranging from 1.0:1 to about 1.8:1. At most points SWR is below 1.5:1.

I have wound a couple of ununs. One is on a BN43-3312 binocular core and the other is on a tiny BN73-202 binocular core. They both work really well. The BN73 seems slightly better.

The load resistor is a 470 Ohm thick film resistor by Telpod.
(Try your own with 470 ohm metal oxide resistors, wired in series / parallel. Ed.)

The grounded end is just grounded by attaching to 160mm aluminium tent peg.

I have been setting the antenna up at between 1.6 and 2.0m above ground, either horizontally or as a very low inverted V. Just really making use of convenient supports like gorse bushes or stringing between tree trunks.

I've attached a sketch showing how I've been setting it up. In the absence of enough trees then I just slope the long end down to the ground and secure it.

Now, it's generally understood that a load or termination resistor will eat up power and with be no good for QRP.. I've read probably 15% when the match is bad, others suggest maybe 25%. But that's a fraction of an S unit, and means I don't need to use any tuner and I don't need to make any antenna adjustments when changing bands; a massive plus for me as I only get 15 to 30 minute operating sessions. This antenna I can set up in 1 minute flat and just get on the air.

What has really surprised me is that I have had far better results with this than I've previously had using an end fed sloper with my Elecraft T1 atu, or the ATU on my KX1. This is operating from the same locations.

As well as having a terrific QSO with W3DF yesterday while running my little 5W, I had a similarly great one with NY2PO last week and have had plenty of other great QSOs across Europe. And reverse beacon network has reported spots of my CQs far and wide. Really happy considering the limited time I have had, and that I've been getting out at the worst times of the day.

Attached are the sketch of how I've set this up, and also a drawing from Bushcomm of other ways to set up.

I'd be interested to hear your thoughts!

73, Pete M3KXZ

Pete's QSO notes using the antenna…

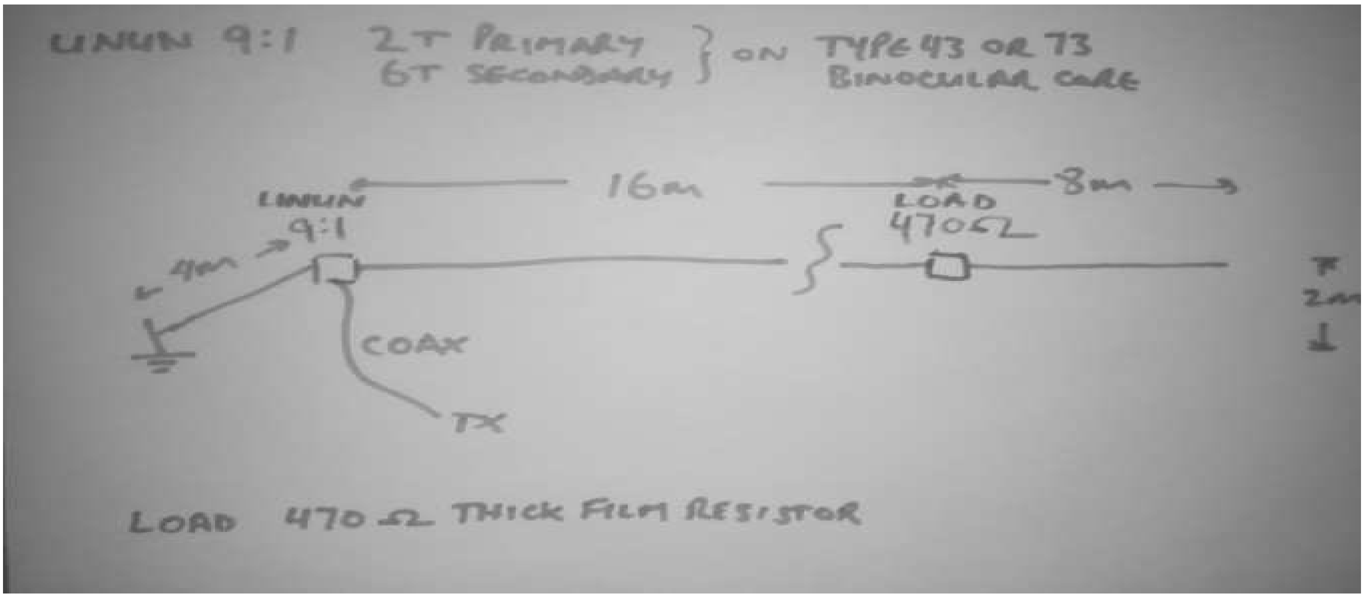
I set up in the woods with the antenna strung up at 2m above ground level and had a couple of terrific QSOs with my 5W.

First was with IK3XJU, Roberto on 30m who was fairly close at 675 miles (1080km) with a closing band and very heavy QSB.

The second QSO was on 17m with W3DF, Dan, just before I was about to go QRT due to freezing cold hands and needing to pick my wife up from rehearsal for the Christmas pantomime. This QSO was amazing. Dan is in Westminster, Maryland - a distance of 3674 miles (5878km).

Really very happy indeed. Considering I only had 20 minutes to operate, being able to set this antenna up in about 1 minute and not have to worry about a tuner and antenna adjustments is fantastic.
73 de M3KXZ

Pete's antenna is shown below. Neat, simple, effective. What more could you ask? It's always thought that resistors lose power; yes, this is so, but power lost is related to the current running through them. In this design, the current through the resistor adds to the radiated field by flowing into the "post resistor" element - the resistor losses are far less significant than in a fully terminated antenna like a VEE or rhombic.



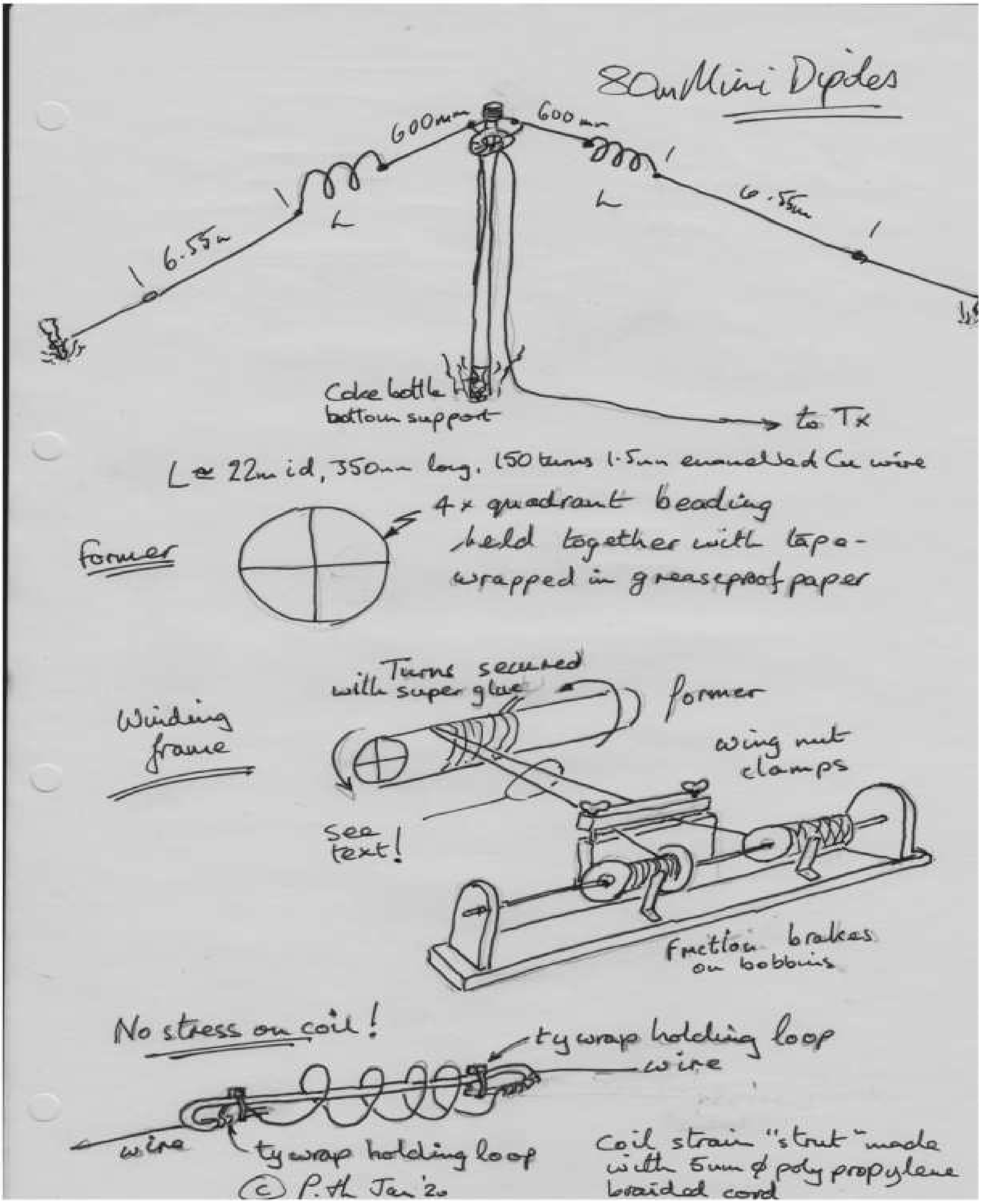
A Mini Dipole for 80m

Folded dipoles for 80m are nothing new but it's such a good "fit" into typically small UK households it bears repeating, and my favourite method of winding high Q coils is shown below.

Eternal discussions arises about such "loaded" dipoles having narrow bandwidths of resonances, but for those who are squeezed into a tiny garden (or "none" in many cases) such designs can make or break an effective station. One tip: use the heftiest copper wire you can get your hands on: lower losses, tougher construction, higher Q. Polypropylene strain "struts" keep the coil from deforming in tension: make them of the heftiest polypropylene you can get your mitts on if it's at all windy where you are.

Another point of conjecture is the use of PVC covered wires for antennas. The PVC coating does increase the capacitance by a few percent; this modifies the resonance a little, but the massive advantage of structural strength pays big dividends. One point with PVC covered wires, often overlooked, is that they offer significantly easier connection to a guy rope or other end harnessing method, as compared with open or enamelled copper wire. The stranded core gives much superior flexibility too, for those in very windy or coastal aspects. Though it's a rapidly fading memory (hopefully…) the acid rain that used to drench the Northern UK was effectively blocked by PVC wire covering; it did get somewhat brittle after a year or two, with the sulphuric acid getting at the bonds in the PVC; the same goes for polypropylene guys, nylon monofilament "secret" end insulators, PVC waste pipe used for loading coil formers and the like. Remember too that sunlight UV will attack the bonds in a lot of plastics, so best look out for “UV resistant” types if you want a good few years out of plastic used in antenna construction.

Note the technique of using string alongside the wire in winding the loading coils; it automatically spaces the wire as winding progresses and a few dabs of super glue as the job progresses helps keep everything in shape. I wind on top of greaseproof paper, this allows peeling the string off after the assembly is slid onto a plastic pipe or slotted perspex “combs” to hold the coil turns firm. Once the string is peeled off, the whole coil can be slathered in home made polystyrene dope for a permanent job. My simple coil winding gizmo is made of wood from a broken shipping pallet, the string is the sort butchers use and the wire is scrounged from transformer winders as tail end bobbins, they don’t like starting a winding with doubts as to whether the wire will run out before the winding is completed!



A possible money saving antenna option?

It's a fact: RF power travels in the few outer mils of a copper wire. Fact. It's because the inductance in the centre of the wire is far higher than the outer, so the RF naturally chooses to travel in the lowest impedance region! It's often suggested that receiving antennas are made from Copper-weld wire, which is steel inner with a copper coating, designed for MIG welding (amongst other more esoteric methods).

So why is it that all the high power RF generators I've worked on over the years had resonant coils made from very hefty copper pipe: Admitted, in most cases, it was to allow cooling water to the load coils (inductive heating) or for generating very high energy VHF plasmas for etching silicon wafers.

Copper pipe lends itself beautifully to power RF coil construction with brass compression fittings, ideal for making repairs - water does eventually create pinhole leaks in copper, it's the nature of the beast - and demountable connections for load changes, and the like.

I've never heard of a RF transmitter running more than a few watts using anything but solid copper; though above roughly 50 watts small bore copper pipe, silver plated, is *de-rigueur.* It should be perfectly feasible to use copper coated steel wire for power RF, silver plated or not, as the steel will most definitely increase the core inductance!

Which leads to the question: is it because micro-bore copper pipe is cheap and easy to use, or is it that the ancients just made it big when RF power was required, and we've simply followed the pattern all down the years, and bunged in the hefty copper?

I'd like to hear from anybody who has - or is willing to try- in the nature of RF experimentation, copper weld wire in a transmitter tank circuit running 50 watts or more. I can't promise everlasting fame, but it would make a decent difference to those winding coils for the lower bands, bless 'em!

A useful skin depth calculator is at:

https://www.allaboutcircuits.com/tools/skin-depth-calculator/

Hot Iron # 116

End May / Start June 2022

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CQ-CQ-CQ

Theory ain’t everything: from Eric Nichols, KL7AJ : *“SWR meters make you stupid”*

In days gone by - - -

“You were likely to make a useful accidental discovery from time to time. Theory is great, to a point. It helps explain what you already have discovered by accident, but it doesn’t often lead to new discoveries, at least on its own. You need to get knocked on your keister a few times and singe a few eyebrows to really understand radio.”

This puts me in mind of Michael Faraday, the original - possibly - arch experimenter. Nature is a very shy girl; she hides her secrets well and only show glimpses sufficient to attract further approaches. You can take thing theoretically far; you can wrap volumes of abstruse mathematics around Nature’s gifts, but never forget that our feeble human maths is but a fleeting shadow of the truth hidden deep in Nature.

As any business manager will tell you, “it’s not theory that makes results: it’s the end product, the bottom line, the working system that makes the World go round”. Maths and physics can get us a long way into sneaking a view of Nature’s secrets: but, never forget, they both are mere tools in your kit, not the controlling influence. Ohm’s Law is well and good, it helps us sort out problems, design circuits and think through a faulty system, but it is merely a convenience, a short cut to what is actually happening in these components, not the command that tells Nature how to behave.

Nature is far deeper and more mysterious than we hominid apes can ever understand (or imagine); the Universe wasn’t designed for our benefit or entertainment, so respect Nature in all you do!

Receivers

From Kevin, ZL3KE

…. who wrote an email to me which I think is well worth sharing: it might bring a few more amateurs “into the fold” of appreciating super-regen receivers:

“I've previously played quite a lot with what could be described as the
‘standard’ FET super-regen circuit i.e. the grounded-gate one that's
been published in various articles over time. Remember the old PW "CQ2"?
And of course Roger G3XBM has provided more recent inspiration having
used this circuit in his 2m "Fredbox" and related 6m/10m designs, see:
https://sites.google.com/view/
and
https://sites.google.com/view/

I've generally had good results with this circuit but it does seem to
need a half-decent FET and preferably "ugly" construction to get
repeatable performance at VHF/UHF. By far the best results I obtained
generally were with a 2N4416 (TO-72 metal can, with the can
spot-soldered directly to the ground plane). I still have a few of those

2N4416s somewhere! These days a J310 or similar would seem like an obvious candidate - have used U310s (metal-cased equivalent) on a couple of occasions with good results. (Hint: thin enamelled copper wire wound round a plastic encapsulated device, secured with super glue, hot melt or wax and earthed can imitate a "canned" device for use at VHF / UHF… on bottles, too, when screening can unavailable. Ed.)

The "dead spot" problem I found was mainly related to antenna coupling, and the use of an untuned preamp/buffer stage (either CG FET or CB bipolar) lightly coupled to the detector largely eliminated this in the several circuits that I built. I wouldn't build a super-regen without such a preamp now, unless it's being used as say an IF stage where the loading conditions on the main LC tuned circuit can be more closely controlled.

I found that the characteristics of the RFC in the source of the FET can be more critical than you might think. What's needed of course is a high enough impedance at the working frequency. I once had this circuit working as a fixed-tuned 10.7MHz IF, but found that instead of an RFC I needed to use a tuned 10.7MHz parallel tank circuit (old 10.7MHz IFT) in the FET source lead, instead of an RFC (very good at a single frequency but due to the high-Q resonance, no good if you need significant tuning range). These days I have the luxury of a spectrum analyser with tracking generator and I look for an RFC out of the junk box which has a low-Q parallel self-resonance reasonably close to the intended frequency of operation.

Having said all that I'm keen to experiment with a bipolar circuit with audio reflexing, as one downside of the CG FET circuit is that it needs a highish-gain audio amp. I look forward to seeing your published circuit.

I derive more enjoyment from playing with these simple and almost forgotten circuits than I ever got from designing high-performance and increasingly complex VHF/UHF radio systems for the likes of Racal, Codan and Tait (that could sometimes be likened to chainsaw juggling - fun at first but can age rapidly...). I know a number of professional RF engineers who do this kind of thing (and/or playing with thermionic stuff) as an antidote to the day job. It's a funny old game.

Anyway enough waffle from me already! Cheers & 73,
Kevin
ZL3KE"

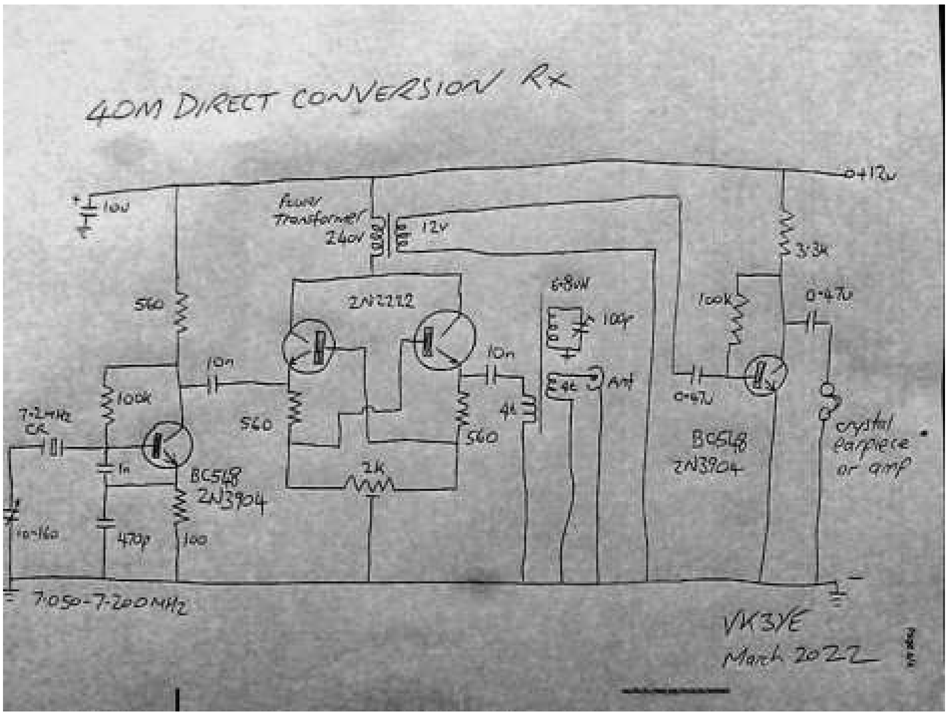
Peter Parker's cross coupled transistor experimental DC Rx

Peter Parker, VK3YE, wrote to me:

"*Thanks Peter,*

Yes it's for publication. The main shortcoming is the use of the transformer. You can get away with just a resistor but audio is less. I've tried various other transformers and there's some odd effects. I think it's possibly more promising as a balanced modulator or in a simple transverter but I haven't tried it yet. High level balanced modulators were popular around 1960 as a cheap way to get on SSB but there have been few if any solid state versions published. But a version using this configuration with two BD139s followed by an IRF510 PA could be an interesting DSB or digital modes adapter for a CW tx".

Peter's circuit:



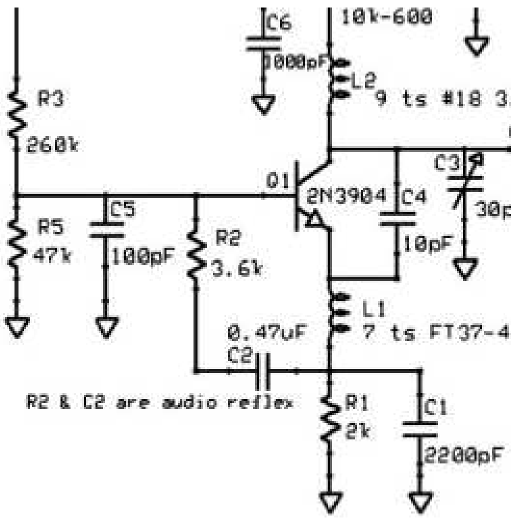
Peter noted that this "cross coupled" circuit appeared in "Amateur Radio Techniques" by Pat Hawker, G3VA. I had the circuit in a bench notebook from years ago, as well as the cross coupled triodes. I've a suspicion cross coupled pentodes can be used too.

I must have thought the circuits worth noting at the time, as well as some notes about the "Gilbert cell" - a clear derivative of this circuit.

Rush boxes and reflexing

I'd written to Kevin about a reflexed super-regen circuit, using bipolar NPN transistors: I must have knocked up dozens of these little beasties over the years and I had one running on 23cms at one stage. I wrote in reply to Kevin:

"*One thing I will add (for what it's worth) is that a few correspondents have told me that they have "dead spots" and erratic operation using jfet's: this might be because jfet's have specs as wide as a barn door, and consistent oscillation can't be guaranteed. I like to use high Ft NPN transistors in a super-regen "reflexed" circuit - I'll put a note in Hot Iron # 116 that you have a super-regen project in the pipeline and suggest my favourite circuit as a possible alternative.*" So 'ere tis!



Super-regen addicts (yes, once you build one of these damn things, and hear for the first time a single transistor providing >100dB gain you'll not stop playing with super-regens!) will recognise the typical features: an emitter (source) choke; the quench generators R1 and C1, the RF decoupling of the base connection and the emitter to collector feedback capacitor.

Note the inclusion of R2 and C2 - these feed the audio signal that's present below L1 back into the base circuit which is earthed at RF signal frequencies, making the oscillator a grounded gate type, and a common emitter audio pre-amp all-in-one.

I claim no originality for this circuit: if any reader recognises it, please let me know and I'd be most grateful. I think it formed part of a 6m transceiver but I can't be sure.

A fascinating resource is at: http://zpostbox.ru/super_regenerator.html#google_vignette

...where you'll find some simple and interesting circuits.

The Bond Box

Here's the classic transceiver original, which Terry, VK5TM told me about:

Hi Peter.

Re the QST Bond Box circuit - you can download the whole mag with article here https://worldradiohistory.com/

Cheers

Terry, VK5TM

Thank you to all the readers who sent me emails about this absolute beauty of a mobile VHF transceiver. It's a superb design by Doug DeMaw, dating from the late 1960's, and well worth a go with modern components and updates. It's on page 11 of QST issue 8 , 1968, HERE or if the link won't work for you, https://worldradiohistory.com/Archive-DX/QST/60s/QST-1968-08.pdf .

The skill involved in designing the Tx / Rx switching - the downfall of many transceiver projects - is simple and straightforward: indeed it prompted my memory for an item later in this edition.

Transmitters

Hot Iron's magnificent archivist, Frank Barnes, W4NPN, pointed me to an article which details specifically the construction of valve power amplifiers and earthing techniques, see:

https://www.w8ji.com/designing_ham_transmitter.htm

This is the absolute Mutt's Nuts of the job: a magnum opus of sound engineering in an amateur scenario and is vital reading for all bottle power amplifier enthusiasts. It brings memories of repairing some equipment, which relied on the earthing around the power amplifier stages being exactly as the manufacturer had built it.

Each power amplifier had a hefty brass bolt for earthing and return current connection, and the tags that went on this bolt had to be in the right order, or the stage would burst into parasitic oscillation at some point. Stan had told me; I forgot and got a couple of lugs in the wrong order. This caused power stage return currents to pass through more sensitive driver amplifier earthing, thus unwanted feedback from the µV drops in the earthing stack. Easily done, but I didn't forget again!

Similarly, when a lug crimped on a cable parted company from the copper cores (don't ask…) a fork lug, rather than a full circle lug was used as a repair. This gave bother when a new valve was fitted; the stage was only marginally stable as the new bottle had plenty of g_m and hooted at the least provocation. A new heavy gauge full ring lug fitted, and screen grid decoupling capacitors replaced for good measure whilst we were in there put the job back on track.

Never take on grounding or return current design without some deep thought, and plenty of testing!

Medium Wave "local" transmitters

We've talked about that typical trade off paradox of "local" MW transmitters; designed to give a MW signal in a very small radius (no more than, say, 20m) as beloved by Harry Lythall, SM0VPO.; and of course very applicable to Top Band operation over considerably longer distances (plus possible interference to next door's electronics).

Harry pointed out to me that modern pocket sized audio recorders and the like are very capable stereo devices: this means that TWO audio channels are available for use.

Thus TWO low power "local" A.M. micro-transmitters could be modulated with different material, recorded on ONE device. Neat, huh?

Not that I condone copyright infringement, music ripping or unlicensed transmission over the airwaves…!

As Harry wrote to me:

"*Hi Peter, yes, please feel free to use any info or ideas. One small addition is that an MP3 player has two stereo channels. There is absolutely no reason why you cannot take two mono recordings (Radio Caroline and Radio Luxenbourg, perhaps) and save the MP3 file as a 2-channel mono recording. You only need one MP3 player to feed two transmitters and have 2 stations on your AM "local" service*.

ECL / PCL 80 series triode - pentode transceivers

I came across a design years ago which used the (then) very popular triode / pentodes of the ECL 80 / PCL 80 series, much beloved by record player audio and frame output TV scan amplifier designers of yesteryear. Yes, these bottles are particularly useful for transmitters, and, nowadays, the PCL (300mA TV series connected heaters) bottles are cheap as chips and lots of "NOS" available.

"So what's new?" you ask… well the design I recall was a full **transceiver**, comprising a regenerative receiver using the triode as an RF amplifier with twin tuned circuits, feeding the pentode as a tuned regenerative detector plus audio output via reflexing. The transmitter was a Colpitts crystal oscillator - which if I recall gave a very clean note - and used screen grid modulation from a carbon microphone; the power supply switched to give more "ooomph" on transmit, and stabilised with voltage regulator tubes on receive. I recall "borrowing" a carbon microphone from an office telephone for lower audio noise!

I built one; it used a 12 pole rotary switch to change the circuit from transmitter to receiver and vice versa. I was amply warned that the wiring and layout would be the critical thing: "stick exactly to the layout and wiring harness diagram" quoth Stan, which I duly did.

It still took a fair bit of tweaking to get it to perform, but it was an excellent little project, and here's the kicker: does anyone have any notes, or better, a link to the original article? I think it was in a magazine; PW, Short Wave mag, I can't honestly recall, but it would be very much appreciated and bring my eternal gratitude to the sender!

WW2 TRD sets: not a PWM "secure" system?

After the Nazi occupation of Western Europe, after 1939, UK "stay behind" units of essentially civilians were trained to become resistance fighters, to tackle the invasion forces and be a "pain in the 'arris" to occupying troops. They built remarkable disguised hideouts, some under ash piles, compost heaps, scree slopes and farm middens, and they were issued radio transmitter / receivers, the TRD sets, designed so the occupying forces could not eavesdrop on the conversations.

Many ideas as to how these sets worked, a common theory being they used a super-regen receiver "back'ards" as a transmitter - injecting audio at an appropriate point causing the quench frequency to vary in proportion to the audio, this being a primitive pulse modulation, the super-regen set receiving the signals would synchronise onto the quench frequency and demodulate the audio.

Why not examine the TRD circuit schematic, or the actual transceivers themselves, you might ask? Because, once the "stay behind" resistance groups were disbanded in 1944 / 5, all the TRD's were dumped into a disused (and unknown) colliery shaft in Lancashire, and many tons of wet concrete dumped on top so the secret of the TRD sets would be secured forever.

I've tried a few experiments using valves as close as possible to the WW2 bottles, and although I built some fairly potent VHF / A.M. sets, running on 60 – 65MHz, I couldn't get pulse modulation, be it pulse position, width or anything else. I had conversations with Tim Walford (of Walford Electronics fame) and several other interested parties and the general position was the circuit / technique was (for ongoing security reasons?) just plain unavailable.

So, it was with surprise I came across a reference that not only had information about the TRD sets, but chassis layouts, operating and antenna notes and other details. See:

http://www.wftw.nl/111%20TRD%20%20v%201%2000%20.pdf

This is a welcome relief: it puts to bed most of the guessing and wondering, and forms the basis of a dandy 6m or (in the UK) 4m A.M. transceiver. Obviously, no need (unless you're a purist) to replicate the 6 volt lead acid battery / vibrator power supply - the specification was, if I remember right, a 72 Amp Hour battery, and this would be one hefty beastie, far from portable!

Power Supplies

From Bob Liesen, WB0POQ

"Peter,

Loved the story in the latest "Hot Iron" (# 115, Ed.) *about finding a HV transformer with a shorted turn.*

I remember years ago working on early color TVs with their enormous power transformers and learning very early on that low B+, a buzzing transformer and LOTS of heat coming off it, meant the customer had a big bill coming to replace that beast-O-iron.

Fast forward to a few years back......I work for a company that makes a product that incorporates an in board signal transformer. That is, on two of the internal layers there are two small copper foil spirals with a hole cut through the PCB to insert one leg of a U core. This transformer is used for galvanic isolation betwixt two parts of the circuit.

When the VERY high permeability U cores are inserted through the holes in the PCB, the inductance of this small coil is around 30uH. With no cores in place it is about 1uH or less.

Part of the production process is to do an ICT (in circuit test) to measure the inductance of this coil.

Well at one point the alarm bells went off as many of the boards were failing this ICT test with measured values around 1uH.

The engineer who was my supervisor, (nicest guy you'd ever want to meet, and VERY smart) assigned me to figure out what was going on.

I got some failed boards and set off to find the cause.

I first speculated the U cores were wrong. Nope, they checked out. Well could something be wrong with the circuitry attached to the windings? Nope, isolated the windings from other circuits and still had bad values.

Hmmmmm.....shorted turn???

I took two U cores, wound 6 turns of wire on them (same number of turns as in the in board transformers) and measured the inductance. Got about 30uH. Shorted one turn to its adjacent neighbor.....1uH.

So.....I go to my supervisor and tell him the coil(s) have a shorted turn. I get the look like when your dog turns his head on his side as if to say "You want me to do WHAT!?" He had no idea what I was talking about. I explained that with a high permeability core, all the turns are so tightly coupled that shorting two shorts them all. Still no idea. So, I took him to my bench and hooked my two cores wound with wire to an LCR meter and demonstrated what happened to the measured inductance when I shorted one turn to its neighbor. He stared at the fixture for a moment, and said......"Well....I see what you are doing here, but I don't understand it, so we are going to look for the cause somewhere else."

We spent the next 2 weeks trying to tie the failure to temperature, humidity, phase of the moon and wind direction. No joy.

So, I took a sample board stripped of components down the road to the PCB manufacturer. (Ahhh the days where your suppliers were on the same continent). They had a machine that could sand layers off a multilayer board to reveal inner layers and asked him to post me a picture of the layer with one of the coils on it. I then headed to a meeting back at my office to plot the next round of testing to find the problem (was it pressure, radiation, extraterrestrial intervention??).

In the midst of the meeting I got an email from the board manufacturer with a picture attached. I opened the picture and smiled an ironic smile. Two of the engineers were at the white board

plotting the 6th derivation of Gauss's field equation, and I piped up......"Can I show you something?"
"Yes, go ahead" one said in an impatient voice.
There on the screen was a 6ft x 6ft image of a cute little spiral of copper with a HUGE RAGGED CHUCK-O-COPPER between adjacent turns, I turned to my supervisor and asked.........."Are you STILL going to tell me it is not a shorted turn?"
To his credit, he responded "Yup, you nailed it"
The board maker was not using sufficient agitation in the etching process and as this was an unusually delicate etch, they left copper in place where it did not belong.
In the future I got presented with somewhat less of the dog's head on its side looks.
There is simply NO substitute for getting into circuitry when you are young stupid and foolish....getting bit, burnt, and gassed teaches volumes more than sitting in a classroom deriving the 6th derivation of Gauss's field equation.

Bob WB0POQ"

Discrete regulators far better than IC types?

From Zetex, comes a design for a discrete regulator that out-performs the usual "IC" types. This can be scaled ansd populated with any devices you have to hand, not specifically Zetex types: but from experience Zetex devices not only "do what it says on the tin" but a whole lot more. - they are noticeably robust and withstand overload magnificently.

I would recommend you look up the whole AN51 application note for a full desription, by clicking this link and using the "GO" box, upper right. (Note: Zetex is now part of Diodes Inc.)

You'll find application notes of interest to the radio amateur in the library - have a look! The following is very gratefully taken from AN51:

AN51 Precision voltage regulation for ultra-low noise applications
Isaac Sibson

Issue 1 - October 2007 1 www.zetex.com

"Introduction
A simple discrete regulator circuit using Zetex voltage references and transistors can realise performance levels that are beyond IC regulators, whilst being of reasonable cost and with very little board space overhead. Although Integrated Circuit (IC) regulators dominate the marketplace through their combination of simplicity and low cost, there are situations where lower noise and better regulation are requirements for the highest level of circuit performance. In applications where performance is critical and efficiency and cost may be of a lower priority, such as data conversion in audio and video, instrumentation and low noise power for clock circuits, this discrete circuit can be immensely useful.

This application note details the design of a high-performance discrete regulator and shows how to easily tailor it for new or existing designs."

It's a simple question...

...but rarely, if ever, answered! "How many µF's do I need for the smoothing capacitor for a ripple voltage of XXX?". Easy, huh? Whoa there, Tiger, just think a moment about what's being attempted here: we have full wave rectified AC coming from our bridge, a shunt capacitor for "smoothing" and a load in parallel with the shunt capacitor to be fed with relatively "smooth" DC - i.e. with little ripple, mostly pure DC, plus very little AC.

To achieve perfectly flat, ripple free DC, with no AC component to drive any variable load (up to the limit of the circuit) *instantly*, requires an infinite gain amplifier that produces zero noise, and reacts in zero time. If you have of one of these I'd be very much like to know about it!

Most practical designers know from experience that if you want a 12 volt DC supply, at a couple of amps load current, you'll need 4700µF - 10000µF or thereabouts, and that's exactly where we leave the topic, yes? Well, what about that confounded nuisance, who wants to build a "direct conversion" receiver, eh? What's being asked for is considerably less ripple: even a few mV's are a bit much when we're looking at powering an audio amplifier with gain approaching 80 - 90dB!

It's often suggested that fitting a voltage regulator to the output, the ripple a'top the DC will be "chopped off" by the regulator: but, when tried, although the ripple is reduced, the voltage regulator isn't providing dead smooth, glass level DC. What gives?

Well... say hello to the real World! The regulator has to run its internal electronics from the power fed into the "input" pin, which has ripple: the manufacturer quotes "ripple rejection" figures, so acknowledges the basic problem: the regulator cannot provide a perfectly flat smooth DC - it can't be done. Why? Consider the job the regulator has to do: it continuously monitors the input voltage and changes the conductance of a power transistor to maintain a fixed output voltage. The power device that is the series regulating element has to be driven on it's base (or gate, if it's a power mosfet) by the internal electronics - all of which are subject to the ripple voltage to a greater or lesser extent. Every device in the control circuitry inside the regulator is susceptible to ripple on the input: differential amplifiers eliminate much of this ripple by common mode rejection, but each active device has capacitance (base - emitter, collector - base and collector - emitter), that the (AC) ripple loves to flow in and out of; and the power device is notoriously slow (try making a 2N3055 work on 200kHz!). I've only ever seen voltage regulators working at MHz rates in Harry Lythall's (SM0VPO) voltage regulator 78L05 amplifier:

http://sm0vpo.altervista.org/tx/317-tx.htm?

...where Harry uses an LM317 adjustable regulator as the active device, to 14MHz or thereabouts. This indicates the active power transistor is indeed a capable HF power device!

The point I'm making is that no voltage regulator will "chop off" ripple: yes, they will reject a fair amount of ripple, but a direct conversion amplifier at 90dB gain will easily pick up the AC ripple.

Of course, you can add more smoothing µF's, but you'll run into problems with huge capacitors appearing as a short circuit at first switch on. Soft start circuits are one solution, but the rectifiers get a hammering on every charging cycle as they have less and less time to deliver the top-up charge, to replace that discharged into the load. This can be a very big spike of current - and cause all sorts of hum problems as low impedance earthing may be hard to achieve, and big current spikes have masses of harmonics just itching to cause trouble.

It's a fair approximation that the basic relationships apply: C x V = i x T; this is the relationship between capacitance, volts, amps drawn and time the discharge takes place by calculating the energy stored in energy in Joules. C is in Farads, V is volts, I is the current in amps and T is the time between the charging pulses. For example, μF (10^{-6} Farads); Volts corresponds to the ripple, as shown by the capacitor voltage falling on discharge after each charge pulse; I represents the current drawn from the capacitor by the load in Amps; T is the time between charging pulses (50 Hz, full wave rectified, is 10mS or 10s seconds.

Components

Epitaxy - how transistors are made

Conundrums, conundrums: bipolar transistors are very mixed little beggars, they need extremely conductive silicon to keep the Collector - Emitter volt drop as low as possible (<200mV if possible), yet need high resistive silicon to get gain and low leakage amongst other things. So how do you make a transistor that in one breath is both highly conductive and highly resistive? That's two polar opposites! Answer: use an extremely thin layer of high resistivity silicon deposited on top of highly conductive silicon substrate, that's how - and there you meet the idea of epitaxial deposition of silicon.

The problem is, you can't just plaster some high resistivity silicon on top of a substrate. Oh, no, life isn't that simple! The silicon crystal lattice has to be preserved for the transistor to work, right through all the device layers. This means you need to heat the silicon substrate upon which you're building transistors to just under melting point: thus there is enough thermal energy for the new silicon being deposited to "key into" the substrate lattice, and grow atom upon atom in exact locked crystal alignment. The temperature to do this is around 1173 ºC, but modern devices are using molecular beam and other esoteric technologies to run epitaxy at much lower temperatures.

There are many variations of the silicon lattice orientation, the Miller Indices describe the silicon crystal: 100, 110, 111, and so on. You can find some basic background into silicon device manufacturing and crystals at: https://www.youtube.com/watch?v=vQjdUzhFqA4

Suffice to say, the process to make epitaxial silicon takes place in a hydrogen atmosphere, the silicon wafers sitting on a graphite susceptor to accept the RF power from a coil below - much like an induction hob in a domestic kitchen, but a wee bit bigger - like 350kW of RF! The susceptor in the machines I worked on was 24" diameter, an inch thick, made of graphite coated with silicon carbide, to withstand the extremely corrosive atmosphere of hot hydrogen, plus a silicon source gas, like silicon tetrachloride or dichlorosilane. The heat breaks down the source gas(es) into silicon and hydrochloric acid vapour, which back etched the deposited silicon to a slight extent and demanded that exhaust gases of extremely hot hydrogen and hydrochloric acid be handled with some serious plumbing in thick wall stainless steel pipes, valves and toxic gas scrubbers to remove the hydrochloric acid and cool the hydrogen below it's flash point before being released "up the flue".

The one thing I haven't mentioned is the dopant gases: you need these to make the deposited silicon N type or P type, depending on the devices being manufactured, These include Arsine (AsH3) phosphine (PH3), Stibine (SbH3) for N-type silicon; diborane (B2H6) for P-type. These gases are used in tiny quantities, and a good thing too: they are as lethal as bullets in parts per million concentrations. If you can smell them, you're most likely on your way to a pair of wings!

They are very dangerous gases indeed; hydrochloric acid is nasty, but at least you've a chance of surviving if you're unlucky enough to inhale some. Not the case with metallic hydride dopant gases that make the silicon P or N type! These are toxic in the extreme: inhaling a few parts per million results in death - as quick as a bullet.

Controlling, metering and safely disposing waste gases, materials and scrubber water is a tricky job demanding regular maintenance and testing; it's not unknown for gas scrubbers to develop small air leaks and explode without warning. Breathing apparatus is mandatory as is a working knowledge of high power RF, kV's and feeders made from ¼" thick wall copper tube, 6" diameter connected to a changeover switch (so one reactor can be heating up whilst the other is cooling down to be unloaded). The valve used was one mighty bottle: an RS3150CJ triode from Siemens.

With some tweaking of the feedback and tickling the filament supply, the epitaxy reactors I maintained regularly ran 18kV on the anodes, 270 amps in the directly heated filament cathode, 20+ amps in the anode, at around 100 - 700kHz. Mind you, over-running them at these levels they didn't last long; the filament sputtered tungsten off which resulted in the filament Amps falling as the wire got thinner. Boosting the filament transformer got a few more hours running, but eventually the filament just couldn't do the business and it was new bottle time.

Happy days!

Psst… having bother with that overtone crystal?

Trying to VXO an overtone crystal? Or that dratted oscillator won't start on high overtones? Try removing - or not fitting in the first place - the earthing wire to the tin case; and try a subminiature style cased crystal. The reduction in stray capacitance to ground might just do the trick.

Audio Topics

Speech processing

It's accepted audio technology that speech processing can give an extra OOMPH to your transmissions: but too much compression, clipping or limiting sounds - well, being honest - lousy to the receiver's ear. No matter what modulation system you're using, filtering to keep within acceptable transmitted signal bandwidths is important; as is no "flat topping" or other distortion. It just makes the received audio very hard to understand. Therefore, it's important to keep the speech quality as good as possible, without the limiting introducing too much distortion, yet coming into effect very quickly on spikes and releasing just as quickly so no faint signals are lost.

This is exactly the conundrum hearing aid designers face every day, and as amateurs we can learn a lot from these designs. After all, they try to make signals audible for those with hearing problems, just as amateurs try to dig faint signals out from noise, and limit loud noises, just as amateurs take phones off a bit quick sometimes!

A design I came across whilst hunting for a resolution to the paradox of distortionless compression with bandpass filtering "Q" and centre frequency that can be adjusted "on the fly" uses 3 OTA amplifiers: Operational Transconductance Amplifiers, where an input voltage controls an output current. The design is for micro sized on-chip amplifiers, but building with discrete chips is of course perfectly feasible so long as the amplifier specifications are similar enough. The design is at:

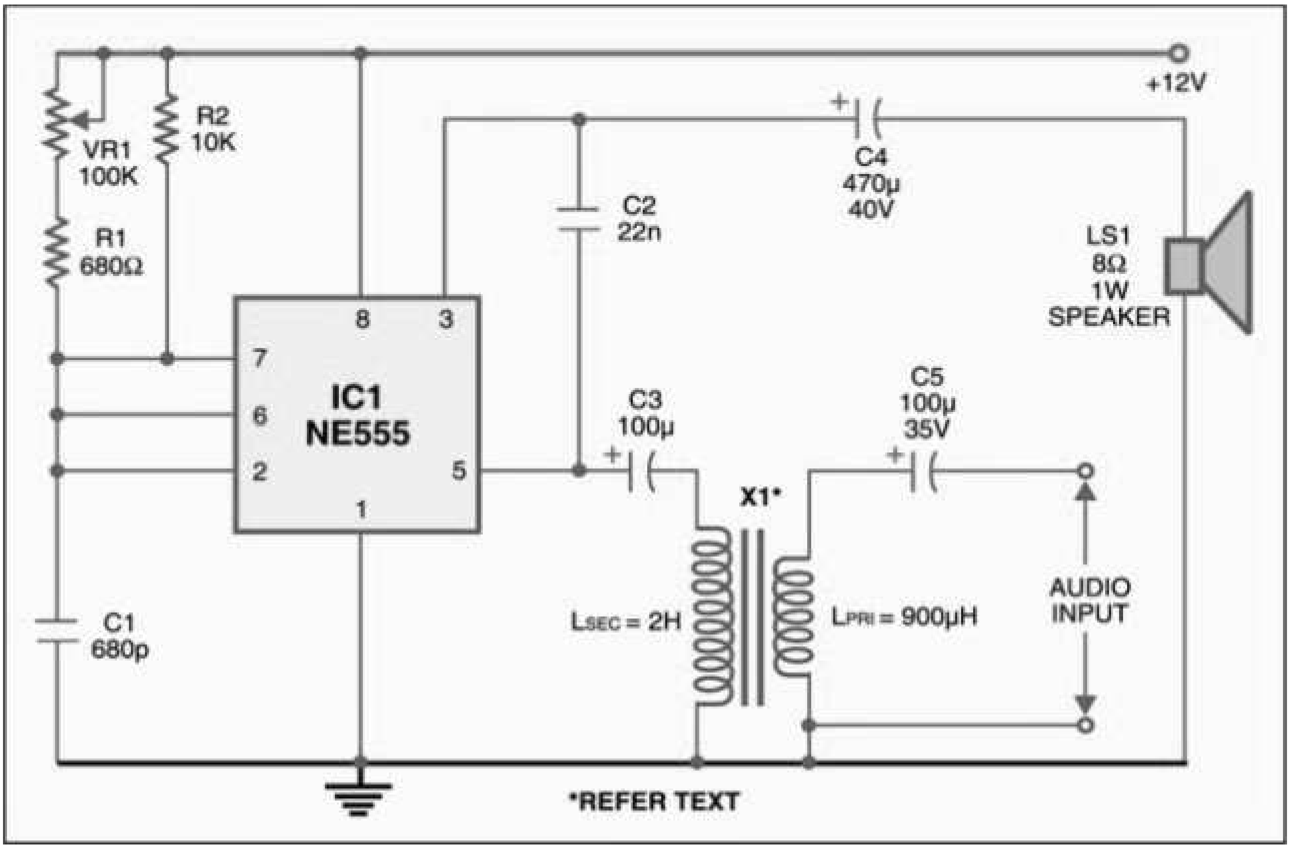
https://cpb-us-e1.wpmucdn.com/sites.dartmouth.edu/dist/f/1307/files/2017/06/A-Bandpass-Filter-With-Inherent-Gain-Adaptation-for-Hearing-Applications-r88h6p.pdf

The limiting is especially noticeable: the circuit need barely one cycle of audio frequency to "attack" and "release". Amateurs could learn a lot by studying the hearing aids now being designed. After all, the most important part of a receiver is the listener's ear, you can have all the fancy RF techniques you like, but if the signal can't get into the listener's brain via his ears "it ain't no good to nobody"!

Another 555 PWM audio amplifier

We've visited this topic a couple of times but this design has an interesting twist: instead of driving pin 5 (control voltage input) with audio, this design uses a transformer to achieve higher audio drive on pin 5 for more output "OOMPH". The transformer isn't noted - but I'm thinking a miniature 5k to 8 ohm job, run backwards for step-up duty, will generate more pulse width modulation on the output.

Please note that the 555 appears in various disguises; the internal construction can vary quite dramatically from one maker to another. As ever a bit of "cut-n-try" will be needed! If any reader has the original of this diagram / article, so I can "refer text" then it would be very useful; the purpose of C2 is a bit of an oddball too as I can't see the point of feeding hefty switching pulses back to the control voltage input an thus into the audio transformer.



Test Gear and Fault Finding

Psst… Need a Spudger?

Yes, a spudger is a good friend to amateurs: for opening those damned snap fit electronics cases or gizmos there is nothing better! They are cheap as chips, and oft used by the mobile phone fraternity for getting into those portable electronic nightmares.

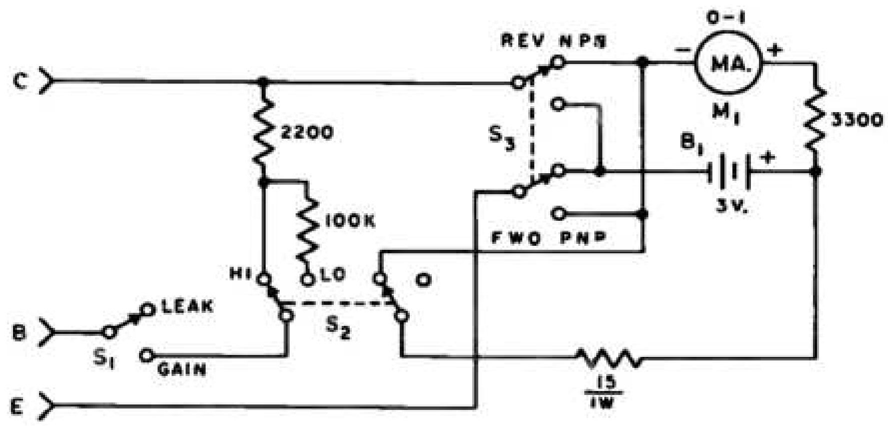
Our friends at Wikipedia say “A spudger or spludger is a tool that has a wide flat-head screwdriver-like end that extends as a wedge, used to separate pressure-fit plastic components without causing damage during separation.”

So now you know, a quick Goggle search will bring up many variations for your delectation!

