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

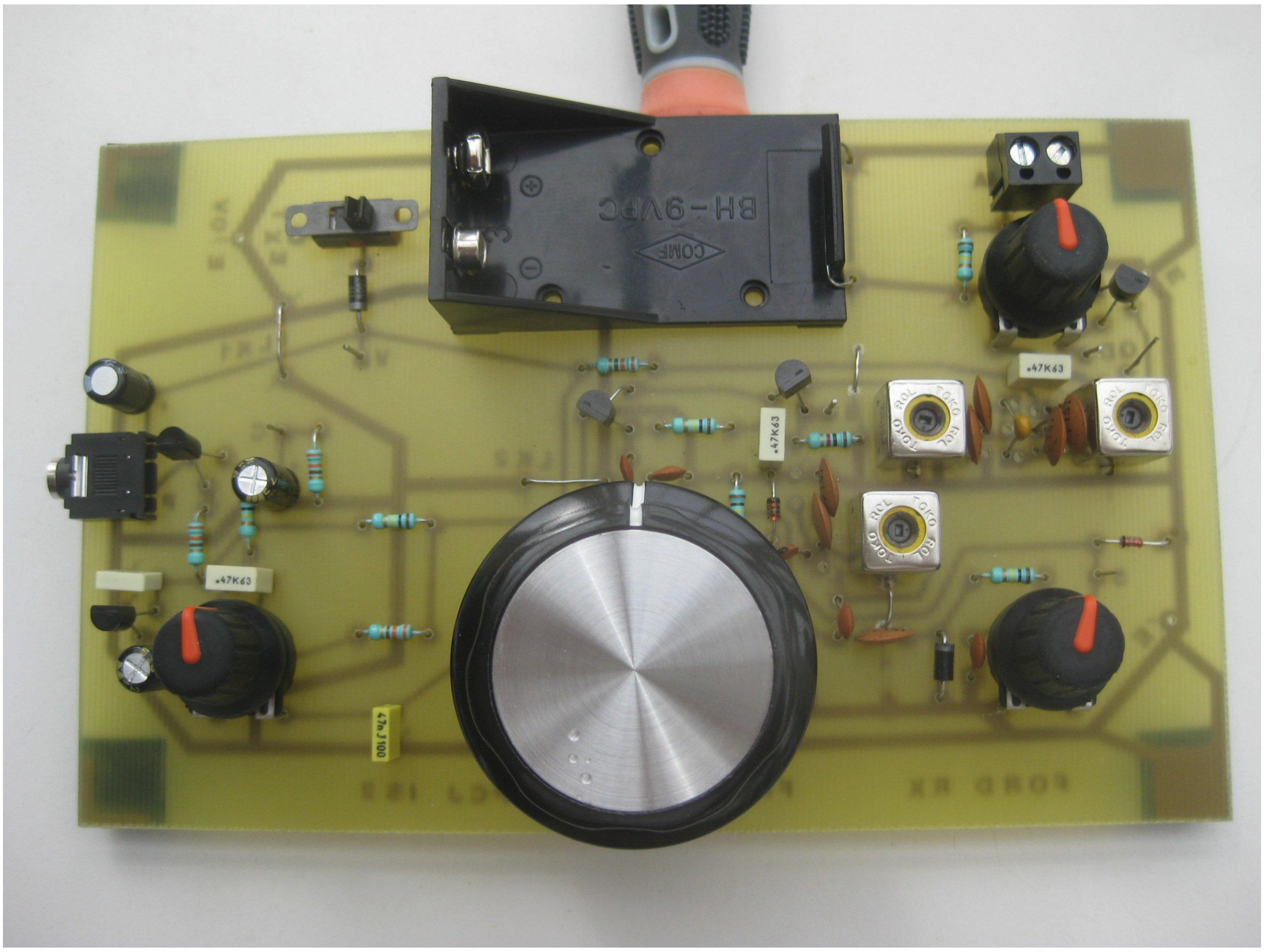
Kit news from Tim G3PCJ

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!

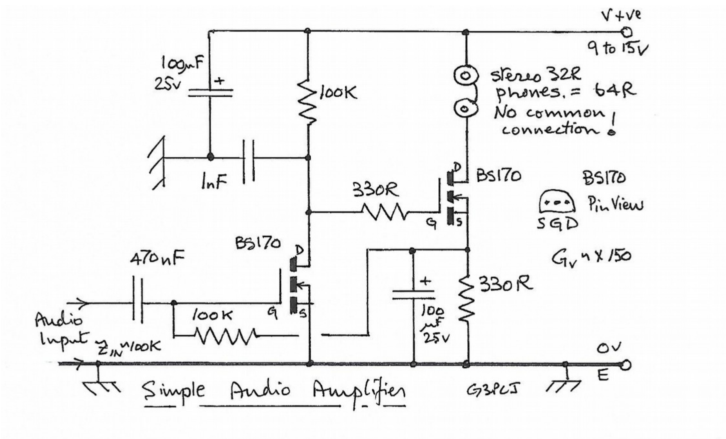
Shared impedances

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

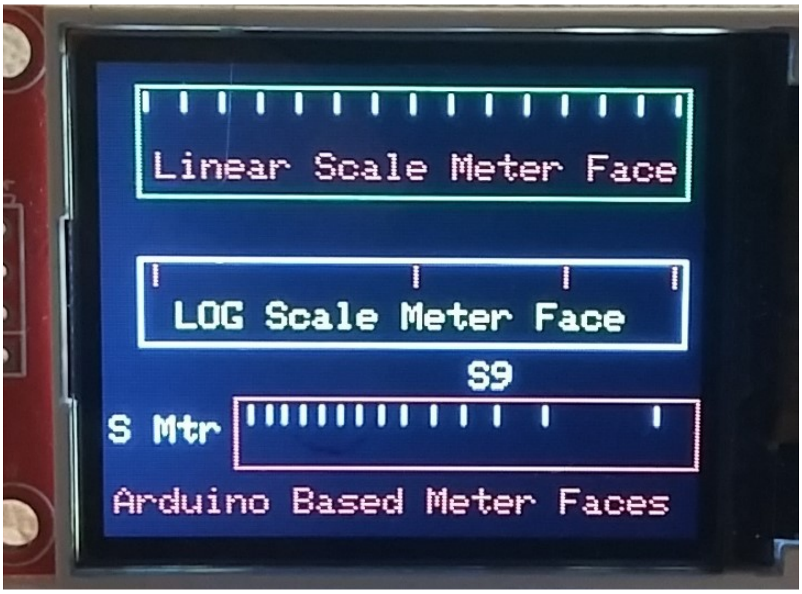
By Pete Juliano, N6QW n6qwham@gmail.com

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.