A simple transistor tester

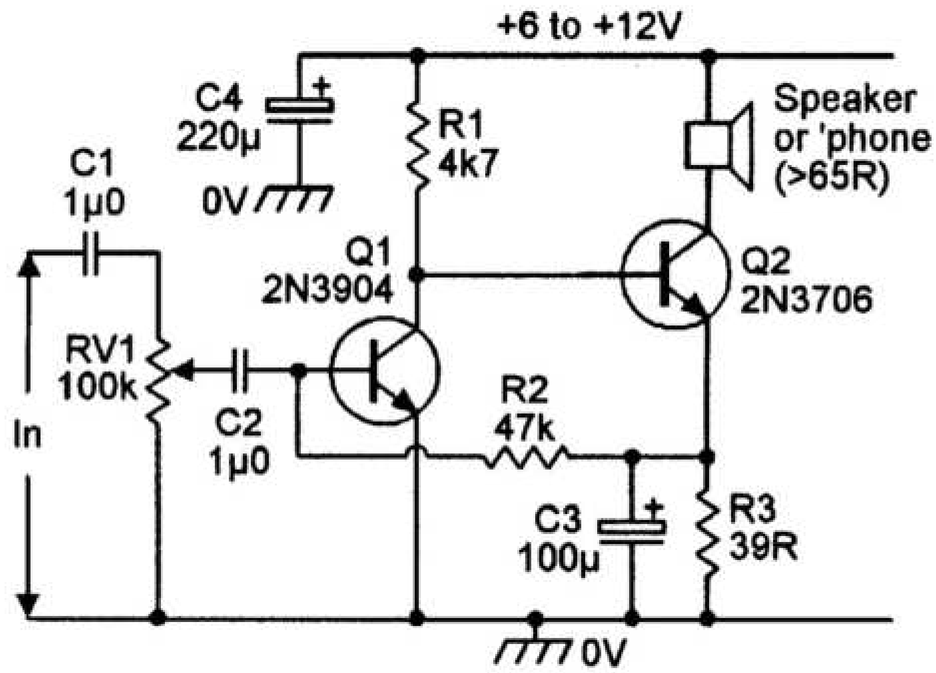
This design is dead simple, and with appropriate supply voltages, can deliver go / no go testing and a basic leakage test. Whilst modern silicon bipolar transistors are virtually leakage free, those junk box items might have suffered static damage or be just plain knackered, so a quick test to check (keep this little box on the back of your bench with some of those weeny croc clip leads for instant connections and a “push to test” button switch). The design is more or less generic but the diagram I believe is from an ancient QST or ARRL year book, to whom I give my thanks.

Note the design can be adapted to power mosfets: feed the top of the 2200 ohm base bias resistor from a pot connected between “C” and “E” , the wiper providing a variable voltage to the “B” terminal to bias the gate “on” so the actual bias point for conduction can be found. The mosfet Drain => C, Source => E, Gate => B.



The first thing to test...

...in a “dud” circuit, is the *power supply*. Be it motor boating, noise, distortion, whatever, TEST THE POWER SUPPLY IS DELIVERING THE EXPECTED VOLTS ON LOAD. I would bet 95% of all faults, in a previously functioning circuit or system, are power supply issues! It’s wisest to start at the power supply output(s) and then diligently track the volts downstream to every destination. Take a look at the circuit below (it’s from the bipolar amplifier cook book, many thanks). It’s a nifty audio amplifier that forms the basis of many audio output stages.



You can see the supply voltage is 6 - 12 volts… well, is that what you read on your Whizzo Multi-Meter, set to read DC Volts, with your meter negative probe on the power supply "0 volt" negative output terminal, to measure:

- the power supply positive output terminal
- the positive plate of C1
- one end of R1
- at least one terminal of the speaker

If, and ONLY if, you get all these readings as correct, can you be sure the positive power supply is reaching all the points of the circuit. Similarly, with your meter negative probe on the power supply "0 volt" terminal do you read zero or thereabouts - a few mV's is OK, it indicates the volt drop along the return leg - on the following nodes:

- the chassis connection of the input - usually the screen connection of the input cable
- one end of RV1
- the emitter of Q1
- the negative plate of C3
- one end of R3

If, and ONLY if, all these voltages are a few mV's (which helpfully illustrate current is flowing back to the power supply) can you be sure the circuit is being supplied with the required volts to function as the designer planned. If the circuit still misbehaves, then go deeper in fault finding, keeping these facts to mind:

- the most common component to cause bother is an electrolytic, they dry up, lose µF's, develop a high series resistance.

- Electro-mechanical items wear out, drop to bits, melt under fault conditions (imagine the effect of the wire from the speaker to Q2 collector shorting to 0 volts?).
- variable resistors are notoriously short-lived: keep that in mind, those who would use potentiometer connected variable resistors to control varicap tuning - they can be the source of some very weird faults as the wiper losing clean contact to the track can create a non-linear (rectifying) element in the circuit.

Only once you've proved the power supply is good, and power is getting everywhere it should, do you dive in and start analysing the circuit and it's corresponding node voltages. The above is a very simple circuit; imagine if you're faced with a much more complex circuit, and on several PCB's for instance?

ALWAYS do your power supply checks as illustrated and you'll nail most faults in double-quick time. That doesn't sort out all problems, I accept; but you'll eliminate a huge amount of trouble - once you've eliminated all possibilities, whatever's left, however improbable, must contain the problem. Well, it always worked for Sherlock!

Resistance Signature Analysis - "cold testing"

Most multimeters are good for testing "ohms" - use that capability to help you identify areas where faults lie, by testing whole blocks of circuitry: get those probes across the electrolytic (or input power Molex connector, etc.) that's the de-coupling capacitor for that section! The idea is that the entire block fed from those points will have a resistance reading that you can compare to the value you read when the circuit was working properly. Well, you DID measure and note it when it worked fine, didn't you? And watch your meter's polarity on ohms test: some meters reverse the polarity. Test a known good diode to quickly reveal the prod polarities. The only snag is you have to wait for the electrolytic to charge; but it's a small price to pay as you're testing a huge block of circuitry.

Take the little audio amplifier above as an example. Connecting your meter on ohms across C4, power OFF of course, then allow C4 to discharge for a few minutes - the time is exactly that needed to brew a mug of tea - and you should read R1 (4k7)+ Q2 base emitter + R3 (33R). If it's much different than this, your one test has identified a possible fault.

You can go further than this: look at Q1, and test on ohms, negative probe still on C4 negative, each pin of Q2. The base should read ~ 47k; the collector should show 4k7 + Q2 base-emitter + 33R, but you'll probably see C4 charging up, swamping the ohms reading for a few moments; the emitter should be solid zero ohms. If you had noted the results in a chart <u>before</u> putting the circuit into service, you could compare your results and see if any degradation has occurred. Make a simple spread sheet or chart, and note the resistances to 0v. And test to +ve supply from each pin or node for future reference.

Taking this further, you can test IC's by noting resistance readings from every pin to both ground and supply volts, and comparing with "working" results taken previously. It's a good idea to use your meter in a low test voltage mode which can't forward bias a PN diode junction; many IC's have clamp diodes on input and output pins to avoid damage from static, over-volts and the like which might swamp the resistances. This is a very powerful test algorithm; but you can see if it's done purely by hand, it can be very time consuming (to say the least). A work colleague of some years ago (thanks, Ray W.) found that ohms testing across the power supply pins of an IC would find duds: this is particularly true for CMOS digital IC's, they are virtually open circuit unless faulty. These were, mind you, the old 4000 series; I haven't tried this on TTL or 74CXXX chips. I tended to do a quick ohms test round all the output pins; a blown output "totem pole" driver would show either short to +ve / Vcc or ground. This technique finds op-amp output faults too.

These techniques are used in computer controlled "bed of nails" test stations to identify dud PCB's, and can fault find to component level, indicating the dud part with a spot of light or an ink dot. As amateurs we don't quite need this level of automation; but resistance signature analysis is a very powerful tool for those involved in amateur radio gear test and servicing.

Use some standards...

When building gear, it's a great idea to standardise your wiring, like below:

Wire Colour	What it does
Yellow	Heaters
White	Cathodes
Grey	AGC and Negative grid bias supply(s)
Red	HT Positive supply(s)
Pink	Stabilised Screen supply(s)
Black	HT Negative supply
Blue	Control Grid
Green / Yellow	Chassis Earth

Where two different voltage sources are employed for AGC and Bias then number "ident" sleeves (or coloured insulating tape "collars") are fitted at appropriate points along a wire run, i.e. after entering a screened box or sub-chassis - the collars following the resistor colour code, and fitted as thin strips of insulating tape cut from the wider roll. Thus a grey wire with black collar = bias supply zero; with brown tape collar, bias supply one, and so on. The same identification is used where two (or more) positive supplies or two (or more) screen stabilised voltages are employed.

Control grid wiring might often be in screened cable, so again coloured insulating tape collars are used as screened cable doesn't often come in any colour other than black.

Transistor circuits rarely need such identified wiring; but red for positive supply and black for negative is a good idea, saving time and effort in fault finding or, that most frustrating job, de-bugging a circuit you've just designed and built.

It's a fact, beyond doubt, the hardest faults to find are wiring errors or construction errors *you've done yourself*. The human psyche that prevents you from fault finding your own work!

Antennas

From Frank Barnes

who prompted me to see some notes on antennas, this I did, so take a look at:

https://www.qsl.net/va3iul/

which would take a lifetime or two to absorb, and...

http://www.w3pga.org/Antenna

...which would account for a few more lifetimes too! All good stuff: “seek and ye shall find” is a good principle!

Condensation in "balun" antenna matchboxes

It’s one of those perennial questions: do I drill a "vent" hole in my bottom-of-the-mast matching unit / transformer / balun / what-have-you? What you’re really asking is about condensation and Relative Humidity. It’s a topic not many amateurs understand, but a few words of explanation and a look at what our friends in the power distribution (overhead lines division) do might help.

Here’s the gist of it. You’ve made a neat “matchbox” that does the business for your super new Whizzo Wonder Sky Blaster, and you want to box it up neat and tidy to (1) stop the kids sticking fingers, sticks, the dog’s tail, etc. into the works; (2) keep next door’s cat / ferret / kids / dog from doing something “orrible” in it (and themselves); (3) preserve the electrical magic smoke by keeping the lashing rain and gales that we call summer here in the UK out; (4) stop condensation causing short circuits and corrosion. I think that’s about it, but no doubt your location will have other nasties just waiting to get at the matchbox innards.

Some basic facts for consideration: air, the stuff we breathe, has water in it, as water vapour, and this water creates the “humidity”. The amount of water air can carry depends on the air temperature: warm air holds more water than cold, and the air pressure. If you try to put too much water vapour into air, or the air temperature drops, or pressure falls, then the air can’t hold the water vapour: liquid water condenses on surfaces. This is called “saturation”, the air has so much water it can’t take any more. Thus we measure how close air is to condensation (saturation) by “Relative Humidity”: that’s the % of saturation the air currently is. 100% Relative Humidity = condensation, and that’s an end of it. Until the weather turns warmer, warm air can hold more water than cold, so the condensation becomes water vapour in the air.

Now all that means one thing: if you mount your matchbox in a sealed box with a small vent hole, then as the weather turns cold of an evening, the air inside will dump it’s water as going cold has saturated it. The air inside has a connection to the air outside, and that, in the UK, is generally pretty much wet. So a vent hole guarantees condensation, that’s a fact. As atmospheric pressure changes, air with water vapour in it is forced into the enclosure; vice versa when outside pressure falls, air is drawn out. Consider too the diffusion of gases: no matter how small the hole, molecules of air and water vapour will intermingle - and the smallest hole will allow millions of air molecules to pass to and fro!

Now consider no vent hole. The cables are entering and exiting via sealing glands, no outside air can get in, or water for that matter. Will there be condensation inside the box on a very cold night? “Yes” if the box was sealed up with humid air inside, “No” if the box was sealed up in a very low humidity environment. How can you create a very low humidity environment? From dried compressed air, or nitrogen, like they do when making double glazing sealed units. Not an easy job for the amateur! You can buy desiccant material, which is designed to soak up water and hold it, so you can assemble your matchbox in your kitchen, bung in a bag of desiccant and seal her up tight as a drum: the job’s a good ‘un, if (and it’s an enormous IF!) the box seals are completely air tight (not easy, no sir).

Enter our power distribution engineers, and let’s see how they handle 415 volt 3 phase electricity on overhead lines, up on top of poles. The use **big** ceramic covers to protect their joints and lead-ins, open to the elements at the bottom, water tight at the top, the outside air can blow freely around them. Rain doesn’t bother them; the high voltages are safely up inside the ceramic covers. Nor does temperature; being wide open, the air in the covers is at the same temperature as the air outside, and pressure: no problem there. The only time flash-overs happen is when dirt in the air makes a conductive path across the insulation, but this is rare as the dirt tends to fall due to gravity and won’t stick to the dry (and draughty!) surfaces up inside the ceramic covers.

The answer is, for amateur matchboxes, mount them in the top of an inverted waterproof box, with an open bottom covered with mesh and / or gauze. Run your wires in and out through holes in the mesh, forming drip loops appropriately to prevent water ingress but the box being closed at the top and the components tucked away up inside, you won’t get problems.

Make your coils from enamelled wire and use transformer varnish (from various online sales outlets) to coat the windings, seal carefully all coax cable ends but keep in mind employing quality BNC (“Bayonet Navy Connector”) or , if you can get them, TNC (“Threaded Navy Connector”) or gasket N-Types; form the coax into downward facing loops to deter water ingress into the open ends - but DON’T coat variable capacitors (for obvious reasons…).

The open bottom lets the innards breathe, the box above keeps the rain off, and the mesh keeps the kids and bugs out. Hopefully!

ATU / matching and Cos φ, the Power Factor

Don’t over-think it, low dipoles and multiple “fan” dipoles for other bands adjacent modify the impedances far more than anything else! VNA’s and the like are all well and good, but if your SWR reading is around 2:1 you’re not going to get much return for the effort in getting it lower. It’s very easy to get waylaid by measuring everything in sight, then trying to decipher the results. I’d bet my shirt that as the weather changes, the wind blows the wires, next door erect a steel mesh fence, your “exact” measurements are way off!

Most amateurs far prefer the ATU / matching network to be adjacent to the transmitter: inside, warm and dry, easy to tweak is thought better than going outside to adjust the match at the aerial. This means you’ve no idea what’s going on in the coax - or what’s actually getting to the bit of sky wire that’s doing the radiating. One thing you are sure of: your coax in this situation isn’t a feeder - it’s part of your sky wire, with RF on every surface! The antenna starts immediately after the matching unit, so put it at the feed point of your antenna!

Albert Einstein is alleged to have said “make things as simple as possible; but no simpler” and that’s good advice. You can measure any variable you want, with whatever esoteric gizmos you fancy; it’s the translation of those measurements into real life electrical components that’s the hard bit!

Truth be known, you only need basic tools, and some electrical engineering knowledge to find out where the optimum conditions are with your antenna. If you add at the feed point some equal capacitance to each half of your dipole and the indicated match improves, your dipole wires are too long; if adding capacitance makes the match much worse, they are too short. The electrical engineering behind this is proven: it's all to do with resonance and AC theory. For your dipole (or single wire half wave end fed come to that), the best radiation occurs when the wire is a resonant multiple of ¼λ - be that mechanically OR electrically - and is described as Power Factor by electrical engineers. Power Factor describes watts i.e. when the wire is truly resonant. If the wire is too long, it's inductive and the Power Factor falls; similarly if the wire is short, it's capacitive and the Power Factor falls.

Only real watts radiate, any capacitance or inductance still draws current, but out of phase with the voltage: it's reactive current and won't radiate! Reactive power is measured in VAR's, "Volt Amps Reactive", and it's your job to ensure you maintain a Power Factor of near as you can to one. For reference, Power Factor = cos φ, and Watts = VI cos φ where φ = the phase angle between amps and volts. If the amps are in phase with volts, then cos φ = 1. All watts, zero VAR's!

Electrical engineers frequently have to compensate for poor inductive Power Factor loads - motors are notoriously inductive and cause bad lagging Power Factor on the distribution network. This is a universal AC theory: it doesn't matter whether its at 50/60Hz, or 1 GHz, Power Factor still applies! To correct poor inductive (lagging phase angle) Power Factor, electrical engineers add some VAR's of opposite phase (leading phase angle) so the reactances cancel out, leaving pure watts being drawn from the distribution network. In radio terms, to cancel out inductance (lagging Power Factor), add capacitance (leading Power Factor) in equal amounts thus creating a purely resistive load (resonance). These are fundamental relationships of AC theory, and are just as true for amateur radio operators as to power electrical engineers.

Keep in mind that this gets the best resistive load; and that load might not be 50 ohms! Maximum power transfer occurs when the resistance of the transmitter equals the resistance of the load; you might need a transformer (of some form) to match the antenna to the transmitter. The radiated signal will be highest when these resistances are equal, so you've two jobs to do: (1) get rid of the reactive component of your antenna and (2), make sure the antenna resistance equals the transmitter resistance (usually 50 ohms, but can differ in some instances - particularly home brewed gear).

SWR can make you stupid...

...is an article written by Eric Nichols KL7AJ: I asked Eric if I could quote it, he was happy with that, and commented it was part of a bigger project. The article is - to put it mildly - superb. I've been involved with transmission lines of one sort or another all my working life, and Eric's simple descriptions and examples make transmission lines much more understandable.

I mentioned to Eric I was thinking about antenna tuning as "Power Factor Correction" (see previous, above) and he agreed with me: it's a universal AC principle and applicable at any frequency, and describes getting as many real watts into a sky wire as possible just as much as correcting the lagging Power Factor of an induction motor.

That's the gift of amateur radio: although RF power can be an unruly beast (if you let it) she still has to dance to the music of the Universe, and a few basic electrical principles go a long, long way to understanding what's really happening.

I have put a link to Eric's article HERE. It's from eHam, whom I thank very kindly. If the link won't work for you, see: https://www.eham.net/article/23317

Balanced or unbalanced?

Imagine the scene: you've a transmitter feeding an antenna via a twin wire feeder, and you're concerned that the currents in each of the feeder line wires aren't equal; i.e. the line is unbalanced. The same principle - sort of - applies to coax, the signal is supposed to be entirely contained inside the outer screen.

Frank Barnes, W4NPN, pointed me towards Lloyd Butler's (VK5BR) work on measuring line currents: see HERE or if the link won't work:
http://users.tpg.com.au/ldbutler/Line_Diff_Long_Meter.htm

Lloyd's system is to insert toroidal current transformers into each line (or coax inner & outer) and observe any difference - this difference being taken to be the "unbalanced" current. Lloyd gives a simple schematic which shows how the current that represents the imbalance returns to the transmitter without going through the appropriate feeder path.

This is very similar (if not identical?) to a modern "ELCB" safety trip: it looks at the live and neutral currents, and if any difference in either causes a trip, this being assumed to be earth leakage. The measurement is made by a single toroid current transformer, the currents flowing "forward" being cancelled by the "return" current, the magnetic fields from each current cancelling. This is to ignore standing waves, as these don't bother 50 / 60 Hz ELCB's - the wavelength is 6000km / 5000km! I think unbalanced twin wire feeders will show a reading equal to the imbalance if the twin feeder is passed through a single current transformer.

One other thing crosses my mind. As Eric Nichols, KL7AJ, points out in his write up about SWR meters, it's a fundamental fact that a wire can't have two different voltages on it in one place (or two different currents, for that matter). It's an interesting measurement that Lloyd proposes on coax cables: measuring the core and screen currents by separating the screen from the core into two separate wires, each going through a toroidal current transformer causes me think of how coax works by skin effect keeping the RF current on the OUTER of the INNER (core) conductor, and the INNER of the OUTER (screen) conductor.

The RF energy travels in the insulating medium between inner and outer conductors, guided and constrained by the conductors; it manifests itself in currents *on the surfaces* of the coax conductors. Lloyd's measurement to see if RF current flows in the coax core and a smaller proportion of this current returning in the screen because of imbalance in the antenna load (by an external wire and resistor *outside* the current transformer to create artificial leakage perhaps?). I believe a *single* current transformer would give an imbalance reading, as per the ELCB imbalance principle.

I have absolute respect for Lloyd, I'm sure it's me that's missed or misread something. Maybe I'm oversimplifying things… and that's *exactly* what Einstein tells us not to do!

I'd welcome any feedback, please feel free to enlighten my darkness.

Lightning strikes...

I worked on contract for a security alarm manufacturing company in Rossendale, in the Technical Support group and in between phone calls from customers I analysed faulty items returned. One aspect of this work was examining dud land line telephone diallers. These devices had to comply with British Telecom regulations as BT (Now “Open Reach”) are quite fussy about what’s connected to their network.

This work taught me some salient facts about lightning strikes - either striking directly onto the phone line or induced in the line by nearby strikes. These I list below:

(1) Direct strike: dialler blown to smithereens, nothing much left of gas discharge tubes, spark gaps, wiring, PCB, et al;

(2) Induced over-volts: Some bits of the dialler still in one piece but with big holes in IC’s, circuit boards, gas discharge tubes blown to bits, PVC wires blown apart with no insulation left.

Now some simple engineering facts I observed in my working life:

- A spark to jump 1” needs 30kV between needle points; from flat plates or wires you need considerably more;
- Lightning strikes contain vast energy: take a look at the copper bars used to Earth the lightning rod on a tall building or church spire;
- Gas discharge tubes can shunt not too many Joules of energy before they explode, see HERE;
- Gas discharge tubes are slow to switch on;
- Forget zeners - they are but mere chaff in the wind when hit with a few HV Joules;
- Spark gaps (like a ¼ λ stub, for instance) need plenty of kV’s to flash over, and once arcing can have many hundreds of volts across the arc, all of which impinge on your radio gear;
- A PCB holding gas discharge tubes and the like connected to a sky wire is likely to explode / catch fire / vapourise in strike conditions;
- The strike, in running to Earth to equalise the electrostatic charge induced in the ground, can cause Earth wires of adjacent equipment to inject many hundreds of Volts (if not kV’s!) right up the circuit board’s Earth connection (it’s called “ground bounce”). Recall Corporal Jones in Dad’s Army: “They don’t like it up ’em - they DO NOT like it up ’em!” Certainly true for PCB’s!

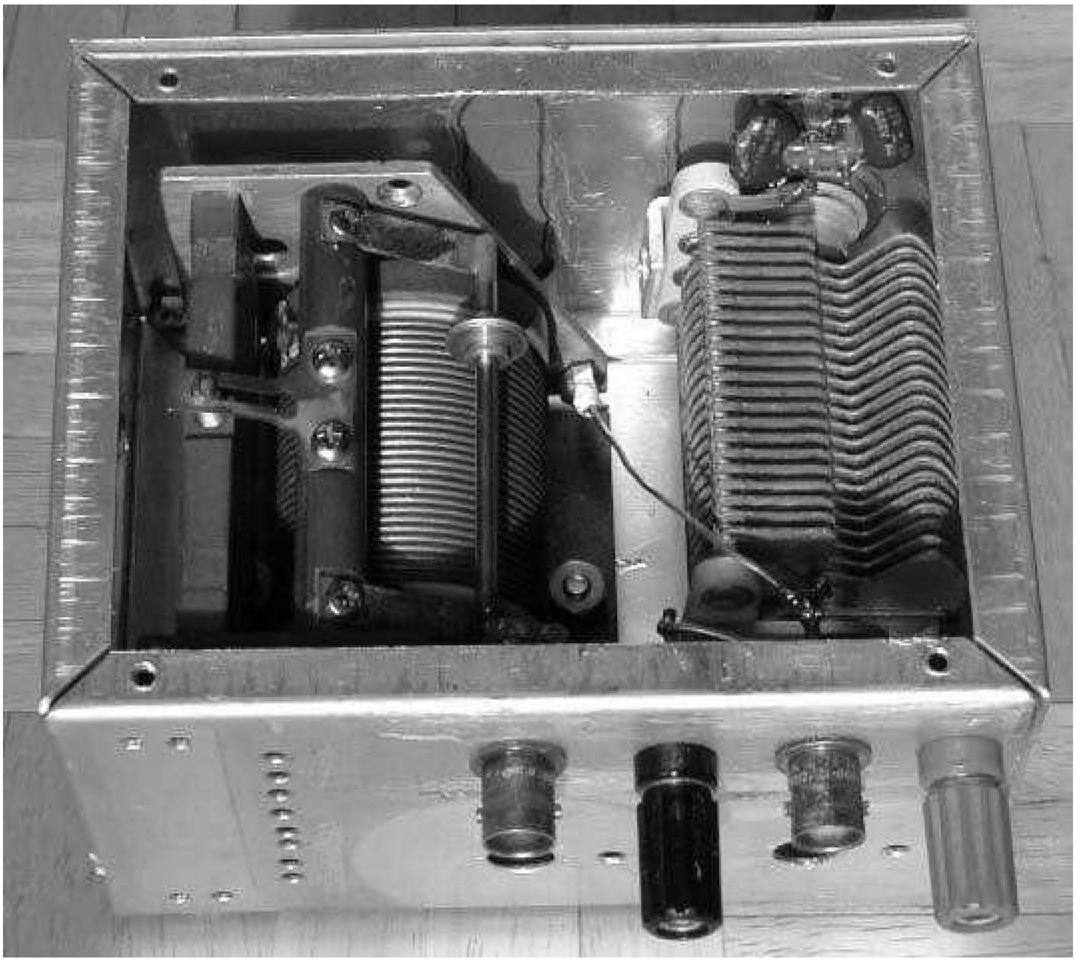
In short, if you live in lightning alley and get a lot of strikes every lightning season, don’t muck about: switch your amateur radio gear to valves, as at least they don’t object to a few kV’s and withstand flash-overs without too much damage.

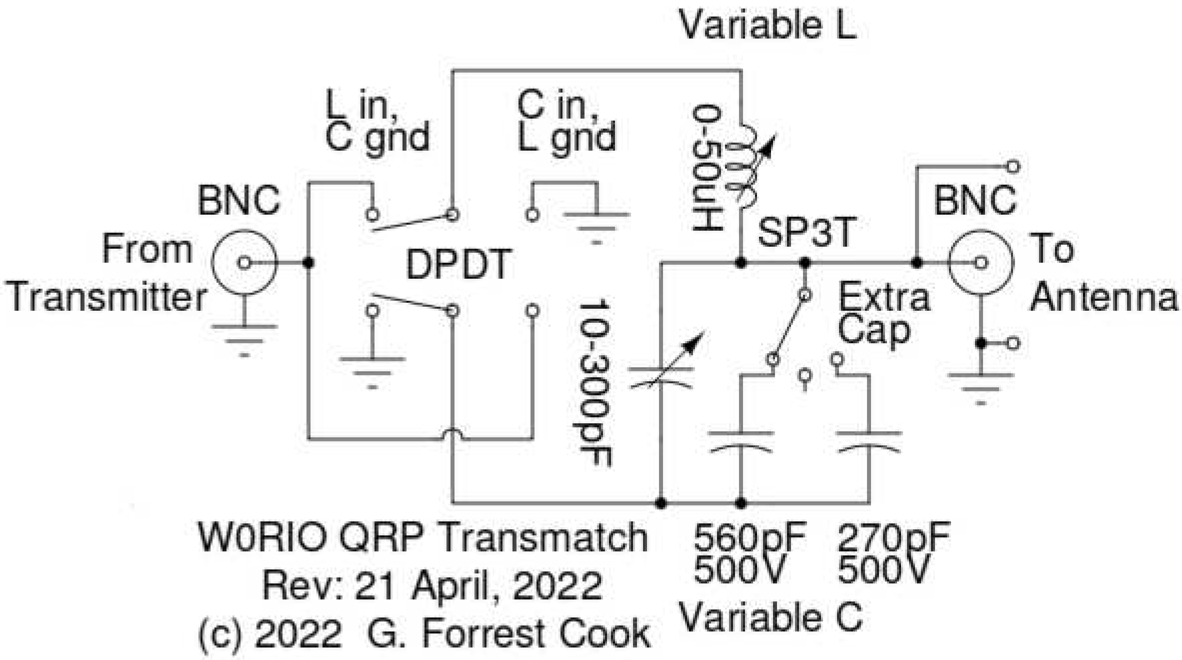
Slowly induced or wind generated static charges, which can easily be many kV’s on an outdoor dipole, it’s a very good idea to connect each antenna element and feeder(s) to a deep planted Earth rod - (which any half decent antenna installation should always possess) via 1 - 10 MΩ hefty HV resistors (NOT tiddly ¼Watt jobs).

An ATU of thorough pedigree…

From that very capable constructor, Forrest Cook, presented below:

QRP Antenna Tuner





Introduction

This project is a QRP (low power) antenna tuner (trans-match) for use in the short wave amateur radio (Ham) bands (3-30 Mhz). It allows a wide variety of antennas to be connected to a low or medium power transmitter or transceiver. When the circuit is properly tuned, the maximum transmitter power will be delivered to the antenna. The tuner is normally is used in conjunction with a standing wave ratio (SWR) meter, this meter may be built in to some transmitters. This is an updated version of the circuit, one extra switch has been added to greatly increase the tuning capabilities. See the Original Circuit for reference, note that the photos are from the earlier version of the circuit.

This tuner is fairly efficient and it is very simple to build and use. With the parts shown, the maximum power through the unit is approximately 50 watts. The tuner is small enough for backpacking and is useful for matching many of the types of antennas that one might set up on a camping trip.

The tuner can be used for getting a more perfect impedance match to an antenna that is resonant at or near the frequency that is being used. It is also useful for using an antenna that is designed for one frequency (band) with a transmitter that is set to a different band. A good rule of thumb is that it is usually much easier to run a lower frequency antenna with a higher frequency transmitter than vice versa.

Theory

The purpose of a trans-match is to match the impedance of a transmitter, typically 50 ohms, to an antenna system with a different impedance and reactance. A trans-match can add series or parallel capacitance and inductance to produce a more resistive (non-reactive) load to the transmitter. The circuit in this trans-match consists of a variable inductor in series with a variable capacitor (L-network). The transmitter typically connects to one end of either the variable capacitor or the variable inductor. The antenna connects to the junction of the inductor and capacitor. The input and output connections can be swapped for more matching possibilities.

Construction

The tuner was built into an old aluminium project box that had been used for at least one prior project as indicated by the numerous holes. This box was just large enough to hold this tuner circuit, a larger box would make construction easier. A rectangular piece of aluminium was added to the front of the box to cover up some of the old holes. Several new holes were drilled in the box for mounting all of the components required by this project.

When laying out the parts, it is a good idea to leave room around the sides of the variable coil and capacitor to prevent RF arcing. Be sure to keep both sides of the variable inductor insulated from the box, you may need to use insulated bushings (non-conductive washers) on the inductor's shaft. The variable capacitor should also be isolated from the box, insulated washers were used to mount the capacitor's shaft to the box. Insulated shaft couplings can also be used if you have them. Use heavy hook-up wire to connect the various components together, 18 gauge or heavier tinned copper wire is recommended. Use the shortest wire lengths possible. Teflon insulation can be used on the wires, although it is optional.

Use

Connect the transmitter output to an SWR meter, connect the SWR meter output to the input of the antenna tuner, and connect the antenna to the output of the tuner. An SWR meter that has two meter elements is much easier to use than one with a forward/reverse switch and a single meter element. Antennas with a coaxial feed line can be connected to the BNC output connector. Random wires and antennas with balanced feed lines can be connected to the banana jacks. An external balun transformer can be inserted between the tuner and a balanced feed line if one is available. The transmitter should be connected to a good earth ground at its chassis if a ground is available. Random wire antennas will typically work the best if a counterpoise wire is connected to the ground terminal and run in the opposite direction of the antenna wire.

With coax-fed antennas, the best location for an antenna tuner is the point where the coax feeds the antenna, or as close to that point as is practical. This can usually be achieved with vertical antennas. With horizontal antennas such as dipoles, it is usually difficult to mount or adjust a tuner that is located at the antenna feed point, so most people will locate the tuner on the transmitter side of the coax. When using a dipole at a frequency that is not at a resonance point, the coax will become part of the antenna system and will vary the radiation pattern.

There are two normal ways to use the tuner, feeding into the inductor or feeding into the capacitor. Either of these two methods can be selected by the DPDT switch. The antenna is connected between ground and the junction of the inductor and capacitor. In cases where a good match cannot be found, it may be possible to find a match by connecting the transmitter to the antenna connector and the antenna to the transmitter connector.

Start by feeding the transmitter into the inductor with the DPDT switch. Set the extra capacitance switch to 0 (center), adjust the variable capacitor to near the minimum capacitance. Adjust the inductor to near the minimum inductance. Transmit a CW carrier and observe the SWR reading. Adjust the capacitor and inductor and try to find a setting where the forward power peaks and the reflected power dips. If the best match is found with the capacitor at the maximum value, switch in either the 270pf or 560 pf capacitors and re-adjust the variable capacitor and inductor. If you still cannot find a good match, change the DPDT switch to the other setting to feed the transmitter into the capacitor, then start the tuning process again. Once you achieve a good match, make a note of the trans-match settings for the particular frequency and antenna combination for future reference.

A well-matched condition is usually associated with a dip in the swr reflected power that coincides with a peak on the swr forward power. In some cases, the reflected power will dip but the forward power will not be at its peak value. If this happens, you may get more power to the antenna by tuning for the max forward power while accepting the fact that there will be a small amount of reflected power. When using a tube-based transmitter with a PI output network, it may be necessary to find the best match with the antenna tuner, re-tune the transmitter's output tank, then tweak the antenna tuner for the peak match.

If your transmitter has an adjustable output power level, it is a good idea to adjust the antenna tuner using low power. When a good match has been found, increase the power and re-adjust the coil and capacitor for the lowest SWR. Be careful not to leave the transmitter on for too long in the unmatched condition, doing so can damage a transmitter's output transistors. Tube-based transmitters are generally better able to handle mis-matched conditions for longer periods.

Caution: higher power transmitters can generate high voltages within this circuit, don't touch any of the internal wiring or the antenna wires when the transmitter is operating. If the roller inductor's adjustment shaft is connected to the inductor's wiring, the shaft should be mounted so that it does not come in contact with the metal box. The set screw on the knobs may become electrically hot during use, it is a good idea to cover them with a drop of hot-melt glue or candle wax after the screw has been tightened.

Parts

- variable inductor (roller), approximately 0-50 uH
- variable capacitor, 0-300pf or 0-360pf, can be scavanged from an old tube radio
- DPDT switch
- SP3T rotary switch (or center-off SPDT switch)
- 270pf, 500V silver mica capacitor
- 560pf, 500V silver mica capacitor
- two BNC connectors (or PL-259, the connector that won WWII, if you prefer)
- two banana jacks (optional)
- two insulated plastic knobs
- miscellaneous screws, nuts, and washers
- solid hook-up wire, 18 gauge or similar
- aluminium box, big enough to contain all of the components

The variable inductor may be difficult to find, the best places to look are at ham radio swap fests and surplus electronics parts companies. Variable inductors are preferred since they can be fine-tuned easily. A fixed inductor with switched taps or a flexible wire with a clip lead on one end can be substituted. If you plan on using a fixed inductor, an air-core type is recommended. A toroidal ferrite core inductor will also work, but the core may absorb some of the available RF power.

See Wikipedia's Antenna tuner article for more background information and Ulrich L. Rohde's (N1UL) antenna tuner circuit which can tune a wider range of antenna impedances. Ulrich Rohde has also published a more detailed article (zip) in German.

Mr. Veritasium and his “question”

Whether or not this is a deliberate “teaser” or a genuine attempt to enlighten the darkness prevalent in electrical engineering, I don’t know; this is an area of electrical theory “where there be dragons”, and a lot of very strange people (that’s me included, I should add) who deal with that electronic hinterland that is “neither fish nor fowl” as Shakespeare has it - the World of fast pulses and transmission lines.

As radio amateurs, we are more or less familiar with bunging RF signals down transmission lines and reflections, SWR and the like: but keep in mind a pulse, with an edge time of 1nS, represents a bandwidth to transmit it without distortion of (roughly) 2 divided by the 10% to 90% rise time. Thus a 1nS rise time edge requires a circuit of bandwidth capability of 2 divided by1 x 10^{-9}; i.e. 2GHz. That’s well in the microwave region, just as a 1pS rise time represents a bandwidth of 2 divided by 1 x 10^{12}Hz, a staggering 2THz.

You might think generating such speeds is well beyond practical means; well, you can do it by using a small blob of mercury and a needle as a switch: the mercury has an incredibly fast open and close electrical characteristics. I don’t recommend you play with liquid mercury; it’s a shortcut to the Mad Hatter’s mix of craziness and toxicity. No, just get a “mercury wetted” relay, that will do just fine. Of course, the switch might be fast, but you’ve got wires and connections to get the signals in and out of such a switch, and that’s the added L, C, & R that drops the speed. The switch itself is incredibly fast.

Mr. Veritasium posed a question on YouTube that involved - at first glimpse - two 300km long open wire transmission lines, to connect a battery to a light bulb. This is a theoretical light bulb; it responds instantly, and needs only the merest sniff of juice to light her up to full brilliance. The question was, “how long after closing the switch does it take for the light bulb to illuminate?”.

See: https://www.youtube.com/watch?v=bHIhgxav9LY and my diagram #1 (below a bit)

My initial thought was to look at the time delay round the loop, i.e. two one second delays - but no, this isn’t what is proposed. The positioning of the bulb and the switch are the key: Mr. Veritasium proposes the time delay for energy to cross the 1 metre space between the switch and lamp is the delay; about 3 - 5nS (roughly a foot per nanosecond).

Now consider my picture #2. This shows the condition of the switch, lines and lamp after connecting the battery. The positive side of the battery has now made all the wire marked “+” positive with respect to the short wire connecting the switch wiper blade to the battery (voltage source) negative.

The switch closes as shown in my picture #3; the falling edge races out to the right, current flowing to neutralise the “+” charge on the wire and eventually the negative edge reaches the lamp, after surmounting the discontinuity caused by the folding at the right hand end. Once the edge has reached the lamp, there is full battery volts across the lamp, and she lights up to full brilliance.

Meanwhile, Mr. Veritasium believes, the electric field created by closing the switch crosses the 1 metre gap, and initially lights the lamp (maybe a bit dim…!) in roughly 3 - 5nS. This I struggle with; any capacitance across the 1 metre gap to a very short length of wire between battery negative and switch wiper will be orders of magnitude less than the line capacitance, both line to line and line to earth (roughly the same as free space, 8.854 pF per metre). Mr. Veritasium thinks the electric and magnetic fields cross the 1 metre gap after t = 0 and this proves the whole of the energy is transmitted more or less instantly, not in the wires, but in the E and H fields across the 1m gap.

Due to the storm of protest Mr. Veritasium aroused with his thought experiment, he set up a short line version of his theoretical circuit, and by using a fast oscilloscope, produced what he claimed to be proof of his concept. I've seen these signals and measurements in his video: he used - as far as I could see - single point 'scope probes, the type where you clip an earth lead to the "common" and touch the tip of the probe to the point being examined. A low level step appeared on the oscilloscope screen a few nS before the expected exponential rise of voltage which eventually produced full power at the lamp terminals. Mr. Veritasium could have used a fully differential 50 ohm probe set, that needs no earth clip "common" connection - but these are as rare as hen's teeth, and (probably) wouldn't "prove" his point - or did he "float" his oscilloscope, and thus pick up noise?

The whole point of measurements in an experiment is that the measurements don't disturb or alter the experiment in any way. This is ignored in Mr. Veritasium's experiment: indeed, he significantly alters his results by having the oscilloscope and probe leads draped all over the critical bit of the circuit. The outer screen of the probe leads would easily pick up the "wanted" signals (see Ivor Catt's notes on "crosstalk" at: http://www.ivorcatt.co.uk/em.htm) and these "wanted" signals, coming into the load resistor (that replaced the "magic" light bulb) from opposite directions, thus would ADD in a differential probe; not to mention dangling 20pF / 1M-ohm oscilloscope probes on the end of an open wire line. One other point: just where does Mr. Veritasium connect his oscilloscope probe "ground" clip(s)? Battery negative? I think not; this would shunt the 300km line with the probe's 1M-ohm and 20pF!

Too many questions, a dodgy experimental measurement, absence of a clear diagram to show how the measurements would not disrupt the results expected. Not good, not no how!

We now get the situation in my picture #4: all the right hand line is now at battery -ve potential; all the left hand side is at battery +ve potential. The lamp is fed by current from the battery and a magnetic flux surrounds the wires; as does an electric field between the different potentials. Note however the capacitance to earth. The right hand side I've lumped as one big capacitance: if the switch is opened, and in light of this capacitance, how long does it take for the lamp to extinguish?

All this is a re-iteration of the "for and against" discussions Ivor Catt suffered way back in the 1970's; thankfully Ivor's work is now fully accepted and is available on line at:

http://www.ivorcatt.co.uk/em.htm

which I thoroughly recommend you see.

This was a “bible” for those of us who struggled with nS / pS laser LED driver circuits went to for help. Ivor had nailed the problem, found the proven historical background from Oliver Heaviside’s work and applied it to printed circuit boards, capacitors, inductors, semiconductors and the like. The energy in an electrical circuit is indeed in the fields surrounding the wires, which guide the energy from a source to a load just as a waveguide or a coax cable guides RF. I would strongly recommend you read Ivor’s work, and keep it in mind if you’re finding “weird” effects in printed circuit boards, cross talk, ground bounce errors and the like. Ivor was spot on the money 50+ years before Mr. Veritasium!

As was Tektronix, by the bye… take a look at the Tektronix model 109 pulse generator, a device used a’plenty by yours truly in my formative years, see: https://w140.com/tekwiki/wiki/109 .

The interesting point is that when the contacts of the relay Tektronix used to discharge the “charged” line closed, the pulse moved both into the “empty” uncharged line to the right, and into the “charged” line to the left to reflect off the open circuit left hand end. The nett result is an output pulse twice the duration of the delay line, and half the voltage charged on the line.

We were using pS pulses in semiconductor and LED manufacturing, production & test every day with good results. You can learn a lot by looking at what engineers did yesteryear, and find respect for those who trod in those dark hinterlands all that time ago.

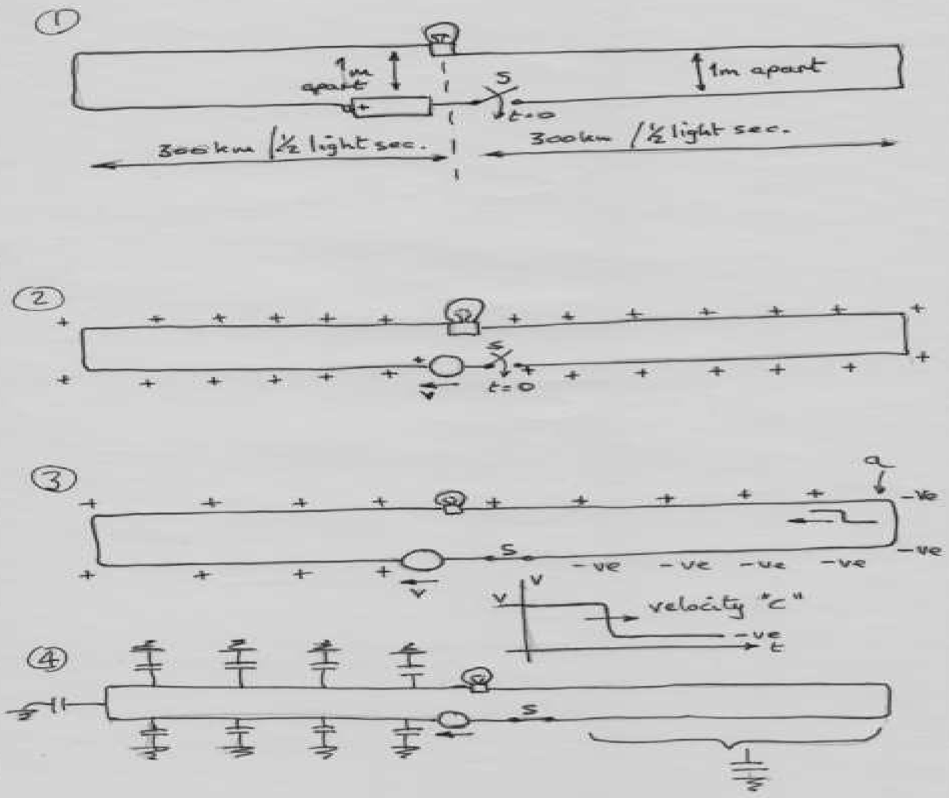
An experimenter (see: https://www.youtube.com/watch?v=2Vrhk5OjBP8) set up a line, and found similar but not exactly the same results as Mr. Veritasium; but, for me the interesting point is around 19.34 in this video: this clearly shows the negative going reflection from a deliberate open circuit in the right hand end of the line. By introducing deliberate reflections, the time delays around the circuit can be seen and thus what is exactly happening displayed.

An interesting version of the Veritasium circuit is the Blumlein configuration, much beloved by high energy thyratron users, typically on large particle accelerators, cyclotrons, and the like. This next reference shows merely a sample; the co-axial lines used can be very complex in higher energy pulse generators, much beloved by the Mega-Watt laser crew, who inhabit some very strange electrical lands indeed.

See: http://www.kentech.co.uk/index.html?/tut_blumlein_pfl.html&2

and: https://www.researchgate.net/figure/Circuit-diagram-of-the-basic-Blumlein-pulse-forming-system-with-one-closing-switch-only_fig1_5404010

If any Hot Iron readers are in contact with Mr. Veritasium, please pass on my thoughts!



1
1m apart
1m apart
S
t=0
300km / ½ light sec.
300km / ½ light sec.
2
S
t=0
v
3
a
-ve
-ve
S
-ve
-ve
-ve
-ve
v
V
V
velocity "C"
-ve
t
4
S

HOT IRON #117

CQ-CQ-CQ

Moving house - again - an apology

It seems only a few months ago I moved to my present home in North West Wales, on the Lleyn Peninsula, but, as ever, external influences have caused me to up sticks and sell my house here ready for a move back to the sun-drenched paradise that is Pennine Lancashire. I'm hoping for a quick resolution and move; no doubt Serendipity will throw the odd spanner or three in the works to derail my plans - that's life and there's nowt tha' can do about it!

Meantime I'm apologising (again) for a somewhat 'slimline' Hot Iron; I'm trying to expand the skills base as you'll shortly read. Hopefully all will settle once I'm ensconced in new Chez Pierre and I'll beg your indulgence until then!

Wanted!

Co-writers who can write about amateur radio. Wages? Nil. Hours? Long and frustrating. Why? Hot Iron doesn't cover to the depth Hot Iron readers deserve: SSB, CW and Digital methods, to name but a few, as these are of interest nowadays - though many "radio" topics might be universal, the more specialised topics, like digital methods of modulation, need an expert to keep abreast of, to keep Hot Iron of sparkling freshness.

It will be obvious to most readers my experience is broadly based on my industrial "working RF life" and my amateur exploits with A.M. - this being the de-rigueur telephony mode I was introduced to in my tender apprentice days: we never forget our "first loves". This has been my core interest in amateur radio - HF, VHF and GHz - with all the ancillary topics like power supplies, fault finding, antennas, and so on.

I'm concerned that Hot Iron is not covering the interests of many amateurs who would enjoy Hot Iron, so I'm seeking co-writers to help covering SSB, CW and Digital operations. If you'd like your ideas, thoughts and discoveries being spread throughout the World via Hot Iron, please drop me an email at equieng@gmail.com where you'll be made most welcome.

Explanation of terms...

...sometimes allocated to radio amateurs - thank you, Alan! - https://youtu.be/kwz-Md6OoyA

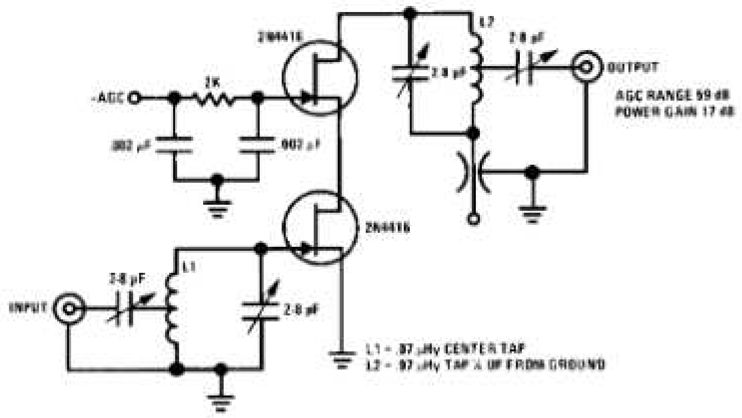
Receivers

http://dpnwritings.nfshost.com/ej/hybrid_mixer/ illustrates how "totem pole" series connected tube plus mosfet(s) in switching mode can be very good mixers. The series connection though, unless designed specifically balanced, cannot eliminate the carrier .

The cascode circuit is a very powerful and well behaved RF amplifier; it's also the basis of a potent mixer. The circuit isn't limited to two active devices: providing you have supply volts high enough you can stack 3 (or more?) devices, to accommodate Local Oscillator, AGC and "signal" inputs. An interesting variant variant to the series connection (unbalanced) cascode is:

https://www.researchgate.net/profile/Corrado-Carta/publication/254021688/figure/fig8/AS:668502918709248@1536394924012/The-two-circuit-topologies-simulated-A-single-balanced-mixer-B-cascode-mixer.png

...where you can see the origins of the Gilbert Cell SA602 / 612 mixer stages, which uses a multiple device cross coupled cascode / long-tail pair(s). Below is a proven rock solid design that I've used many times with easy success:



TL/H/6791–29

200 MHz Cascode Amplifier

This 200 MHz JFET cascode circuit features low crossmodulation, large-signal handling ability, no neutralization, and AGC controlled by biasing the upper cascode JFET. The only special requirement of this circuit is that I_{DSS} of the upper unit must be greater than that of the lower unit.

Transmitters

An interesting balanced modulator...

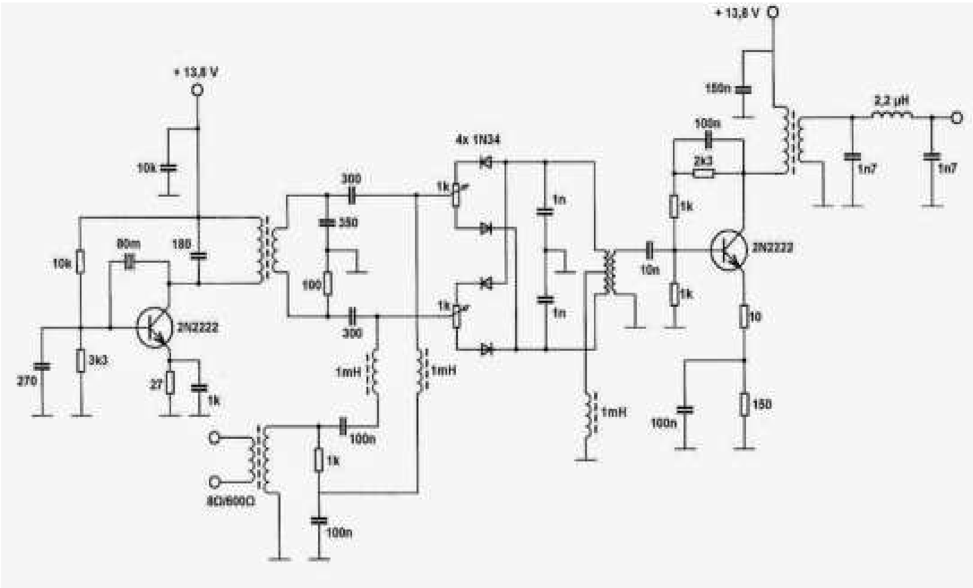
In automotive electronics systems, a "signal" bridge rectifier is often required, rather than the more common power supply rectifier. Fast low current diodes are easily obtained, but automotive electronics designers far prefer IC's for better reliability, easier assembly and test. Fast "signal" bridge rectifiers are available in SMT packages, and as such are perfect for balanced modulator work: they are fabricated on one piece of silicon, at the same temperature, gas flows and other processing: in other words, the diodes are usually well "matched" - thus ideal for simple DSB mixers.

The RH 02 bridge from Diodes Inc. is one such bridge, featuring diodes with 13pF capacitance, not very much more than a 1N4148 at 4pF - but assembled, and beautifully electrically balanced in a SMT package, see:

https://www.diodes.com/part/view/RH02#

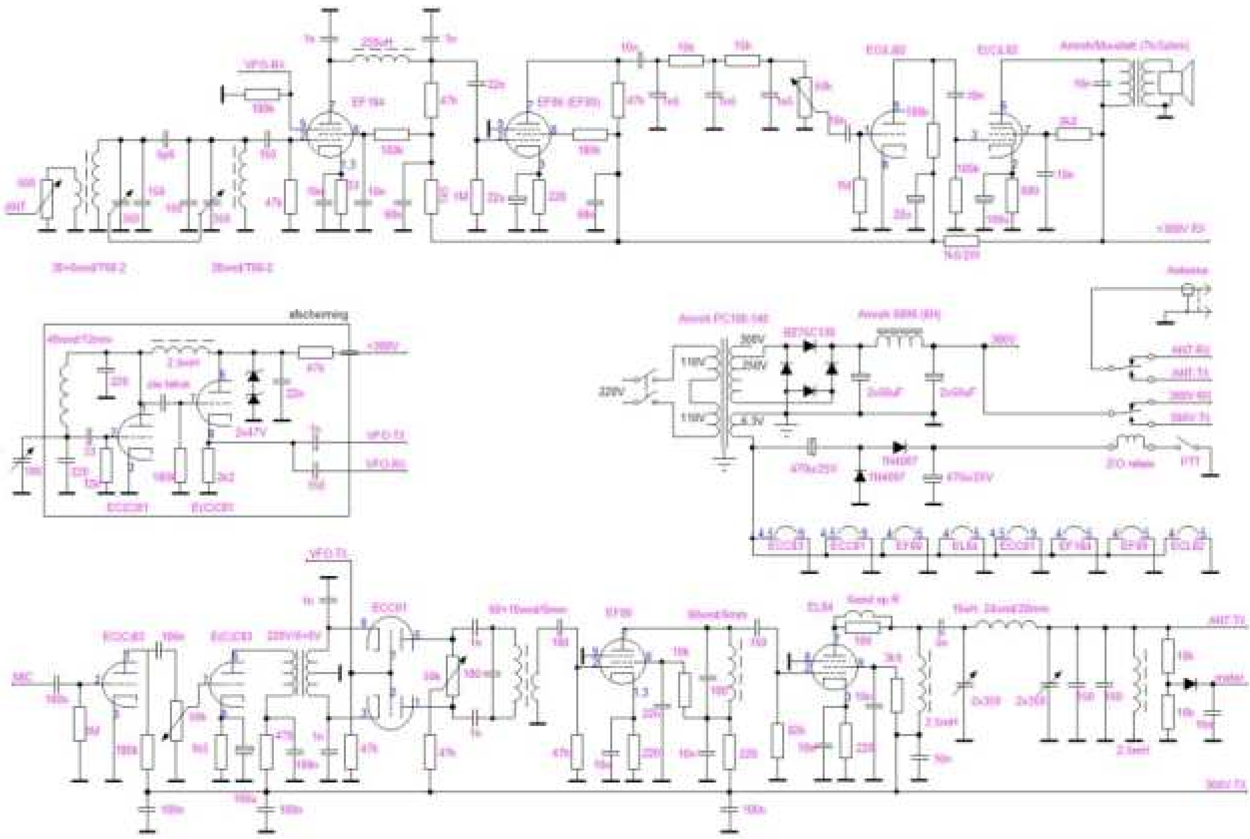
In simple balanced modulator jobs like the "Soldersmoke" (thanks, Pete, Bill & Co.) circuit below.

The RF from the oscillator and the audio (via RFC's are applied (effectively) to the "AC" ports of the bridge. Another option would be to use two SMT packaged dual diodes, and solder the two together to form a bridge, but that loses the inherent balance and matching that a full bridge on a chip offers.



An elegant design...

The all-valve DSB transmitter by http://www.pe1jpd.nl/index.php/80m-dsb-transceiver/ is shown below. It has some very attractive design features, yet maintains elegant simplicity, is an easy to reproduce design, and is readily adaptable to other (low HF) bands by implementing simple plug in (or switched, if you prefer) input filtering selectivity.



Note, for instance, the use of the internal screening available in a pentode to create the receiver mixer, right at the front end mirroring modern (solid state) practice. Neat!

Oscillators

Pulling crystals

You can use multiple crystals, but don't heave too far as their drift characteristics become very much worse, eventually losing sync and becoming a free running L / C oscillator. Ceramic resonators are better for pulling but aren't *quite* as stable as a crystal; note too that ceramic resonators fare better being pulled DOWN in frequency; it's nigh on impossible to pull 'em up and retain stability. See: http://www.homepages.ed.ac.uk/jwp/radio/projects/resonator.html#vfo

Note too that crystals - especially sub-miniature and tiny SMT types - are more susceptible to static damage; more than ceramic resonators. Having said that, quartz and ceramic are much more robust than semiconductors but it's something you shouldn't take for granted:

"Electrical parameters of piezoelectric crystals are deteriorated by excessive driving current or from high voltages that cause mechanical stress and movement to be generated in the crystal plate When the voltage is excessive, mechanical forces cause motion in excess of the elastic limit of the crystal. This results in crystal fracture, such as a lifted platelet. Such fractures, when occurring in sufficient number, will cause enough change to the operating electrical characteristics for the crystal to go out of specification or to cease operation entirely."

Let's make a few simple calculations, based on reasonable assumptions (and my memory). The capacitance of a human body to earth - assuming you're wearing your finest plastic or rubber soled shoes - is ~120pF. Typical static voltages range from 2 - 5kV or more, depending on floor coverings, air humidity and a few other variables so (guess) estimate at 3kV, the static voltage most people just about feel when discharged (or so the ESD trainer told me all those years ago).

The stored energy in this human capacitor is $\frac{1}{2}.CV^2 = \frac{1}{2}.[120pF \times (3kV)^2] = 540\mu J$.

Assume this energy is dissipated in 0.1 mS, therefore Power = Joules per Second = 5.4 Watts

This heating, in a "chunky" crystal, will most likely cause minimal damage: but on a tiny flake of quartz? Or, from a previous paragraph, would 3kV represent too high a voltage?

You might not see total destruction but more a "deterioration" - a wandering signal perhaps a sure indicator.

Power Supplies

Surges and a Commodore PET

Many years ago, I was called to a Commodore PET computer that wouldn't switch on. We had a few of these running simple test equipment, matching the forward voltage of varactor diodes for use in WG16 applications around 12GHz. The PET computer would start and run fine on another (switch mode) power supply, from an adjacent test station; the fault therefore surely in the individual power supply. This was duly "benched", a dummy load attached, and mains - as per the rating plate - applied. No Go! The power supply made a few desultory attempts at starting before cutting out and shutting down.

No circuit diagram, of course; so it was out with multimeter and dig in, seeking shorts, opens, burn marks, loose connections, and a myriad and one other thoughts as to why the thing wouldn't start. All electrolytics tested good; as did all semiconductors (no IC's, all discretes).

The switch mode supply was obviously trying to start, you could hear the transformer pinging, the indicator LED’s flickered, the output tried to rise, but… something was shutting the thing down. No amount of load adjustment worked; it was only when I tried bringing up the mains input via a 60 watt tungsten lamp (yes, the old current limiting dodge) did the power supply wake up, and run, from virtually zero to full output, given that it was running via a 60 watt lamp. A switch, to short out the lamp, quickly fitted, and yes, the power supply ran - providing it was started via a current limiter - and delivered full rated output for a day’s soak test.

A quick chat with Stan brought some light. He’d seen a 100 amp DC supply used in the electroplating shop do similar stunts; it took many tries to get the power supply up and running - the clue being it was designed for 60Hz, and we were on UK 50Hz supplies lower inductive reactance?). Stan had wired a 2R2 ohm resistor in series with the AC input; this had done the trick to get his power supply up and running, but was limiting the full power output. Stan rigged up a relay to short out the 2R2 ohm limiter once the power supply was up and running, to avoid any volt drop.

I couldn’t do this on the PET; it was all plug and play via Molex style connectors, and I didn’t want to modify the computer itself. So whatever I fitted to do the start-up current limiting had to go inside the power supply, which, fortunately, had a bit of room in the mains section. Stan again came to my rescue, he recalled thermistors fitted in series valve heater chains in TV chassis to do just this job: a quick look through the catalogues brought an answer: SurgeGard thermistors (see: https://www.mouser.co.uk/manufacturer/ametherm/).

So, the job proved successful: just as to the exact cause I can only surmise, but I reckon it was something to do with the 50 / 60 Hz difference. The unspoken, ruthlessly enforced rule in production plants is to “get it back on line yesterday”, and for zero cost. The SurgeGard thermistors proved 100% successful and were widely used in a lot of other equipment, improving reliability noticeably across the plant. Job Done!

Audio

Noise Cancelling Headphones

“In order to create anti-noise, headphones must constantly monitor and sample ambient noise using tiny built-in microphones. They “listen” to the ambient noise around you, and then the onboard electronics take it from there. As well as your music, the headphones create sound that is exactly opposite to that sound wave to cancel it out so that all you should hear is the music coming from your headphones—and not anything going on outside.

Of course, this is all theoretical. In practice, noise cancellation is hard to do, and far from perfect. Constant noises like the low hums of jet engines on airplanes are easier for headphones to recognize and cancel when compared to sudden, random sounds like people talking.

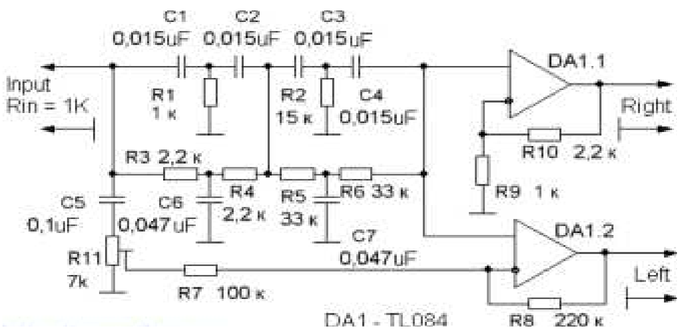
While the physics remains the same, some companies are better at active noise cancelling than others. But now that you know how it works, you can pick the pair that’s right for you.”

A noise cancelling scheme might be tried along these lines, and my initial thoughts were for CW only, but doubtless a scheme could be adapted to speech - the hearing aid industry has used this system for years and helped countless partial hearing people to enjoy a much better life.

Now a sideways slant: in a direct conversion “I / Q” receiver, it’s an idea to present the I / Q signals as “Left” and “Right” signals to stereo ’phones - you get a “soundscape” in your head, thanks to the computer between your ears resolving spatial location from the different sound(s) in each ear. This trick is by no means new: it was (part of) a recording studio trick for “synthetic stereo” and if you want a sample of how powerful an effect this can be, listen to the “Sergeant Pepper” LP on stereo earphones. An amateur approximation - which can be very realistic - is to pass the mono output of a very simple direct conversion receiver through two audio filters, one high pass, one low pass, and present the filtered outputs to the left and right channel of the stereo phones. Set the filters to a cut off of about 800 Hz, but by all means try others ; also an idea is to try an all-pass filter to introduce a (variable?) delay in one channel, giving a slight “echo” effect.

You’ll find an entire gallimaufry of techniques if you search for “pseudo stereo” or similar; below is a typical circuit:

http://zpostbox.ru/how_to_create_stereo_from_mono_signal.html



I would suggest an LT1113 dual op-amp here, it’s much lower noise than the TL084, though the ‘084 is an otherwise excellent op-amp, I should add.

You can see the high and low pass sections; by adding an all pass section, as shown in https://www.allaboutcircuits.com/technical-articles/focusing-on-phase-the-all-pass-filter/

...you can add (variable) delay very simply to one channel; by switching in the “all-pass” filter section to either channel.

Armed with these, you’ll hear Morse (and SSB…) spread across your head as a “soundscape”, the background noise is spread too, which your ears and brain can actively cancel by the signal processing between your ears. A “chirpy” transmitter sounds truly wondrous!

Replacing a carbon mic with an electret

The simplest way to modulate a carrier - as was used in the very early days of wireless telephony - was to put a hefty carbon microphone in series with the power supply, or the antenna feeder.

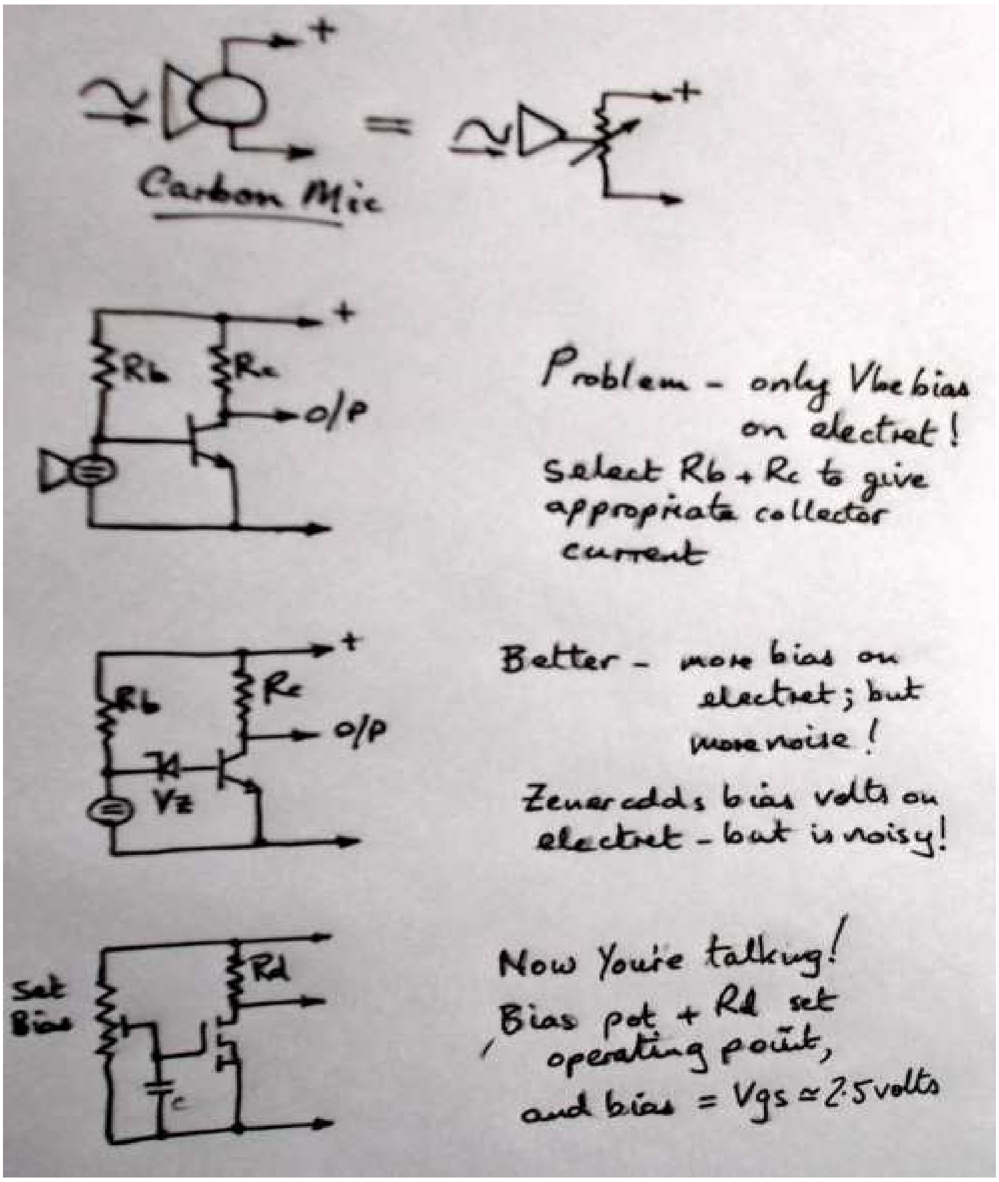
A simple telegraphy (CW) transmitter can be modulated by a carbon microphone in the power supply; not the most elegant, admittedly, but it will get you on A3E telephony with **any** CW telegraphy transmitter. If we take this principle, and bring it up to date by using an electret mic insert strapped to a power semiconductor - a power mosfet is a good choice - to modulate the power supply to the CW transmitter. Note, however, you won’t get 100% modulation; you have to limit the negative swing to a (low) positive voltage voltage to keep the oscillator running.

A better solution is the “plug in modulator” where a modulating signal was applied to the keying input of a cathode keyed transmitter: a “plug in modulator” can be easily constructed with a power mosfet or search for BU, BUK, BUS, BUT, BUV, BUZ prefix transistors, all of which are high voltage types to do the job. Incidentally, these transistors, connected as a cascode (solid state tetrode) circuit - see previous Hot Iron notes on this topic, and below, by Dr. H Holden:

http://www.worldphaco.com/uploads/WORLDFETRON.pdf

{Which, for valve / tube fans, includes a remarkably low noise 12 volt to 250 volt HT inverter power supply.}

It's possible to mimic a carbon microphone using a transistor (or mosfet) and an electret microphone by using an NPN transistor resistor biased collector to base, with the electret base to emitter. This only biases the electret with the Vbe of the transistor (or an N-channel mosfet would yield ~ 2.5 volts but you'll need a pull down resistor, gate to source, for appropriate gate bias). More bias volts on the electret makes for better linearity and dynamic range - simply add a zener, in series with the base to do this easily.



Of course, you can get more bang for your bucks if you apply some gain compression and levelling: by keeping the output of the microphone amplifier roughly constant for any input level (or thereabouts) means a vast increase in speech power. You effectively get a lot more modulation for your money and that equals more miles of DX. To that end, see:

https://www.analog.com/media/en/technical-documentation/application-notes/AN-1326.pdf

...which can be obtained from our favourite online auction source ready mounted on a small pcb, with all ancillary components.

Audio distortion shrinks DX

The audio signal and it's surroundings are all part of the audio chain that modulates the carrier - even if that carrier is later suppressed - audio distortion prevents efficient and comfortable understanding of the recovered signal. Use only the highest quality audio processing you can, in the transmitter, and don't neglect damping curtains or similar in the shack. Think recording studio!

Similarly, it's well worth the effort to create a first class receiver audio chain: the audio is the link between your dandy electronics and your brain, via you ears (please forgive me, RTTY / digital operators…) .

Old faithful LM386 is probably the bare minimum, good for portable operators but not for the keen DX man. Only the best will do for deep signal reception, as well as quality "4 quadrant" filter / audio processing - which, by sheer necessity, must be analogue. Why? You're digging out a fraction of a µV of RF from thousands of miles away that's making it's way to your ears: adding in a digital clock signal, (essential for a digital filter section) no matter how well shielded and screened, is just asking for another source of interference and distortion that might make all the difference.

It has to be 'said' (groan) is it's far more pleasant listening to quality audio than a distorted mess!

Noise, op-amps& audio

741 vs LM308? The "better" LM308 op-amp has much better input impedance, bias current spec. and offset characteristics; but lower gain / bandwidth product and thus lower noise factor because the bandwidth is limited, which gives treble cut (heard as bass lift) when used in an audio amplifier.

So for speech it makes sense to use 741-style (5534 is a good example) op-amps for full audio bandwidths, and an LM308 for "narrow bandwidth" jobs like CW or "data" (tone modulated, and the like) applications and you'll hear and see, for those with digital waterfall displays, the difference.

Test Gear & Fault Finding

Cleaning circuit boards

One dodge I found whilst working on industrial bakery equipment (yes, your daily bread manufacture, that sort of "industrial") was that "contaminated" pcb's could be readily cleaned in a domestic dishwasher, using 60°C heat and half a dishwasher tablet. The pcb's, contaminated with indescribable grease, dust, and other extraneous "contaminants", came out sparkling, bone dry! Tested initially on trial pieces of strip board, soldered with wire links, but otherwise completely untreated, flux residues and finger marks clearly visible, the results were - to be blunt - excellent, and Megger testing within 30 minutes of the wash cycle finishing (to allow cooling and finish air drying, whilst not obviously wet straight from the dish washer) showed "infinity" ohms, track to track, 500 Volts and 1kV test potential.

I can hear voices raising clamour about water contamination, de-ionised water being absolutely necessary, corrosion from using the slightly caustic dishwasher tablets, and much, much, more: but I should tell you I continuously tested an oven pcb in a test oven running product continuously (the aroma of baking bread around the workshop!) for 9 months after dishwasher cleaning, with ne'er any problems at all, including a multi-lead flat pack controller chip, a plasma discharge display and associated HV power supply, and the push button front panel too.

Since an industrial oven pcb usually ran flat out for 20 weeks or thereabouts before succumbing to the blistering heat, grease, steam, "livestock" ingress and general detritus, I reckon 40 weeks testing without any problems being a fair trial: what's more, there are hundreds (if not thousands) of industrial bread ovens running on "dishwasher" pcb's to this day!

One caveat for radio amateurs: let no-one see you've bunged your grubby circuit board in with the plates and bowls, 'cos I'm not responsible for the ear bashing you'll get!

Keep in mind when doing "favours"

The fastest way to lose friends is to offer to fix a bit of gear, then either (1) discover it's beyond all hope of fixing ("all ye who enter here, abandon hope" should be printed on every micro-controller pcb…); (2) find it's going to need real money to fix; (3) slip during de-soldering a component and wreck a multilayer pcb; (4) be liable forever more for every little hiccup or glitch… the list goes on and on (and on and on and on…).

Said friend trusted you to fix his bit of kit, and you (most likely) have now got it for life, or become responsible for replacing it if it proves unfixable. That's why I very rarely offer to fix things for friends, and why professional repairers carry professional liability insurance, and use professional equipment for professional repairs. Fixing recalcitrant electronics part of an amateur's learning curve; you learn how to fix things yourself and thus how to "adopt, adapt and improve" your gear.

By all means offer advice, teach someone how to de-solder, explain how a multi-meter can't automatically diagnose faults, but as an amateur, think thrice before you take on a repair!

Cross head screws on electrical terminals

...Robertson "square" (Canadian) screwdriver bits fit very nicely in (most) electrical cross head screws - better than Philips or straight slots; but not *quite* as well as the "ECX" bits, which are designed for the job.

The moral, of course, is to get the best fit with whatever you have available, and go easy: you need a snug connection, but you're not torquing cylinder head bolts here! I once saw a demonstration of conduit earthing: one steel tube pushed against another, no threaded coupler; it passed 100 amps simulated fault current with barely a whisper. Moral: by all means earth all "extraneous conductors" but don't swing on earthing screws like Tarzan!

Battery Charger Blues…

Lead Acid & Gel Batteries

A few days after the lead - acid battery was created, the issue of charging cropped up: how to get the juice back into the cells. It wouldn't have been too long before it was discovered you couldn't bung in a huge current and recharge the cells very quickly. Too many amps cause plate buckling and a host of other problems, so the idea of 10% "C" charging (C being the amp-hour battery capacity) was applied - and lo! the battery liked that. Rates of 1% C proved even better, telegraph and telephone exchanges often used 0.1% continuous trickle charging, the cells gently gassing off and needing topping up with distilled water every few days.

The advent of gel batteries changed this: these gel batteries were often gas tight, for mounting in any orientation, so gassing of the electrolyte was taboo: the battery would explode if forcibly over-charged. Thus the design, common in countless million burglar alarms and the like, of a constant voltage, current limited charging circuit became de-rigueur. This results, in applications that drew little (if any) current from the gel battery, in a dud battery after a few years. What the actual cause is, I don’t know, I suspect they needed substantial current to be drawn to keep the plates clean and active, but eventually the terminal voltage falls below that required to hold off the alarm bell and you’ve got a knackered gel battery and very annoyed neighbours).

NiCad Batteries

These batteries were very common in telephone exchanges and standby power applications: the didn’t suffer as lead acid cells do, decaying when never asked to deliver substantial current. One thing NiCads didn’t like was over-charging: they die the death of a thousand cuts and fade into obscurity. The telephone companies discovered that constant voltage, constant current charging at 0.1% - 10% “C” was appropriate; the lower rate particularly good in obtaining long battery life.

These were big, caustic soda electrolyte batteries, much like the lead acid units they replaced (but not weighing anywhere near as much) so when smaller sealed NiCads came along, they were welcomed in mobile and similar applications. These were notoriously short lived: the number of charge / discharge cycles very limited (and bearing little relation to the initial cost). As time went on the number of charge / discharge cycles increased, but the charging requirement remained: you can’t used a simple unregulated trickle or rapid charger. The terminal voltage must be held constant, as must the charging current. The lower charging current the better, it gives better cell life.

A characteristic not often appreciated is that NiCads self discharge, at about 10 - 15% per month; cell life can be increased if cells are fully discharged then fully charged, as are most lead acid batteries.

Li-ion batteries

...are similar in charging requirement to NiCads. They follow a similar lifetime relationship too: they have limited charge - discharge cycles, but prefer not to be fully discharged or charged beyond 100% (i.e. not trickle charged). Automotive batteries are best kept between 20% - 80% according to some sources (https://blog.evbox.com/ev-battery-longevity).

A common problem with battery chargers is often a blown "0R0" (zero ohm link, otherwise known as a fusible link) or a thermal trip - usually a simple low melting point wire fuse embedded deep in the inductor winding that goes open circuit when too hot. Not that your device has got too hot: these components are known for going pop after a few dozen hours running, or heavy vibes (man).

Faced with a recalcitrant charger, it’s out with a meter, "ohms" continuity, WITH THE CHARGER’S AC POWER UNPLUGGED and BATTERY DISCONNECTED then trace the input AC power feed, following the pcb tracks making sure the continuity is good as far into the charger as you can. Do the same for the DC output, back into the beast as far as you can.

Check the continuity of each of the "sense" and charging wires, and check a resistance exists across the battery sense wires - often a thermistor is embedded in the battery pack. If this goes open (or short) the charge control shuts off the charger (hopefully).

The fusible links can be replaced by surface mount fuses (or temporary very fine wire links, for testing purposes). The thermistor can be substituted by a 100 - 470 ohm resistor, again just for testing purposes, but it's been known for a resistor to be left in circuit and a weather eye kept on the battery temperature to make sure they don't get too hot on charge.

More about charging Li-Ion batteries, see:

https://www.homemade-circuits.com/simplest-safest-li-ion-battery-charger/

for some very useful, cheap and cheerful ways to do the job.

Pot spindle diameters…

Life used to be simple: pots, variable capacitors, rotary switches and the like came with one spindle size: ¼”, or 6.24mm if you must *really* insist; the odd ⅜” shaft (oh, alright... some 10mm spindles too, but you could always drill out a ⅜” to fit) cropping up on things like Volt Stat / Variacs.

Then the Orientals stuck their little fingers in: 6mm became common, as did 5mm, 4mm, 3.5mm and a host of other odd sizes for reasons unknown (and unwanted). Nowadays of course, we don’t often use tuning knobs and the like: digitals are here to stay as are their damned “up / down” buttons with the infuriating acceleration effect which causes you to shoot straight past your desired set point.

I personally believe every designer should be taught that simplicity is to be valued: customers (that’s us, remember!) deserve less hassle, fuss, unwanted “options”, “features” and the myriad of unnecessary bells and whistles the sales department insist we must have.

Viva simplicity, and build your own!

De-soldering multi-lead flat pack IC’s

One trick mentioned previously in Hot Iron that can be very useful is to build a modelling clay “dam” around SMT IC’s solder pads and flood the enclosed area with solder, gently (!!) lifting the aforesaid flat pack IC all the while. You’ll need a fairly hefty soldering iron for this; 50 watts being a minimum in reality, to get a fair amount of the solder within the dam to melt.

Obviously a temperature controlled iron is de-rigueur; you don’t want to lift the ever so delicate pcb pads. One approach to this end is to use two irons of lower wattage and an accomplice. A ‘novel’ method is to heat up the pcb over a hotplate, using a brass, copper or steel block just a bit bigger than the flat pack solder pads, and contacting the back of the pcb directly below the flat pack pads. Assuming of course, no IC‘s are on the underside! The whole idea is to get enough - but *only just* enough - heat into the job, so go easy on the hotplate temperature!

It’s an idea to look out for metal clad power resistors at flea markets, radio junk sales, and the like: a single 250 ohms 250 watts, run via a 230 volt lamp dimmer will be superb as a hotplate, with the flat side upwards and the body mounted on stand-off studs in a thermally insulated enclosure; or perhaps a flat back heatsink running a bunch of 2N3055’s in power tab packages, biased “on” to a few amps would do just as well, fed a diet of raw DC from a bridge rectifier. A bunch of 22 ohm, 25 watt resistors, mounted in a square formation, flat bottom ’uppards would do the job too; all you need is some way to get heat into the back of the pcb. It’s not unknown (ahemm…) to heat up the aforementioned steel block with a blowtorch and sit the pcb on the hot block (well away from the flame, of course).

Another possibility is to set up an old die cast box (or a steel conduit box?) as a support, with an aperture in the lid just a bit bigger than the IC outline and a hot air paint stripping blower set on low heat (those things get stonking hot if you run ’em on full chat) set to blow hot air into the box through a side hole with the pcb stood off the aperture 5 - 10 mm to allow the hot air to exit - you’re on your way to a DIY Hot Air Rework station!

I’ve seen this knocked up on-site to replace dud chips by using a vented box (conduit boxes are good, as are die cast boxes, etc.) over the top of the pcb, some light tinning of the pads, well fluxed pads and careful placement of the new (programmed) chip. As soon as the solder runs the heat is removed sharpish and the board cooled and tested. Soldering is a very tolerant means of connection, but soldering each pin individually with an iron sets up big stresses in the component - the hot air gun “reflow oven” solders all the leads simultaneously.

Antennas

Gin pole mast lifting

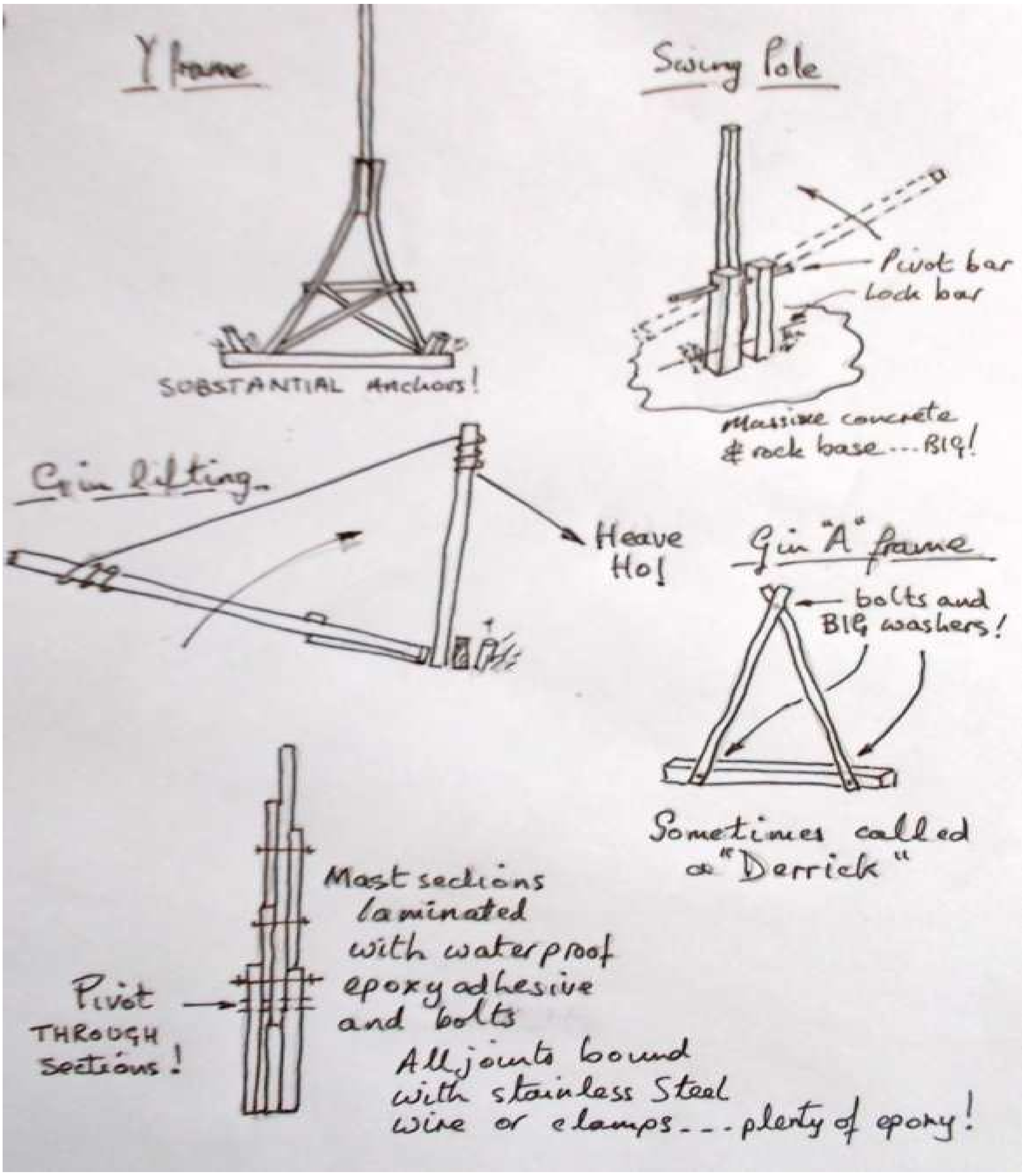
I have used Gin poles, A-Frames and the like to heft heavy loads (like 300kVA transformers and 100HP motors) and big tube sections (for toxic gas exhausts) whilst in the depths of night shifts, aided by a minimum of “hands to make light work”. These simple mechanisms are as old as rope and knots; huge weights can be lifted and moved as the Gin pole approaches “top dead centre” where the ‘velocity ratio’ approaches infinity. Several caveats:

- The fixed lower point of a Gin pole or A-frame must be on solid ground and fixed mechanically as rigid in every direction except the desired pivoting angle;
- The initial “lift” should have the pole or frame at near as right angles to the actual element to be lifted, and have a secure anchor close by to tie off the “hauling” ropes;
- Use as many ropes to the side and top (for the “rocking over top dead centre” moment) and SOMEONE TO HOLD THEM WITH EARTH ANCHORS NEARBY TO TIE THEM OFF;
- Before engaging in a lift, you MUST have prepared the locking mechanism(s) of the mast, once upright, AND HAVE SOMEONE ON HAND TO SECURE THE LOAD;
- If using a “Y” frame mast, the lower “legs” of the Y must be of sufficient cross section and material to support the load mass above, even in the worst of weather, and sufficiently rigidly braced with cross members to eliminate bending or distortion of the legs;
- Use external “saddle clamps” to tie off mast support members. Stainless steel is far better than other materials in withstanding weather but whatever material you use, keep to an absolute minimum (ideally ZERO) the holes drilled in mast structure: they WILL weaken and break when you least want (or expect) it to;
- If in ANY doubt, follow George (“Rocket” locomotive) Stephenson’s advice: “if tha’ can fit mair metal, then fit it!” (roughly translated from the original Geordie lingo);

This, of course, flies against accepted construction and design nowadays, but keep in mind a Stephenson era locomotive runs every day in the Museum of Technology, Manchester, UK.

Moral: if in doubt, make it BIG!

A useful reference can be found online: https://www.towerclimber.com/gin-poles



For those 'long wire' devotees…
https://youtu.be/QLl9NCJvZjw

This (ancient!) video was filmed predominantly in Northern England that I am familiar with, being born within a mile or two of the more "interesting" scenes: nothing like the extremes of weather seen in some parts of Europe and North America, admitted, but a salutary lesson for those who want to build antennas appropriately for all *possible* weather conditions!

Hot Iron #118

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CQ-CQ-CQ

With both hands?

'Ambidextrous' means capable with both hands; whilst 'ambisinistrous' means unable to use both hands (that's me!). An ideal word therefore for early telegraphers to use, to describe a less than capable keying operator - and hence, taking the first sound - 'am' - is this the origin of terming an amateur telegrapher (assumed to be not much cop with either hand) 'ham'? Just a thought…!

SSB via phasing method

The 'Tucker Tin' by Fred Johnson, ZL2AMJ used AF / RF phasing to make a simple SSB transmitter; before economical crystal filters were available and was a real 'home brew' breakthrough for amateurs. You could put together a functional SSB rig using resistors and capacitors for filtering, add a couple of balanced modulators and you've got a decent job ready to go. Yes, I know the carrier suppression with phasing isn't as good or reliable as the filter method - but - so what? Since, as amateurs, we can use any of our licensed modulation modes - including full carrier A.M. - anywhere in the allocated amateur bands so a minute sniff of carrier, from the 50 dB of suppression achievable with phasing, isn't the end of the World. Nowhere is it written in stone that 'thou shalt not allow less than 60dB carrier suppression'!

The phasing method is a means the impoverished amateur can get on the air with SSB; it's simple, cheap and very (relatively) easy to fabricate. Pat Hawker G3VA gave some excellent 'preferred value' audio phasing networks in his 'Technical Topics' book, that work well for the amateur. What most SSB crystal filter devotees forget is that it's just as much the screening, physical layout and construction that counts, as well as the crystal filter specification to 'eliminate' the carrier; and that's not including the input / output matching of the crystal filter over the bandwidths required.

Yet nowadays you see nothing but the (crystal) filter method. Why? it's cheap(ish), yes; effective, yes; but without very careful construction to avoid carrier leakage at the filter stage and use a mixer that can cancel the carrier perfectly it's almost impossible for an amateur, in an amateur scenario, to create (or perhaps more appropriately, *measure*) anything like the quoted carrier and unwanted sideband attenuation.

The overwhelming drive to create a 'perfect' SSB signal is not really an amateur capability - by sheer definition, 'amateur' indicates a more relaxed specification than 'professional'. Fine if you want to strive for a specification that matches or beats commercial or professional products; but, for the home brewing amateur, on limited budget, with limited fabrication facilities, the the phasing method is a viable and acceptable means of producing SSB.

The 'Way Back Machine'

Kay Savetz, K6KJN, has emailed me asking if Hot Iron can be included in the archives at the Digital Library of Amateur Radio & Communications. Well, my 'gast' was truly 'flabbered' with this request! The library (abbreviated DLARC) is known for holding the 'Wayback Machine' where you can find masses of information archived; it's practical 'time travel'!

In the spirit of Andrew Carnegie, I'm all for the dissemination of information, free for all, open to all - and am myself a member of the magnificent Central Library in Manchester (UK), set up specifically as an open learning resource in the first truly 'modern' city of the World.

Therefore I'm greatly honoured to have Hot Iron included in the DLARC archives. Have a look below and see, you'll find yourself down a proverbial rabbit hole wandering amongst the past - all for free. What a magnificent resource for all radio amateurs - and all the other topics to be found there - see:

http://www.arrl.org/news/amat
https://youtu.be/ZNPtKMoGagg
https://archive.org/details/d

Simplicity? Yes please!

Thank you to all readers who have requested that I continue the 'simple designs' theme in Hot Iron. I accept it's fair to say you're not going to get that delicious gem of Dx with a one transistor receiver; nor are you going to reliably call up our Transatlantic or Antipodean colleagues with an ECL82 one bottle transmitter - but you get a real buzz in building such a transmitter in an evening and calling up local - and not so local - amateurs with it; and a transistor or two to receive the reply.

Our GQRP brethren have proved beyond shadow of doubt you don't need radiated kW's to have a lot of fun, learn new skills and discover fundamental radio truths, so onwards we go - 'simple is as simple does', I'm with you all the way.

I have received emails about reflex and super-regenerative receivers, apparently these receiver techniques aren't too well understood, and even less, appreciated. One of my favourite designs - that fires up reliably with little, if any, faffing about - is a reflexed super-regen, using an NPN transistor of the 2N2222 or 2N3904 variety. The design (shown later in this edition, and in previous Hot Iron editions) is a good example of how one transistor can do several jobs *at the same time* if the surrounding circuitry is set up to enable this; and how altering the operating mode of a transistor from common emitter to common base can result in very different frequency capability from a common-or-garden transistor.

Mains sockets UK…(1)

A YouTube video I saw t'other day sang the praises of our UK mains outlet plugs and sockets (type G), as compared to the common US plugs (types A & B). On the whole, the video considered our chunky UK 3 pin plugs as being very safe, as compared with the smaller US 2 pin plug. As a finale, the video pointed out 3 "problems" with UK 13 amp plugs: the size of a UK 13 amp plug, the installer having to work out current distributions in a 'ring' circuits, and finally, the problem of standing on a UK 13 amp plug in bare feet, saying it was worse than standing on a 'Lego' block!

Here's my response to the "problems" noted by the video, and, as ever, I welcome any comments, one way or t'other.

The size: yes, UK plugs are big - and perfect for gripping with old, arthritic fingers. It was noted that you can't pull a UK 13 amp plug from the wall socket with the cord; the UK plug tilts and locks in place which the video thought a 'good idea'.

The video thought that installing electrician had to work out the load distribution in a ring circuit: no Sir; not at all. Each ring (covering < $25m^2$ floor area) is fed by a 32 amp miniature circuit breaker into which are connected the two ends of the ring, 2 off 'twin and earth' (T&E) $2.5mm^2$ (~12 AWG) cables in parallel, so it doesn't matter where the loads are, with two cables feeding every load point and the floor area limit (with diversity) means the cables in the ring circuits don't have volt drop issues or surge current limitations.

And standing barefoot on a UK plug? Yes! It does hurt!

Mains Sockets UK...(2)

The 'functional earth' terminals behind a 13 amp socket used to be wired in cream coloured wire; the latest UK 'Regs' demand they are wired in pink, and I'll bet you didn't know that, did you?

I can already hear the voices - "earth wire coloured cream, what's he talking about?"

Well, if you look at modern UK electrical outlets, you'll notice the earth terminals - the ones that go to the screw hole bushes to earth a metal back box and connect to appliance cases to protect us from shock - have some others adjacent: unlike the "CPC" (**C**ircuit **P**rotection **C**onductor) earth terminals with their earth symbol in a full surrounding circle, the 'functional' earth terminals are in a semicircle moulding, and are for a 'clean' or 'low noise' earth connection for electronics, IT data cable screens and the like - and are **NOT connected to the mains (CPC) earth** . It won't be long before somebody thinks that they are the CPC safety earth, and finds out the hard way,!

Be sure you earth to the mains earth (the 'CPC' in green//yellow) **all** the 'touchable' metal bits of your gear, and keep your 'functional earth' **completely separate** from the mains earth.

Here's something useful I found, from https://incompliancemag.com/article/the-grounding-symbols/ whom I thank for being accurate and succinct:

"With the various markings available to identify ground terminals, how do you know which specific symbol should be used? The international standards are the right place to go for guidance, and this column will outline these best practices for use of earthing (grounding) symbols and markings.

The Grounding Symbols

Identifying the ground terminal is critical to ensuring the products you design can be properly used and serviced in a safe manner. The actual symbols used to indicate ground terminals are found in IEC 60417 Graphical symbols for use on equipment (Figure 1).

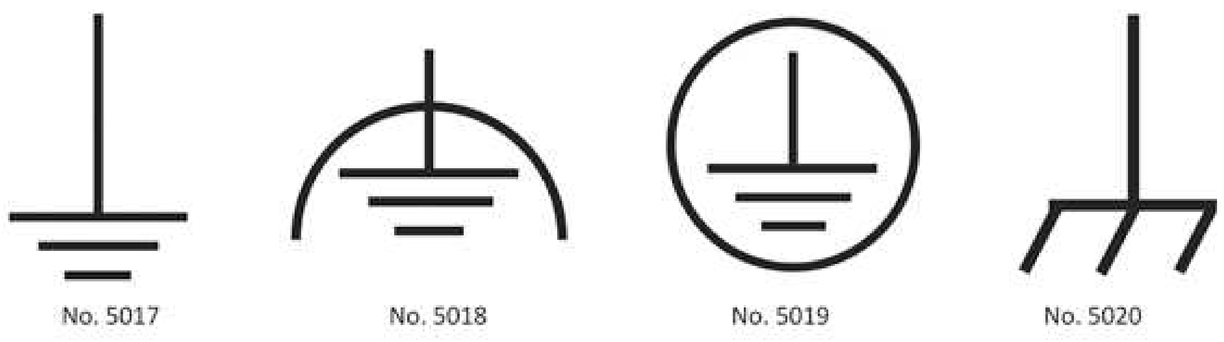


Figure 1: IEC 60417 ground symbols

Here are the IEC definitions for each symbol:

No. 5017 Earth (ground): *To identify an earth (ground) terminal in cases where neither the symbol 5018 nor 5019 is explicitly stated.*

No. 5018 Noiseless (clean) earth (ground): *To identify a noiseless (clean) earth (ground) terminal, e.g. of a specially designed earthing (grounding) system to avoid causing malfunction of the equipment.*

No. 5019 Protective earth (ground): *To identify any terminal which is intended for connection to an external conductor for protection against electrical shock in case of a fault, or the terminal of a protective earth (ground) electrode.*

No. 5020 Frame or chassis: *To identify a frame or chassis terminal."*

Now you've had a taste of UK Regulations…

I was once sent on a training course, which taught me how to size cables by Prospective Fault Currents and the like. Back at work, I bumped into Stan and told him of my newly acquired knowledge. 'Hmm…' quoth Stan; 'keep to mind the original IEE Regs: volt drop is the most stringent requirement for cables, and has been ever since the Regs were first written. Prospective Fault Current calculation will most likely give a cable size equal to or less than the volt drop requirement: but you MUST keep to volt drop limits above all else'.

He was, of course, right: you size cables to comply with the volt drop limits (that date from 1882!) as copper is still copper, volts is still volts, and I^2R is not a passing whim, nor to be discarded as 'out moded'. I work to 2.5% volt drop at the load; in the USA it's 2% if my memory serves.

So we come to today, with earth leakage circuit breakers, miniature circuit breakers and the like. The Institute of Electrical Engineers (who created the UK 'Regs') are viewed differently by different users: some installing electricians see the IEE Regulations as a license to print money, the public see them as a complete mystery. The IEE Regs authors love abbreviations and terminology that puts the fear of the good Lord into the average reader; solicitors and lawyers love 'Regs' as they profit from ensuing litigation. Now local UK town hall 'jobsworths' have a finger in the pie with 'Part P' electrical regulations - all legally enforceable - and can charge £300 for a house owner notifying them of simple electrical work i*n their own home*. Of course, if you employ a member of one of the Electrician's Unions (NICIEC, the National Inspection Council for Installing Electricians, for example, there are others) then you pays your £300+ to a sparky (this was quoted to me for a minor job recently) and ½ an hour later he gives you a bit of paper with some ticks on it that take care of your legal obligations.

Being a professionally qualified electrical engineer with 55 years or more experience, designing, installing and maintaining electrical machinery (and the factory building they reside in) for the safety of 2,500+ operators counts for nothing: if you're not an 'Installing Electrician' your professional experience and qualifications count for naught. You have to ask an 'Installing Electrician' with an automatic test instrument to look over your work and pronounce it safe.

It's a good job the UK 'Regs' are not retrospective: otherwise every Consumer Unit (incomer distribution panel) in the UK would have to be updated as AFDD's came around (see what I mean about abbreviations?). This is why the IEE Regs writers rapidly issued an errata; now only certain buildings have to have AFDD's, like Care Homes, Houses in Multiple Occupation and a couple of others. AFDD? **A**rc **F**ault **D**isconnect **D**evice, or **A**rc **F**ault **D**etector **D**isconnect, or… perm any 4 words from many!

This reminds me of an earlier 'Regs' fiasco demanding 'extraneous conductor bonding' some years ago, which resulted in irrelevant earth wires all over the place - even floorboard nails had to be earthed to fully comply. I witnessed this manic earth bonding in a bathroom: it was a fibreglass bath, with plastic hot and cold water pipes and a PVC waste trap, all solidly earthed!

Part P Building Regulations and amateur radio wiring

I'm busy reading the Part 'P' Building Regulations which cover domestic Electrical Installations here in the UK. Part P states that it applies to 'all **fixed** electrical installations'. This therefore includes any wires (and co-ax?) we fasten to a wall, shed or outbuilding, in and around our houses. The Part 'P' Regulations say '**ALL fixed**' wiring… it makes no distinction between AC mains, DC or RF wiring; nor does it define '**fixed**'. I'm ploughing through pages of convoluted 'legal' documents and explanatory notes; I've even found explanatory notes for the explanatory notes!

Suffice to say I agree with the safe installation of electricity in houses, but Building Regulations have nothing to do with amateur radio wiring. Watch this space, and if any UK sparkies are amateurs reading Hot Iron, please email me as I want to get to the bottom of this fiasco.

End note: fires caused by faulty electrical installations have dramatically increased in the UK since the introduction of (very costly) Part 'P' regulations. Who'd have thought it?!

Receivers

A remarkably beautiful receiver

From: https://antiqueradios.com/forums/viewtopic.php?t=373629

'*A Google Image search for Direct Conversion receivers using the NE602 (NE612 SA612) double balanced mixer will reveal numerous, perhaps over 100 similar schematics designed for the 80 to 10 meter amateur bands. Kits used to be sold by Vectronics and Ramsey.*

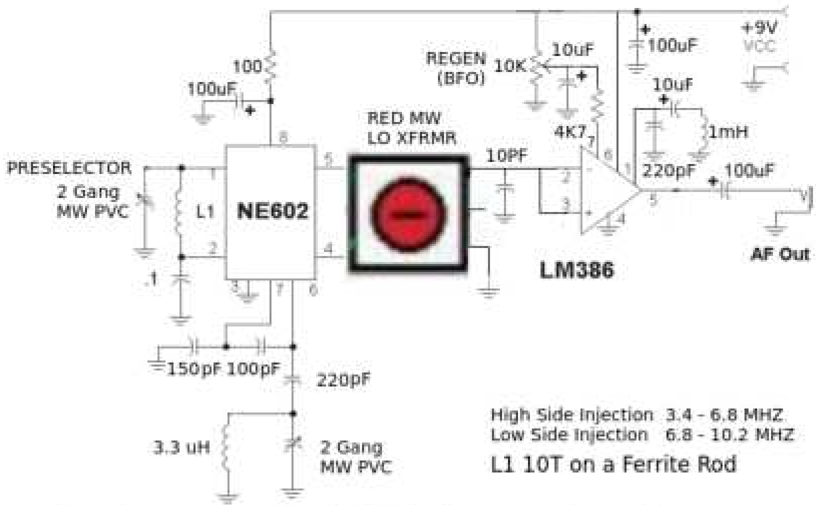
I was never happy with their performance and for this reason I built a simple superhet using an LM386 audio amplifier as a regenerative IF detector-amplifier. Using 10 turns on a ferrite rod as a preselector enables the receiver with the values shown to use both high side and low side injection to tune from 3.4 MHz to 10.2 MHz in 2 bands.

No external antenna is necessary for casual listening and selectivity and performance are comparable to my best commercial portable short wave receivers using their built in whip antennas. I use it most evenings to listen to SSB on 80 and 40 meters up and down the East coast of the U.S.

The IF transformer is a 'red' medium wave local oscillator transformer which in my case is tuned to 1.7 MHz. A variable local oscillator frequency of 5.1 to 8.5 MHz permits 2 band coverage using both low side and high side injection by tuning the front end preselector variable capacitor. Image rejection is good and by properly arranging the IF and LO frequency values there is little chance of *overlap. Unlike a pure regenerative receiver, a superhet using a regenerative IF permits tuning across the bands without having to vary the regeneration control.*

The LM386 audio amplifier is set up as a high gain regenerative RF envelope detector which when oscillating allows the reception of CW and SSB signals. Although adding varactor fine tuning would be an asset, the regeneration control varies the receive frequency slightly and is useful to fine tune SSB reception.

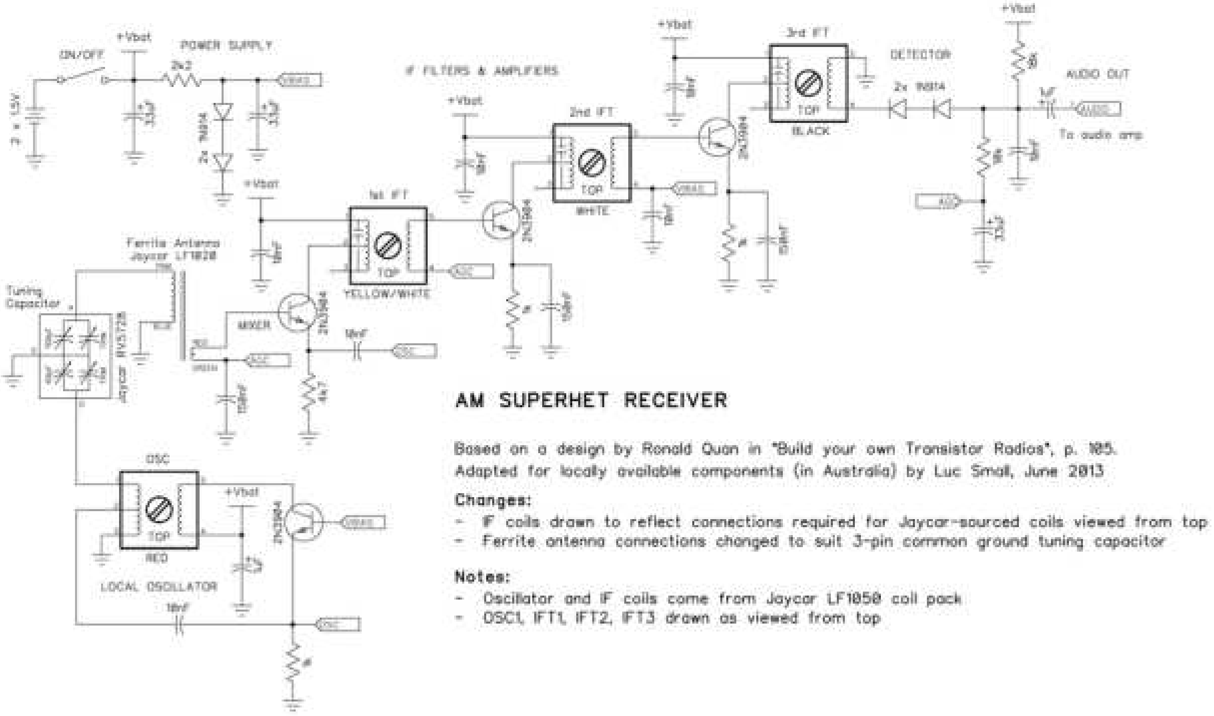
The photo shown below is that of a modified QRP Kits EASY Direct Conversion receiver which has a varactor fine tuning and after modification uses the original audio volume control for regeneration.'



Shortwave Superhet With Regenerative IF

Isn't that a neat way to use an LM386? The 'red' transformer is detailed in another design, from :

https://lucsmall.com/images/2013-05-10-am-superhet-radio-schematic.jpg



The transformer has a centre tapped winding on one side, and a single winding on t'other - thus the windings can be identified in the regenerative IF receiver.

A ZN414 Gallimaufry

As I searched for some data, I came across:

https://cool386.com/zn414/zn414.html

I worked in the Ferranti Semiconductors Test Gear Maintenance workshop, adjacent to the Applications Lab, from whence came 120dB whistles, bangs, flashes and musical interludes as a daily symphony. We were frequent visitors to the 'Apps Lab', to ask about the various circuits we came across in repairing commercial instruments and test gear, and the Apps Lab staff were always interested in seeing circuits inside the commercial test gear we had in for repairs and calibration.

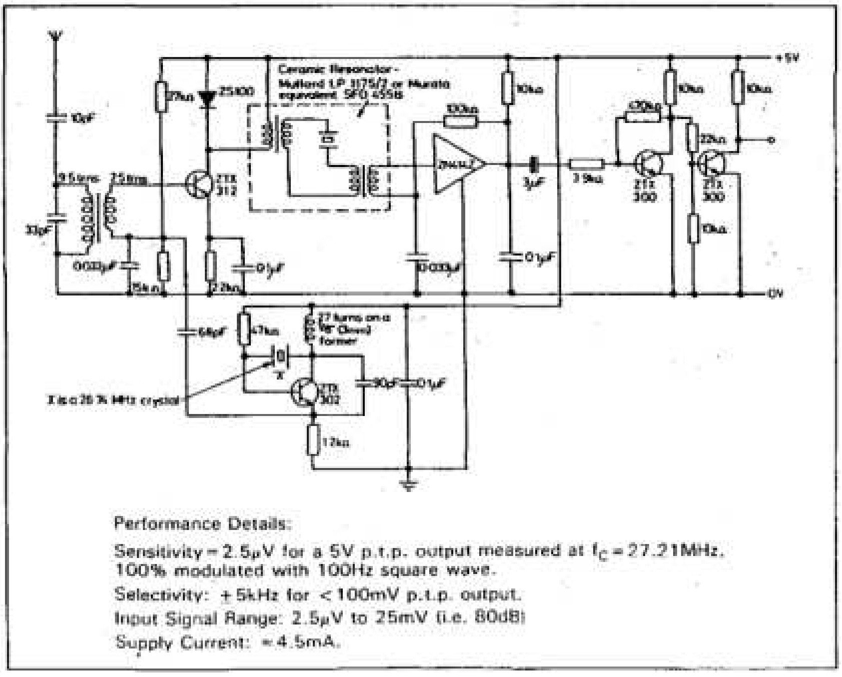
The ZN414 was in many Apps Lab RF experiments, and powered our Maintenance shop radios - since the medium wave broadcasting of the day was limited to a local A.M. music channel, it was a strange effect walking the length of the workshop, hearing the echoes and time delays of the numerous radio outputs, all tuned to the same station! A favourite was the 'Triffid' receiver, a neat design that worked magnificently, see:

https://www.cool386.com/zn414/PE_Triffid.pdf

...though nowadays we'd use a one chip audio output stage, most likely an LM386, and probably a more sophisticated AGC / power feed to the 414, rather than the usual 10k & 100k resistors.

The ZN414 makes a potent superhet too in the IF stages, as below:

The circuit below shows a ZN414Z used as an I.F. amplifier for a 27MHz superhet receiver.



With a little adaptation, this circuit will run 10, 12, 15 metres - or any other HF band you care to try. The weakness of this design is the rudimentary mixer using the ZTX312; not that the ’312 is in any way inferior, but a ‘stronger’ (balanced?) mixer and tuned RF amp. will likely perform far better. The input impedance of the ZN414 is stated as 4 Meg-ohms, so matching the filter is relatively easy. Crystal filters are very good contenders for a superhet with a ZN414.

Here’s a novel take on the ZN414 (a.k.a. MK484) that provides good performance - and can benefit from some of the more esoteric ZN414 drive / AGC enhancement circuits. This looks like an 'Elektor' schematic - my grateful thanks to them - and it will certainly perform on Top Band and 80m; if you try really hard, you’ll get a hot ZN414 / MK484 up to 60m and possibly 40m.

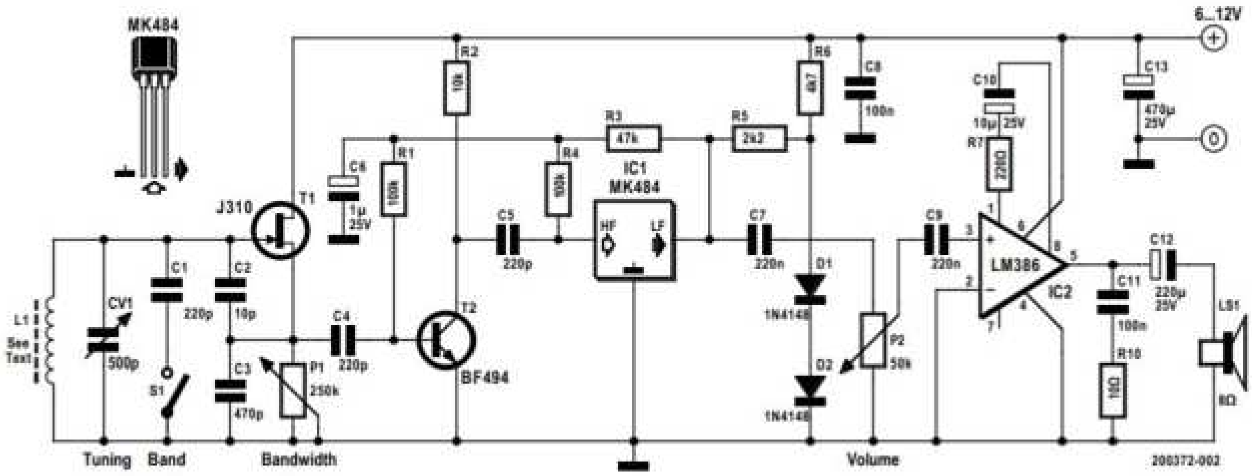
'*Three RF stages permit the reception and detection of AM radio signals in the MW band (usually 500-1600 kHz). T1, a type J310 junction FET,* (try a 2N3819? Ed.) *provides positive feedback for the antenna tuning circuit. The feedback limits coil damping, increases sensitivity, and narrows the overall bandwidth. The antenna, L1, consists of a 120-200 mm long, 10 mm diameter ferrite rod holding a coil with 55 turns of 0.2 mm diameter (~ #24 AWG) enamelled copper wire (ECW), close-wound. CV1 is a mica- or air-spaced 500 pF tuning capacitor providing a frequency range that matches the MW band. The tuning range can be extended down to about 150 kHz by closing the band switch S1.*

The second stage, comprising of a BF494 (T2), increases the receiver sensitivity and amplifies the MW signal for the input of the third stage at IC1, an MK484. This 3-pin integrated circuit, originally launched as the type ZN484 by Ferranti in 1972 contains a complete RF amplifier, a detector, and AGC circuitry, making it one of the most popular solutions for building straightforward AM-receivers. Although the original ZN41 devices are long since obsolete, modern equivalents of the original 3-pin ZN414 are available, such as the MK484.

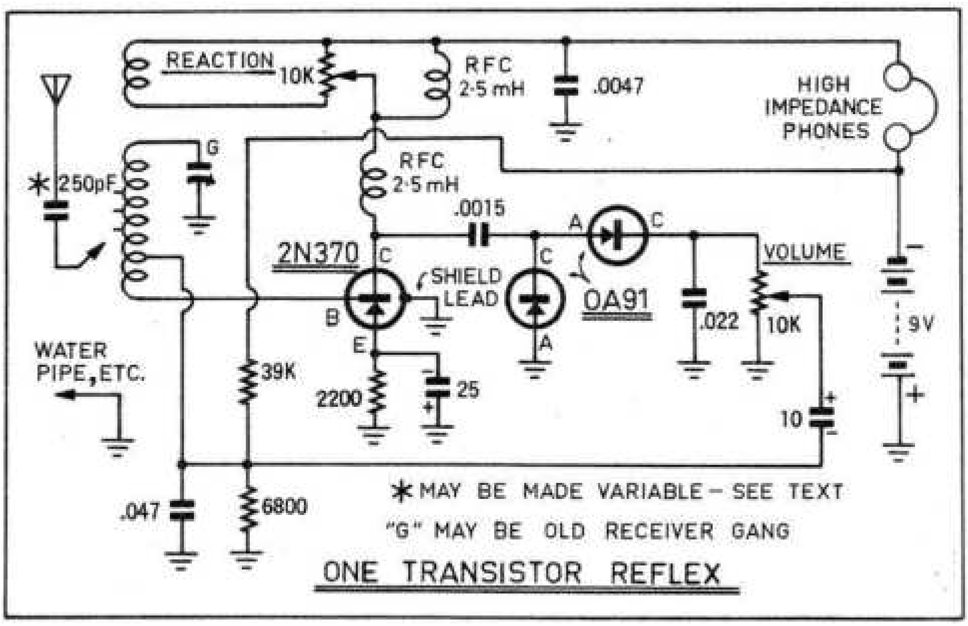
Lastly, we have the good-old LM386 (IC2) acting as an audio amplifier and loudspeaker driver, *complete with the prescribed Boucherot* (Zobel? Ed.) *network formed by C11 and R10. The '386 is sure to ring a bell with many readers.*

Reception is optimal with bandwidth control P1 correctly set — simply make the adjustment by ear. The tuning range can be extended down to LW with a fixed capacitor, C1, connected in-circuit by S1. With the additional damping this introduces, the positive feedback at low frequencies may drop excessively. Fortunately, this can be compensated for by using a smaller value for capacitor C3.

Some tuning, tweaking, and experimenting may be required to get it just right for MW and LW. A larger value for C1 can also help to extend the tuning range. At frequencies higher than 'official MW,' i.e., above 1.6 MHz or so, you're unlikely to find any (legal) AM stations. By mounting two ferrite rods side-by-side, the cheap and simple antenna can be improved in both directivity and selectivity.'



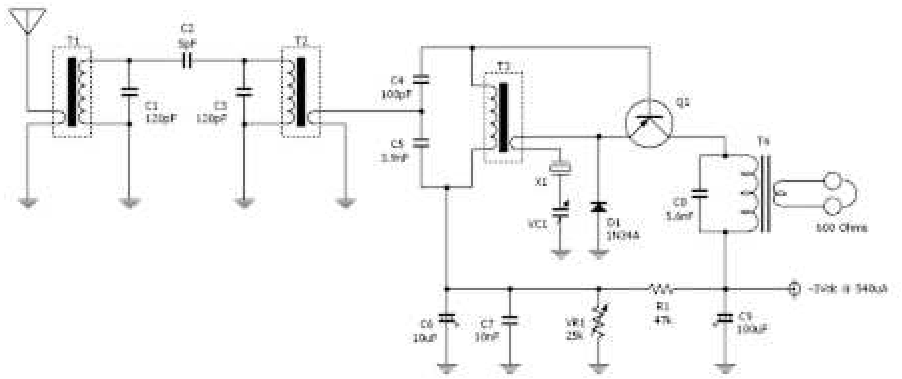
Reflex, Regens and Super-Regens



The circuit above is a *reflex*, you can see the demodulating OA91 diodes, and the audio they develop is fed back to the 6k8 resistor and 47nF RF decoupling capacitor to be amplified by the transistor as audio. The 47nF capacitor is the crux component: it presents a low impedance path to earth for RF, yet doesn't 'leak' too much audio to earth. Such circuits were very popular in the late 1950's and early 60's, when transistors were very expensive (note the odd-for-today transistor symbols!) and of very wide spread characteristics. Reflexed designs tend to distort the audio on large signals as, like a regenerative receiver, they overload easily - the single transistor is dealing with double the signals a single non-reflexed amplifier has to cope with.

This next is a regenerative (or 'TRF') from Mike Rainey, AA1TJ, and is an absolute beauty - I've built a few of these and they really do perform. This is magnificent engineering, as are all of Mike's designs. Mike's truly a master of the 'art of RF'.

Using crystal control in a regenerative receiver renders it ideal for CW enthusiasts, as such amateurs use only small sections of the HF bands and crystal control is (almost) mandatory in the UK. A crystal dramatically cuts the receiver's bandwidth, some shunt pF's and / or a resistor across the crystal can help speech quality by opening up the bandwidth a bit. The article below is from Mike Rainey's web pages.



T1, T2: 10mm, shielded "IF can," 16-turn main winding, 3.5 to 6uH; 2-turn coupling
T3: Ditto above, except 1-turn coupling
X1: 40m quartz crystal
VC1: 20-360pF -> 3kHz frequency shift
VR1: bias set/regeneration control; adjust for maximum signal sensitivity
Q1: 2N504 Germanium transistor (AF124, AF125, 2SA71, 2SA121 and 2N966 also worked well)
T4: small ex-power trano (junk box find); primary 11H, secondary 500mH (15k Ohms: 600 Ohms)
C8: Select value to cancel residual T4 inductance at ~ 700Hz

Xtaflex

40m VXO Regenerative Receiver
Based on Sir Douglas Hall's "Spontaflex"

de AA1TJ

6/1/2009

This circuit is based on the Autoflex/Spontaflex receiver designed by Sir Douglas Hall. It turns out that Sir Douglas' clever circuit works well as a one-stage, crystal-controlled (VXO'd) regenerative receiver.

As he explains in his June, 1964 article (thanks Geoff!), the transistor functions as a common-collector radio-frequency (RF) amplifier in which the gain is augmented by regeneration. The high impedance looking into the base helps to reduce the input tank circuit loading. C8 places the collector at RF ground. Demodulation is provided by the Germanium diode at the emitter. The base of Q1 is at ground potential for AF. The parallel combination of C8, T4 and the headphones provide a 15k Ohm collector load resistance (15k + j0 Ohms) at **700Hz**. Q1 operates as a common-base amplifier at AF. The circuit may thus be described as a crystal-controlled, regenerative, reflex receiver; or, Xtaflex, for short!

This crystal-controlled regenerative detector is virtually immune to frequency shifts due to hand-capacitance or antenna "swinging." Neither does the frequency pull when receiving strong signals at a low beat note. Here is an audio snippet sampled at the headphone terminals. Please notice how it's possible to tune through zero-beat with a strong, incoming signal without the slightest hint of synchronization (frequency "pulling"). In operation, this circuit "feels" more like a direct-conversion receiver than a straight-regenerative set (of course, a regenerative set is a direct-conversion receiver "at heart").

The circuit shown in my schematic diagram is built for 40m. I've used it on the 30m band by changing the frequency-sensitive components. In fact, the rock-solid frequency stability of this regenerative receiver will shine progressively brighter as the frequency is raised. What's more, the degree of VXO frequency shift will increase along with the operating frequency. My **40m** prototype exhibited a VXO shift of **3kHz**. On **30m** the shift was **5kHz**.

Under crystal control, a stable regenerative receiver for 15, 10 or even 6m appears to be a practical proposition (an RF amplifier placed ahead of the detector will likely prove useful on these higher bands). On these these higher frequencies it may be possible to eliminate the bandpass filter and connect the signal source directly to the C4/C5 node.

Generally speaking, there are a few tricks for obtaining smooth regeneration using modern, high current-gain, transistors. Wes, W7ZOI, recently mentioned a friend of his that builds smooth-operating regenerative detectors from (modern) bipolar transistors by swapping their collector and emitter in order to reduce the current gain. I've been achieving the same results (without needing to swap the emitter - collector) using early, low current-gain, Germanium transistors. The Xtaflex, for example, uses a Philco, **2N504** MADT (Micro Alloy Diffusion Transistor); date-coded, September of 1959. Another example is my Talking Doll, which uses a **2N107** in the regenerative detector.

Charles, N1TEV's well-known bipolar regenerative detector achieves the same end with a **2N2222A**, running at an unusually low collector voltage.

Lacking such methods the device transconductance will increase dramatically with collector current; as noted on page two of Ian Hickman's Imp (click-on "PW Imp: I. Hickman," third from the top) receiver article. Ian cleverly linearises the regeneration control by using a differential-pair in his bipolar transistor-based detector.
I would like to express thanks to my friend, Jim Kearman, KR1S, for re-planting this idea for crystal-controlled regenerative receivers. I happened to be doodling with a Spontaflex receiver when Jim's message arrived, telling of his experiments with crystal-controlled regenerative detectors. Talk about serendipity!

Links/Reference

http://qrp.kearman.com/html/vxoregen01.html Jim, KR1S's, JFET, VXO regenerative detector

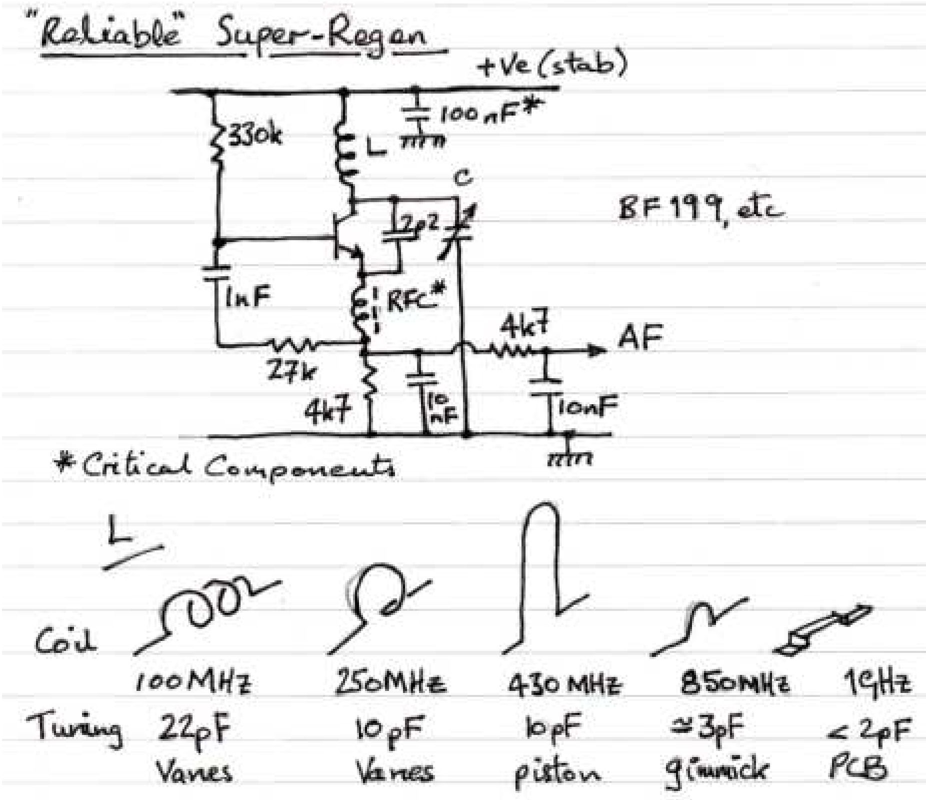
http://home.comcast.net/~phils_radio_designs/ Dee/Mitch-Dyne; the JFET diode is interesting

http://www.io.com/~nielw/3tube_xtal/3tube_xtal.htm Quartz crystal inside regenerative FB loop

"An Ultra Simple W1AW Receiver," QST Magazine, May 1997, by N1TEV and WU2D

<¬¬¬¬¬¬¬¬¬¬¬¬¬¬¬#¬¬¬¬¬¬¬¬¬¬¬¬¬¬¬>

Below is my favourite super-regen receiver. Needless to say, it MUST have an antenna isolating RF stage to prevent unwanted radiation! The key to this circuit are two components: the emitter choke and the decoupling capacitor (100nF). Keep to accepted VHF /UHF practices, minimal lead lengths, heavy *plain* copper wire for coils / hairpins. It just works, unlike a lot of the j-fet super-regens I’ve tried; I think the wide spread of j-fet parameters are a problem, but don’t quote me!



Critical components:

RFC = 6 turns on ferrite bead (100MHz), reducing proportionally to wire straight through for 1GHz

100nF capacitor = mounted in a through slot in double sided pcb (FR4) material; earth on top side, +ve on underside. Component leads are via chamfered holes (to prevent shorting on top side earth plane). MUST be fitted immediately adjacent to cold end of 'L'.

Tuning capacitor = piston trimmers are good but for 850MHz and 1GHz, a small piece of earthed pcb board material can be moved near the hairpin / bridge or cut and try a small square adjacent to L and filed down until frequency is set. Manhattan pads make ideal low-pF capacitors!

Apply the RF input to any of the transistor leads with a gimmick capacitor or proximity coupling; see which gives best results.

The super-regen above has worked faithfully for me at GHz frequencies, by using as near zero component lead lengths, or preferably, chip components soldered through slots in the pcb or on earthy top side as appropriate. Try several BF199's, they can be quite different in performance at these frequencies, and the 2p2 collector to emitter capacitor isn't often required above 250MHz unless you've got a BF199 of exceptionally low internal capacitance.

The 27k and 1nF to the base is a reflex circuit: the BF199 is in common base for RF (hence very high frequency capability) and common emitter for audio. You can hear the difference!

LF and VLF thoughts…

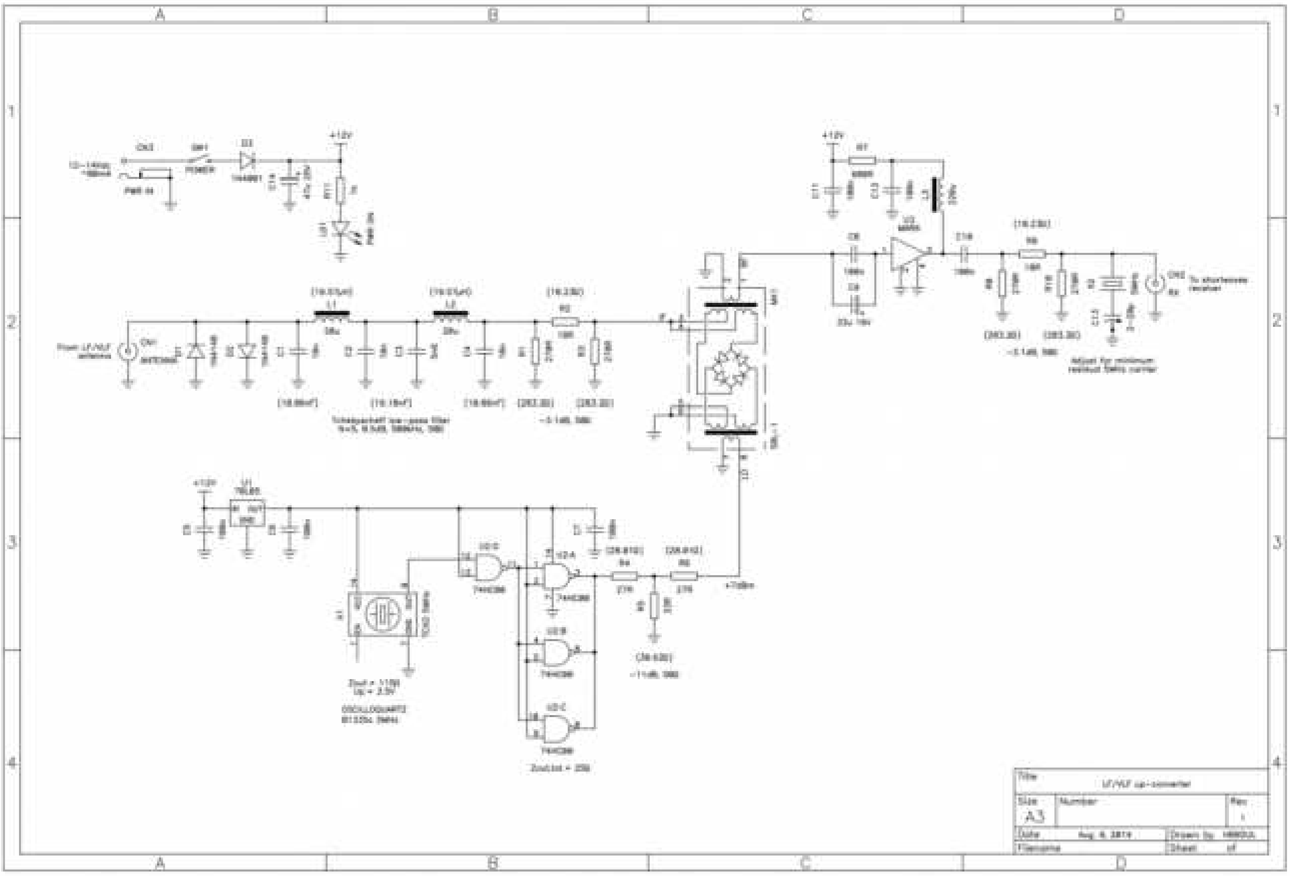
I've always had an interest in the lower end of the RF spectrum; simple receivers and loop receiving antennas make the listening comparatively simple. There's lots of fascinating work to be done down there towards DC; Schumann resonances, earth signals and all sorts of weird and wonderful

phenomena that are little understood, even nowadays. See:
https://en.wikipedia.org/wiki/Schumann_resonances

There are simple methods that make your HF gear able to investigate these signals, an ‘upconverter’ will do the job very nicely, meaning all your HF technology - Software Defined Radio, digital signal processing and the like - can be brought to bear. This being amateur radio, though, you’ll know that simple ideas can soon become very complicated! The design of the upconverter is critical, just as much as in HF Rx. You need to consider very carefully things like mixers, input filters and all the rest of good receiver design, and one such design is:

https://www.giangrandi.org/electronics/lwupconv/lwupconv.shtml

The circuit is reproduced below to give you an idea of the thoroughness Iacopo Giangrandi HB9DUL has applied to this job; take a look around his web pages and you’ll be in no doubt as to why Swiss precision engineering is the best in the World, bar none. Iacopo’s workshop (read ‘laboratory’) is far better than most of the workshops I’ve worked in professionally!



Note the crystal filter in the output section to remove the local oscillator signal - very simple and effective, as is the input signal conditioning. That’s quality engineering and design - Swiss style.

Oscillators

Simplicity and Crystal power (1)

Crystal current is a topic relatively unexplored - until now? I can find few, if any, really definitive articles to explain what is really happening inside a quartz crystal, for my deeper understanding of what can - and can't - be done with our little geodesic gems.

To replace an 'FT' brick crystal in an old valve design, it came to me to consider the *paralleling or series connecting* crystals. If my fundamental electrical theory still applies (you never know in this day and age!) then two *identical* crystals in parallel or series would dissipate 2x the power allowable in a single crystal.

I put this question to a crystal supplier here in the UK, with this reply:

'*The answer is not that simple I am afraid, firstly, in general, as soon as you over-drive a crystal the output distortion and spurious responses increase, too much power and the crystal will shear from its mounts. However, it will be frequency dependent and the higher the frequency the thinner the blank leading to more risk of damage.*

The old low frequency crystals were larger, thicker blanks which could handle more power depending on the mounting system.

I am afraid I am not aware of a 'wrap around' circuit such as you describe.'

Best wishes, &c., &c.'

So, it would seem, that the basic principle of parallel or series connected components sharing the applied voltage *is not applicable* to crystals: the reason (to my limited thinking...) being - that even if the crystals are nominally of identical frequencies - the crystals are NOT exactly electrically identical and can't be assumed as such. But see this article:-

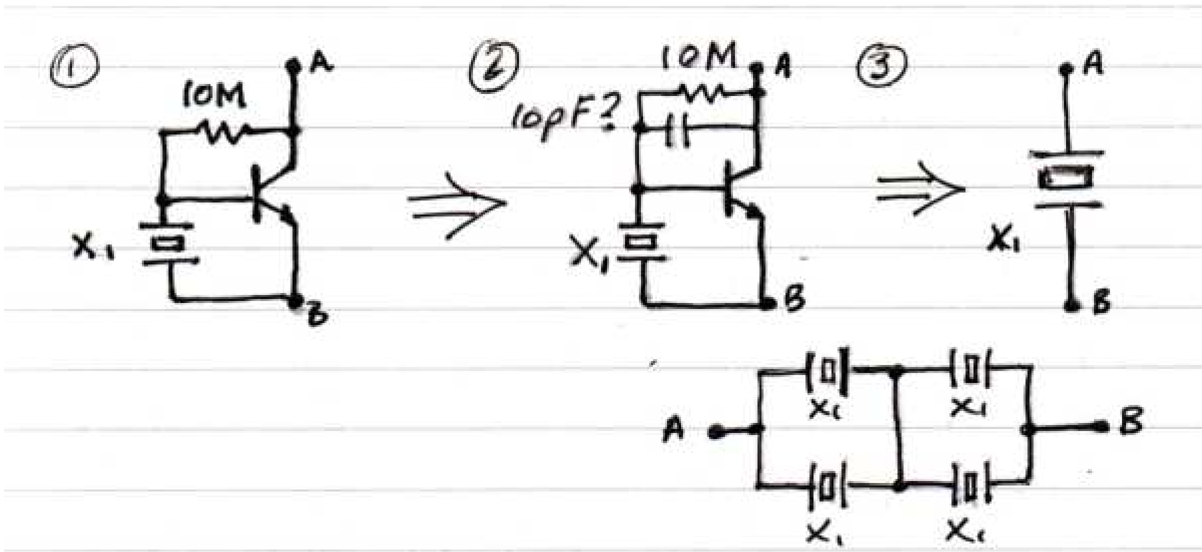
https://electronics.stackexchange.com/questions/413054/confusing-quartz-crystal-impedance-graphs

...illustrates, in the responses to the article, a whole host of different thoughts and interpretations regarding the 'simple' crystal's electrical characteristics.

I was thinking about the old 'FT' crystals - the 'brick in a box' type, *tour de force* pre 1960 and how they could possibly be mimicked by modern crystals, the 'speck of dust' SMT types arranged in a series // parallel matrix to get a watt or two dissipation: the idea being to replicate old valve designs that gave crystals a real shellacking in terms of current.

It seems from the crystal supplier's reply you can't just shunt together a host of crystals; but my thinking is along these lines, that in this Universe it's a fact that if several objects are sharing a load, the energy will be shared amongst them according to their resistance - or in crystal terms their internal friction - and in any crystal you care to name, a Watt's a Watt; a Joule's a Joule, and never the twain shall be anything but.

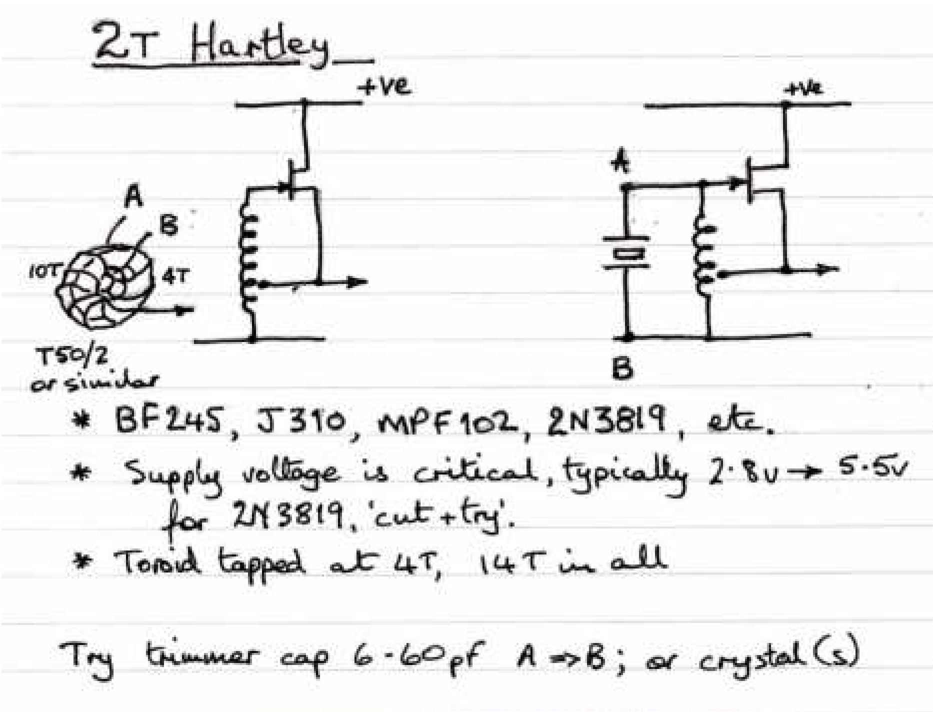
I thought about 'wrap-around' schemes - as you would 'wrap' a PNP transistor around a 78L05 regulator to gain extra 'wattage' - from a mini crystal, series and parallel (below). A and B are the connections for an 'FT' crystal in the original valve circuit.



The idea in (1) is that the 10M resistor feeds a sniff of forward DC bias (not enough to allow self oscillation) and signal to the base and X1; thus X1 controls the base of the transistor and modulates the collector current. (2) is similar, in that a small value capacitor feeds some RF signal to the base; the 10M resistor adds a sniff of DC base bias to put the transistor in to conduction at a low collector current until the crystal, at resonance, creates Q factor mV's in the base circuit so the transistor mimics the crystal. (3) is a series - parallel matrix of crystals, all nominally the same frequency; the energy applied A to B is shared between all the crystals. Well, that's the theory, anyway!

The series connection of crystals is common in amateur designs: think of the crystal filters in an IF strip. Thus we deduce crystals CAN be operated in series, albeit in a filter at very low dissipation; so who's going to try a handful of nominally identical crystals in series // parallel and see how many watts can be safely run through the assembly? Over to you!

A 'minimalist' 2T Hartley



Minimalist oscillators, ideal for quick Rx tests, are a useful bit of kit: here's a down and dirty solution, a very simple j-fet Hartley (from Elektor via http://qrp.gr/2cosc/index.htm). The basic circuit (above, left) relies on self capacitance in the coil; try a trimmer A to B, or a crystal and see what happens.

Simple circuits can be extremely frustrating: they either sing like a bird or refuse point blank to do anything, and with so few components, you're left little choice as to what to change! In this case it's the +ve supply volts, tap point and j-fet type. I tend to go for 2N3819's; they are pleasant little beasties, happy to give their all, and not at all fussy, but please try whatever you have to hand. A variable power supply (current limited) is a God-send!

Taming a VFO… (1)

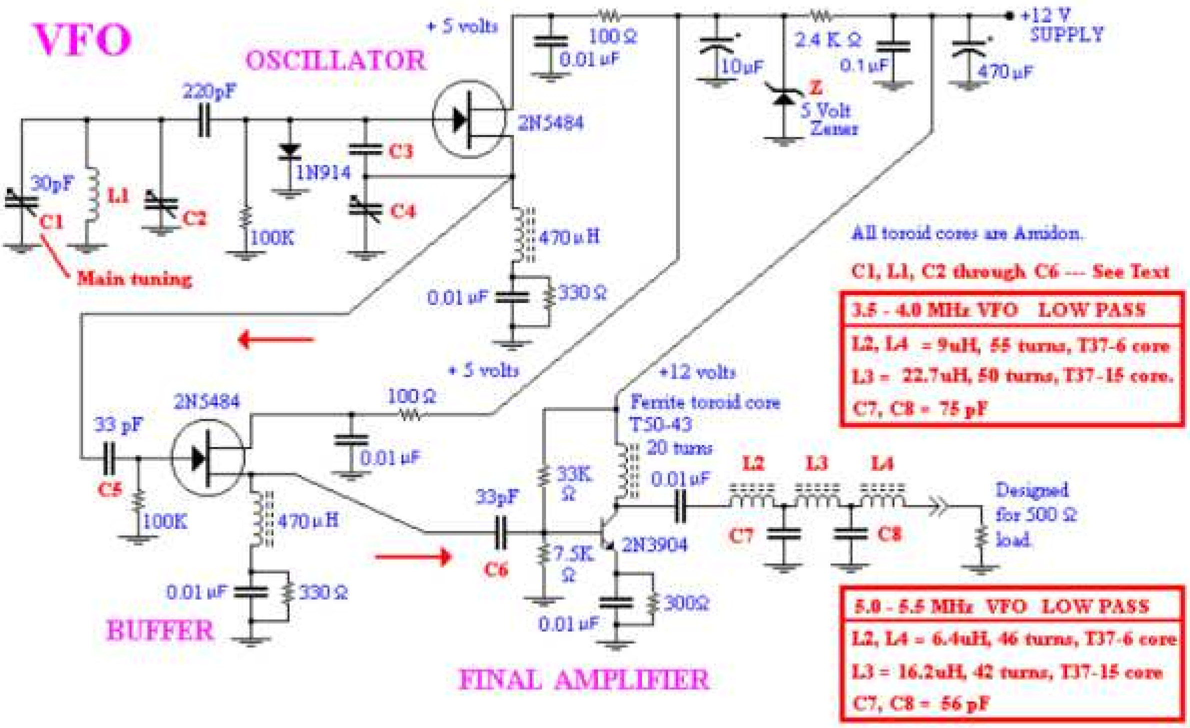
If you would wind your VFO coil with chunky copper wire, you might choose a threaded former, like a 15mm or 18mm (¾' UNC?) steel bolt, then once sure the coil is of satisfactory turns, the coil is 'unscrewed' and a similarly threaded rod made of tufnol or other insulating material can be 'screwed' in and out of the coil to vary the self capacitance of the coil - thus giving you a capacitive 'fine tune' function, not 'permeability' tuning. This however, relies on the coil turns being very rigidly fixed which is not easy in such an assembly! Any insulating material, moving into the centre of the coil, will give fine tuning (as mentioned previously in Hot Iron) so how's this for an idea?

A tufnol former, having threads die cut round the outside, is an ideal former; leave it in the centre of the coil, varnished with 'Q-Dope'. If you drill and tap the centre of the former, thread a brass bolt into the former, you've got much more mechanical stability and a fine tune option on your coil.

Taming a VFO… (2)

There are many ways to make a VFO; very few to make a stable VFO! I have had queries from amateurs wanting to build an 'analogue' VFO, after using a 'digital' VFO; why, they didn't say, but below is just about the best article I've seen on the subject. It's from "Crystal Sets to Sideband" by Frank W. Harris, a most valuable reference: look it up, the entire book is available online and is a gem in every respect. You can rely on it!

Once you have built a stable(ish) analogue VFO you certainly feel you've accomplished something and indeed you have - and you've trodden a well worn path. If you can get to ±10Hz you deserve hearty congratulations!



'Suppose you were to build the above VFO without reading the details in the following paragraphs: When you first turn it on, you will be disappointed to find that it drifts a hundred Hz per minute or more. The drift is caused by temperature change. The components expand and contract with temperature change and this causes small changes in the capacitance and inductance of the components. Air wafting across the board doesn't allow the temperature to stabilize. Drift is prevented by preventing temperature change and by choosing components that change as little as possible with temperature.

VFO building is an art form as arcane as Grandma's secret pie crust recipe or the fine points of building Cub Scout Derby racers. As you'll see, there must be 50 ways to improve the drift problem. I have never built a VFO that was a completely "stable" and probably never will. But perhaps that's because I only know the 14 secrets listed below. If you apply as many of these as possible, you should get within the 20 Hz target - and maybe even under 5 Hz.

Secret # 1.
Junction Field Effect Transistors (JFETs) The first secret of a stable VFO is using a JFET instead of a bipolar transistor. As described earlier, a field effect transistor is better because it is less sensitive to temperature. I have used 2N3823, 2N5484 and 2N4416 N-channel JFET's for VFO oscillators. My impression is that any small N-channel FET works well.

Secret # 2.
Seal the VFO in a cast metal box. Simply protecting the VFO from air currents makes a huge improvement. Use a heavy, cast metal box so that the temperature will at least change slowly. In contrast, a flimsy, sheet-metal aluminum box will heat and cool relatively rapidly. On the other hand, ANY box is a huge improvement over not having the circuit sealed from air currents.

Secret # 3.
Use single-sided PC board. A double-sided PC board is constructed like a capacitor. That is, thin metal sheets are bonded to a layer of insulator. Unfortunately, the resulting capacitor has a significant temperature coefficient. As temperature increases, the board material expands (thickens)

and the capacitance across the board drops. If the VFO is built on traces and islands that have changing capacitance to ground, the frequency of the oscillator will drift slightly.

Secret #4.
Mount the oscillator PC board away from the metal case on stand-offs. Using the same principle as above, do not mount the single-sided PC board flush against the metal case. By standing the board up and away from the case, the capacitance between the traces and the metal case can be minimized.

Secret #5.
Choose and mount all components affecting the oscillator LC circuit carefully. All the L and C components in the oscillator should be designed for minimum temperature drift. Referring to the diagram, it is not just capacitors C1 and C2 that affect the frequency. Capacitors in series with the 220 pF capacitor, C3, C4 and even C5 affect the frequency. To at least a tiny degree, ALL components in contact with these capacitances can affect frequency drift. These include the diode, the RF choke, the transistor and the 100 K resistor.

Secret # 6.
Mechanical variable capacitors should be chosen carefully. Although good mechanical variable capacitors are hard to find, they may be the best solution for you. Pick a capacitor of about 30 to 60 PF, not larger. High capacitance variable capacitors are too sensitive to temperature change. Smaller ones don't tune far enough. Don't use a capacitor with aluminum plates – they warp too much with temperature. Brass is the best metal. Try to find a capacitor with thick, widely spaced plates. Paper-thin plates are compact, but warp readily with temperature change. If the capacitor tuning is linear with degrees of rotation, the frequency it produces will be somewhat non-linear. Ideally, the capacitor plates should have a non-linear shape that allows it to tune an LC resonant circuit so that the frequency will be linear. Rotate the capacitor through its range and you'll see that a compensated capacitor has rotor plates that are not simple half circles. As they rotate, they do not mesh with the stator plates at the same point. The non-linear correction isn't a big deal, but it is something to be aware of.

Secret # 7.
Varactors (Varicaps) are the most stable tuning element. It's hard to buy mechanical variable capacitors that are mechanically and thermally stable. Collins Radio formerly tuned their VFOs with special powdered iron slug tuned coils, but I've never seen any for sale. A varactor capacitor controlled by a quality pot is a good solution to these problems. Varactors are a kind of silicon diode biased with DC voltage. In my experience varactors are an order of magnitude more thermally stable than mechanical capacitors. They are at least two orders of magnitude more mechanically stable. You can slap the VFO with your hand and, although other components may vibrate, the varactor doesn't change its capacitance. Unfortunately, varactors produce a non-linear scale on the frequency tuning knob. This means that the high frequency end of the VFO range will be extremely detailed while the low end may be compressed into a few degrees of rotation. For this to be usable, the potentiometer should be non-linear to compensate.

Secret # 8.
Use NPO fixed capacitors. When selecting capacitors, look for type NPO. These are supposed to have minimum temperature change. Use these for ALL fixed capacitors affecting the LC circuit.

Secret # 9.
Use multiple NPO capacitors in parallel to achieve a given value. If you must use fixed capacitors in parallel with C1 or C2, it is better to use several small ones in parallel than one large capacitor.

The temperature of a small capacitor stabilizes quickly, whereas heat builds up more slowly in a larger capacitor.

Secret # 10.
Temperature compensation for the LC circuit is essential. It took me four prototypes to accept this, but temperature compensation is as important as putting the VFO in a box. Lots of guys claim to have succeeded without it, but I never have. Not using temperature compensation implies that every capacitor and inductance in the VFO must have a zero temperature coefficient. Alternatively, all negative coefficients must be balanced precisely with components that have positive temperature coefficients. Good luck doing that!

Secret # 11.
Use an air core inductor. As usual, it is most convenient to use a powdered iron toroid core. Unfortunately, powdered iron changes its permeability (magnetism factor) with temperature. Therefore, by not using iron, another variable is eliminated. I have successfully used old plastic pen caps as little coil forms for air-core inductors. I bore little holes in the plastic to accept tiny pieces of stiff copper wires to serve as wiring terminals.

If you do use powdered iron, among the CWS (Amidon) cores, type 7 is supposed to have the best thermal stability. Amidon #6 cores have worked reasonably well for me but maybe #7 would be a few percent better. If you make a coil out of turns of copper wire on a plastic form, the copper will change its dimensions slightly with temperature too. And because an air core inductor requires more turns of wire, there is more opportunity for the copper to change its dimensions, its inter-winding capacitance and also its resistance. Finally, an air-core coil will couple like a transformer to nearby parts whereas a powdered iron toroid couples far less.
After you have your coil wound and working over the right frequency range, epoxy or clamp it to the board. Without the epoxy, the frequency will warble with the slightest vibration. I once tried to use slug-tuned coils. They were convenient to adjust, but were mechanically and thermally unstable.

Secret # 12.
Precision voltage regulation for the VFO supply is vital for precision frequency stability. The 12 volt supply for the VFO as whole must be regulated. Ordinary voltage regulators like the LM317 or LM7812 gave me regulation within 0.1 volt. This was OK for frequency stability down to about 20 Hz drift. But to get down to less than 5 Hz, I needed to regulate my VFO power supply to a few millivolts. To achieve this, I built a precision supply that just powers the VFO. The less current the supply has to deliver, the more constant its output voltage will be. The supply is discussed in detail below.

Secret # 13.
The VFO should draw as little power as possible. The less power drawn, the less heating that occurs inside the VFO box. Also, the less power drawn, the easier it is to build a precision voltage supply to drive the VFO. That is why the VFO was designed for a 500 load rather than 50 ohms like most ham RF circuits. The VFO as a whole should draw less 20 mA DC. 10 mA would be even better.

Secret # 14.
Forget tube oscillators. You old timers may be tempted to use a tube oscillator. I first tried to update an old tube VFO, but tubes get hot and make temperature compensation too difficult. You'll have plenty of trouble without this extra burden. You may use bipolar transistors for the final amplifier in your VFO, but not for the oscillator. For good measure you may as well use a JFET for the buffer as well'

From experience, the ideas presented above are solid and reliable: they will make a very good VFO if you follow Frank's advice. Here are some thoughts:

- "6" material toroids (air cored preferred IF you can make them very robust);
- Multiple NP0/C0G capacitors for under 120pF and styroflex (polystyrene) over that value
- Design for less than 10MHz;
- Short, wide pcb tracks; a minimal pcb etch layout is best - in other words, remove the minimum copper (a 0.5mm radius tip pcb router is ideal for isolating islands of copper);
- Single sided glass fibre pcb material; if you have only double sided, make topside ground, underside power and liberally sprinkle decoupling capacitors around the assembly using slots or countersunk holes to guide leads through the pcb without causing short circuits;
- A better stabilised power supply than a raw 7805 or similar can provide.

Complexity and crystal power (2)

Kosta, SV3ORA, has described a crystal oscillator with THREE crystals, that oscillates on all three frequencies! Just how useful this is not immediately clear to me, but it's yet another of those good ideas looking for somewhere to happen. See:

http://qrp.gr/multiosc/index.htm

Hans Summer has looked at this too; see:

http://www.hanssummers.com/multiosc.html

Any ideas gladly accepted!

Transmitters

ONE component transmitter

Let's get this established before we go on: spark transmitters are, for most purposes, not allowed: they've been (voluntarily) banished since 1929. Of course, radio amateurs being what they are, 'certain' amateurs just couldn't resist and rebuilt ancient radio gear, especially airborne spark transmitters from WW1. In those days reliable communications needed enormous 'flat top' antennas and loading coils to resonate antennas in the VLF and LF bands so the 'short wave' sets carried aloft in Vickers biplanes (a.k.a. 'string bags') were a prime target for investigation, and what I discovered in the reference below was an eye opener to say the least. Not only did the pilot of a 'string bag' have to fly a rickety collection of canvas, wood spars and leather straps whilst sat on gallons of petrol, being shot at from all directions, whilst running a spark transmitter to guide artillery and report reconnaissance to those on the ground. Intrigued thus, W5JGV obtained permission to test an airborne transmitter from the FCC and the result is in the web page below:

Legal spark transmitter: http://w5jgv.com/375%20Meter%20Spark%20Transmitter/

I first came across spark transmitters as a nipper, reading an old book at my grandparent's house, called 'How it Works', that described spark transmitters. To me, this represented a wonderful experiment: I made a spark transmitter with a 6 volt ignition coil, a 6 volt ‘lantern’ battery and a file as a mechanical circuit breaker to buzz the primary of the coil - all mounted on a bit of plywood with brass screw terminals. I strung out a wire from my bedroom window to back garden fence, connected an earth lead to a water pipe, and proceeded to make some ‘Hertzian Waves’.

I knew I’d transmitted, no doubt about that: how could I be so sure, since I didn’t have a receiver? My parents, that’s how, who soon told me to ‘give over doing whatever it is you’re doing!’ (in NO uncertain terms) as I’d wiped out the VHF TV they were watching, with screens full of white flashes and sound laced with crunching crackles. I was most proud of my success, but couldn’t repeat it without getting a four-penny one from irate parents; so, advised by my uncle who served as a ‘sparks’ in Atlantic Convoy Royal Navy Destroyers in WW2, I began to look at amateur radio.

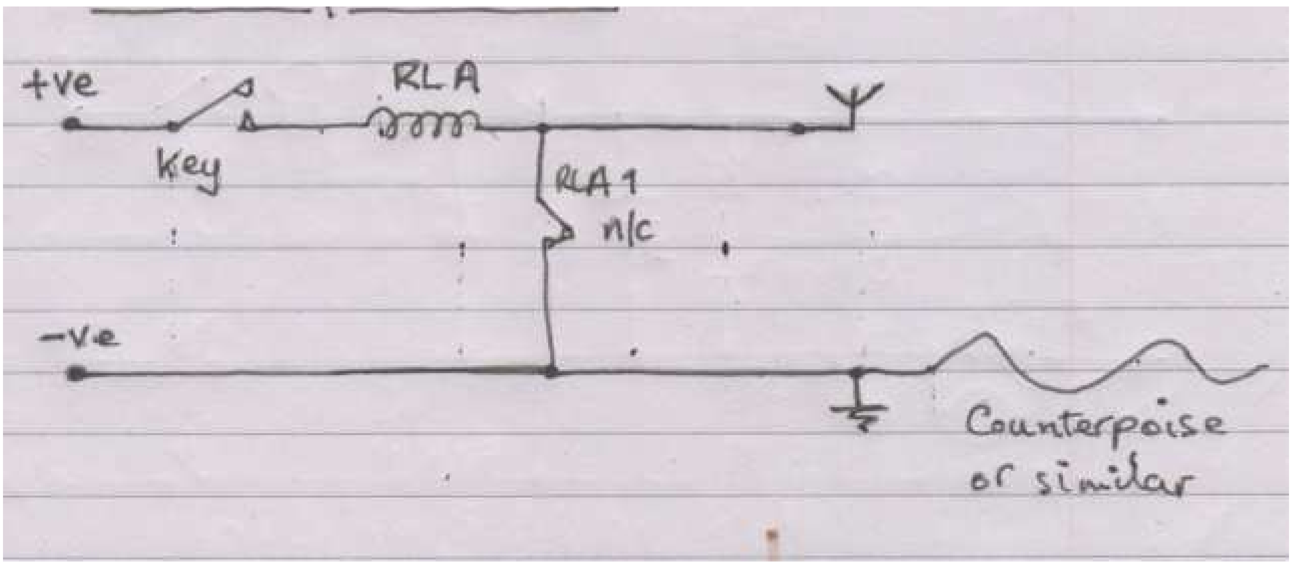
And the rest is history! I was launched headlong into an electronic age where valves ruled the serious stuff, and transistors were just beginning to poke their noses in (early 1960’s) and I soon began playing with all sorts of circuits, made from bits scrounged here, there, and everywhere.

It was during my apprentice days a few years later I met spark transmitters again: in high voltage, high vacuum glass work you test for air leaks with a ‘Tesvac’: a Tesla coil with a hand-held EHT probe. A pinhole leak drew a spark (2” long mind you) and showed a discharge inside the evacuated glass vessel - be it an 807 on burn in or a Royal Navy cathode ray tube.

Anyway, below is the schematic of a ONE component radio transmitter. It’s primary purpose is to test the noise immunity of receivers, logic circuits, and any other gear we have around our radio room. An old open frame Arrow relay - the type with ⅜” // 10mm diameter silver contacts and a huge coil - is the one to go for. 3Φ contactors with a low voltage DC coil culled from a scrap control cabinet are good, too. Note the use of the operating coil as both an actuator for the relay, and as an RF choke. Neat!

The unit makes an excellent test set with a few metres of wire for an antenna plus counterpoise for checking how well your gear rejects broadband noise, its earthing and screening capabilities and logic noise immunity. Admitted, it’s a shotgun approach, but it don’t half find problems!

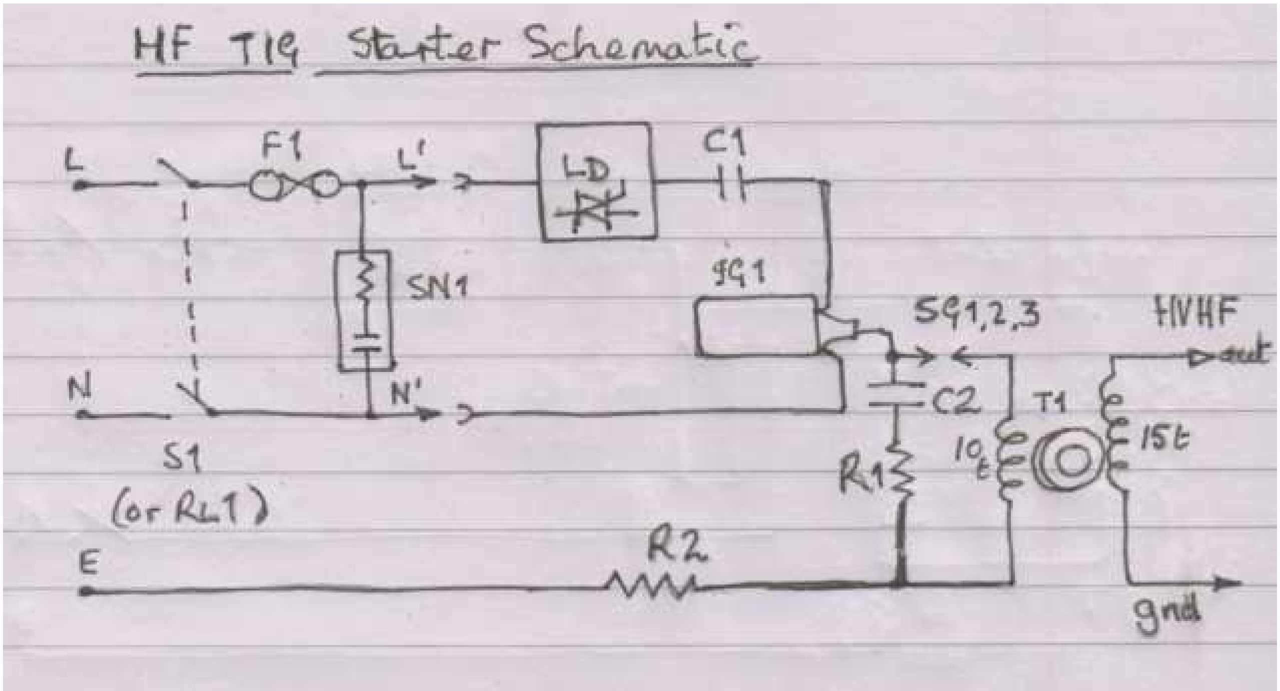
To stop the loonies out there from blattering the aether, no details given re. antenna or counterpoise - capable amateurs will soon sort these out.



Should you need a more potent wideband HF noise signal, the circuit below is useful. Normally used in TIG / MIG welding, it's a hefty source of wideband HF.

WARNING: this circuit generates high energies powered directly from the mains (*use an isolating transformer! Ed.*) Unless you're familiar, experienced and aware of the precautions needed to build and run such a circuit then DON'T BUILD IT IF YOU'RE NOT EXPERIENCED WITH HIGH VOLTAGE AND RF SAFETY. I was trained by experienced engineers who taught me to respect beasts like this to ensure my continuing to draw breath.

I'm not responsible for any injuries or damage units like this CAN and WILL cause if mistreated or mishandled. The component values are deliberately left off the schematic to deter the uninitiated.



Down at DC...

Are you still playing 'down near the DC' at 10 GHz? Take a look at: http://www.modulatedlight.org/optical_comms/optical_index.html

...and be ready to be amazed. Marvellous stuff, and exactly what amateur radio (optics?!) is all about - and easily reproduced too. Amateur radio is a very broad Church; Nature has given a magnificent playground to those who would strike out into the wide blue yonder and experiment.

Driver level shifting

In designing bridge type switching circuits for RF induction heating and much beloved by our LF brethren - before chips were available for this job, or weren't up to more than a few kHz - designing your own is the only answer. The trick that is simple and very effective is to drive the 'top side' power device(s) is an HV PNP silicon bipolar transistor 'level shifter'. With suitable drive from a totem pole logic output (74HCXX types) the circuit below gives a good solution and can achieve nS edges if set up properly.

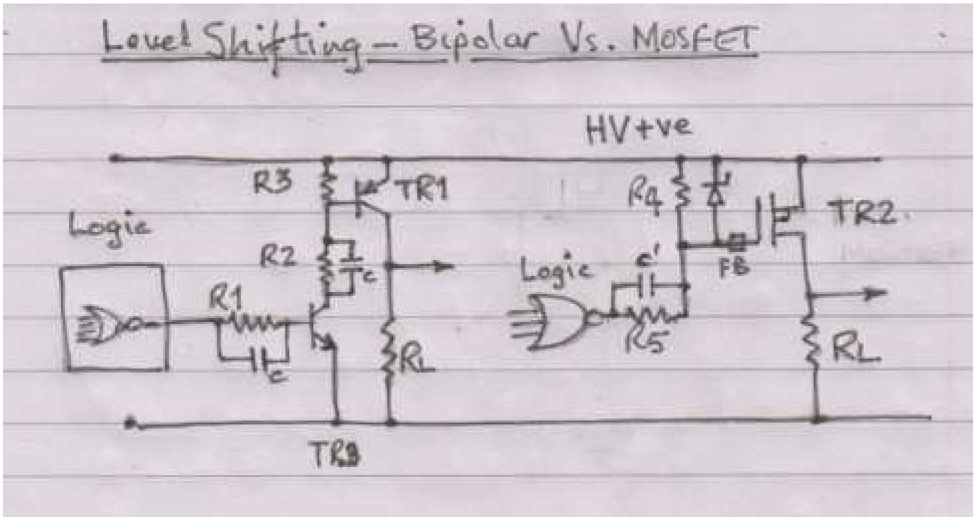
The trick is the capacitor ‘C’: this is chosen to be equal to the stored charge in the PNP base / emitter junction, so on the rising edge drive from the logic, the capacitor instantly transfers charge into the empty base / emitter, resulting in very fast TR1 switch on. The exact opposite on the logic output going low occurs: the stored baser charge is removed as fast as the surrounding circuitry and wiring allows. R3 (and R4) remove any false switching due to noise; not always required.

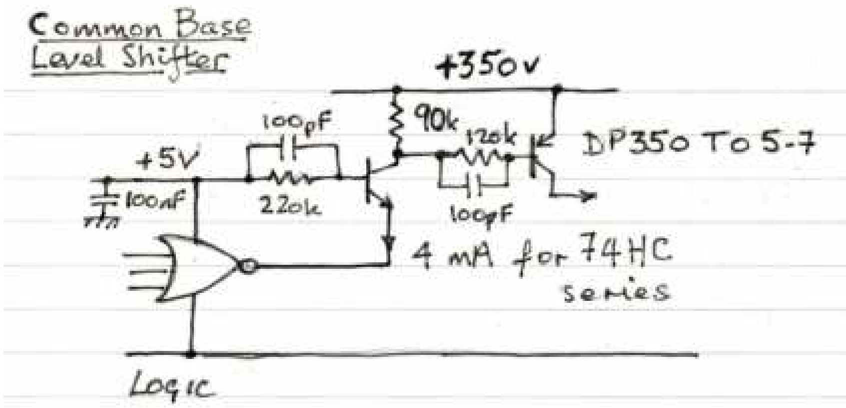
A similar drive technique is used with a P-Channel MOSFET, shown right. Note however the need for a zener to stop the gate / source insulation (normally good for ~15 volts) being broken down by the much higher voltages available in this circuit. Whilst a MOSFET is by it’s very nature a very fast little beastie, the stored charge in the gate / source is generally larger than in a bipolar device; and adding the zener (9V1 to 12v. or so) adds to the charge the logic has to switch.

In the bipolar PNP drive, a transistor, TR2, is used to remove the amps of charge very quickly; far more effectively than the logic 10mA capability. The same trick can be done with a MOSFET by adding a driver transistor to shift the stored charge as fast as possible.

We used these techniques with multiple HV line output transistors to bridge drive an inductive heater coil wound around quartz reactor tubes containing a graphite susceptor for vapour phase epitaxy on gallium arsenide wafers at 1000°C+. We ran an HT supply of 600 volts, at ~10 amps to give just shy of 5kW of heat; the efficiency of the drive circuits relied on very fast switching edges and exact timing, otherwise the power transistors very quickly shuffled off their mortal coil.

We did suggest trying a 4CX1000 tetrode, but since we were a semiconductor manufacturing plant, the ‘powers that be’ frowned upon us buying and running such esoteric beasts!



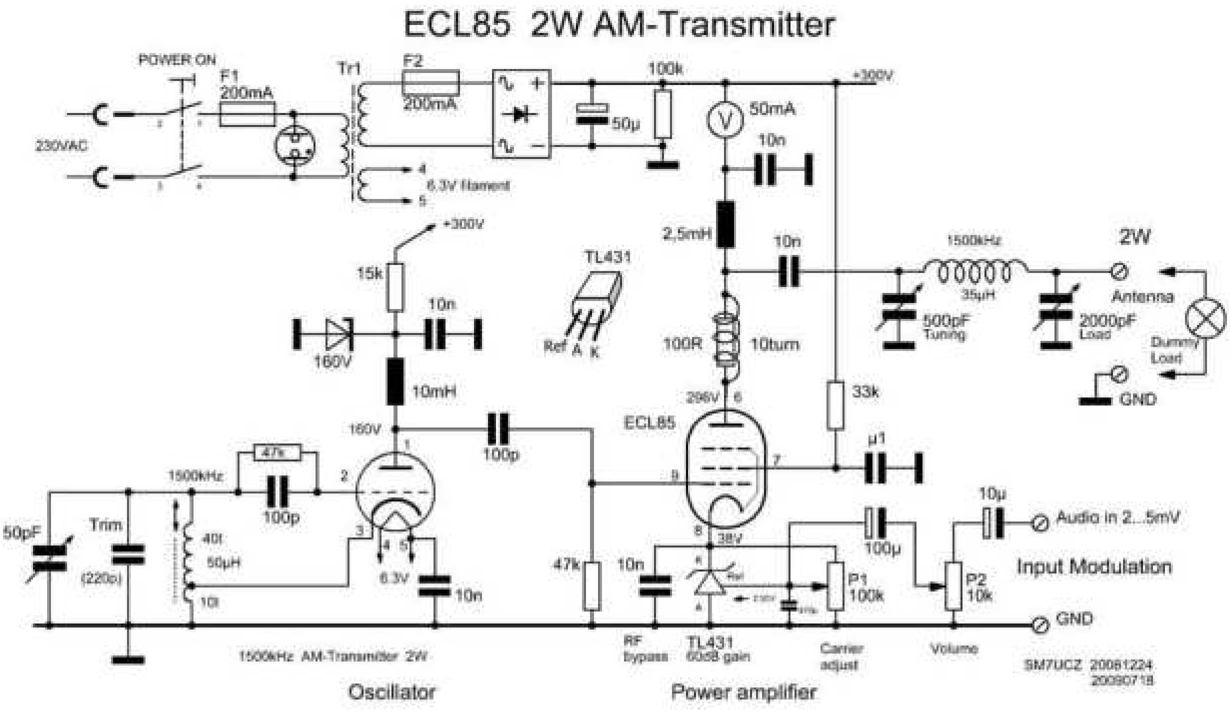


This is a very canny way to drive the PNP level shifter; admittedly the base drive is limited to the logic low ‘sink’ current but despite that it ain’t half fast! Try it and see; be ready to cut-n-try the base drive C // R networks to get the best switching times.

How simple can it be?

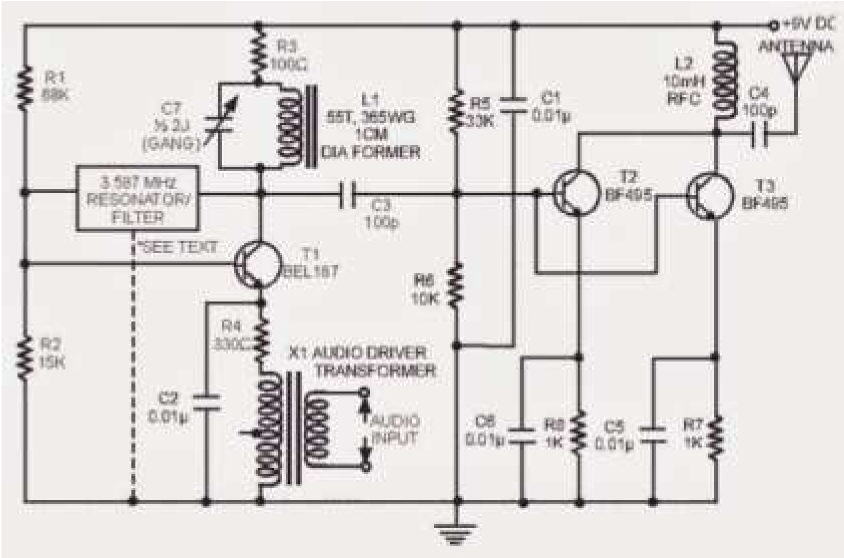
Here is a neat transmitter, which use a TL431 regulator as a cathode modulator. You could easily use a crystal rather than a VFO if you wished. The circuit round the cathode will need adjusting to get 50% carrier on zero modulation, but it shows just how simple A.M. phone can be!

The use of a TL431 is an excellent idea, simple and direct to get grid and plate modulation. For Top Band try an L/C VFO - well built as per this edition of Hot Iron - and if it’s an excellent performer you could get A.M. on 80m too. If you prefer to be spot on every time, substitute a crystal for the L/C oscillator and you’re sure of frequency.



http://www.sm7ucz.se/AM_Transmitter/AM_transmitter.html

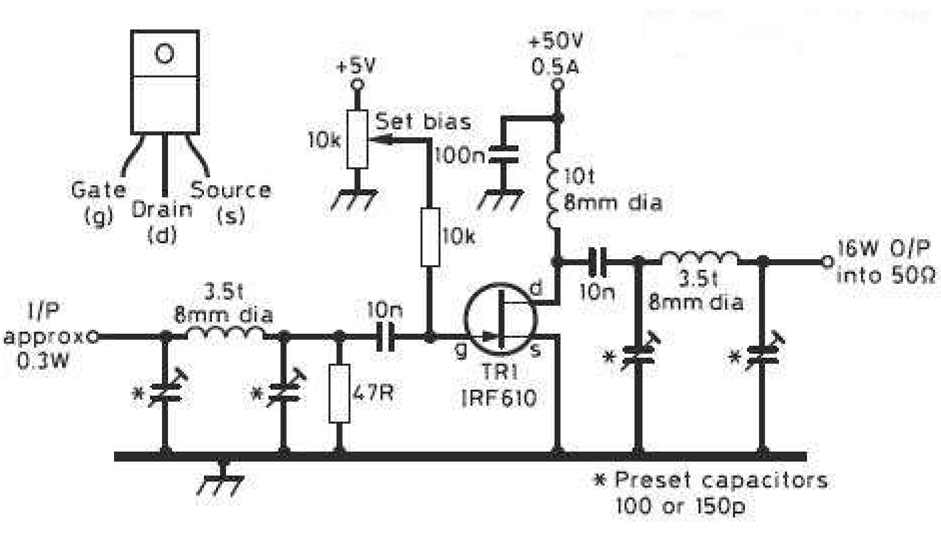
Here’s a neat little transistor A.M. transmitter; simple and straightforward, of the ‘JABOT’ approach (‘Just A Bunch Of Transistors’) for a very nice linear PA.



Power Supplies

A review of 12 v. power supplies

12v was nominally chosen as it was commonly used in automotive engineering, but nowadays it's easier (and cheaper!) to find 19 volts in laptop power supplies. I checked on our favourite auction site and 65 watt 19v 3.5 amp supplies are a couple of ££'s, far cheaper than if you tried to make one from parts, and it's in a safe and neat small case. You've got the issue of SMPS noise, but mounting the unit inside a steel conduit 'knock-out' box (or diecast box if you're rich) kills a lot of that, as does AC common mode input chokes. The low cost of such SMPS's allows stringing 3 of them in series (the outputs are usually isolated, but CHECK!) and you've got ~ 50v at 3.5 amps: use that to power a single (low cost) mosfet HF linear amplifier, the higher drain volts gives far better linearity and gain, as below:



Mysterious 'hash' from Switch Mode Power Supplies?

Watch for noise being spread in the earth wiring in your house! High frequency 'hash' has to run to ground somewhere, and it's most likely your mains incomer panel where, under 'PEN' or TNS/C wiring, the earth is joined to the neutral - and thence to the Earth point on the sub-station transformer winding. The whole point is that screening picks up the radiated noise signal and runs the noise current to ground - somewhere. That's how it works! Current running through a wire is exactly what's needed for radiation: current in a wire is the definition of an antenna!

The principle of screening is that a charge on the inner surface of a sphere cannot be detected on the exterior; and vice versa (Gauss's Law, Faraday Cages). But… practical screening isn't a sphere, nor does it completely enclose the inner surface - we have to get signals in and out of our gear somehow, so that's where the noise currents travel, either on cable screens or power wiring. Our knowledge of screened cables tells us that the earthed screen stops external noise getting to the core, but that's a problem: the noise can propagate on the **outer** surface of the screen.

The way to reduce any radiation from such earthing is to use as near enclosed screens as you can, earth through short, fat copper strips to a 'solid' earth plane. Enclose your gear in steel or diecast alloy boxes: the magnetic property of steel absorbs the magnetic component of radiated noise and diecast boxes have very low resistivity, making a path to earth easier - IF you can solidly earth!

Refurbishing 'sulphated' batteries

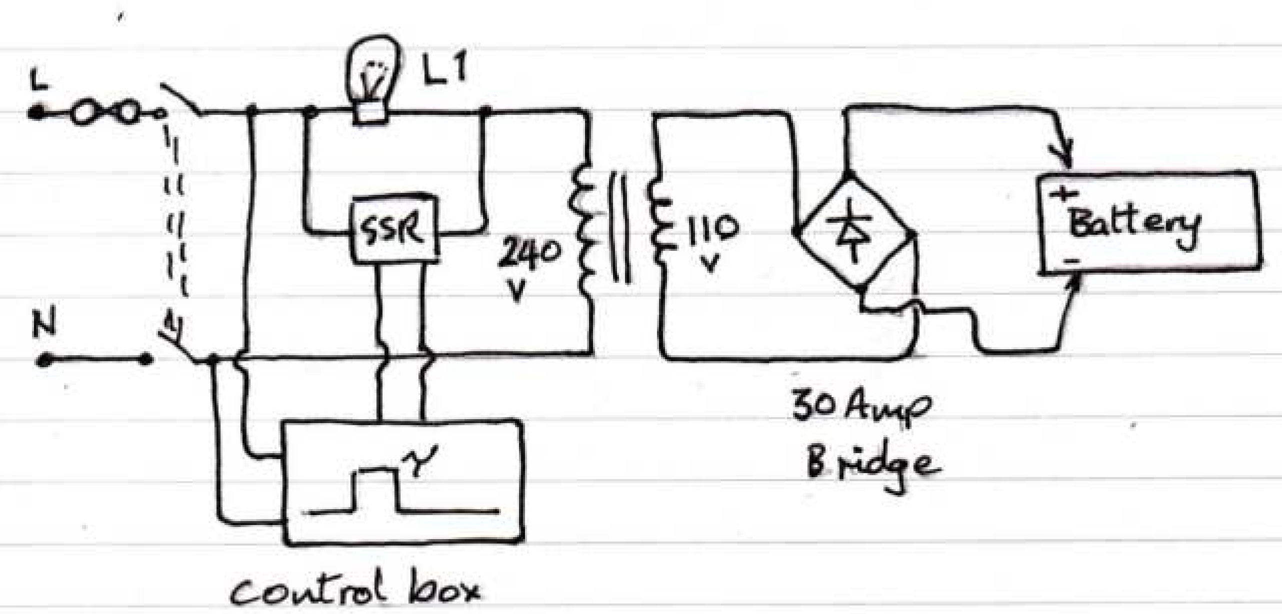
It's a common question, especially by those stood by an old lead acid battery, automotive or 'leisure' type, saying… 'it won't hold / take charge any more, what can I do?'

Well this question is about as old as the invention of lead - acid batteries! The short answer is 'get a new one' but it's always worth a shot to try rejuvenating dud batteries - and plenty of ideas abound on the internet, some sensible, some away with the Fairies and Cosmic Earth Energy. Here's one I built many years ago to Stan's design, and it works providing the battery hasn't been left for weeks flat as a pancake, frozen, drained of electrolyte, or otherwise ill-treated.

The basic principle is to use pulses of current at high applied voltage to break down the high resistance of the plates, then slowly return the sulphated plates back to lead; if there's a chance, this method will do some good. The real problem is to remove the coating of 'clagg' from the plates, which drops as sludge to the bottom of the cells. The sludge is conductive and shorts out the plates. It can be swilled out with water (once the electrolyte has been drained and sieved), and the electrolyte replaced into the now clean(er) cells.

Here's the gist of the Battery Bumper. The points to note are the use of a current limiter in the primary circuit, bridged by a solid state relay which featured zero crossing switching - the SSR will only trigger if the control voltage is present within a mS or two from zero volts. Stan set the output pulse (T) to a touch under 10 mS (for 50Hz) thus ensuring that whenever the input trigger pulse arrives in the 50Hz sine wave, it will catch a single zero crossing and statistically, catch as many positive as negative half cycles to avoid DC bias flux in the transformer. The timing was about a minute per pulse from a 555 astable timer; the 25 watt current limiter lamp briefly flickered off as the battery (or more likely, the transformer… Ed.) gave a pronounced "BMPP!" which could be heard across the workshop. The current limited rectified pulses in between the BMPP! pulses made a low buzzing from the battery. The clagg typically dropped off the plates in about 15 minutes; Stan turned the BMPP! pulse circuit off, allowing trickle charging via the lamp current limiter overnight.

The following day, the battery went back on the stacker truck and proved serviceable for another 2 months, then died again. No amount of BMPP! treatment did anything; Stan reckoned the plates were just plain wore out ('like my dodgy knee…' sayeth the Stan) , so it went for lead scrap.



Stan reckoned the high voltage with limited current plus the BMPP! pulse was the trick; it certainly gave some more life to the battery, but you can't restore brand new performance. Lead acid batteries have consumable materials in the plates; when it's gone, it's gone - no amount of messing will put it back. It's in that sludge you swilled out down the drain - oops, I meant 'ecologically recycled into the appropriate waste stream'!

One other thing: those gel cells and similar - the usual problem is the electrolyte eventually evaporates out through the vents. You can try introducing some distilled water into the cells (if you can get the top cover off and get to the vents); not always possible, and don't try drilling holes in the top. Not recommended!

Arc Fault Detection (or 'Disconnect') Devices (AFDD's) and neighbours

The IEE, that collection of venerable experts who publish the 'wiring regs' for UK electrical wiring, have heard about some remarkable devices much beloved by our pals across the pond, who (for interesting historical reasons involving carbon filament light bulbs and Thomas Edison) use more amps per kW than we do here, as we have 230v AC supplies, they 110v AC.

'More amps' is the key: to make true arcs you need amps, and lots of 'em: think of an arc welder. Arcs ain't Sparks; no sir: an arc needs enough heat to vapourise the metals involved, thus creating a plasma, an electrical conductor. The volt drop across the arc of a manual metal arc ('MMA' or 'Stick') welder is in the region of 20 -70 volts peak after the arc is struck by running 60 - 130 amps through an electrode, depending on dimensions and material. It is almost impossible to strike a true arc with a copper to copper contact; copper to brass (as in a terminal block, for instance) is touch easier, as the metals shunt heat away so effectively. If - and it's a big 'if' - a true arc strikes, then you've got a very dangerous heat source and fire hazard, so AFDD's are generally *a good idea*.

In the USA (and other 110 volt regions) cables are far thicker than our Euro / UK cables to carry enough amps to for the kW's; thus a poor connection, creating I^2R heat, has plenty of 'ampacity' (isn't that an magnificent word the USA has given us!) behind it causing a very real fire hazard and possibly an arc.

Thus was the ‘AFDD’ designed; it detects the characteristics of an arc - namely the HF components of the plasma, apparently around 18 - 32MHz. I don’t know the exact means an AFDD uses to sense the HF, but suffice to say those caring people at the IEE, ever vigilant in looking after our interests (whether we want them to or not..!) have insisted that AFDD’s are fitted in various special locations, as noted earlier in this edition.

What I don’t see is how somebody transmitting on 14m, 17m,15m, 12m or 10m can avoid tripping nearby AFDD’s with RF picked up on nearby cable runs: or how somebody down the street on the same phase running an arc welder avoids false tripping nearby AFDD’s. Any readers with experience of AFDD’s please let me know how you get on with them, and false trips please!

Incidentally, there is a formula for converting AWG to mm²: $0.012668\ mm^2\ (92^{(36-n)/19.5})$

where ‘n’ is the AWG number. I can feel you cringing at that formula, so check the table in the Hot Iron Data section at W4NPN.net!

You need the right connections…

Whilst we’re on the subject of electricians, Regs, and all that malarkey, I note with interest the popularity amongst our “T&E” fraternity of electricians of ‘push fit’ and cage clamp quick connectors. It seems like every 20 years or so some ‘bright spark’ decides to have another go with these devices: I recall years ago Klippon (I think?) trying to flog these as the next best thing to sliced bread, which, of course, they aren’t. “Why?” asketh thou; and lo! I shall tell!

Many years past, around the time of Tesla, Edison, Westinghouse, Steinmetz and a plethora of others of similar electrical bent, discovered that if you wanted reliable electrical connections then the beat method way ‘copper to copper’. Any intermediate material **always** degrades reliability and increases volt drop - as true today as it was then, believe me. I learned the hard way; in an electroplating shop, tin plating transistor lead frames prior to having the transistor chips bonded.

These tin plating baths consumed tin anodes at a rate of knotts; the finished anodes had to be removed and sent for reclaim (tin anodes aren’t cheap!), a new anode connected to the DC with hefty stainless steel (to resist the acid environment) ‘choc-bloc’ connectors. Stan normally did this job; he was busy elsewhere, so I had a go. I stripped the insulation off a new anode wire, shoved the exposed copper into the new choc-bloc, and nipped up. Power up, 50+ Amps, no bother, and off I went to my next job, happy as Larry.

30 minutes later, Stan arrives and drags me out from under the diffusion pump I was rewiring. ‘what’s the matter, Stan?’ uttered self: ‘That anode replacement has failed, and burned the wiring back to the bus bar, that’s what!’ quoth a somewhat effervescent Stan. I followed, looking suitably sheepish, behind Stan to the offending scene in the plating shop.

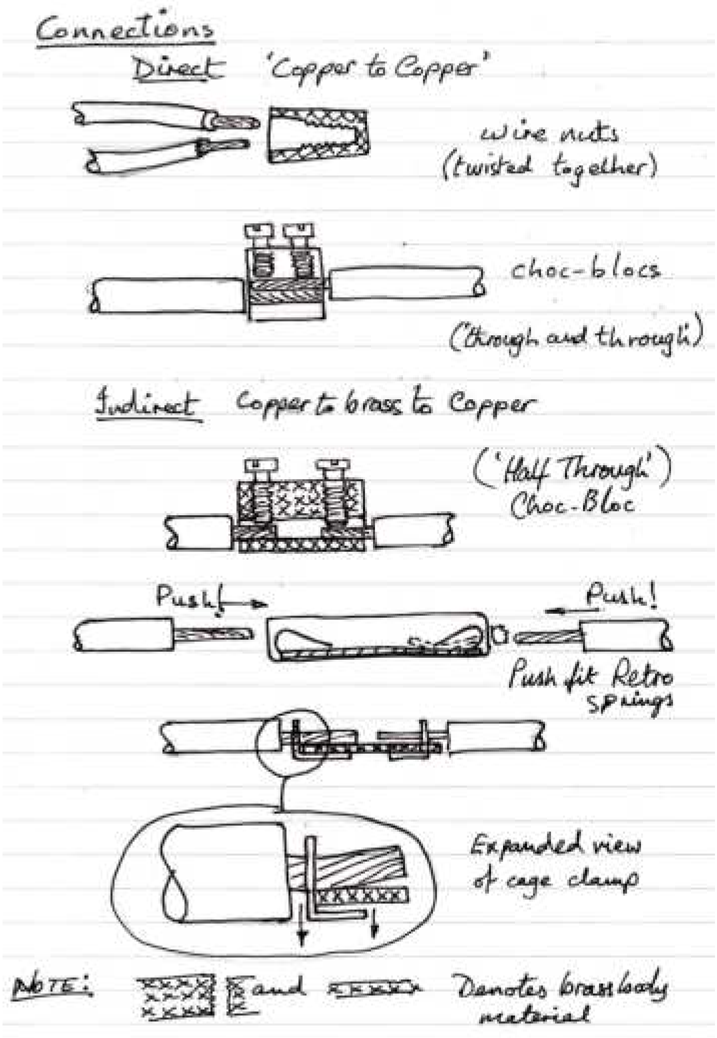
Derek L., the Plating Shop manager, waited with steam coming out of his ears - that tin plating line was numero uno in work, and the line had stopped because of the burn up. Stan, investigating for a few seconds, simply said ‘I’ve told you to connect these ‘through and through’ haven’t I? Why have you done it only half through?’ No excuses, I had rushed the job, and told Stan so. ‘Right, you get another 100 Amp choc-bloc, I’ll clean up here - and bring 10 yards of 100 Amp TRS welding cable, a few 100 Amp lugs and the crimp tool’.

Thus I learned about making a ‘copper to copper’ connection by stripping enough copper for the cable core to go **right through** the choc-bloc from both sides; **not** halfway in from either side.

New cables installed, choc-bloc tightened to full four white knuckles, current running a steady 50 to 60 Amps and the choc-bloc no warmer than the cable. ‘job’s a good ‘un, Peter - d’you not wonder how I knew exactly what you’d done?’ I had to admit Stan had sussed the fault within a second of knowing the line was down. How? ‘Easy,’ sayeth Stan, looking a bit smug… ‘I did exactly the same years ago meself…!’

Below are some diagrams showing some connections and the consequent reliability - knowing this has stood me in good stead for 55+ years. Some here in the UK think that wire nuts are illegal; no, they are perfectly acceptable, as long as they have the steel spiral thread insert in them. Choc-blocs - always use ‘through and through’ if possible. Far more reliable, and far lower volt drop than any other choc-bloc method.

The whole point is to maximise the copper-to-copper contact area - and how the ‘push fit’ connectors often don’t. OK, they work for a while - but I don’t like them on any circuit with more than an amp or two flowing.



Note the area of contact! Look carefully at these ‘quick’ connectors; they might be well rated but I’ll bet you’ll be revisiting them not too many years hence.

Audio Topics

Tap Codes

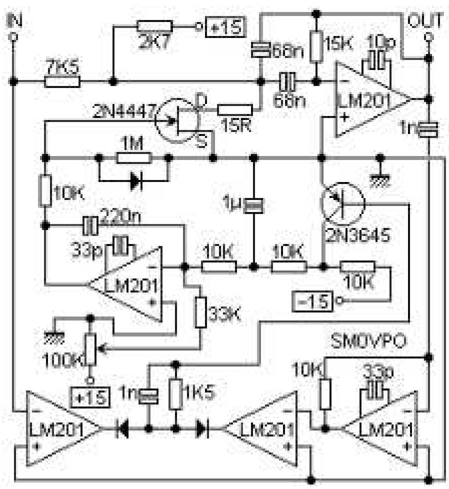
An ideal way to start learning a CW mode that the unskilled can use, on the simplest of transmitters. Easier, simpler and more readily digestible to ‘non Morse’ amateurs is the ‘Tap’ code. This uses a Polybius square, (lots of articles on t’internet) and has a history far deeper than Morse, Semaphore and the like. It’s not quite as efficient as the more complex codes like Morse, but is vastly simpler and easier to learn, and lends itself to simple telegraphy; mental decoding comes within minutes, unlike Morse. A typical ‘Polybius Square’ is shown below, the outer number squares indicate the number of dits:

	1	2	3	4	5	6
1	A	B	C	D	E	F
2	G	H	I	J	K	L
3	M	N	O	P	Q	R
4	S	T	U	V	W	X
5	Y	Z	0	1	2	3
6	4	5	6	7	8	9

Thus, a sequence of 1 ‘dit’ followed by 3 ‘dits’ indicates ‘C’; 3 dits (space) then 5 dits gives ‘Q’. Yes, slower than Morse; but vastly simpler, easier to ingest and mentally decode - and capable of more Dx miles (it’s simpler and slower). Such telegraphy gives dexterity training, so useful for the transition to Morse in the future. Automatic generation and decoding of Tap codes is a doddle compared to Morse coding / decoding, as you’ve eliminated the ‘dah’ and consequent spaces so less to worry about. Keep it simple!

CW tracking filter (SM0VPO)

This is a cracking good circuit that automatically tracks the audio frequency of an incoming signal and subjects it to band pass filtering, so no more losing fading CW signals as often occurs with a tight fixed frequency band pass filter. Keep that weak signal without having to continually adjust!



As Harry says...

'*The Op-Amp with the 10p compensation capacitor is the filter which is tuned by the 2N4447* (try a 2N3819…Ed.) *FET acting as a variable resistor. The remaining OP-Amps form comparators (no compensation capacitors) an integrator (the middle one) and a differentiator (bottom right). These adjust the frequency of the filter so that there is 180 degree phase difference between the IN and OUT signals to the filter. This only occurs when the filter is tuned to the incoming audio frequency. With the values given the filter will track an incoming tone from 330Hz to 3KHz.*'

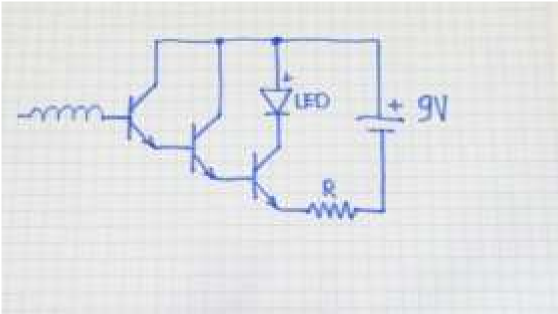
You can, with some impunity, substitute other op-amps and get the beast to fly. The original article can be found on Harry's web pages should you want further information (and a whole lot more!).

Test Gear, Fault-Finding & Repair

AC / RF field sensor

Here's a lovely little circuit for detecting E-fields, as from buried mains wiring, LF-RF signals. It's worth a shot for detecting RF in a co-ax feeder, too.

Yes, it's a triple Darlington, and yes, you can add another stage if 3 stages aren't sensitive enough for your application. 'R' would be 2k2 to 8k2 or so, depending on your LED. I used ZTX300's as I had a few to hand. It will detect RF fields quite well; might make a neat side tone trigger? The pick-up is ANY 30cm bit of wire, cut & try, the coil is just a bit of decoration.



From the Maestro… Harry Lythall

Hello Peter,
Thank you for the latest Hot iron. I usually read every word in all your articles. I do have a couple of comments about de-soldering. Perhaps your readers may be interested in the info? (You bet! Ed.)

Desoldering ICs
As always I find Hot Iron really interesting and I look forward to receiving them. In #117 I read the article on de-soldering components. There were some very good tips. But when desoldering components it is usually because something is defective so you normally have two choices:
1 - Sacrifice the chip and preserve the board
2 - Preserve the chip and sacrifice the board

Sacrificing the chip is a no-brainer. The important component is the board and so one needs to avoid any damage to the PCB. I normally clip off the legs of the IC then de-solder the legs one-at-a-time with the soldering iron set to about 260°C and use lead-based solder on the iron tip after thoroughly cleaning it. I also stagger the pin-removal sequence eg. 1, 3, 5, 7 etc. so that I do not bathe the board with heat. Never de-solder adjacent pins. SMD chips can be difficult to cut with a standard pair of wire cutters. The Dremel drill with a circular cutter can be carefully used to cut the legs where they enter the chip.

I also have a stock of silicone rubber tube that I put over the nozzle of my solder sucker. Solder suckers have a powerful recoil that can lift the tracks of some boards, especially the cheaper bonded paper boards as was commonly used in older equipment. These boards are characterised by the deep brown colour. The silicon rubber tube forms a good seal over the hole and gives a good suck to remove solder from the hole. The rubber prevents the recoil from gouging up the PCB tracks.

Did you know that you can dilute solder with mercury to lower the melting point? Clean the iron, put a small amount of lead-based solder on a bit of wood with a couple of drops of mercury. Clean the iron tip well and use the colder/mercury mix to tin the bit, and carry a blob of it to the board. Some audio chips, eg TDA810, have a wide tag for heat sinking. This can be a problem to desolder if it is soldered in a slot in the board. Adding a little low melting-point solder can make it a lot easier to desolder without destroying the board.

Incidentally, you can mix mercury and solder to make a solder that will melt in your hand, and this was common in older antique radios to make a spring/solder switch to break the circuit if the transformer became too hot. It is difficult to get mercury these days, but I have a small jar of it I got from a priest when they renovated the church clock. It was used for temperature compensation of the pendulum due to its high expansion coefficient.

Sacrificing the board can be a bit more difficult. I once removed a Z80 (40-pin) microprocessor from a board and it worked perfectly after removal. I clamped the PCB to the edge of the workbench with the Z80 underneath. I put a huge car-battery charger crocodile clip (modified a little) across the chip, lengthwise, and hung a 1.5kg weight on it. I then heated the track-side of the board using a blowtorch and the chip just fell out in about 4 seconds. I figured that if I am going to use heat, then let's make it fast. This technique works well to de-solder board-mounted power connectors, battery holders and switches that use plastic.

One tip with large DIL ICs is to use a Dremel with a circular model cutter and cut around the chip. Then gently make a cut of the board lengthwise so that the 2 rows of legs of the IC are separated. This halves the number of legs that are to be de-soldered. Be careful when you cut the board, it is only too easy to cut too deep and mark the plastic case of the chip. I also did some modification to an old worn-out bit for my Weller TCP soldering iron. I cut it in half, tapped it with a 3mm thread and fitted a triangular piece of brass plate, 3mm thick, so that I have a soldering bit that is about 25mm wide. That can be used to de-solder all the legs on one side of a chip simultaneously. Just be sure to file and tin the brass spade really well, regularly.

Larger SMD components are really easy to de-solder with a little practice. If you play with SMDs then you probably already have a heat gun. You can put a small length of fibreglass PCB on top of the chip to help buffer it from the heat. After removal then the board can be cleaned using the heat gun and wiping the solder off the tracks with a slightly moist cloth. I also put painters masking tape around the chip to help protect the rest of the board. The tape should be the more expensive blue tape. The cheap yellow tape can decompose and leave a sticky residue on the board after heating.

Occasionally you just have to forget about desoldering SMD components. Even the small diodes can be difficult to remove, even with the two soldering irons technique. I recently received a Christmas present of an Icom IC-7300. I wanted to remove a couple of the programming diodes to extend the TX range to include 27MHz. (*That sounds interesting…?! Ed.*)The diode panel is fitted with diodes only about 1mm long and about 0.5mm wide. They are also spaced about 0.5mm apart in a large matrix. The last thing I want to do is to destroy the control card in a £1300.00 rig. Sometimes you just have to know your limitations as well as the limitations of your chunky tools.

Having written all this, I find that almost every situation needs a different solution. I have recovered 100s of IF transformers and re-wound them for home brew projects. With these I find that it is best to de-solder the two tabs securing the can. Then dismantle the can and ferrite screw. The coil assembly can then be de-soldered very gently. The pins are mounted in plastic and they are very easy to break. It is better to clean off all the solder then wiggle the pins to be sure they are all free, then push the pins through the board from the component side.

I hope that this has given you a bit of food for thought. If you have any unusual desoldering solutions then I am sure Peter would welcome them.
Very best regards from Harry - SM0VPO (http://www.sm0vpo.com (note that there is no S in HTTP))

Making Manhattan pads

Use .020' thick double sided pcb material - cut with scissors, and can be soldered down for a more permanent fix than Super Glue; or use discarded 2mm thick double sided FR4 material from your local PCB manufacturer, and scribe deep cut lines guided by a steel rule, with:

- A tungsten carbide tipped tile cutter
- A triangular or semi-circular Swiss file
- A short length of hacksaw blade in a home-made holder
- A Stanley craft knife
- A small jeweller's screwdriver, held at an angle so the corner of the blade tip cuts a line

Then use pliers to shear off the scribed squares / shapes. You get hundreds for free…!

Antenna Topics

Turnbuckle tensioners

These are the tensioners sometimes seen on commercial antenna poles, masts and the like, and on some amateur radio antenna masts. I came across them supporting the upright exhaust ducts from semiconductor clean room machinery, on the factory roof and gantry walkways.

Yes, those things! After a week or two in UK weather, the waterproofing spray used to keep them rust free has washed off; stainless steel types are much better (and far more expensive) so how to keep these things serviceable?

Neat trick Stan taught me: mix a few teaspoons of 'petroleum jelly' (or any other 'grease' that takes your fancy) into half a pint of boiler juice (kerosene, or paraffin in the UK), Turps Substitute or White Spirit, and paint your turnbuckles (or any other steel bits you want rust free) with the mix. The kerosene evaporates, leaving the thinnest smear of grease behind on the surfaces - and, more importantly - inside all the nooks and crannies. Costs pennies, lasts for months (depending on weather, of course - don't expect miracles in more extreme places).

Hot Wire ammeter - measure REAL RF Amps!

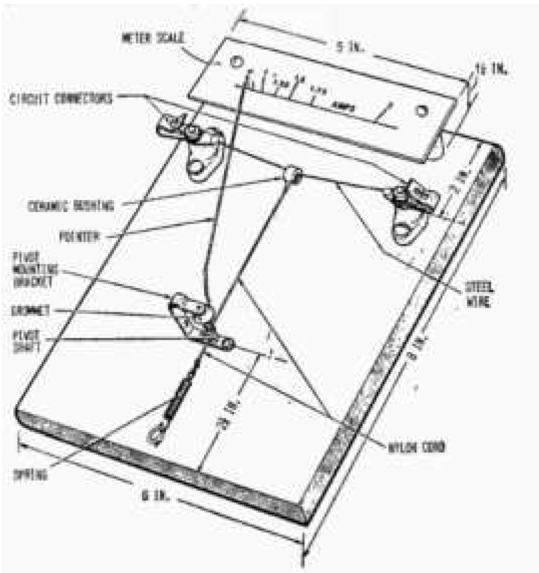
Here's a design that can easily be reproduced in modern materials, as the principle is a universal truth: heat is proportional to RMS amps. Not peak amps; not average amps; not scaled for sine waves only - no, this is your genuine, no nonsense real antenna amps, them as what does the business!

Of course, nothing under the sun is new, this design mimics old 'hot wire' designs - not often seen nowadays, but if you find one (very likely dud) at a flea market, on eBay, radio rally, car boot sale, whatever - then grab it, pay pennies, and take it home with a sly grin, never looking backwards. The operating principle is so simple most likely it can be repaired with some fine work with tweezers, watch-maker's screwdrivers and the like. Don't confuse these with 'thermocouple meters' though, which are unfixable (more or less).

The original came from https://worldradiohistory.com/Archive-Radio-Logbooks/Science-and-Electronics/Science-and-Electronics-1969-08-09.pdf and the diagram is below. Obviously you won't get this home-made design to run properly oNorth of 40 metres, but by using sensible RF principles, like putting the steel (or brass, copper, what-have-you) sense wire down the centre of a copper tube to make it (more or less) a co-axial assembly, and taking the motion nylon cord drive out through a hole in the tube wall, will make a useful TRUE RMS RF amps indicator.

It won't instantly respond to RF amps, but it WILL tell you the truth, nothing but; for tuning up an antenna for maximum amps a hot wire ammeter will need a second or two to respond but will indicate without any doubt the 'sweet spot'.

Anyway, enough waffle: here's the design:



You might like to look at the nearby articles in the magazine, all 'reet good stuff'!

Ionisation test for antennas finds hidden problems

WARNING: this test uses very high voltages. If you're not familiar with 'one hand tucked behind your back' and other standard HV safety techniques, DON'T DO IT. I'm not

responsible for explosions, fires, electrocutions, or anything else however remotely connected to this test method, the circuit or it's use in any way.

Make an earth hook and keep it on the kV output at all times you're not running the test rig, and earth out the antenna connection AND kV output from Cockroft-Walton multipliers when finished testing - capacitance in cables, antennas and the like can hold hefty charges. The earth hook can be made from the hook from a wooden coat hanger - they are threaded where it was attached to the wooden hangar. The insulating rod can be tufnol, perspex or polycarbonate - NOT WOOD - and should be 400mm long or more. The cable to the earth clip is copper extra-flex wire inside 6mm i/d flexible clear wall PVC tubing and all joints are firmly soldered and braced / re-enforced with heavy plastic tie-wraps.

Ceramic seals, klystrons, 4CX250's and the like are tested this way; a REAL test of your antenna insulation, and that includes the co-ax feeder, tuner and low-pass filter, as well as insulators. Nearby trees can alter the air insulation dramatically by increasing the relative humidity; as can next door's boiler exhaust or tumble drier vent. All these and many more can affect your 'Wonder-Whiz-Blaster' 10kHz to 10GHz antenna!

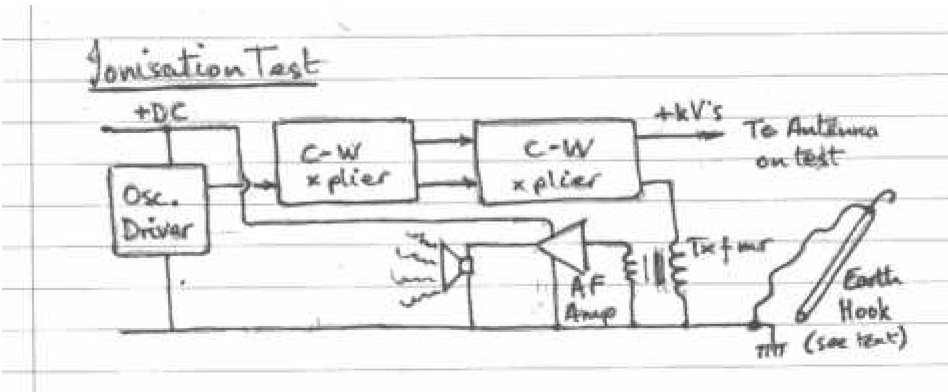
The idea is to use an audio oscillator and power audio amplifier (or a 555 driving a power mosfet?) to feed a Cockroft-Walton multiplier chain (chosen because the output impedance is very high, and thus current is limited) and sense the HV current in the earthy return side (with multiple signal diode clamps) in an audio amplifier, thus any leakage is indicated by sound. Ionisation leakage causes an abrupt rise in volume with a hissing, warbling, wandering note; flash-over breakdown is announced by a loud 'crack'.

Rather than go through the whole construction of such an HV generator, I advise you look at:

https://hackaday.io/project/176220-diy-cockroft-walton-voltage-multiplayer-100000v

...where you'll find construction described far better than I can. I'd recommend using 15 - 20kHz drive ('cos you can't hear it, and it's vastly more efficient than 50Hz) and good HV diodes, like the types sold for microwave ovens, or 1N4007's in series. The multiplier in the article is driven from 5-10kV AC transformer; I'd recommend you build several multiplier modules, then you can string them together to get the multiplication you need to get to the magical 10kV or more output.

You can drive this circuit with an valve transmitter HT transformer; 350-0-350 will yield 700 volts which fed into 20 stage multiplier gives 11kV as you get losses in every stage, it's not a perfect multiplication. You're looking for 10kV; you'll certainly get ionisation results with that, just keep stacking up the multiplier modules. Neon sign transformers are another good driver; search our favourite online auction house for lots of low cost HF output choice. Go for the highest kV's you can justify.



It’s wise to fit an inverse parallel diode clamp to the transformer secondary to limit the surge voltage. This clips the loud crashes on flash-overs but you’ll need to experiment to find out the best number of diodes; or fit the diodes directly on the audio amp input. The transformer is any you have to hand, it’s job is to safely isolate the earth line pulses from you!

Stop Press

Being born many years ago in Rochdale, Lancashire, it was impressed on me that a significant historical and humanitarian feature of the town was that it was where ‘co-operation’ (the Co-oP), a movement that created a wholesale and retail system whereby customers shared the profits of the enterprise, once all the bills had been paid. This spurred to action luminaries like John Bright, who, with Richard Owen, got the Corn Laws overturned which put bread into millions of hungry mouths in Victorian Britain. ‘Co-op’ shops are still a feature of modern Britain, and the principle of ‘Divi’ (the sharing of the shop’s profits with the customers) still exists and is to be valued, in my opinion.

The principle of helping others is very much in the amateur radio spirit. I was asked to put a link in Hot Iron by G6XMO as he’s set up shop to make 3D printed parts on ‘cost plus upkeep’ terms, true to the spirit of co-operation.

Hot Iron is non-commercial, and doesn’t carry advertisements: G6XMO’s enterprise, on ‘cost plus upkeep’ basis, is welcome (as are any others) in the true co-operative ilk. You’ll find his web pages at:

https://www.whizz3dparts.co.uk/

...and I wish Toni the very best in his co-operative enterprise.

HOT IRON # 119

February 2023

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CQ-CQ-CQ

An apology…

I've been ill recently, my having bronchitis (or 'COPD' as it's known nowadays) was caused - so I'm told - by a lifetime's inhalation of rosin flux fumes, tobacco smoke, electro-plating shop fumes, dichlorosilane and coal dust, and not necessarily in that order. This ended up with me in a local Hospital r4ecently, and on antibiotics to clear up a cracking good lung infection.

This came just after a death in the family before Christmas; so my usual Hot Iron writing time has been much truncated - this Hot Iron is briefer than usual, and I hope you don't mind. I've had some positive emails about Hot Iron (and its contents) which have helped frame out this edition; please keep the feedback - good or bad - coming, it's very welcome.

Radio links

Tom McKee K4ZAD sent me a link to an archived collection of radio information, from an old friend of Hot Iron, Roger Lapthorn, G3XBM:

https://archive.org/details/dlarc?query=G3XBM

In the archive you'll find Roger's notebooks and lots of his other links and ideas. Roger has always been an avid experimenter in all things radio; his circuits and results are superb and always worth reading, be it VLF to THz optical.

Touching outer space?

I spent a lot of my working life in Test Gear Maintenance, on-site breakdown service repairs, R&D and general production improvements and the like. I met many 'old hands' along the way whose guidance and experience rubbed off on me (or so I'd like to think!). One such was Ronnie B., who was the High Vacuum genius and very talented engineer who, by pointing out the basic skills of high vacuum engineering and pump maintenance, gave me my first glimpse of what outer space - and 10^{-8} Torr - looked like from a maintenance point of view. Ronnie was at home with high voltages, high currents and plasma etching, metal deposition, ion implanters and a host of other applications associated with semiconductor manufacture that involved the generation of vacuum conditions. Take for instance the plastic encapsulation around a semiconductor device - you'd think it was a simple enough task to encapsulate an IC or transistor chip, wouldn't you?

Consider this: the plastic encapsulation has to be applied in a Production line - i.e. quickly, hundreds if not thousands at a time, over and over again, without any human intervention. The molten plastic has to be as gentle a flow as possible, or the tiny bond wires that connect the chip to the outside world will get broken; it has to be an insulator par excellence, as good if not better than the finest glass; it has to be as cheap as chips and readily available to known electrical parameters - for instance, you can't get fast edges from a logic chip if the encapsulation has high ε_r, the stray capacitance would be too high. All in all, it's one massive engineering job to encapsulate a tiny SMT transistor , let alone a 500 point 'solder bump' processor chip and it was in this regard I first met Ronnie B.

Ronnie was struggling with a vacuum pump; it was refusing to start after he'd shut it down to replace a shaft seal (the bane of rotary pumps, a problem high vacuum engineers amongst us will recognise) and I was fixing a temperature controller which, for reasons I found out after much investigation, was becoming unstable in controlling the temperature of a moulding press platen - a block of precision milled steel that the lead frame of 64 devices slotted in, and a similar block that clamped down above it to create the mould chamber for each device. These steel blocks weighed upwards of 2 tonnes each; the press closed under 500 tonnes of hydraulic pressure to ensure no 'leaks' which show as side flashes in the product (you'll sometimes see the 'halfway' mark on IC's and plastic transistors, where the two mould halves fit together).

Ronnie was there as the mould platens MUST be pumped out to a low pressure - the hot liquefied plastic is injected under immense pressure into heated steel moulds, which, because they are under vacuum, draw in the molten plastic to the very edges and corners of the mould chambers - with NO AIR BUBBLES guaranteed.

Bubbles cause serious problems in encapsulating a device: a sudden discontinuity in the distributed capacitance of a device plays havoc with the high frequency capability, and air bubbles, no matter how hot they might be when encapsulated, contain water vapour which at -20°C on cold test will condense and cause electrical problems (water has $\varepsilon_r \sim 80$), not to mention possible future corrosion and premature failure. Ronnie B. was stumped; he couldn't use his leak detection equipment as the vacuum in a mould was nowhere near high enough to run his helium leak detector - typically needing 10^{-6} Torr to function.

It's always a fascinating moment to peep into a high vacuum system through an armoured glass window - pressures inside are often down to 10^{-8} and are those of space, and where electrons roam free. A beam of electrons, inside such a vacuum system, is a sight a high vacuum maintenance engineer will never forget - that thin ethereal blue light from electrons impinging on nitrogen atoms create is truly unique! Ronnie B. had to rely on his experience and to that end he was stripping out the shaft seal to replace it, working on the principle it was the only place the particular fault could be. I was nearby trying to find the source of instability in the mould platen temperature control circuits which maintained the mould platens at 210°C. ± 2°, and so Ronnie pointed me to his pump starting problem to be resolved as soon as I got a minute.

Ronnie, to aid his leak finding at mid vacuum pressures, developed a bit of kit to attach to his high vacuum helium mass spectrometer leak detector - a small aquarium air pump, and - as Ronnie so delicately put it - 'a calibrated hole', namely, a long, very small diameter coil of stainless tubing that could run a high vacuum on one end (the helium leak detector), and atmospheric pressure on t'other - allowing a 'sniff' of helium via the aquarium air pump, to be detected. Thus, Ronnie's 'sniffer' could be attached to the *exhaust* of the pump he repaired, and detect any hint of helium presented to the outside of any leaks. Ronnie thus gently played a stream of balloon gas (no point wasting 'six nines' helium for leak detecting) over his repaired shaft seal to test if indeed he had a good seal. recall, however, the pump wouldn't start! Every time he clicked the circuit breaker in, it immediately jumped out. It was one of a bank of the old style lever actuated sort, with a hole in the lever for a padlock. Ronnie called me over and asked if I'd anything to measure the start surge amps to the pump motor (20HP, 3 phase). I had; my Hall effect clip-on ammeter soon found the problem - there was no problem! The surge was ~ 80 amps, (later found to drop to ~ 30 amps once started) as expected and thus a dud circuit breaker diagnosed. A type "C" 40 amp MCB was jumpered in and the job left running for tidying up at the next production halt.

Thus was my fault found, too: the whole bank of circuit breakers had suffered much heat over the years living right next to the hot platens, and the temperature control MCB had gone intermittent: it would run for a few hours then give up the ghost. Just why was no issue; Production demanded we got the line running and so we did. And that's How I met Ronnie B.!

I did ask where Ronnie had got his micron sized bore tubing, to make his helium 'sniffer'. He looked at me with a slow sidelong glance, and said 'allow me some secrets, Peter…!'

Radio communications with ZERO power transmitter

Yes, you read that right… ZERO power transmitter. The technology is in it's infancy, just managing to send a signal across a 10 metre gap at 26 bits per minute - but it's a start, and it looks like a whole new territory of RF engineering is opening up. How does it work? It uses a natural phenomenon we'd all like to be without, given a choice: Thermal, or Johnson Noise, that's how.

Consider a transmitter, with resistors and the like: all components make thermal noise if they are above absolute zero temperature. What these RF explorers did was alternately connect a noise generating component (a 50 ohm resistor) to ground, then to a wideband microwave antenna in a code sequence. Result? In a "distant" receiver, the noise received on a wideband microwave receiver rose and fell as the "transmitter" was alternately 50 ohm terminated or 'radiating' .The noise levels received shifted in synchronisation with the 50 ohm load switching and data was thus transmitted with pure (random) noise as a carrier!

That lousy SMPS that wipes out the entire 80m band might - just *might* - have a new lease of life, if this principle can be refined - an amateur project if ever there was one!

You can read all about it at:

https://arxiv.org/pdf/2111.08629.pdf

The wonders of RF technology have many more amazing discoveries still to be explored; this is just another facet opening up. Who would have thought it?

Receivers

Oranje clandestine receivers

Radio Oranje was the clandestine radio transmission in Holland during WW2, the highlight for most listeners was when Queen Wilhelmina broadcast speeches to raise morale and the passing of covert information to the Dutch resistance movement. The transmitters of the BBC in London were used for these broadcasts, which were deliberately short (15 minutes or thereabouts) so those listening in could escape detection by radiated oscillations from simple regenerative recievers.

The occupying Nazi forces banished all radios, and listening the the BBC was illegal, with confiscation of equipment, severe fines and corporal punishment in some cases. Clandestine receivers, often powered by bicycle lamp batteries, were popular and the disguises were novel to say the least - food boxes, tins and anything into which a midget receiver could be squeezed was fair game for the constructors. The Philips employees and radio amateurs worked together in the Resistance movement to create these gems right under the Nazi occupier's noses - and what a great job they did of it, too.

The proximity of the Philips electronics factories to most Dutch civilians helped; no doubt plenty of 'moonlight' illicit components came out of those factories under the noses of the occupying forces. The receiver designs had to be physically small, economical in power consumption, and capable of decent (headphone) reproduction. These miniature receivers have always attracted my attention; anything with thermionic devices is by nature not very 'miniature'! For an example of these receivers, and amazing miniature construction, see:
https://www.cryptomuseum.com/spy/oranje/acorn.htm.
Just look at how the components are squeezed into every available corner - how this design ever worked without howl-round is a tribute to the constructors! Gives a clue though to the desperate ingenuity these constructors had to employ in those very trying times.

Mighty midget receivers

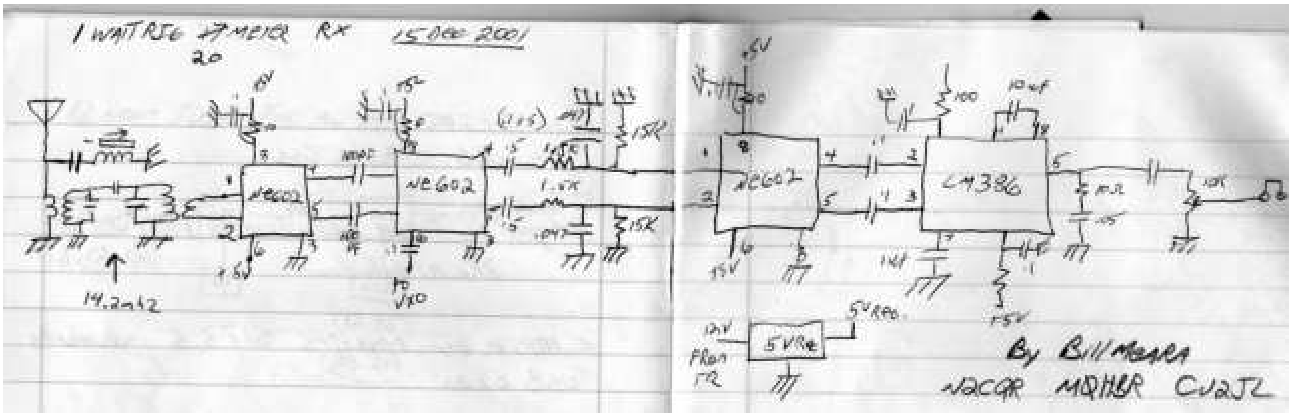
These are tour-de-force for small (but very potent) valve receivers and have been copied and duplicated many times. The design is straightforward; a goal not often witnessed when combined with the performance these simple receivers deliver. See:

https://www.jvgavila.com/mmrx.htm

The page has comprehensive links to the construction of these receivers; and to see folk of such standing as Bill Meara N2CQR involved then my attention is certainly piqued.

SA612 balanced mixer receivers

Talking of Bill Meara, you should know about Bill's SA612 direct conversion receiver: see Bill's sketch below:



 The points to note in this superb fully balanced design are the use of the SA612 Gilbert Cell as a balanced RF amplifier; not only in the front end with a double tuned top coupled input section, but as an 'IF' amp too. I asked Bill about this circuit - he tells me (as far as he recalls) it's from a 'VK' operator; and apparently the circuit has appeared in the GQRP Club magazine, 'SPRAT'. If anyone has any links or information, I'd be most obliged if you'd let me know, so I can give credit appropriately.

The SA612 chips, superb as they are, have a hang-up: they don't like strong signals. SA612's are very susceptible to overload; adjacent strong signals can wreak havoc. Now this can't often be helped; the proximity of broadcast bands to amateur operation frequencies often means millivolts of A.M. are right alongside fragile µV's of amateur signals. The top coupled double tuned input filter will certainly help; as willm the series tuned trap, but no attenuation, right at the front end, means these powerful unwanted signals can get deep into the mixer and do their damnedest to upset the apple cart.

Help is to hand, however: PIN diode attenuation set up as front end AGC can help keep the leviathans out the goldfish bowl. Not got any PIN diodes? Oh dear, what a shame, never mind! Use 1N4148's as noted below, or try 1N4007's, they have a P-I-N structure to get a reverse bias stand-off of 1kV or more, and they could be useful on the lower bands (they are quite high capacitance). See: http://www.waveguide.se/?article=ne612-receiver-experiment

To implement this, you can pick off the signals required from the mixer chip output(s) and with a bit of juggling values so as not to mismatch the output too much. I'd bet this would turn a 'sovereign' receiver into a 'golden guinea' of a job!

Transmitters

We often need HV ceramic capacitors for tuning output networks, ATU's and the like: these capacitors are called on to handle, with low losses, hefty RF power. Even the QRP operators need low loss HV capacitors: not for the power handling, but to preserve every single μW of power by eliminating losses. A lot of amateurs equate high voltage ratings with low losses; 'taint necessarily so' The figure to look for is the 'tan δ' , the 'loss angle', Dissipation Factor, or 'ESR'.

Basic electrical theory tells us the perfect capacitor has current flowing which is 90° leading the applied voltage, but unfortunately in the real World, the angle between current and voltage is more often 89° or so: the 1° difference is the 'loss angle' of the capacitor, and tan δ is the trigonometric value of that angle, used to calculate the actual watts lost. A capacitor is made by setting conductive plates spaced apart by an insulator, and it's these metal plates that possess resistance - any current in the capacitor has to overcome the resistance of the plates and this represents ohmic loss.

These are capacitors I'm familiar with: https://www.vishay.com/docs/22168/715c-dk.pdf
You can see the Dissipation Factor (DF) is quoted at: 20×10^{-3} (1 kHz). Now we can calculate several important values:
ESR (Rs) = DF x Xc (capacitive reactance) and Q = Xc / ESR.

The actual watts lost in this capacitor is the $(ESR)^2$ x Current (RMS) i.e. the I^2R value. Note that in tuning and ATU work, the current is almost always considered as true sinusoidal; in DC power supplies, this can be very different, so average values can be used as an approximation.

A hybrid DSB Tx offers 'bombproof' simplicity

If you were to follow an SA612 balanced mixer with a grounded grid double triode, running 350 volts on the anodes, you get good linearity and unconditionally stable 3 - 5 watts output, top band to 6 metres (or more!).

Refer to https://frank.pocnet.net/sheets/184/1/12AT7.pdf , for full data sheets showing grounded grid push pull operation.

figure 313.69, top right. The grounded grid push-pull amplifier as described in paragraph 4.51, where the input impedance of the grounded grid configuration is given as roughly 180 ohms (~ $1/G_m$) for the 12AT7. The SA612 output transformer, probably a toroid, would interface an SA612 output very nicely into the cathodes of a 12AT7; thus a simple hybrid DSB transmitter could be built, that offers the unconditionally stable performance of grounded grid push-pull, capable of 3 - 5 watts clean output and not be bothered in the slightest with mismatched loads or other 'experimental' situations - unlike a solid state version!
It would be advisable to employ careful screening round the SA612 section to prevent unintentional feedback; but the (low-ish) input impedance of the push-pull P.A. at 180 ohms will tend to reject feedback.

Terra Tertia RF Communications

(literal translation: "1/3 rd. of the earth") - radio through solid ground!

https://pe2bz.philpem.me.uk/Comm/-%20ELF-VLF/-%20ELF-Theory/Th-115-EarthCurrents/com.pdf the best I've found on this topic
The professional approach - and very useful to those on low bands, LF and VLF:
https://www.vermilliontesting.co.uk/globalassets/get-connected/cic/icpsidnos/g81-library/new-pages/planning-and-design/cp333-earthing-design-distribution-networks.pdf

https://icestuff.com/~energy21/roger.htm
is a simple practical approach
https://pe2bz.philpem.me.uk/Comm/-%20ELF-VLF/-%20ELF-Theory/-%20CaveTheory/CaveRadio1/radio1.htm is cave radio and proven technology

Earth injection 'Terra Tertia' of VLF // LF cave radio at 70kHz SSB // Earth telegraphy - what an experiment! Inject (say) 30Hz - 30kHz at 1kW between two wide spread earth electrodes, what received signals miles away on widely separated earth electrodes? Nicola system et al is worth investigatring.

https://nvlpubs.nist.gov/nistpubs/jres/65D/jresv65Dn2p189_A1b.pdf

A Classic Tx - and all the construction notes you could ever desire!

W1TS vintage Tx (and notes):

http://www.arrl.org/files/file/QST%20Binaries/Jan2012/w1ts_project.pdf

Contact bounce, CW and CdS photocells…

Hard to believe, but it's true: metal contacts, as in relays, contactors and Morse keys, exhibit a characteristic known as contact 'bounce'. The metal contacts touch, bounce off, re-touch and repeat a several times. You can see this with a decent oscilloscope; you can use logic circuits (typically a SR bistable or a Monostable) to eliminate the 'bounce', but that rather defeats the object in a simple CW transmitter. You might describe the 'bounce' a key click; you can apply a CR snubber circuit to slug the HF components created in the 'bounce', but again, that doesn't really solve the problem, but rather partially remove it and hope for the best. Well engineered keys are designed to minimise 'bounce' but not everyone has Vibroplex and the like kicking about the shack, or willing to throw them around when outdoors! No matter how well a key is made, 'bounce' is a physical property of metal contacts impacting, mechanical solutions involve dash pots, dampers, spring tensioners and other mechanical methods to 'kill the click'. The situation with 'logic gate' keying is a similar case to direct keying of an amplifier stage; the bounce is squared up by the gate and the keying again becomes 'clicky'.

Here's a neat rick that you can try to defeat the 'bounce' and give almost perfect control of a transmitter: use a photocell and an LED as a 'break-beam' system, so your Morse key interrupts the light from the LED reaching the photocell. Which type of photocell to use, though: yes, you can make a miniature photocell with integral photo-transistors and LED's, or you can make a very simple add-on unit to fit your Morse key - and being crafty, you might choose a Cadmium Sulphide photocell.

Why Cadmium Sulphide (CdS)? because CdS is slow (in electronic terms!) to respond; you get a sweet edge that's bounce free with beautifully shaped edges containing few HF components. As a guide, any switching edge has a relationship between bandwidth and edge speed, i.e. $F_{bw} = 2 / T_{edge}$ so as an illustration, an edge speed of 1mS requires bandwidth of 2 / 1mS = 2kHz! No wonder your key generates 'clicks', each 'bounce' (and 5 - 10 bounces are not uncommon) is another edge full of HF frequency components. CdS cells are photo-resistors: dark they are high resistance; illuminated, low resistance (resistance change depending on levels of illumination and colour). Typically a CdS cell takes a good few mS to switch, depending on frequency and intensity of illumination.

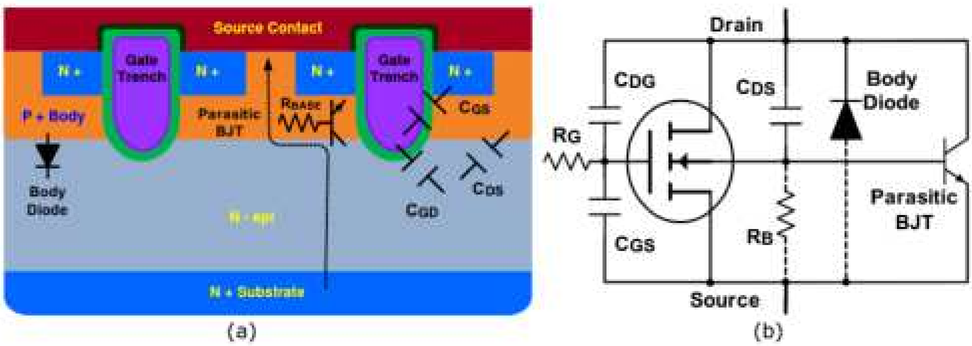
Another reason CdS optical switches as described reduce clicks is that *the beam isn't broken instantly*. The flag (or key arm if you build it so it fits your key) that interrupts the light falling on the CdS photocell moves *across* the light path at a speed determined by your keying - thus the keyed edge is a ramp, not a fast (or 'bouncy') edge. The timing is set by the physics of the system and key clicks from 'bounce' are thus non-existent. You can tweak the ramp times by altering the illumination intensity too: the brighter the LED, the slower the CdS photocell switches ('stored charges' I'm told), allowing adjustable edges to suit your keying. Keep in mind too that the set-up needs to eliminate ambient light affecting the CdS photocell; a used ball point pen body (the black tubular type) cut down and mounted makes a great collimating tube! Or - consider this: just mount the CdS photocell close the the key arm, and let ambient light do the illumination. What could be simpler for your next SOTA expedition? Build the photocell buffer transistor into your Tx, and you've got a neat combined system. A small CdS cell, a few odd components added to a transistor or two, controlled by the CdS photocell - is sufficient.

MOSFET's and all that…

Whilst it would seem a relatively simple job to make a mosfet P.A. stage to deliver 4 - 5 watts from a 13.5v supply rail, these little darlings can be very frustrating: they are lightning fast devices, and given the least opportunity, will be off and away in self oscillation - 'Hooting'. Most people imagine the innards of a mosfet are simple: just a lump of silicon, an SiO_2 insulating layer and a few bits of wire and that's it.

Well, a recent flurry of emails caused me to recall the non-linearities inherent in the capacitances inside a mosfet. These can behave as varactors; as volts change, so the energy stored can make it's presence felt by oscillations at particular points in a waveform, where dV/dT is changing dramatically. Below is the innards of a 'simple' trench gate mosfet… not perhaps as simple as you imagine! Taken from:

http://www.how2power.com/pdf_view.php_
url=/newsletters/1703/articles/H2PToday1702_design_VishaySiliconix.pdf



Illustrates clearly the parasitic devices created when constructing the device in silicon. Not perhaps as simple as you expected? And then you wonder why this thing 'hoots' at many MHz with a sniff of feedback and a few pF's and µH's?!

Power Supplies

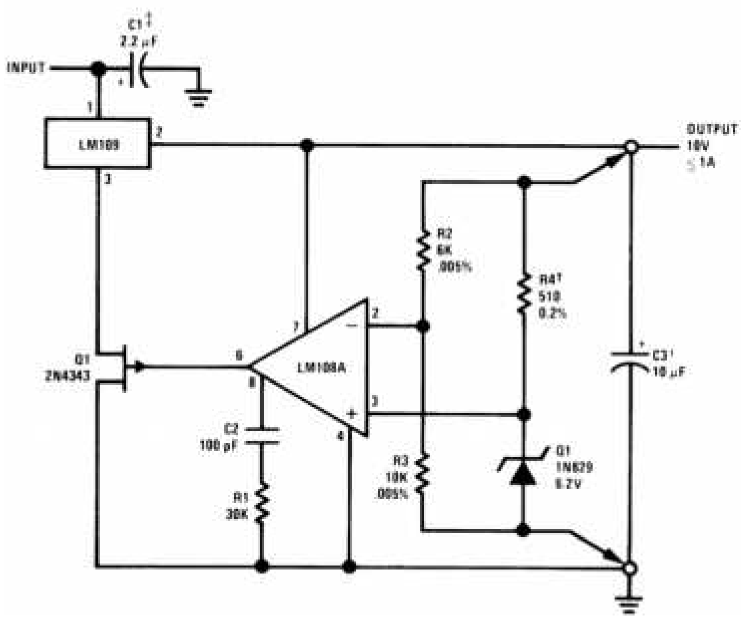
Discrete regulators to improve 78XX outputs

Monolithic voltage regulators do an amazing job, no doubt about that: day in, day out, they deliver the power that makes all the rest of a circuit function. The power supply and regulator(s) are probably the most stressed parts of a circuit - even power amplifier components get a rest between peaks, but the power supply soldiers on.

Good though they are, it's possible to improve the 78XX (and 79XX) types with a bit of external circuitry. From:

https://www.edn.com/simple-circuits-reduce-regulator-noise-floor/

This little add-on will give substantially improved performance. Note the zener D1 can be a far better component: a band gap reference, like LM4040 from Diodes Inc.



Constant current supplies for fault finding

An honest opinion: a modern ‘surface mount’ pcb isn’t for your convenience. No, they are purely for profit, manufacturers love ‘em, they are like printing money! You get a microscopic (compared to through hole or - dare I say it - thermionics on a chassis) assembly that works miracles. But you try fixing it when that ‘miracle’ goes AWOL!

The moist common fault seems to be any component that is connected *directly* between power supply rails: decoupling capacitors, voltage regulators, IC’s, and the like. Think of a simple switching transistor circuit: there is usually another component between the device and one power rail - a collector resistor for instance. The resistor precludes a *direct* connection between the power rails. If however that resistor is a choke, then yes, you have a *direct* connection (for DC) between the power (DC!) rails, and thus a short circuit for DC power.

Finding these faults is a bitch. And that’s putting it mildly; I’ve spent hours trying to find power rail shorts with a multimeter; even on lowest ‘ohms’ you’ll get a vague indication but you’ll not pin down the offending component. The favourite candidates for ‘short circuit’ failures from my experience are:

1. SMT Decoupling capacitors
2. Voltage regulators
3. LSI chips (the rarer and most expensive inevitably fail first)
4. Mosfets and bipolar transistors in RF circuits with choke loads (as noted above)

Under such fault conditions the unit’s power supply will either:

1. Shut down safely
2. Destroy itself as the designer couldn’t be bothered to fit a fuse or current limit
3. Set the pcb on fire

(1) and (2) above are common; I've known a few (3) scenarios, where I've sawn off the burned bits of PCB and fitted an external replacement (good if you've got room or safe enclosures).

All are utterly useless for fault finding - see later in 'Fault Finding' section.

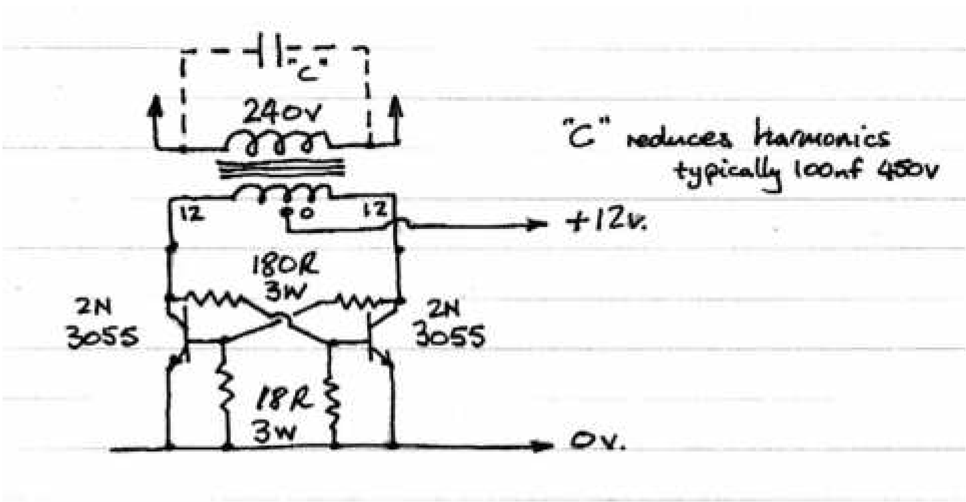
Vibrator Power Supplies

These are found in ancient bits of RF gear (like WW2 wireless set No. 19, for instance) running from batteries: they are akin to a buzzing relay, switching battery volts alternately one way then then other across a centre tapped transformer primary to simulate 'AC' inputs; the secondary being the HV to be rectified for B+ supplies.

These being electro-mechanical, and umpteen years old, they are worn out - ne'er any buzz left in them. Some crafty designers soon spotted power transistors could be coerced into doing this job, at a similar standing burden power too: the coil drive amps of the mechanical job roughly equal to the base currents needed in power transistors. What the original transistor men missed though was the 'dead time' taken for the contacts to cross the gap between 'open' and 'closed': this dead time gave far better output waveforms and saved a lot of wasted power in forcing flux reversals before the natural decay of core flux had taken place in 'dead time'.

The design below is an absolute beauty: it mimics perfectly the mechanical switching dead times by crafty design. Don't try substituting mosfets in this circuit: use bipolars as shown and you'll answer all your battery powered thermionic needs (I suspect the back biased base emitter breakdown volts of silicon transistors at ~ 7v sets the dead time along with the resistor selection).

Mount the circuit in an old vibrator housing (use the biggest heatsink you can fit!) and you've a plug in replacement for easy servicing; try various transformers as the core iron differs widely in transformers; being driven like this might not suit one transformer but happily drive another. As always, it's a question of suck it and see!



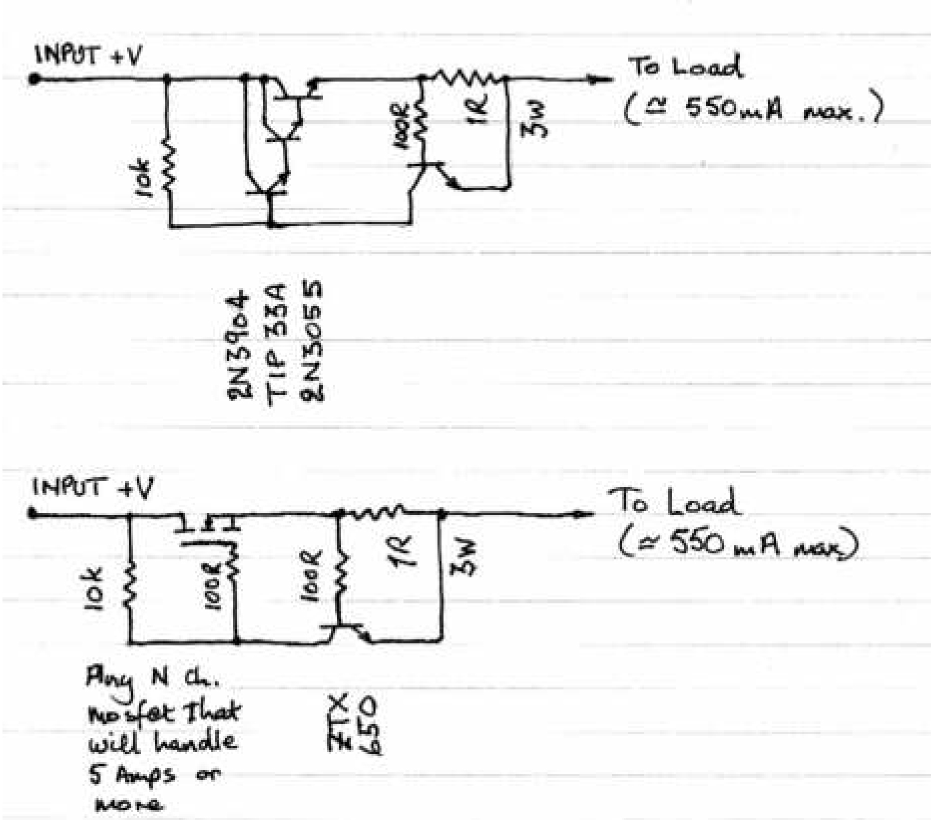
Test Gear & Fault Finding

AD9851#

type dds dip oscillators from a sig gen: https://www.george-smart.co.uk/arduino/arduino_ad9851/
Removes the annoying “pulling” as you approach resonance(s)...

Voltage Injection to find shorts

Using voltage injection into identifiable pins on a micro controller or IC can really help find a shorted component on a pcb. Most of us have a bench DC power supply, but not all PSU’s have a current limit function - so an add-on current regulator is a useful item. Below are two very functional implementations of such an add-on, that you can fit to your 5 volt bench power supply:



The current output is set by the sense resistor, 1 ohm. The current = 0.55volts / 1 ohm = 0.55 amps, where 0.55 volts represents the base - emitter drop. A 2 ohm sense resistor would yield 0.275 amps, and so on. One thing to keep in mind is the maximum output voltage, so as to not over-volts a sensitive chip on the pcb. This is approximately 2.2volts (for the three base emitter drops plus 0.55 volts for the sense resistor drop) deducted from the input voltage. Suppose for instance you want no more than 3 volts to be applied to your PCB; thus set your input +V to (3 + 2.2) = ~ 5Volts. You can do a similar calculation for a mosfet limiter, where you need the turn on Vg-s for your mosfet to take into account.

IR viewing screens are expensive but worthwhile if you've lots of surface mount pcb's to fix; IPA to find hot spots with current limited voltage injection can be a useful substitute. The general idea is to set up a test current into a PCB with a shorted component, then find which component is getting hot.

The canny amongst us use fingers, or iso-propyl alcohol on a cotton bud, to see where the heat is: your finger tip will certainly let you know you've touched a hot spot! The iso-propyl alcohol will do the same (without destroying your finger tips) by sizzling and evaporating very rapidly.

The components I've found to be likely culprits of a rail to rail short are: smt de-coupling capacitors, voltage regulator chips, many-legged IC's, and melted wire insulation in the centre of bundled cables. Finding a melted wire in the middle of a bundle need careful opening out of the wires; you're looking for the pair that are stuck together but these can be infuriatingly intermittent.

Isolation Transformer safety

Most people think that an isolating transformer is guaranteed freedom from electric shock: true if either of the output wires have absolutely NO connection - a megohm at least - to ground. In a typical amateur shack that is far from easy to assure!

There are literally hundreds of paths to earth that might not be obvious: Stan M. taught me this by pointing out how power line filters, often inmtegral in "IEC" power input sockets, have bleed resistors across their filter capacitors, thus giving a path to earth on the output of an isolating transformer. Fit an ELCB (earth leakage circuit breaker) to the isolating transformer output so any imbalance exceeding the milliamp rating of the device will disconnect safely.

Be aware the defibrillation current of a human heart can be as low as 2 -5 mA, and you'll struggle to find an ELCB that sensitive. Fit the lowest trip current ELCB you can find, and remember the old adage still applies: for voltages above 50v RMS, keep one hand tucked behind you in your belt!

AVO meter, anybody?

You might like to consider, when studying the voltage chart of that vintage valve radio chassis you're resurrecting, making an add-on to present the same 'loading' to the circuit when diagnosing faults with a modern 10M digital multi-meter. Knowing a little about the meter used to make the voltage charts, often quoted for reference, you can soon make loading resistance to mimic the original and get 'true' readings. It's worth noting too that despite what a modern digital multimeter might infer; those dancing mV's are of no account whatsoever; the original value noted was written by estimating from an analogue scale so an accuracy of ± 10% might well be more applicable!

One major point to consider is adding damping capacitors to such loading circuits. This removes those confounded dancing mV's, which are not relevant in any case, and allows much more stable peaks (or minimums) to be set up - a job a digital multimeter is exceptionally useless at doing.

The value of loading resistors is easily found: take for instance if the voltage chart specified "measurements made with an AVO Model 7" which is 1000 "ohms per volt" on DC ranges - so if I set the meter to "300 volts" full scale deflection (commonly termed FSD) then the meter represents a loading of 1000 ohms/ volt x 300 volts fsd. = 300,000 ohms, 300kΩ. I made up a shunt resistor of

300k by paralleling 270k, 27k, 2k7 and 330Ω (near enough!) and shunted this with a 450v 0.47µF capacitor with 10k in series to reduce initial current draw. I fitted this in a small box, with 4mm test plugs and sockets for easy test lead connection. I made up loading resistors for other common ranges required and thus my 10Megohm digital multimeter mimicked the AVO 7 loading for the job in hand.

The capacitor proved very useful; the digital multimeter gave damped steady readings on peaking (or minimising) circuit adjustments. Stan preferred faster readings; he fitted 0.1µF, 450v capacitors + 10k limiting resistor to his load box. I didn't bother with most lower voltage ranges; the typical voltage charts covered 90 - 800 volts so I made up loads and dampers to suit the ranges I wanted. It made repairing ancient (but unbeatable performance) GenRad Z-bridges used in manufacturing 10GHz varactor diodes an absolute doddle!

A curious "C-Beeper"

An interesting "C-Beeper" can be made with a 555 timer; it effectively uses the timing capacitor to integrate the leakage current, until the threshold switching point is reached and the output gives a pulse. See:

https://www.ti.com/lit/ds/symlink/lmc555.pdf?ts=1674234794921&ref_url=https%253A%252F%252Fwww.google.com%252F

I first saw this technique years ago when testing the reverse leakage of silicon and GaAs diodes. Using a long integrating time allows very tiny currents to be gauged reliably without needing instruments capable of Atto-amp (10^{-18} amp) resolution, by measuring the time to charge an integrating capacitor to a known trip voltage.

Chas. Wenzel in: http://techlib.com/Electronics/c_beeper.html

has described various discrete circuits to do a similar job (and that's where the term "C-Beeper" came from, incidentally) and the 555 version is usefully transmuted into the C-MOS 555 version for far lower input current to the comparator section in the 555; this allows remarkably low currents to be gauged, as, for instance testing the insulation of antenna assemblies and strung wire antennas.

One point to note that will make far more capable circuits at the extremes of measurements, is to build the circuits 'dead bug' over an FR4 pcb material ground plane, using super glue or wax to set the IC's into place; building upside down 'in fresh air' over FR4 ground plane allows ultra high resistance checks as fresh air and wide component spacing reduces leakage to a fraction of that found in strip board or other 'perf. board' constructions, on DC and LF testing.

Capacitor test kits

...are available for home assembly with far more functions than mere capacitance measurement: they will measure ESR (equivalent series resistance) and tan δ (dissipation factor). But, the mere presence of such information doesn't tell you whether or not a capacitor under test is 'good to go' or fit for the bin!

A useful guide for electrolytics (our favourite component for replacement) can be taken from the manufacturer's obligations: a capacitor, marked as 470 µF, will always be equal to or above that nominal value. A reduction of nominal µF's greater than ~ 10% and raised ESR surely indicates a worn out capacitor! It's important to note the capacitor value and voltage rating affects the ESR characteristics: gauge the validity of your decision by referring to an ESR table online, like https://www.jestineyong.com/wp-content/uploads/2012/05/ESRTable1.jpg) .

Construction

Superb mini boxes: https://community.element14.com/technologies/open-source-hardware/b/blog/posts/making-mini-circuits-style-tiny-metal-boxes---rf-module-enclosures from square section ally extruded stock; search for "aluminium extruded box section online suppliers"

And… https://hackaday.com/2021/09/15/the-many-ways-to-solve-your-enclosure-problems/

Boxes… https://www.youtube.com/watch?v=yrb1Oh0aJM4&ab_channel=PaskMakes

Soldering stainless steel

It's not often radio amateurs need to solder stainless steel; special fluxes are available to facilitate this, and they come with 'special prices' too. Try Phosphoric acid mixed with 10% water (from de-rusting fluids) or Boric acid (from borax dissolved in water, NOT borax substitute!). A close look at the ingredients list on the containers will show these ingredients, as will the safety requirements . But… I emphasise most strongly DO NOT INHALE THE FUMES from these materials.

Desoldering SMT components without specialist hot air guns

We've discussed these methods previously but I was reminded of some other tricks of the trade in an email (thanks, Bob). As well as a modelling clay barrier around a chip, filled with liquid solder, you can use two cheap irons set side by side with a jury-rigged clamp to get the right spacing (for shifting RF power transistor tabs) and brass blocks or plates clamped to a 200 watt iron bit to get the heat exactly where you want it.

One caveat: be highly aware of the damage done to components and pcb's when keeping the heat on for more than a few seconds. Semiconductors abhor heat; in reflow soldering it's vital that the process engineer sets the time in the hot reflow zone to be less than the manufacturer allows, often 200°C for no more than 20 seconds.

One answer: practice on pcb's from the scrap bin!

Antennas

That chunky high wattage rheostat with burned out windings at the radio rally sale can be a very useful component: substitute a toroid core for the original ceramic former, and add multiple turns of heavy gauge enamelled copper wire to replace the resistance wire and use the rotary mechanical contact assembly to make a variable auto transformer, with which you can easily adjust the turns ratio to match those ‘difficult’ loads. make sure the enamel is removed to allow the sliding contact get a low ohms contact.

One point to note: extend the control shaft with a perspex or tufnol rod to avoid RF flash-overs to your hand!

Location, Location, Location

...of an antenna is more important than any modelling and keep to mind that in the UK we don’t often have prairie sized gardens - so try folded designs, and keep the folded sections as far from high current point as best you can. failing that, go up in frequency to adopt shorter dipole lengths - but you can usefully allow the outer 20% ends of a dipole droop down without too much loss; and the centre can be bent out of straight without too much waste.

For those who are blessed with acres of garden, the old motto of ‘high, wide and handsome’ almost guarantees good performance - if:

- you adopt ‘kW’ wire sizes to minimise copper loss
- set as high and clear as possible
- are carefully matched and loaded (this is vital)

...are a good solution for small spaces; loft loops similarly set up can squeeze into a ‘hidden’ QTH.

Accept, once and for all, there is NO magic design that can work anywhere, on any band and have lots of gain and bandwidth.

An old article…

Though still very appropriate!

TRANSMITTING TOPICS

LOADED AERIALS FOR TOPBAND

By O. J. Russell, B.Sc.(Hons.), G3BHJ

CORRESPONDENCE has shows that there is a very great interest in the question of loaded aerials for topband use. This interest is not unnaturally greatest among the citybound amateurs who are anxious to improve the radiation efficiency of their installation upon topband. In view of the fact that a 10-watt topband transmitter may be reduced to the level of a transistor QRP rig by an inefficient aerial, attention to the topband aerial system is in order. As previously stated, the actual earth resistance is an integral part of the Marconi system, and every effort to obtain a really low resistance earth is necessary, including the provision of multiple earth rods spaced over the ground area available. It will be assumed that a really low-resistance earth system can be achieved. An earth resistance of 10 ohms represents a good earth *effective* resistance, and this value will be assumed.

Where multiple earths are in existence, the amateur can readily determine the resistance value by measurements. The use of a resistance meter, such as an AVO meter on the low-resistance range is satisfactory, if only a brief reading is taken. The meter should not be connected longer than is necessary, as polarisation effects may occur due to soil electrolysis. The simple A.C. bridges available will enable resistance readings to be taken without trouble from polarisation effects. However, a "spot" reading with the usual multimeter on its resistance range will enable sufficiently accurate measurements to be made.

Fig. 1 shows the set-up necessary for earth resistance measurements. Three separate earth connections are required, as the return connection to any earth rod can only be effected by using a

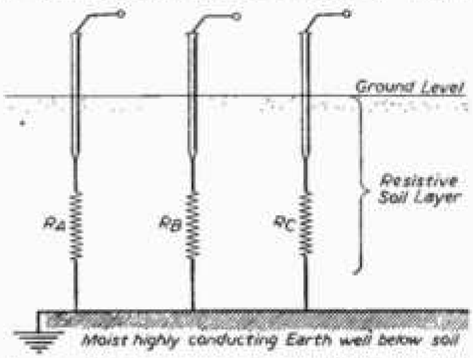


Fig. 1.—The arrangement necessary for measuring earth resistance.

further earth rod as the return. As the resistance of the earth rod is initially unknown, the actual earth resistance must be calculated from cross measurements made on the three earthed rods. Four or more earthed rods may be employed, and in this case alternative checks can be obtained from the resistance figures.

Earth Rod

Referring to Fig. 1, it is assumed that each earth rod has an unknown resistance connected to an ideal buried earth under the soil of zero resistance. Thus the resistance of Rod A is R_A, of Rod B is R_B and of Rod C, R_C. The resistance measured from Rod A to Rod B is thus R_A plus R_B, and so on for the three possible pairs of earth rod connections. Let the measured values of resistance be X, Y and Z, so that we have :—

$$X = R_A + R_B$$
$$Y = R_A + R_C$$
$$Z = R_B + R_C$$

The following simple algebraic manipulation enables the values of all the resistances to be determined. First of all add X and Y. This gives us $X + Y = 2R_A + R_B + R_C$. However as $Z = R_B + R_C$, we have only to subtract Z to determine R_A. Thus $X + Y - Z = 2R_A$. In other words we have now $R_A = \frac{1}{2}(X + Y - Z)$. Thus having determined R_A, we can find the values of the other resistances in turn by using the value of R_A to find R_B, and then using the value of R_B to determine R_C.

A numerical example may help those whose algebra is a little rusty. Thus in one case X was 25 ohms, Y was 30 ohms and Z 35 ohms. Hence R_A was $\frac{1}{2}(25 + 30 - 35)$ ohms, that is $\frac{1}{2}(55-35)$ ohms $= \frac{1}{2}(20)$ ohms $= 10$ ohms. As Y is R_A plus R_C and we now know R_A is 10 ohms, clearly as Y is 30 ohms, then R_C must be 20 ohms. Similarly as $Z = R_B$ plus $R_C = 35$ ohms, and we now know R_C is 20 ohms, then clearly R_B must be 15 ohms in value. As earth resistance values from 10 ohms up to 50 ohms may be encountered in practice, figures of the above order will be obtained on resistance meter tests. Three average-to-good garden earths of say 30 ohms apiece, if paralleled, will give a final effective earth resistance of 10 ohms, so that it really is necessary to employ at least three widely spaced garden earth rods if a satisfactorily low earth resistance is to be achieved! To make a reasonable earth, several feet of copper rod or tube should be driven into the soil. Six to 10ft. is about the minimum, and even greater depths are desirable. It should be noted that the efficiency of an earth connection to the waterpipes can be readily checked by the resistance method. All that is needed is the provision of two auxiliary earths, so that the requisite three resistance readings can be taken. A few tests with a resistance meter may provide a few shocks for those amateurs who have assumed that their earth connections are above suspicion. It may also provide a clue to those missing topband contacts, and the solution is obvious!

While it may seem paradoxical to devote attention to the *earth* as a part of the aerial system, it should be noted that generally this is a very much neglected part of the Marconi type of topband aerial. Moreover it represents a major source of loss that must be attended to if improvements elsewhere are to be worth-while. Thus an 8ft. whip aerial on topband has a radiation resistance of 1/10 of an ohm, so that even with an earth resistance of 10 ohms,

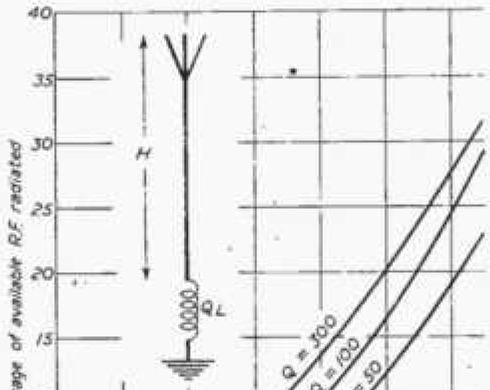


Fig. 3.—Efficiency of vertical aerials on topband. The curves show the percentage of R.F. radiated for loading coils of various Q values, and a ground resistance of 10 *ohms.*

and with a perfect loading coil the efficiency is only 1 per cent., so that a typical 10-watt rig supplying 7 watts of R.F. to the whip would actually result in the radiation of only .07 watts of R.F., that is 70 milliwatts ! Even in the case of a 32ft. vertical, the radiation resistance is only 2 ohms or so, so that with a 10 ohm earth resistance, only 17 per cent. of the R.F. available is radiated, so that our typical 10-watt rig would only radiate about 1.2 watts. However, this is a vast improvement, some 12 db, or two S points above the 8ft. whip case. Increasing the aerial to a 60ft. vertical would add another S point.

Loading Coil

However, these figures assume a perfect loading coil of zero resistance. Practically, of course, a loading coil has a definite R.F. resistance. As shown in the April, 1955, issue of this journal, the aerial radiation resistance, the earth resistance and the loading coil resistance are all in series, so that the reduction of earth and coil resistances is essential for efficiency. Unfortunately, in the case of coils we are unlikely to exceed a Q figure of 300 even by using 14 gauge wire on a ceramic former. For the 8ft. whip, a base loading coil of 350 microhenries (approximately) is required. A really high Q design of loading coil with a Q of 300, has an effective R.F. resistance of 14 ohms, so that with an earth resistance of 10 ohms, the radiation resistance of 1/10th of an ohm now represents an efficiency of less than ½ of 1 per cent. Should we build a coil with a Q of 100, this will have a resistance of 40 ohms, so that our overall figure would become one fifth of 1 per cent.

The contention that " every foot of height counts " is borne out by the fact that a 40ft. vertical only requires a coil of about quarter the inductance, and hence (for the same Q value) of one quarter the effective series resistance. Thus, with a Q of 300 this means approximately 3 ohms of coil resistance. Also the radiation resistance of the 40ft. vertical is 2 ohms, so that with a coil resistance of 3 ohms, and an earth resistance of 10 ohms, we have 13 ohms of wasteful resistance in series with the 2 ohms of useful radiation resistance of the aerial. Thus, 2/15th of the total R.F. power will be radiated, an efficiency of some 13.3 per cent. This is a vast improvmént over the ½ per cent. possible with an 8ft. whip using the best coil we can make !

The lesson is obvious. After we have installed multiple earths to reduce earth resistance to the lowest practicable level, we must think in terms of ceramic coil formers and thick wire. Number 14 or even 12 gauge wire, spaced by approximately the wire diameter on a low-loss former, or self supported, is necessary for obtaining high values of Q. Optimum Q values are obtained when the length to diameter ratio is approximately two, and long coils of small diameter should not be used.

Fig. 2 shows the typical base-loaded antenna set-up, and Fig. 3 gives the approximate radiation efficiency with coils of various Q values, with an assumed earth resistance of 10 ohms. What is startling, is that efficiency may vary over a range of some 300 to 1 when considering aerials ranging from an 8ft. whip loaded by a coil of Q=50, up to a 64ft. aerial with a high Q coil of Q=300. However, even a change from a 16ft. vertical to a 24ft. vertical can make nearly an S point (four-to-one power change) difference. This is a welcome bonus for a mere 8ft. of height increase. While the curves are derived from approximate calculations they should serve to highlight the necessity for extreme care in loading up an aerial for topband. Obviously a makeshift aerial system is unlikely to be efficient. Also, of course, the actual aerial wire itself is relatively unimportant in view of the huge losses that can be introduced by the earthing system and by the loading coil system. Moreover, these losses are "hidden" losses, as even a high-resistance earth and a poor loading coil will tune up in what appears to be a normal fashion.

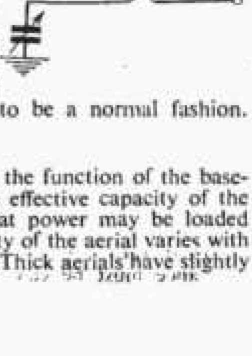


Fig. 2.—Typical base-loading set-up.

Base-loading Coil

As explained previously, the function of the base-loading coil is to tune the effective capacity of the aerial to resonance, so that power may be loaded into the aerial. The capacity of the aerial varies with the wire diameter slightly. Thick aerials have slightly more capacity than thin wires. Fig. 4 shows the approximate capacity of short vertical aerials made of wire, that is "thin" aerials. The approximate inductance required to load these aerials at the base for resonance in the topband is shown in Fig. 5. In practice, of course, a series aerial tuning condenser is often employed to adjust the "effective inductance" of the loading coil to exact resonance. This obviates any difficulty with taps on the coil, or with unused turns. Even with the low power of 10 watts, high circulating currents and high R.F. voltages are developed across the loading coil and the loading condenser. It is, in fact, the high currents circulating that cause appreciable losses with even high Q loading coils. The fact that a neon lamp lights brightly when placed on the loading coil or series resonating condenser is heart-warming to the true amateur. Unfortunately, it is also literally a "red light" warning of the high losses inevitable with Marconi-type systems, unless every precaution is taken to reduce sources of R.F. loss in every element of the aerial system.

An Example

A true story illustrates this. In the shack of a well-known topband exponent, an emergency loading coil was wound with enamel wire on a cardboard former. After some tinkering to load up the aerial system on topband, satisfactory results were obtained. After an interval for tea and refreshment, a return was made to the shack, where it was found that the aerial current was greatly down, and a local contact reported a much reduced signal strength. In the course of the QSO, the aerial current slowly crept back to its original value, and the signals were reported increasing in signal strength. The cardboard former was then found to be appreciably warm. The solution was that the cardboard had absorbed atmospheric moisture, and its R.F. losses had sharply increased during the interval for tea. The heat dissipated due to the losses automatically dried out the cardboard during the QSO, so that the losses decreased, with a consequent rise in aerial current and radiated signal! It is needless to add that the temporary coil was rapidly substituted by a coil wound with thicker wire on a ceramic former!

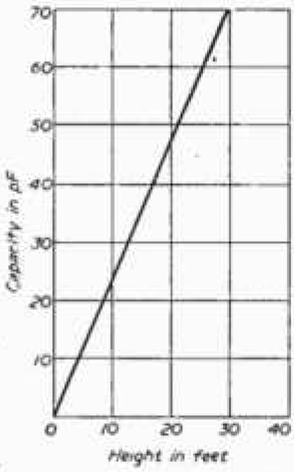


Fig. 4.—Approximate capacity of vertical wire aerials.

While a cardboard former is unlikely to be used for a permanent topband loading coil, it is a graphic example of the dramatic improvement possible by the reduction of losses. While it may seem reminiscent of 1920 practice to use heavy wire and large ceramic formers, it should be remembered that the topband is truly the "long waveband," and to amateurs in restricted locations it offers a severe problem from the aerial point of view. Those fortunate enough to have ample space for long wires and high masts are the fortunate few indeed as far as topband is concerned. Even here, however, if a Marconi system, such as a 132ft. against ground is used, the earth resistance is still important. Radiation efficiency with a 30 ohm ground resistance means only 40 per cent. of the power is radiated. Also if most of the 132 ft. is horizontal, efficiency may be much lower still, a factor that may be considered in a later article, as height rather than length is the important factor in topband aerials.

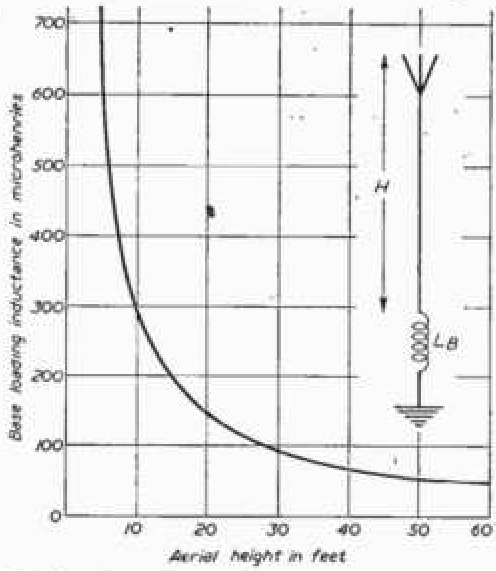


Fig. 5.—Approximate inductance values for resonating vertical aerials to the topband. In practice, slightly larger coils should be used and resonated by the usual series condenser.

My thanks to the original publisher(s) and authors. This describes the fundamentals of radio transmission, the fundamental feature of radio transmission.

Stop Press

One thing Stan taught me…

I was struggling with an Ft measurement test rig; an oscillator running 40MHz, 5 watts into an attenuator (for isolation) feeding the transistor under test via matching networks, the output being detected for amplitude driving a 50 ohm dummy load, again via a matching network. One thing bothered me: the output seemed wander erratically, up and down, even though the drive and power supplies checked out fine.

After a few hours checking power supplies, instruments and attenuators, led me to an SCR controlled water pump on the floor below; running the pump which delivered de-ionised water at a constant delivery pressure to the clean room processing areas on the floors above. This was 3φ 50 kW rated; it worked hard for a living, delivering 17 -20 tonnes of DI water per hour. I had a quick chat with Stan at brew time - he reckoned a double section LC high pass filter to pass the wanted 40MHz signal and reject the interfering radiation from the nearby (unscreened) 3φ cable feeding the pump would do the job, to cut the interference getting into the measurement circuits. I reached for filter design tables; and Stan dug out some likely looking inductors from the workshop "glory bin", added a couple of pF capacitors and had a high pass two section LC filter knocked up in minutes. 'No point pontificating, just try and see how it goes', and, yes, it did the trick. Stan added three off 100 watt, 100 ohm wire wound resistors in series with with 0.1µF / 600volt paper capacitors as 3φ snubbers in a centre earthed star across the lines - hey presto! No more wandering readings, job done.

'Remember the old radio men didn't waste time on abstruse maths: they had to get back on the air quick sharp rapid' quoth Stan; 'the niceties of design are fine if you've time but odds on you'll still need 'cut and try'. No point working out exact numbers; we wouldn't have the special value components anyway'.

Stan proved right (as usual…), and it's good advice: forget the long complex calculations, just make a rough approximation and cut and try. You'll learn the old art of Radio very quickly that way!

Wanted...

Further to my scribbles in the CQ section of this edition of Hot Iron, I have been told, in no uncertain terms, that I'm to avoid soldering, brazing or welding flux fumes, fine particles and other toxic dust by-products which are, for me, strictly 'verboten' - and a face mask restricts my breathing to such an extent I find them intolerable.

I'm told exercise in open air with vigorous exercise will help keep my lungs clear. I already spend a fair bit of my time rock climbing, walking ' o'er hill and dale' in my native Lancashire but I must increase this activity if I'm to enjoy a reasonable later life. I have been given various inhalers and other palliative measures, but practically speaking, I would much rather take outdoor exercise than using chemicals and potions. My being prescribed blood pressure tablets I take as a warning and I don’t intend ignoring it. The hardest bit of this is that I cannot continue to spend the hours indoors I currently do, building experimental circuits, test gear and researching Hot Iron.

Therefore Hot Iron needs co-authors, writers and radio builders / operators to help produce future editions: you know the open framework of Hot Iron and anything you have to say or report about RF is grist for the mill.

So there you have it: if you can offer any help in writing Hot Iron, be it basic thoughts or fully detailed articles, operating advantages, microwaves to milli Hertz, whatever, please let me know.

HOT IRON # 120

End May, 2023

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CQ-CQ-CQ

Thank you for all the good wishes!

Once again, Hot Iron readers have stepped up to the plate, and helped me produce this edition. I couldn't write Hot Iron without the abundant input of ideas, articles, suggestions and circuits; your inputs to me show me the direction you want Hot Iron to go and it's my pleasure to share my experiences and learning from all my years in semiconductor manufacturing.

Every wafer fabrication plant has it's own equipment guiding rules, often using live data from their machines, output and ongoing costs - the Intranet within a facility allowing this very easily nowadays. Live data is collected every few seconds or a certain event happening: the start of deposition in epitaxy for instance. This data, logged, graphed and stored electronically can give a time frame scenario of the real operating parameters - any deviation from established patterns indicates a fault developing, from a slight rise in collector / emitter leakage, or the need for more drive to attain a known output for instance. The hardest part of this technique is to know what parameters to monitor - on reflection you could probably think of hundreds in a simple transceiver!

The Maintenance effort plays an active part in this; just as the user of a transceiver will note immediately any deviation from 'usual' running and take appropriate steps to rectify or alleviate the problem, this might indicate a shift in operating parameters and indicates repairs or re-alignment is required. Not that it might be a problem in the transceiver; maybe a shortcoming in the design, or an antenna issue or an external interference you can do nothing about, like mains AC power noise or voltage shifts.

'Blue Sky' Repairs...

It's often the case you have some elderly bit of gear to refurbish, repair, re-use, and have no access to any spares or replacement parts. What to do? This conundrum was a daily issue in production machinery maintenance in manufacturing semiconductors - some of the military devices (I'm thinking of microwave diodes here, that fit inside Wave Guide 16) were produced, tested and quality assured on instruments long since gone to the great Valhalla as far as spare parts were concerned; an ancient GenRad capacitance bridge, to be specific.

The MOD had specified this particular instrument - no substitutes allowed - and the Calibration Laboratory had passed it to us to repair: a calibration procedure had shown that the bridge could not be brought to balance on a low (0.2 to 2.0 pF) range.

An hour's stripping, cleaning and generally looking at the physical condition inside the double screened innards had shown nothing obvious; so it was 'Blue Sky' thinking time. In other words, anything and everything that could possibly be related to - however abstruse - was examined, and given a good dose of 'maintenance from first principles', meaning: 'take it to bits, clean it inside and out, check every joint / connection / plug and socket, ensure all insulation was in order, no bulging electrolytics, popped capacitors, burnt marks near resistors', that sort of thing.

A trip to the Calibration Lab to collect the test jigs and other ancillary equipment required for the calibration shed some light: a GenRad audio oscillator specifically for this bridge showed rough, noisy (supposedly regulated) supply rails; we didn't have any specifications, but the ripple and noise was definitely more than you'd expect in a precision bit of gear like this.

The discrete voltage stabiliser circuits yielded more: a transistor (an old germanium alloyed device) was definitely leaky, and had an Hfe of roughly - well - one or less. Now - how to replace this device? Not a chance of a spare, this was a custom piece, with GenRad specific markings and encapsulation. The circuit looked 'Wien Bridge-ish', so a quick look at the transistor amplifier showed a bias resistor potentiometer from negative rail (these were all germanium PNP devices) to base of one transistor with a pull down resistor to emitter. A quick tweak of the bias chain allowed a silicon PNP substitute; lo and behold! the supply rails now looked a lot cleaner. The frequency was spot on; so a quick test with a 2.2pF mica capacitor substitute for the microwave diode proved good, but the oscillator was definitely vibration sensitive.

This was narrowed down with the 'standard bump tests', to a slide switch that was part of the range setting function, so this - being part of the mechanical assembly of the job - was stripped, and given a thorough going over with switch cleaner (no, we don't use Tri-chloro-ethylene nowadays!) and that was that. It was an almost unwritten law that complicated slide and wafer switches were never to be dismantled; it entailed hours of struggle to get the damn things back together!

All returned to the Calibration Lab, who went through several days of checking every aspect of the gear to maintain the MOD standards, all provable back to National Physics Standards, and the test rig returned to Production.

They used an acid dip to etch the wave guide mesa diodes until the capacitance came into a set range; this could entail many diodes making bottom limit but not the top (or vice versa), all being discarded (but made for superb microwave mixer modules for my 10GHz experiments!).

This is an example of Blue Sky thinking; no matter how obscure or off the beaten track, sometimes you have to think way out of the box and try repairs with what you have available. Maybe it's no spares available; maybe it's an integrated circuit specifically manufactured for the original maker, now long gone; maybe it's a complete redesign of a section of the equipment. Keep an open mind, try, try, try, substitutes and 'jumpered in' IC's if you can't get the exact replacement. If it begins to work something like, you've nailed the fault; maybe not exactly to the original spec., but at least you've proved the point, found the fault and can work onwards and upwards from there.

If you want to see a modern example of the way I and my colleagues worked in maintaining kit, but in a modern context, see: https://www.youtube.com/resultssearch_query=mend+it+mark+youtube

...and note how he repairs all these bits of kit he works on. Mark has far better test gear than we had; but his approach to repairing gear is exactly as we used! The golden rules:

- ✔ Use ‘maintenance from first principles’ - pull it to bits, clean everything and try again;
- ✔ ALWAYS check power supplies from AC outlet to most remote bit of kit;
- ✔ Find out (if possible) EXACTLY what happened immediately before it faulted;
- ✔ Split complex gear into sections to isolate the faulty bit;
- ✔ Look for physical damage to casings, covers, hand controls, in fact anything a frustrated operator can hit, twist, rive beyond end stops - despite all claims of innocence;
- ✔ ALWAYS physically inspect in minute detail every component, pcb, cable, connector for signs of damage, heat, loose / slack connectors, split encapsulation; swollen or leaky electrolytics; bunged up fans, fried transformers, blackened relay covers, melted wire insulation, signs of mistreatment;
- ✔ Use sensible substitutes to replace ‘unobtanium’ or ‘museum’ spares - it’s not unknown to jumper in a CMOS IC plus buffer transistors on strip board to replace ancient logic chips;
- ✔ Use a DC supply to feed limited power into a dud circuit and use a finger tip to find ‘hot’ component(s)…. your own personal infra-red (‘OUCH!)’ sensor;
- ✔ Keep a few 1Meg-ohm resistors on croc clip leads and jumper EVERY high volts, high µF capacitor. Not all designers / manufacturers envisage open circuit loads that won’t drain away a Stored charge;
- ✔ Your MEGGER is your friend, use high volts to test insulation, wiring and connectors far better than multimeter ‘ohms’ can (after you’ve made all semiconductors safe!);
- ✔ Keep a dim lamp (series limiter) on your bench and use it on unknown progeny equipment;
- ✔ ‘If in doubt, whip it out’ (apply to ANY suspect component) put in a known good new part and test the circuit again, keeping in mind open circuits don’t drain charged capacitors (as Mark demonstrates with some ‘industrial strength’ language in one video…!)

Receivers

Peter Parker’s NO inductor receiver…

Yes, our Antipodean pal Peter Parker, VK3YE has dug out an old reference and built an LF / MW receiver *with NO inductors*. An excerpt from his email to me is below:

“Hi Peter - my video demonstrating the receiver is here:-

https://www.youtube.com/watch?

I don't plan to do further work on it.”

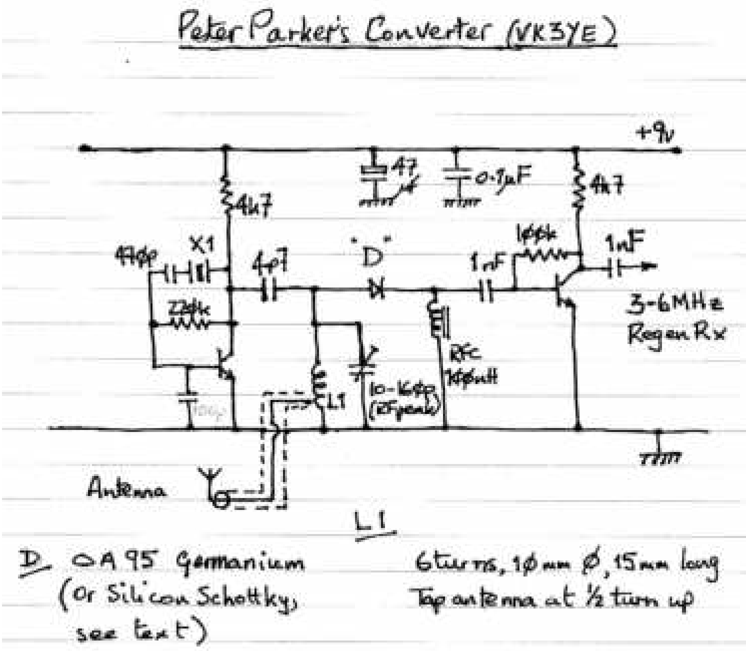
I can’t blame Peter for not spending too much time on this project; the whole issue is the matching of capacitors and the variable resistances for tuning a Twin TEE or Bridged TEE circuit. The capacitors need to be as near identical as you can get and the tuning pots need to be identical value, ganged, with linear tracks that are within a gnat’s whisker of running true right across their range.

These are not easy criteria to meet, and with any lack of tracking / linearity / matching, the Q disappears quicker than a cold beer on a hot day!

The VK3YE converter…

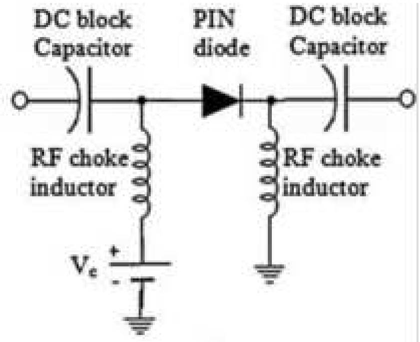
Peter has built an update on 1960’s technology that allows a 3 - 5MHz regenerative receiver to catch 11m ‘CB’ signals and the 10m band; or (by selecting appropriate crystals in his converter and ‘backwards’ tuning) many other bands of interest too. No, not that CB 11m band is of major interest to amateurs; but it is usually active with plenty of signals to help set up a receiver. See:

https://www.youtube.com/watch?v=Lb9XS06nTSU&ab_channel=AmateurRadioVK3YE



(Note: oscillator transistor base capacitor = 100pF)

Peter uses a single germanium diode as a mixer. He calls up an OA95, which might be a bit tricky to find nowadays. There are some significant differences in diode roles: if the diode is used as a detector, you need as low a forward drop as possible, as you’re dealing with µV. In a mixer, you have a local oscillator to drive the diode, so the demands aren’t so stringent - a Schottky will work as like as not. For µV detector service, bias a silicon junction (just) into conduction and AC couple the RF signal in and out. The PIN diode switch circuit (from which the detector diode biasing is an offshoot) replace the bias supply choke with 1 - 10 Meg-ohm resistor, and feed the local oscillator via the 4p7 into the anode of the diode. Thus the local oscillator switches the diode ‘off’, opposing the resistor bias on negative half cycles.



In Peter’s design, the diode is driven by the local oscillator via a 4p7 capacitor. On the positive half cycle the local oscillator biases the diode ‘on’. On the local oscillator negative half cycle the diode is biased ‘off’, mixing the input RF signal with the input. I have seen VHF single diode mixer designs where the capacitor driving the mixer diode was a small area of copper on a pcb beneath the diode, or even a short insulated wire alongside the diode body!

This is a real blast from the past, as Peter explained to me. It’s simple, practical and functional - you can’t expect World class nano-volt resolution from a handful of components, but… all mode capability, a simple regenerative receiver IF and an LM386 output stage, what more do you want? This scheme will easily adapt to VHF or LF too, giving an easy and practical way to build a functional and effective receiver. More at:

https://www.youtube.com/watch?v=CCreItQLzOA&ab_channel=AmateurRadioVK3YE

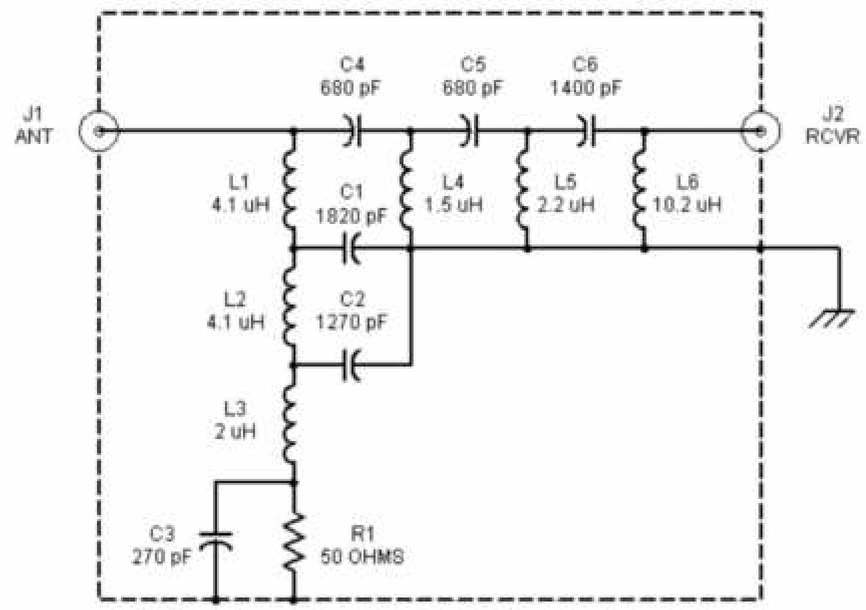
A.M. Broadcast interference filters...

For those who trawl around the lower HF bands, broadcast station interference - medium wave A.M., not much of a problem nowadays in the UK, but I maybe still applicable in the USA and Australia - it can be an issue. Not that the transmitted signals are riddled with harmonics, but after multiple reflections, added to corrosion in steel building structural joints and large steel fences / barriers can cause non-linear mixing products and other cross modulation which can give issues on the lower bands, especially Top Band and 80m. One ‘fix’ is a high pass filter to block Medium Wave (and lower frequency) signals, and below is a simple high pass filter from Dale Wentz, KB9JJA, at:

https://www.wentztech.com/radio/Projects/QRP_BCI_Filter/index.html

This effectively cuts off anything below ~2MHz, assuring no B/C MW - A.M. interference (or possibly more to the point) gross overloading if you’re downwind on one of these powerful monsters.

Below is a neat ‘band stop’ filter schematic, from Joe Carr, which has neat features:



Joe's design features a low pass filter and a high pass filter, which, coupled together, block a full band of frequencies, the A.M. broadcast band. This allows our LF / VLF brethren to operate seamlessly VLF→LF→HF without having to exchange filter modules, a great idea if you're into HF and LF operating all at once!

Joe uses a very powerful trick; he adds a 50 ohm load (R1) termination to the low pass filter section (L1,2 and3). This absorbs the rejected energy, stopping it from possibly circulating in the filter circuit - but is far more complex than Dale's super simple design. As ever, 'you pays your money and takes your choice'!

Stray Magnetic Fields

Magnetic flux coupling from E-I lamination transformers can represent a big problem in a sensitive receiver power supply, it can cause all sorts of wild goose chases trying to get rid of hum and related problems though the dreaded Direct Conversion receiver "hum" can be from a very different source, but at least you can eliminate the transformer in your power supply if you're aware of the issue.

Suppose you have a bargain transformer from an unknown background or original purpose: it has all the right attributes like primary and secondary voltages, VA rating and physical size, but after designing and building your project, you find it's a "hummer" and no amount of decoupling, isolation or other known means can stop the damned "hum".

I'd suggest you try this simple experiment and see if it can find a cure for your problems. Wind a loose 12 turn coil of insulated hook-up wire over your fingers, in a roughly circular form about a ½ inch / 12mm diameter, the turns taped up for some rigidity, and connect your 'scope (or sensitive multimeter set on AC mV) to the coil ends, then move the 'search coil' in close proximity to your transformer, all around it, whilst it's powered up and driving the load. You'll find some positions where plenty of induced mV's appear in the coil - this is the leakage flux from the transformer core linking into your search coil. You might find some positions are almost free from stray flux; others you'll find plenty.

The question is though how to stop this stray flux inducing hum in your circuitry. Well, simple solutions can help: try some pieces of a steel can, cut to screen the transformer; the steel, being far more magnetic than copper or air will shunt away the magnetic flux. In fact any bits of sheet steel will suffice, and earthed to will give both magnetic and electric field shielding - two for the price of one! This isn't always easy or practicable though; you might not have room to do this - so heed the advice Stan M. gave me when I was tasked with building a reverse leakage measurement rig for Gallium Arsenide LED's. These involved current measurements of fractions of nano-amps; Keighley electrometer to the rescue, but I couldn't stop the mains power supplies from causing rectified hum issues (proved by using battery power!).

Stan brought me back to practical reality; he dug out from the "Black Hole" (otherwise known as Test Gear Stores…) an ancient power supply chassis once used for a valve (807's, actually) test rig, which sat on the floor beneath the operator's bench. This separated the power transformers from the bench top side; the underside of which Stan M. had lined with a steel sheet, earthed to the test rig common star earth bolt.

Problem solved: I stripped out the old electronics (carefully preserving the valuable filament and HT transformers…) and rebuilt the power supply module to the required specification, fitted the power supply transformer, rectifier bridges, smoothing capacitors and control relays. This fed the bench top electronics via a hole in the (bench underside) steel sheet. The 'umbilical' feeding the power up to the bench top test rig was fitted with Jones multi pole connectors (the ones with the big flat blades at various angles for polarisation) either end and the job was a success.

Stan M. had a few comments, which interested me. "The girls who did the testing loved this job; the old power supply sat on the floor under the bench made a dandy foot stool, and the warmth from the transformers was always appreciated" quoth Stan. "But keep in mind the idea of physical separation and magnetic screening. We're very lucky as we now have a Transformer Department who can knock up toroid transformers for us, but you might need to use an E-I cored transformer one day if you're stuck. Make up a leakage flux sensing coil… (as above) and check things out. Modular units are always a *GOOD IDEA* (Stan's emphasis…) as you can substitute a known good module and get the job up and running very quickly; and repair the faulty module back in the workshop, rather than struggling with it *in-situ*. You automatically get better screening, isolation and happy operators".

I'd agree every time with modular philosophy. Make your radio gear as modular as practicable, it will help you immensely in improving and / or fault finding. Keep to the motto of 'adopt, adapt and improve' as you've only the faulty module to work on and you can easily go back to your last (known good) circuit if you only alter one thing at a time, then test thoroughly.

The moral of this tale:

- use a modular approach;
- use magnetic and electric field screening;
- fit transformer power supplies in steel boxes for both E and H field screening: steel conduit boxes are cheap and have plenty of knock-outs;
- keep the design of a PC "ATX" power supply to mind, note how the SMPS noise generators inside said beasts are screened with magnetic material - in fact, use scrap ATX power supply boxes, they are often available for free from dud ATX PSU's.

Transmitters

RMS power

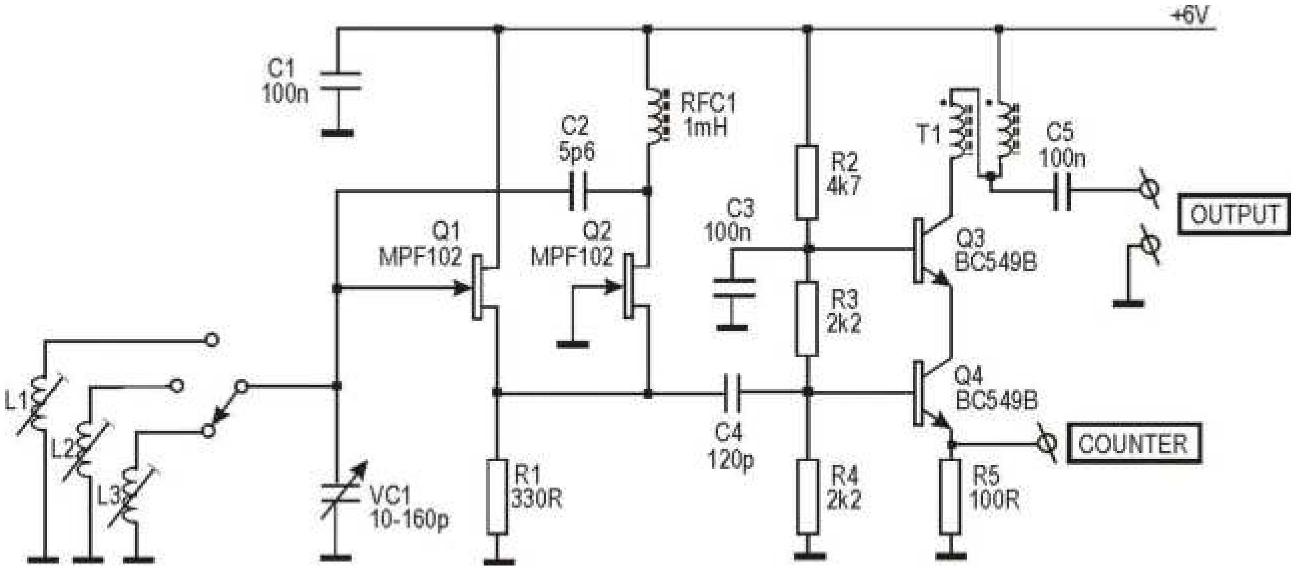
RMS is defined as the heating power of a waveform; it is the DC equivalent. Thus, if you want to check your transmitter output, connect a (non-inductive) 50Ω or 75Ω resistor and measure the temperature rise after some minutes of 'CW' key down. A well shielded and insulated infra-red temperature sensor will give a reliable reading of the temperature rise in the resistor - note it down, and replace the transmitter with your bench DC power supply.

Adjust your bench DC power supply to give the same temperature as noted above; multiply the volts by amps from the power supply and there you have true power indication - job done! For an SSB / AM transmitter, you'll need an audio generator to keep the transmitter well modulated.

This technique will work on any power, it just needs time, care and thermal insulation. This is the core concept of the thermocouple RF ammeter, you can adapt the scheme to suit whatever you have available. You can use a thermistor, a thermocouple, a temperature indicating strip, what-have-you to indicate identical RF and DC temperatures - the absolute value is irrelevant.

Transmitter or Signal Generator?

From Andrew Woodfield, ZL2PD's web page:- https://www.zl2pd.com/HFRFgen.html



Andrew describes this as a signal generator, but those familiar with low voltage power output stages will recognise transformer T1 as being capable of a good few hundred milliwatts, if not a watt or so, of output. The design is simple, but elegantly sophisticated: much like quality commercial or professional equipment.

Note, for instance, the oscillator section. This is a source coupled Franklyn; the use of two active devices gives vastly better performance than the common single active element designs - and allows Andrew to cover ~ 400kHz to 60MHz with just 3 coils. A crystal can be substituted at Q1 gate, though the small (3pF?) capacitance presented by Q1's gate being back biased might mean the crystal runs off the marked frequency as the loading capacitance won't be present (make VC1 a 2 - 20pF trimmer?). The Franklyn is good for waveform quality; the devices being J-FETs they auto bias to linear(ish) operating and the output from R1 (330Ω, the source common resistor) is 'clean' , almost harmonic free.

The Cascode output is a typical industrial technique: not only do you get substantial (and almost unconditionally stable) amplification, you get a low level output of the lower emitter for a counter to connect well matched to low impedance drive - with a significant power output, and load isolation from the Cascode connection. No matter what load is attached, the oscillator section will 'see' an almost constant impedance at Q4's base, a significant advantage over a single active element gain stage.

Andrew's design would make the ideal local oscillator module for my preferred modular approach to amateur radio: you get not only a piece of Test Gear, but a core component in a transmitter and a wide band local oscillator for a (VK3YE?) converter. The Cascode stage could be keyed; but you'll almost certainly get better results keying (or modulating) the later power amplifier stages, not the oscillator!

Power Supplies

Reducing source impedance

Many amateurs think that wiring and components in a power supply don’t need to be too big; after all, electronics in this ‘surface mount’ age are tiny, yes? Wrong!! In a power supply (and all associated power wiring), use the heaviest gauge wire you have, big bus bars, over -rate the diodes, transformers and electrolytics as best you can. Make it big and chunky for sure performance!

Why? Because you are reducing the source impedance with every move to ‘chunkier’ construction: this inevitably improves regulation and helps stabilise the output - giving your regulator circuitry a fighting chance to cope with any load you might attach. And don’t forget fuses; these little blighters can add a fair few ohms, if you don’t believe me, test a few (especially those under a couple of amps) with your multimeter!

It’s not unknown for pcb tracks to be ‘beefed up’ with lengths of tinned copper wire being soldered along the track length to reduce volt drop. PCB designers, in the ‘surface mount’ age, think copper tracks can also be diminished to near zero and still carry amps. ‘It ain’t necessarily so’ as the old song has it: $R = \rho L/A$ (resistance = resistivity multiplied by length of track all divided by the track’s cross sectional area), and that’s physics that won’t miniaturise!

Faulty loads... and solid state relays

….can accidentally stuff AC power back into control electronics - which ‘don’t like it up ‘em’, to quote Corporal Jones. The problems thus created aren’t limited to just one IC or section of a circuit, however.

Most IC’s have ‘clamp’ diodes on inputs, these are to catch excessive volts and dump them into power rails to be safely absorbed. Now imagine some hefty cycles of AC power finding it’s way onto an IC’s input (maybe an internal fault, or a back feed from a power mosfet gate, SCR gate, etc.): those half cycles dumped onto the supply rails go EVERYWHERE on the circuit board that the supply rail(s) run to. Nothing escapes the wrath of a misguided AC half cycle, it will severely damage anything it can. You might not see trouble immediately but rest assured, those errant half cycles of AC power have damaged junctions, blown holes in gate oxide layers, done a real nasty inside electrolytics.

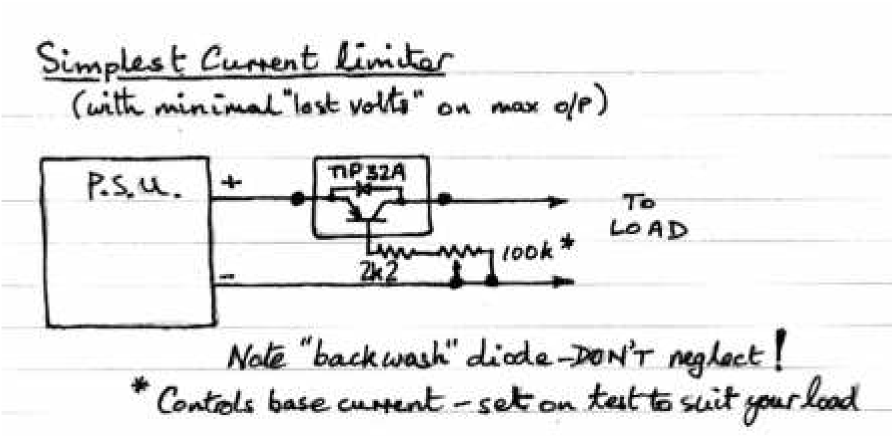
Your first instinct, on discovering an AC fault like this, will be to try to power up the circuit “to see if it still works”, which is the kiss of death to the job. You’re far better using your multimeter on ohms to test, test, test everywhere on that circuit board (before powering up) for shorts to rail or ground for leaky electrolytics, gate - source - drain shorts, blown diodes, in fact, test everything on ohms carefully.

Of course, the cognoscenti amongst us will have avoided most of this trouble by keeping AC power on the right side of devices that offer real input to output isolation: mechanical relays. Yes, yes, I know a solid state relay says it can withstand so many kV’s… I recall Tony H’s face when he first saw the destruction 230v AC power had wrought in his Test rig, in which he used solid state relays. What he hadn’t taken into account were the transients present on the mains in that part of the factory - where the Royal Navy radar magnetrons (10MW pulse jobs, a yard high) were tested.

A few kV down the AC lines in very brief spikes had done the dirty on Tony’s solid state relays and shoved some nasties back into his logic IC’s, all of which had gone AWOL right across the pcb, courtesy input clamp diodes steering energetic pulses onto the positive rail.

Your DC PSU has no current limit?

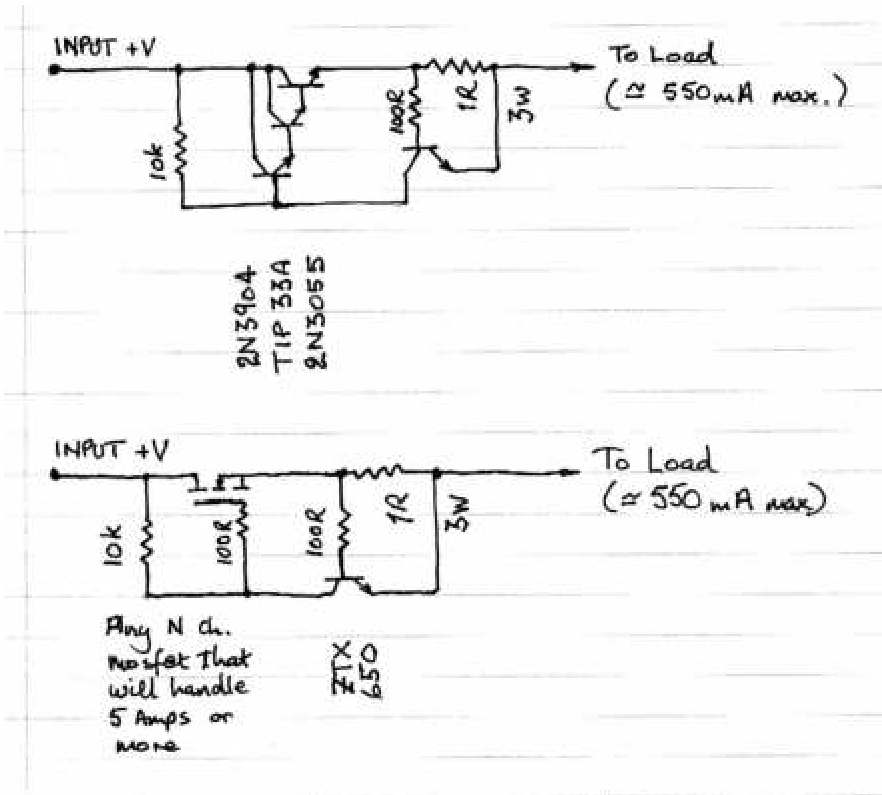
Try an external PNP transistor with emitter connected to +ve output of the PSU, the base biased by a variable resistor (as a rheostat) to -ve and load output connected to the collector, the base rheostat adjusted to give just sufficient current to your load. Simple and easy, this will eliminate most if not all of the ‘bangers’ you might suffer. If the load demand rises beyond the collector current you’ve set up with the base bias rheostat, the output voltage just sags.



Below the current limit set by the base current (collector current = Hfe x base current), the transistor feeds the circuit as a saturated switch, with only Vce-sat, (0.2v or less) drop.

Keep in mind this is a very simple arrangement, relying on the Hfe of the PNP being the current limiting setting so you’ll need to cut and try the base bias rheostat to get satisfactory limiting - but it might just save that lovely little circuit you’ve just built from releasing all its magic smoke.

This circuit needs THREE connections; sometimes you just need to break into the positive feed line to do the job (remote supplies, etc.) Here are a couple of simple circuits to feed limited power into a darkroom where I’d built some cathodoluminescence gear: basically a 90kV electron gun and scan coils swept a beam of electrons across a Gallium Phosphide wafer and the light was collected and measured with an integrating sphere - all in a high vacuum chamber running at 10^{-7} Torr. The gear produced abundant X-Rays when running, so the control gear had to be external. To avoid a major re-design and consequent inspection by the relevant ‘Elf-N-Safety’ authorities, I came up with these circuits. The MOSFET version is a modern take on the original Darlington scheme, you might find trouble with stability unless the MOSFET has a gate damping resistor and negative feedback (gate to drain) capacitance fitted. The Darlington version showed none of this bad behaviour!



Note: you might need a 'backwash' diode on the Darlington circuit. You can set the maximum current with the 1R sense resistor: R=V/I, and V= Vbe of the sense transistor (ZTX650). A sense resistor of 0.47Ω will give 0.55v/0.47Ω, = 1.17 Amps, for instance.

Crowbars…

Use for 'rest assured' protection on power supply outputs, ALWAYS downstream from a fuse! A simple SCR plus zener diode and resistor to gate will work just fine, protecting your precious circuits from a wayward pass transistor (or worse) in your power supply. And… on the feed-in point on your precious gear, fit a reverse biased diode & fuse (a-la the Rockmite modified by Forrest Cook, at http://solorb.com/elect/hamcirc/rockmite20/index.html. Of course, you could make up a stand alone module to fit onto your power supply output sockets / terminals, or keep a free-standing module for testing any 'sensitive' or especially 'valuable' gear.

Note that the fuse can be a filament lamp, following the 'dull lamp' principle, to avoid replacing the fuse after every (inevitable..?) misadventure; if you try a circuit breaker, make sure it's a fast one and can open quickly enough on 12 volt supplies. AC Mains circuit breakers won't, that's a dead cert!!

Components

Logic Diodes?

In amateur radio you often come across various 'sequential' switching situations - like changing over a single antenna from receiving duty to transmitting, then shutting down the power amplifier once the transmitting role is done. The problem comes from the hidden sources, like decoupling capacitors discharging, and the drive signal generated bias shutting off allowing high currents to flow in the finals.

This is a common problem in designing logic circuits - yes, they are still required in some situations where the development of code, proof testing (you DO prove your software under every possible situation, don't you?) doesn't justify going the micro route, in my honest opinion, it's realistic in about 50% of cases to use a handful of logic gates to do the job. Mind you, for those little jobs, simple diode logic is probably more than adequate, and you've probably used diode logic before, many times, but never recognised it.

Take for instance the use of diodes in 'Net', 'Operate' and 'Receive' functions. Yes, these odd diodes scattered about are actually diode OR gates. Selecting one function doesn't activate any of the others, the diodes are reverse biased and block the command from reaching other inputs.

A single +12 volt railed CMOS quad two input NOR gate (plus emitter follower buffer if more current than a CMOS gate can source / sink is required) can do these jobs too: if you only need two of the gates for the logic switching job, leaving you two NOR gates to make crystal oscillators, or other jobs - and don't forget, by fitting a resistor from output to (strapped) inputs, you've a simple op-amp for that bit of audio processing.

One problem often encountered are the delays required in switching from transmit to receive. You have to keep the antenna load connected *after* switching 'off' the transmitter, to avoid the decoupling capacitors dumping their charge into the PA device when no load is connected. Result: blown (or considerably foreshortened) active life for the PA device. On the switching from receive to transmit, you probably don't need a delay; so a simple RC delay that times on both edges (transmitter off and on) isn't satisfactory - it leads to unwanted delays before the transmitter fires up. Some designs eliminate receiver overload issues whilst the transmitter fires up by having a shunt to ground transistor / mosfet that protects the receiver input. Providing this is up to the job (considering a receiver input is connected to an antenna, which can pick up many kV's of lightning impulses and / or static charge destroying dinky MOSFET devices in the wink of an eye) then a shunt can really help.

Logic controlled xtal oscillators…

Talking of logic, I noticed on a Diodes Inc. data sheet a logic controlled precision oscillator with very low noise and jitter. See:

https://www.diodes.com/products/connectivity-and-timing/crystal-and-crystal-oscillator/crystal-oscillator-cxo/programmable-crystal-oscillator-xo/#tab-finder

If I'm reading this data sheet right, ("and that's not always guaranteed with you, is it Peter..." sayeth Stan in the background) then these little beasties output a frequency that's controlled by logic inputs, as the data sheet says, "the programmable oscillator IC contains a very low jitter PLL and can therefore generate any frequency based on your needs."

This chip might well provide the means to make very simple and accurate local oscillators, using for instance thumb wheel switches to create the digital control word, much simpler and cheaper than mucking about with software, and eliminating yet another digital noise generator in your radio environment. I haven't tried one of these on the bench; would a reader like to take up the job?

Diodes in parallel = more amps?

NO! You can’t parallel silicon diodes to get more amps from a rectifier set, as the slope resistance and forward volt drop must exactly match in each diode - and in this Universe, that ain’t necessarily so! So, how to shunt up extra diodes? Easy. Add some *ballast resistance*, ideally nichrome wire (pinched from salvaged firebars...). This has a positive temperature co-efficient; so the **more amps** through it, the **resistance rises**. Adding a fraction of an ohm of nichrome to each shunted diode will thus help equalise the current in the paralleled diodes. Should one diode hog the current (lower forward drop, lower slope resistance and Vbe falling by 2mV per °C as the amps heat the junction) the nichrome ballast resistance will heat up, the consequent rising resistance reduces the current, forcing amps through the other paralleled diodes.

This is exactly how power bipolar RF transistors - a collection of hundreds of low power devices in parallel built on one silicon die - spread the current across a whole array of transistors.

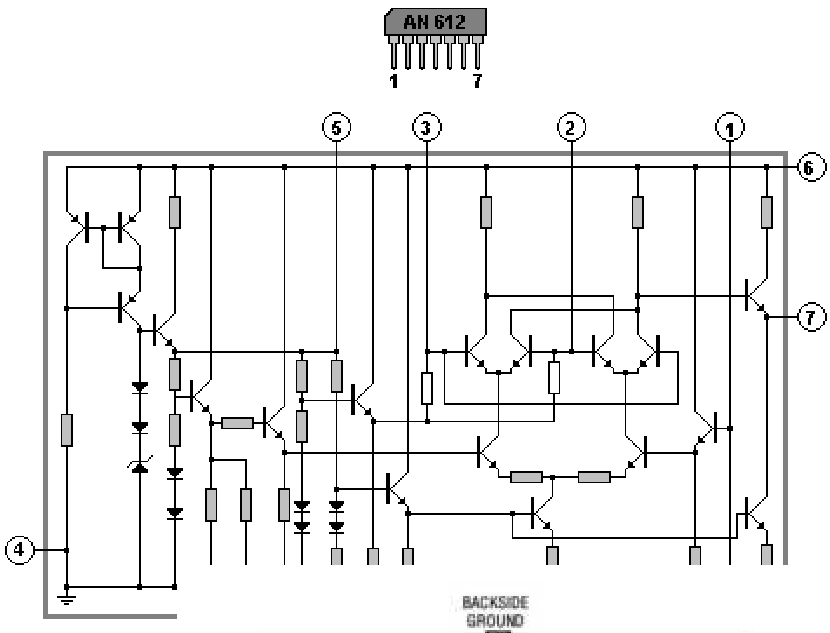
Note that you can’t solder nichrome wire, you have to use mechanical clamp connections (like choc bloc inners) to connect.

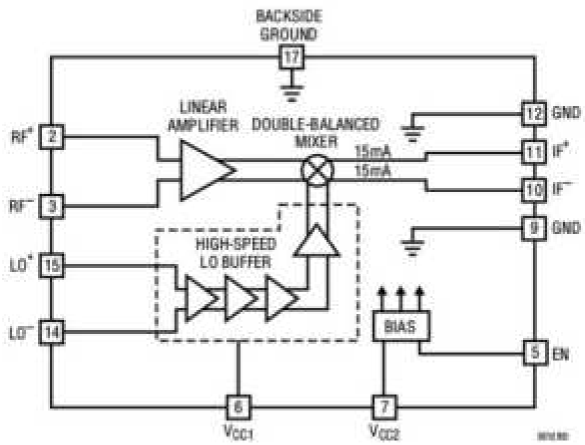
Vaping gadgets...

Commonly ‘discarded’ (i.e. chucked aside anywhere) once the cell is discharged often contain LiPo cells, 400-500mA/H. Careful dismantling and an intelligent charger will yield a useful collection for ‘ /P ’ operators, for FREE!

Goodbye, SA612…

The SIL alternative to the SA602 / 612 is the AN612 and LT5512. Internal circuit of the AN612is very similar to the SA612, and very often found in Citizen’s Band gear, and the like:





LT5512 Internal block diagram

The LT5512 is a similar beast; it has a very high spec. and is a very capable device (but not cheap). Note the enable pin ('EN'). This allows the bias circuits to be switched off for muting and the like.

Negative resistance??

Tom McKee told me of his work and his web page(s) links, for which I am most grateful: negative resistance is a fascinating topic and well worth studying - shunt a negative resistance across an L/C circuit, or a quartz crystal, and you've an oscillator, for instance. Think of what circuits you could create with negative resistance - not just zero resistance losses, but GAIN!

Tom's negative resistance pages:
http://www.radio.imradioha.org

Tom's Index Pages (from which the above is from) are an amazing resource; go take a look!
http://www.radio.imradioha.org/index.html

More on Manhattan construction…

I am reminded that those who enjoy building with mini copper pads, super glued onto an earth plane - a superb way to build gear, right up to UHF - might want a more rounded approach, in that the pads are better circular to allow easier and shorter wiring for 15m and up. Be that as it may, here's an idea by Keith D., and old pal of mine.

Keith notes: 'remember the old REXEL office paper punches? The really robust iron handle jobs? These can punch easily through 0.5mm and 0.75mm copper clad pcb material, FR4, SRBP and the like - the little circular 'waste' bits make perfect solder pads, and the punch can make thousands at one session - plus they all get collected in the storage drawer gizmo underneath'.

Cheers Keith!

Test Gear & Fault Finding

Watt-Meters

Watt-meters* are available now that simply plug in a domestic outlet, with a 'metered' socket on the front, allowing you to see the immediate consumption of a load. This can give immediate indication of a problem, if (and this is the big 'if'!) you've previously noted the draw under the various operating conditions, i.e. "x" watts on receive, "y" watts on transmit and so on.

Any deviation, more than the expected range seen previously, is a sure sign something's amiss. Don't just shrug ¯_(ツ)_/¯ …. check this change out, make sure you're not missing some unwanted shift in operating conditions.

In my previous life, in semiconductor wafer fabrication, machine operating parameters are routinely logged, either by a technician with meters, or (in later times) automatically logged by computer and the values stored, analysed and graphed to see trends, slow changes indicating wear, motor bearings, pumps degrading with time, etc. or sudden shifts in machine parameters, indicating something had broken, a casting had split, or a major change in operating parameters for a new 'recipe' had been called up. These trends or jumps flagged up the day's immediate jobs: data proved very useful in predicting breakdowns to the extent we could tell the Production wallahs that a machine would need routine maintenance in the next few days, or that a jump in a reading had caused a breakdown alert.

In an amateur scenario you might not need such depth of data analysis; or do you? With modern micro-controllers and instrumentation being so readily available, software from open sources (like 'GitHub', for instance) data logging / monitoring could be a very valuable tool. How long will it be before the latest Transceivers will include a data port with all the critical values inside that shiny black box being presented for customers to analyse? Are these parameters already available for the auto testing and alignment in the manufacturer's factory, or in the franchised repair shops?

*Note: for the impoverished amongst us, a moving iron AC ammeter can do a similar job, but let your imagination guide you - monitor heatsink temperature as an indicator of a power fault, etc.

Fake N type connectors...

Chasing that rogue lousy SWR on your latest VHF / UHF construction project? Noted the BNC antenna socket doesn't 'feel right' when engaging? You might be victim of fake components! You can bet odds on that as soon as a useful bit of kit comes on the market, some unmentionable will start making cheap copies of it, nowhere near the original quality or specification, and you've likely fallen victim to a copy.

Not only connectors get copied: fake IC's are rife. In the worst cases, the innards are nowhere near the original; another die completely. At best, they are probably reject dies, not up to full test. Transistors too suffer from this scam; especially the high priced end of the market. Cheaper transistors, in identical packages, are solvent cleaned or abraded to remove original type markings, then a new type number printed on. A simple multimeter check will show an apparent active device; but rest assured the fake won't carry the amps expected, withstand the rated voltage or have gain at the desired operating frequency - or even be the function you're wanting.

Look too for IC markings when buying ‘NOS’ parts from our favourite auction house. Real 1980’s IC’s were printed with ink identifications; more modern IC’s (i.e. the fakes) have laser ablated (burned in) marks - much smaller and finer sized.

This plague of fakes isn’t going to stop; even ‘reliable’ suppliers fall foul to these fakers, but at least they will happily exchange, as reputation is a very powerful marketing plus. If you’ve got fakes, get them back to your supplier. It’s the best thing you can do that will help get shut of the thieves.

Heathkit noise tester (2)

This very useful device (we’ve mentioned a’fore) applied ‘floating’ high volts (hi-Z for safety) adjustable bias to a pair of test probes, and then amplified any ‘noise’ from the device under test. Leaky capacitors make random noise and crackles; corona discharge makes an ethereal wavering hiss; leaky antenna insulators makes ‘hissy’ crackles just before breakdown.

You can make an instrument like this, it’s much more helpful than a meter or led indicator in finding leaky insulators, transformer insulation faults or dud capacitors - especially HV insulators at the RF resonances often found whilst tuning antennas. I’m reminded that safety these days is far more rigorous than years ago (thanks, Martin A.) and some basic operating procedures might be useful.

To make your own, you need a floating adjustable HV supply from a transformer and voltage multiplier circuit to generate the hi-Z, HV supply. The HV output is connected via a 10Megohm (or more) potentiometer, so the probe test voltage and available µA can be set to a suitable value (you wouldn’t want 450v DC applying to a 63 volt ceramic capacitor!). The HV positive output is connected to a simple audio amplifier via TWO 10kV (known good!) 1nF capacitors, so if one goes short, t’other will hold off the volts. The positive and negative outputs are connected to INSULATED crocodile clips for hands free (unlike the original Heathkit job!) operation.

To test a capacitor, ensure the output voltage is set to zero. Connect the capacitor on test to the output croc clips. Turn the audio amplifier gain up to maximum. Turn on the tester, and slowly increase the output voltage. Any breakdown in the capacitor on test will be heard distinctly as sharp crackles. To test antenna insulators in a dipole, test as capacitor above. For a long wire, or suspect feeder: clip the positive output to the ‘hot’ core of the feeder, and the negative to the antenna ground connection. You’ll hear all sorts of noises as the voltage builds up - damp leakage tends to ‘fizz’; bad insulators will crackle, corona discharge from sharp points (like stray strands of wire?) will make a wavering hiss as the breeze blows the wire.

You can ground the negative to an outdoor earth spike; then short the (disconnected) feeder core to screen, attach the positive output to the pair - this will test the antenna insulators and feeder outer plastic sheath to earth.

Your imagination using this tester is the only limit!

Components under test

For safety it's wise to keep both hands well away from test voltages, even using low volts in multi-meters, readings can be disrupted by finger contact.

The best way to hold components on test is to use a piece of 20mm thick of plywood, well varnished, and attach croc clips (with short screws) to hold items safely. You'll perhaps need a few at different spacings or one clip on a flying lead to accommodate larger components.

Testing mosfets: a very neat method is to use a multimeter on 'diode drop' test mode so the full battery voltage is available on the prods, to add / remove Gate - Source charge and check consequent Drain Source conduction. Assuming N Channel devices, connect the positive potential test probe to the Gate, and the negative probe to the Source which will charge the Gate capacitance - the MOSFET will be turned ON. Reversing the probes (or shorting the Source to Gate) will discharge the Gate capacitance, turning the mosfet OFF.

Bipolar transistors respond similarly, but you'll need a source of bias current to apply to the base. An old favourite was a PP3 battery, with wires soldered to the terminals plus a 10k resistor fitted in the positive lead, to 'mini' croc clips to connect positive to the base and negative to emitter leads. The transistor on test should be open circuit with no bias; almost dead short with bias applied. If no reading is obtained as expected, reverse the bias clip connections, it might be PNP!

Home made needle prods

Needle prods are a god-send on surface mount pcb's, but they are not cheap, and very easily damaged. Save time and money, make your own.

Strip out the inner brass connectors from a 1Amp choc-bloc, and clamp a needle in one end (remove the clamp screw from the other end) allowing the needles eye to come almost out the other end . You'll find multimeter probes will push into the (now screwless) open ends, the needle eye jamming the probe tightly in the 1 amp choc-bloc brass inner. You might need to try several different needle sizes to get a good fit on your meter prods.

Lead Free solder troubles...

At long last, lead free solder from the early days of 1980's and 90's is beginning to show it's true colours: dry joint failures in older gear are becoming a common failure point. Look for power supply and other 'hot' joints - i.e. on transistor legs, along 'single in line' amplifier IC's on heatsinks and the like for being open, high resistance or intermittent. Then it's out with the 63 / 37% tin / lead solder and reflow all those unreliable 'lead free' joints with some decent stuff.

Any solder joint that is dull, crystalline and not slightly concave has proved NOT RELIABLE in the long run. After you've reflowed all those dodgy joints (with quality tin/lead alloy), apply the standard 'Bump' test: your insulated screwdriver, held backwards by the blade, has the handle bumped somewhat vigorously all around the circuit board(s) you've suspected and reflowed, with power applied. Any crackles, clunks or other audible or noticeable effects at each bump indicates further - usually intermittent - faults awaiting your attention. Zero in on the culprits by progressively more gentle 'bumps' till you nail the little blighters!

350 volts is nasty...

...if you cop it across your chest! To Valve (or Tube) aficionados this is de-rigeur procedure; but to all you versed on 50 volts and under, avoid these heart- stopping moments by making up a 1Meg-ohm resistor with insulated croc clip leads. Clip this across the main reservoir capacitor in that switch mode power supply you're repairing to eliminate any nasty 350 volt DC shocks across your chest from those charged μF's - in fact, make a few of these Meg-ohm leads up and use them liberally on any valve B+ gear too. Might just save your life!

Construction

Soldering iron sponges after some use are a soggy, mucky mess. SAY 'NO' to such! Use a stainless steel pan scourer pad, in a small glass jar - the jars potted meat sandwich spread comes in are ideal. You can get a pack of 4 scourers in your local "Discount Shop" for pennies; they can be dosed with flux, of just used plain - they clean bits beautifully, don't damage the bit's iron plating and last for years.

Repairing diecast or plastic boxes, et al...

Mix fine powder (cigarette ash, talcum powder, etc.) & super glue for instant casting and repairs. This mixture sets like rock, but be quick! It goes hard in seconds. One very useful trick for repairing stripped threads is to insert a cotton bud in the stripped hole; drip in plenty of super glue to saturate the cotton wool and in seconds you've a rock solid filler with a pilot hole (the cotton bud hollow stalk) to help you re-tap the threads in the hole. Job done!

"Copper to Copper"

I had an email, which, to keep things short, asked about feeding multiple loads from a 'Choc-Bloc' screw connector strip. We've been in this district before! The Golden Rule is, if you want to steer lots of Amps around, any joints have to be "copper to copper".

Most users don't appreciate this when using choc-bloc connectors. Don't just bung your wires into the Choc-Bloc willy-nilly; If you've got several loads to connect, then select the heaviest load current wire, and put it into the same 'hole' as the feed wire: thus you've got copper to copper on the heavy draw connection. The lighter load(s) go into the other side of the brass insert, on top of the feed wire core which goes all the way through so these will be copper to copper too - and you've reduced the current flowing in the brass insert to it's least amount. Proper Job!

I've seen a fair few melted Choc-Blocs where 'temporary' fixes that ignored the "copper to copper" guide became 'permanent' and forgotten, only to fail later because the heavy currents weren't flowing "copper to copper".

You might get away with it for months, then quietly, without making a sound or giving any hint, a Choc-Bloc connection becomes a resistor. And just how do Choc-Blocs know the time? It was always on a night shift when these insidious little beggars decided to do the dirty and blow fuses!

Antennas

ATU polyvaricon Voltage ratings…

See https://www.datasheetarchive.com/pdf/download.php?id=0e3f84f91d06fd368e417b7df22b835fe48dda&type=P&term=Polyvaricon%2520toko

Which gives maximum rating of 100 volts; for a grossly mismatched or o/c load, even in QRP, can easily be more than 100 volts. The failure is likely to 'punch through' the insulating sheets; making a (now carbonised) hole from one plate to another. This will be benign until a voltage - far less than the rated 100 volts - is applied, when, in Royal Navy parlance, 'over she goes!'

To test a suspect Polyvaricon, dig out your Cockroft-Walton / Villard / Greinacher voltage multiplier (you DO have one to hand for high voltage testing, don't you?) and a 6.3v filament transformer to make high impedance high volts DC power supply, and use your fancy 10M-ohm digital voltmeter to measure break-over volts, and your 'noise' tester too. The very low current from a multi-stage multiplier won't carbonise the plastic insulation between the "plates" when it punches through (hopefully). See also previous notes on Heathkit "noise" testing!

Co-Ax Feeders through walls…

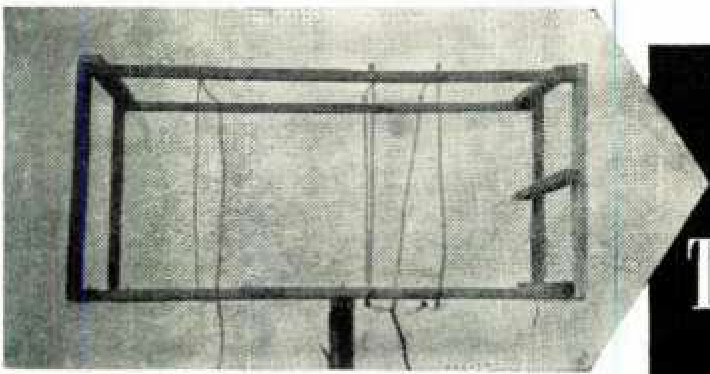
A sure fire solution is decent coax inside (bonded to coax braid) copper pipe, with appropriate connectors in an out (quality / Amphenol N type for instance), using copper end caps, drilled and / or machined to take the connectors. The copper pipe protects the coax, and, assembled in low humidity indoor environment, the plumbing fittings seal against further moisture ingress. Muggins here, in tender apprentice days, tried soldering the assembled copper end caps; Stan soon put me right by explaining that a smear of silver loaded epoxy resin would make a better job of it than the melted ruins I presented to him! The trick, of course, is to select the end caps to be a tight push fit, so pick-n-mix for a good fit. Ronnie B. had seen this sort of thing before when making vacuum feedthroughs; he advocated compression pipe fittings, but (he added) "they're big; use compression fittings only if you've a lot of room, and it's never as pretty as soldered caps - BUT - you can strip 'em out for repairs!".

You'll soon realise that unless you can get telescopic pipe (rare; very rare), the coax needs to be a bit longer than the pipe it's to fit in - this is of no matter, as the coax can scrunch up inside the protective outer pipe. The slight bends are of no consequence unless you're pushing 10kW or more "down the hole".

An ancient 'Quad'…

Could be easily made with bamboo canes and cable ties, and easily scaled for other bands. What's not to like?

Article follows on next page…. my thanks to the original authors. I have often found useful and easily constructed bits of kit in old magazine articles: always worth a good look through the old references.



The antenna is built on a simple wooden frame. A pipe mast is used for support and permits rotation.

A Two-Meter QUAD

By G. P. OBERTO

A three-element, high-frequency version of the quad antenna, giving a unidirectional pattern.

MANY hams and experimenters have been searching for an antenna that will give outstanding results on two meters and still fit into the family b.dget.

The type of quad to be described has a lower angle of radiation than that of the original cubical quad, because it is mounted horizontally instead of in accordance with the diamond mounting system used with the original quad. Height is not too important in using this type of antenna. Getting the array above trees and surrounding objects is all that is necessary for DX work on two meters.

Front-to-back ratio is very good. With a field-strength meter you will obtain readings only within 30°, standing 50 feet away from the front of the quad. Impedance is approximately 150 ohms, with one director loop and one reflector. The results obtained with this quad seem better on horizontal polarization than on vertical polarization.

Making a frame, 18 by 36 inches in size, is the first step, using 1" by 1" wooden strips. Take care to make this as light as possible, yet sturdy enough to withstand bad weather. For good, secure construction, slot the ends of each strip and use small bolts.

The radiator is made by winding two turns of No. 12 wire around the center of the frame with one-inch standoffs at each corner to give the wire a 19-inch length for each side. Space the turns five inches apart; no matching stub is required at this point. The 150 ohm feedline is connected to the ends of the loop.

Construct the director by making one turn of No. 12 wire, spaced 15 inches from the center of the two-turn loop, wound on the inside of the frame with insulators mounted one inch above each corner, leaving a 17-inch length of wire for each side. A 9- to 10-inch matching stub is fastened to the end of the one-turn loop. Proper matching can be determined by varying the length of the stub. A shorting bar will save a lot of time. However, a piece of 150 ohm twin-lead can be used by experimenting with different lengths.

The reflector is formed from two sections of No. 12 wire, 10¼ inches long for each section, mounted on a 22-inch board; the first two insulators are mounted one inch apart from the center of the board, and the last two are mounted 10¼ inches apart from the inside insulators. The board is fastened on the inside, 10 inches from the center of the two-turn loop. A 9- to 10-inch matching stub is also required at this point.

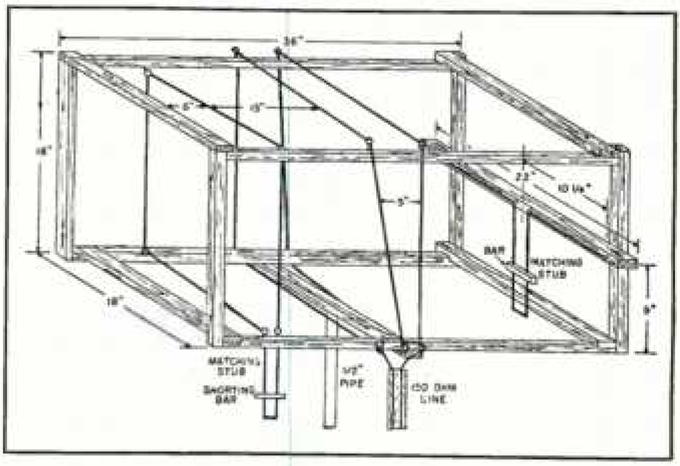
Although it was not tried, it is probable that the reflector could be a duplicate of the director if the reflector were wound on the outside of the framework to give the necessary added length.

The radiation pattern of an antenna of this type is horizontal, and parallel to the long dimension. The maximum radiation is off the director end.

Judging from experiments made with this antenna, it should perform as well or better than two five-element beams stacked.

-30-

Construction details and dimensions for the antenna. Rigid construction is necessary.



Stop Press

AFDD's - another 'official' red herring?

https://www.cibsejournal.com/technical/arc-detection-devices-fault-finding-mission/

Those ‘scope Waveforms look just like my ‘finger test’ touching a scope probe tip; the difference between an arc-n-spark (arcs = amps; sparks = kV’s); Paschen’s Law and 30kV per inch at normal atmospheric pressures (barometer so low it’d have to do 100 full turns downwards); why, and how, in real practical day-2-day scenarios, will a series or parallel arc be created?; Why won’t existing RCBO’s trip? The HF detecting trip - the ‘shoulders’ are indicative of HF oscillations in wiring L and C. https://www.fxsolver.com/browse/formulas/Paschen%27s+Law

Note (1) -

Here’s a quote (below) I found on t’internet (https://physics.stackexchange.com/questions/595577/what-is-the-difference-between-electric-spark-and-electric-arc) whilst exploring the difference between an arc and a spark - they are indeed very different beasties and should be noted:

“According to Wikipedia …. an arc is maintained by "thermionic emission of electrons from the electrodes", that is, in practice it relies on (‘thermal’ Ed.) *energy already being dissipated from the current to heat the electrodes.*

A spark can occur immediately when breakdown voltage for the [‘insulating medium’ Ed.) *air gap is exceeded and the gas is ionized enough to become relatively conductive; depending on the source parameters and overall geometry, the spark can then become an arc (the conductivity rising even more) or extinguish within milliseconds.*

Once both electrodes are hot enough, they present a constant supply of charge carriers (ions and electrons) into surrounding air. Unlike the spark, the ionized conductive channel in the arc can then survive even short drops in power input, like those occurring each 10 ms in AC network or transformer welding. It can also maintain its conductive properties even when extended to several centimetres or even metres - this no more depends on voltage, but rather on the availability of current to keep electrodes and arc's plasma hot.

Typically, an arc is extinguished similar to a flame, either by blow of fresh air, or by its own updraft that stretches it too long to keep hot enough. Both mechanisms are employed in HV power lines, where arcing is a major danger and must be prevented.”

Note (2) - the geometry of the electrodes involved has a massiove influence on the chances of a spark happening:

“While exploring different electrode types, it was noted that where the breakdown voltage was significantly reduced by using carbon rods, the AFDD’s detection of arc faults became unreliable.” NO!! Breakdown voltage is NOT a function of gap material - so long as it’s conductive it’s the geometry of the gap electrodes that affects breakdown volts. He mean “arc voltage”, NOT breakdown voltages!

One simple rule, hammered into every high vacuum engineer, is the simple fact that at atmospheric pressure in clean dry air, you need **30kV per inch** of air gap for a spark to occur; and before the spark jumps, you'll get corona discharge manifesting itself, showing as a leakage current across the gap. The inclusion of PVC (or other insulating medium) in the gap significantly increases the volts required to break down that gap; once the spark has punched through the insulating medium it leaves a trail of ionised particles which can then carry sufficinet current to create thermionic emission of electrons, thus creating a sustained arc, signified by a very low volt drop across the gap (50 - 500 volts or so, depending on the geometry and materials). That's how TIG / MIG welder arc triggers work, they usually use Tesla coil generated High voltage HF to initiate a spark, then an arc can form and sustain itself.

Does this mean arc welders on the same feeder phase nearby will falsely trip downstream AFDD's? Or how about LF / HF induced in house wiring from your transmitter?

Whilst I'm all for fire prevention - and the original IEE wiring Regulations were specifically aimed at preventing fires, using appropriately rated fuses - aren't modern MCB's and the like up to this job? The amps from a true arc being so high the MCB protective elements will open the circuit safely and self-extinguishing PVC insulation complete the job?

Costs quoted by a local electrician to me came to considerably more than £1000 for a simple 'consumer unit' change with AFDD / MCB / RCBO protection. I don't think this reasonable or required; do you?

It's Goodbye from me...

I have written and compiled Hot Iron now for 5 years; I'm most honoured to have been asked to do so by Tim Walford, the originator of Hot Iron. I'd like to thank all the contributors (and that includes all those web pages and references I've found so useful).

My health is not what it used to be, COPD - probably not helped by all the rosin flux fumes I've inhaled over the years - is becoming a big issue in my life and I have to spend more time out: it takes a lot of hours to put together an edition of Hot Iron, edit it, correct all the dud links, wrong references, checking attributes and the like.

Thank you for allowing me to drop into your (amateur radio) lives every quarter, I hope I've brought something useful to your enjoyment of this fascinating pastime. It is with regret that this is the last Hot Iron I will be editing and compiling; if another writer wants to take up the reins please contact me (equieng@gmail.com).

August, 2023 Hot Iron Newsletter #121

If you've been a Hot Iron subscriber for long, you are aware of the large variety of material it brings to subscribers. Please send suggestions and articles, as well as the email addresses of new subscribers to fbw4npn@gmail.com. And send your technical questions to Peter Thornton at equieng@gmail.com

A Hot Iron website page contains the **index of topics covered by the individual newsletters, where** the number of the issue containing the subject of your interest can be found. These are an interesting read on a hot summer's day (or a cold winter's night).

Here begins Hot Iron's August Newsletter, beginning with an informative article by Peter Thornton and containing some reprints from older issues:

Hunting QRM to Order!

QRM is a right b*~~er, it drives you mad - it comes from (seemingly) everywhere; it is a relentless problem that's getting worse all the time. Sometimes a bit of methodical detective work can hush the gremlins; or maybe find a direction from which the noise is quietest. Try some - or all - the ideas below, which helped us when testing RF semiconductors.

Airborne, Earth borne or Wiring trouble?

QRM is RF noise; it can come from myriad sources - how do you find (and hopefully negate) the major culprits? Here are some simple checks that might help locate the QRM source.

- **Does the QRM reduce if you try a Hertz (balanced) antenna, i.e. dipole or tuned loop?**

If the QRM reduces, and is lower in some direction(s) the QRM is inducing equal and opposite currents in each dipole or loop leg, so the noise signals are cancelling (hopefully). Hertz antennas are directional - sorry, MW / LF fans, you'll need some major real estate to do this down in the kHz!

- **Does the QRM drop if you replace the antenna with a (non-inductive) 50 ohm resistor?**

The only way ANY signal can get into the receiver with a matched (and shielded) 50 ohm resistor across the antenna input is via the power supply or by signals getting into the outer skin of the metallic case / conducting screens of your receiver, or coming up the power supply / Earth lead(s).

- **Are you using a Marconi (unbalanced) antenna? Does the QRM reduce if you disconnect the Earth rod and use a 'virtual' earth - like a counter-wound (non-inductive) counterpoise?**

You may have earth borne currents flowing in your area from other electrical installations nearby (and not so nearby - earth currents from distribution networks can travel many km's!).

- **Does the QRM reduce if you use battery (or DC power supply)?**

I don't mean "hum" or related 50 / 60Hz noise, I'm referring to wideband noise, not power supply related. Though the dreaded 'direct conversion hum' is a killer, that is another issue entirely from HF QRM which I'll look at some other time.

Your receiver may be very sensitive to noise coming up the earth wire; the counterpoise (above) might indicate this too if the QRM significantly reduces.

- **Disconnect your household electrical appliances one by one, see if the QRM drops**

Good behaviour begins at home - YOU might be the source of local QRM!

Earth Noise: the insidious Demon

In most urban areas live other electrical equipment users; and **all** installations run currents into the earth, either deliberately or by induction or leakage. Remember you're seeking μvolts of RF!

Delta connected capacitors in the 'filter' mains input sockets or other 'noise elimination' schemes run capacitors line to earth, neutral to earth and line to neutral: all these contribute to noise currents in the earth. The 'true' earth of your supply is the 3Φstar point in the substation feeding your house via cables, usually (but not always!) steel wire armoured and these induce 50 / 60Hz currents in their screens. Being VLF, skin effect is not present to any real extent so can't contain the noise within the armouring; these currents despite magnetic steel armouring induce emf's in the nearby ground and said ground being wet and salty, it conducts well, so the currents can run for many metres through the ground.

Similarly, AC power is distributed over the network with non-linear over voltage 'Metrosils' , 'Transorbs' connected to absorb over-volt surges. These cut transients, thus, as Mr. Fourier's analysis tells, make for HF harmonics. It's common to 'tap change' transformers on load using ballast inductors to limit short circuit currents, but these inductors carry huge currents, and are rapidly switched in and out causing back emf surges (Lenz's Law).

To eliminate problems like this in industry, it's common for 'electrically' clean rooms in semiconductor test halls to use Earth free Faraday cages, where the AC power is fed into a conductive walled room via 230v to 230v isolating transformers with substantial line-to-line filtering, using Class X capacitors and heavy common mode chokes - as *no Earth connection is allowed inside.* I don't think a full Faraday cage in a domestic environment would be acceptable to your XYL(!!); ¾" wire netting lining can be an efficient RF screen in a garden shack. Faraday's law assures that charges can only exist on the **outside** of an enclosure, and that includes QRM.

The only route in for QRM is via mains wiring entering your Faraday cage - and if this is via isolating transformer(s) and substantial line filtering creates 'double insulated Earth free' supply inside the cage, though this is often beyond the average amateur's means (and your local Sparky's experience) and needs serious safety considerations. Almost any radio gear can be run inside a Faraday cage on DC supplies; burglar alarm batteries are an option (but charged outside the cage).

The cheap & cheerful way forward

- Find the source and eliminate it *(a directional loop antenna can help here and look for noisy / sparking commutators in electric motors, SCR dimmer switches, etc.)* and try snubber networks *(low ohms resistors in series with µF's are commercially available for this job) across AC Line 1 to AC Line 2 of the offending supply or item. This can often entail 'delicate' conversations with neighbours who might have no idea they are blotting out acres of radio reception.*
- Shield out air borne noise with screening cages *(galvanised wire mesh with ½" or ¾" holes is solder-able and can form effective screening, even if not a completely closed volume).*
- Balanced Hertz antennas cancel common mode noise (*loops, folded dipoles, in fact any Hertz antenna that needs no earth connection*) and can help with QRM reduction.
- For Marconi antennas, try counterpoise grounds (not connected to a ground rod!) to eliminate Earth borne noise (try *twin core flex (a.k.a. Zip Cord) shorted at the far end, and only connect one core to the receiver so clockwise turns always have an equal counter-clockwise partner*).
- Establish a time and date record of the QRM. (*It might tie in with a local factory start time, a neighbour's lawn mower, or another regular onset. Any pattern helps find the source.*)

There is no guaranteed technique to eliminate QRM, but these industrial practices adapted to domestic environs usually reduce the bother. If all else fails, consider VHF / UHF: 6m and up can be noticeably QRM clear with only electronic shot noise to contend with - and effective bandpass audio filtering can work wonders shifting most of that.

***Donder und Blitzen* - Station Grounding:** Grounding information can be integrated with Peter's information about QRM, presented above. Such information might be helpful, both in terms of QRM reduction, ground loops and safety – see below.

Be sure to read **W8JI's web page concerning station grounding**, which explains different paths lightning can take to wreak havoc on your equipment. Suitable grounding is needed, especially in certain lightning-prone areas. W4NPN's first home in North Carolina was hit twice; the first time it exploded a 100+ year-old Poplar tree ten feet from the house, throwing bits of it over 300 feet away and the second time it slightly charred a few rafters. Both times resulted in some commercial equipment loss (but the tube ham gear survived). Yes, I moved to a different home, and yes, it really gets your attention when it happens at 2 AM.

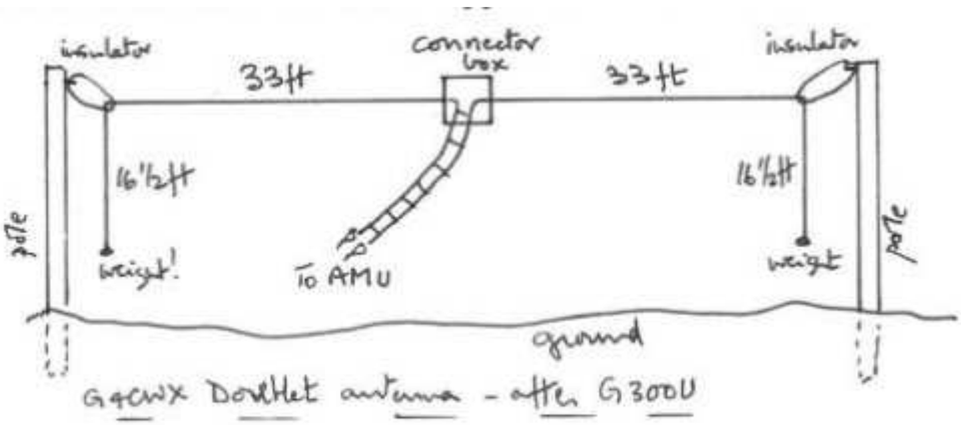
Click here for the ARRL's notes on station grounding.

The Smoky Mountain Amateur Radio Club has a good web-based publication regarding station grounding.

What's a SNUBBER? A snubber network was mentioned above. What's a snubber? **Go here to find out.**

A Simple Doublet Antenna, Field Strength Meter, 1:1 balun:

Google reports 8,210,000 "HF Antenna" articles but "only" 204,000 (!) are about doublets. Some are good, some are bad and some are Goldilocks antennas – "just right." For those with restricted horizontal space, Hot Iron #66 contains one originally designed by G3OOU and submitted by G4CWX. Feed it with low-loss "ladder line" and terminate it at the antenna tuner with a 1:1 or 4:1 Guanella (i.e., current) balun (whichever ratio works for you, 1:1 being slightly preferred):

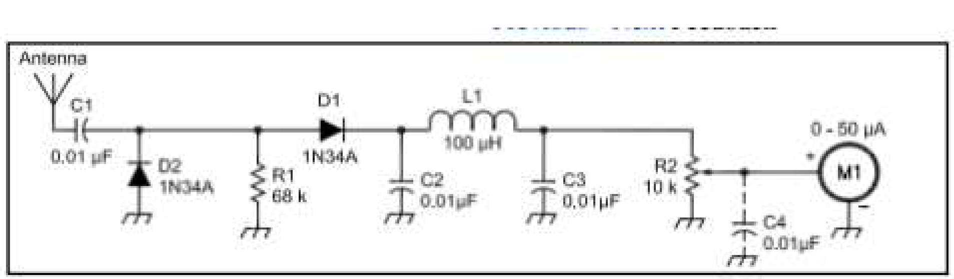


Its impedance will of course be different on each band and a good tuner match will likely be found by trial and error, unless some sophisticated equipment is at hand. I think this one works on 40 meters and higher bands. Be sure to avoid a "wrong" length of ladder line. **See information about that here**.

W4RNL (SK) has also described one hung vertically, with 20 foot legs on either side, and fed with ladder line. W4NPN just installed one of these to play with and will soon test it, comparing it to a 137 foot Vee on receive/transmit and a 450 foot ground loop for receiving.

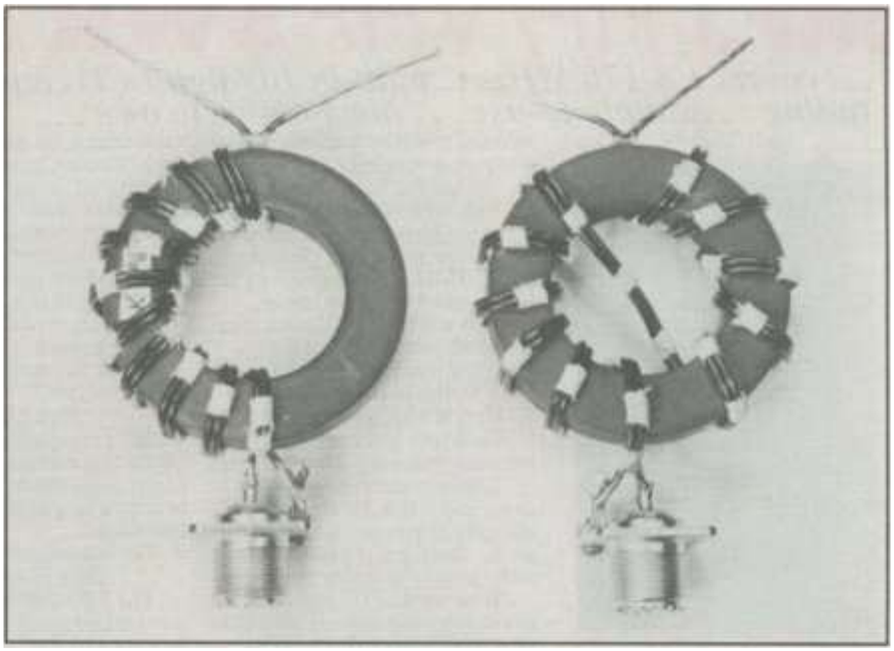
This information can be applied to any ordinary wire doublet or dipole. **See this Antenna Page.**

A field strength meter is a handy gadget for ensuring that the antenna is radiating. A circuit for a simple FSM, from the Sept 2002 QST is below. The meter could be 50, 100, 200 ua, etc. and the antenna can be a short length of wire or one rescued from a discarded radio.



Note that, if an L-C circuit is installed directly after the antenna, and tuned to the desired band, you can be sure that the L-C "tune" circuit of the transmitter's tank circuit is tuned to the correct band and that radiation to the wrong band is not occurring. Of course, you can do the same thing with your receiver.

A Simple Current Balun:
Jerry Sevick's (W2FMI, SK) designs for **1:1 current baluns are below** (source: April '94 CQ magazine, illustration H). Mine are wound on a T200-2 core, using #14 (1.628 mm) insulated house wire. Since I used insulated wire on a bare core, I added one more turn. My windings use the full circumference of the 2" toroid and both my homebrew tuners like it on 80 – 10 meters.

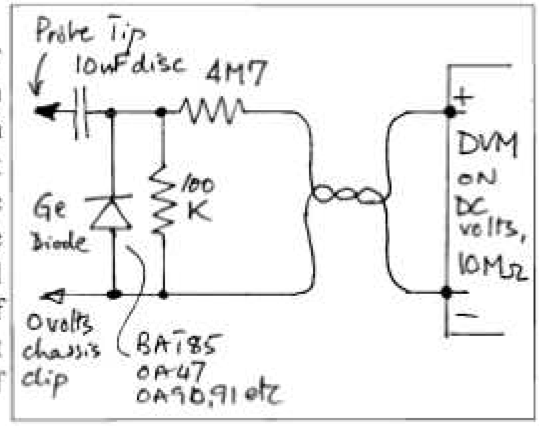


There is a huge amount of Web info about baluns; some good and some not so good. **Try this page** to get started. I am no expert whatsoever on baluns, no matter how much I read, so I rely on experts like Sevick. And finally, much information about Ladder Line (a.k.a. twinlead) **can be found here.**

Read Peter Thornton's QRM article at the begining of this newsletter: Man-made QRM was so bad at my QTH's inverted Vee (from computers and other radiating gear) that I laid a large loop directly on the ground and fed it with 450-ohm "ladder line." The noise reduction was dramatic and very little signal strength was lost. The improvement in signal-to-noise-ratio was excellent. If you are in the same situation, consider a ground loop for receiving. They can even be made somewhat directional. Google "loop on ground antenna" for information. Mine is 450' because I converted a large, very low level random wire into an on-ground loop. A 60 to 100 foot loop is quite adequate. Just run it around the border of your garden or back yard.

RF voltmeter

None of you have submitted anything for the Question Corner so her is a space filler! It is a high impedance peak reading rf voltmeter, which when connected to a digital voltmeter with 10 MOhms input impedance will show the RMS value of the voltage providing it is sinusoidal and sufficiently large for the approx. 0.1 volt drop in the diode to be ignored. It will provide some indication for rf voltages down to tens of millivolts but the actual value shown will be way out and it can only be used as a rough indicator. It is good to VHF if the component leads are short. Tim Walford G3PCJ



Perhaps some clever person will figure out how to integrate this RF vm into the Field Strength Meter circuit, as a switchable option, using the installed meter, calibrated for volts.

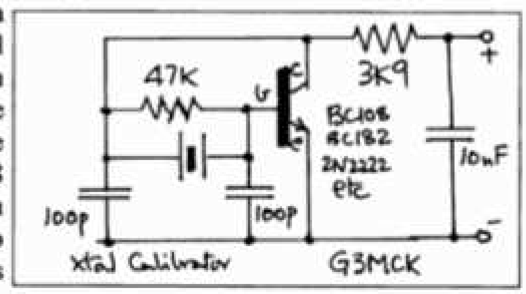
Crystal Oscillator/Frequency Standard (Hot Iron #33):

A trivial project to encourage very new constructors!

(I am delighted to welcome Gerald Stancey, G3MCK, as a new contributor - he warned me that this article would be too simple but I think it is just right! Ed)

This project is trivial but useful. It does not take much skill, time, or money so it is a good thing for the novice constructor to cut his teeth on. Please note that when I say his, I also mean her as I believe lady amateurs are honorary chaps. If that upsets you that is your problem not mine. PC does not exist in my QTH, the XYL doesn't allow it.

Now back to radio which is where we started. Anyone who plays about with receivers has the need for some sort of signal generator. Such a device will tell you that the receiver is working, that it is receiving on a particular frequency and it also gives you some idea of how well the receiver is working. Signal generators come in many shapes and sizes varying from the ridiculous to the sublime. This project falls into the first category. The circuit diagram right shows a simple oscillator that can be run from a 9 volt battery or a 13.8 volt PSU. You can build it in any way you want, from ugly construction to perf board. Etched PCB is far too complex but veroboard is a good bet. The choice is yours.



There are no hard to find bits. Crystals can either be bought for the job, the QRP frequencies are readily available or for the more financially challenged, the colour TV crystals on 3579.4 KHz can often be yours for the asking. At most rallies it is possible to buy crystals for pence. These may appear to be useless frequencies but a handful of non-amateur frequencies can be helpful when making general coverage receivers. Also near and non-favoured frequencies in the amateur bands can sometimes be found; for example at the Yeovil QRP Convention I bought a 3596 KHz crystal, in the band but not much use for transmitting and a 3484 KHz crystal, which is OK for setting the low band edge of a receiver.

Just wire up the oscillator, apply power and drape a bit of wire from the receiver aerial terminal over the unit. When the receiver is tuned to the appropriate frequency, you will hear a loud clear signal. The signal strength depends on how tightly you couple the receiver to the oscillator. Check the strength on a known receiver, then substitute your home brew receiver and see how it compares for gain. This is a bit iffy but at least it does gives you some idea.

Next issue, we will look at boxing the unit, getting consistent output and attenuators, all simple kitchen table stuff and no maths. Gerald G3MCK

More about Oscillators: An excellent book about oscillators of all types is the extensive John Rider book *Oscillators at work*. **A copy may be found here** and this web page also has many articles about crystals and their operation, grinding, pushing and pulling, etc.

Have a mystery transformer? **Go to this website** to find manufacturer's catalogs which might solve the mystery.

Future issues: Thousands of regenerative receivers have been built; even my father built them back in the 1920's (wow, that was 100 years ago, and so was he!). They are great fun! A future issue of *Hot Iron* will have some concentration on the subject. Please send any information or comments you might have about regens, including your favorite designs, to W4NPN.

I'm thinking of a possible concentration on simple VFO's in a future issue as well. Perhaps some chassis manufacturing articles; maybe simple tuners. Maybe even a few digital or SDR thoughts. Suggestions are welcome.

A listing of good ham-related websites might make a good subject so suggestions about these would be welcome. **See what's already available on this page**.

This is all for this issue; please send your articles of interest and suggestions to me or Peter at the email addresses contained in the introduction. I will continue to troll through back issues for articles that seem to merit repetition and will look for new topics on the great Web. I wish I could find time to work on my own projects (retirement is SO BUSY)!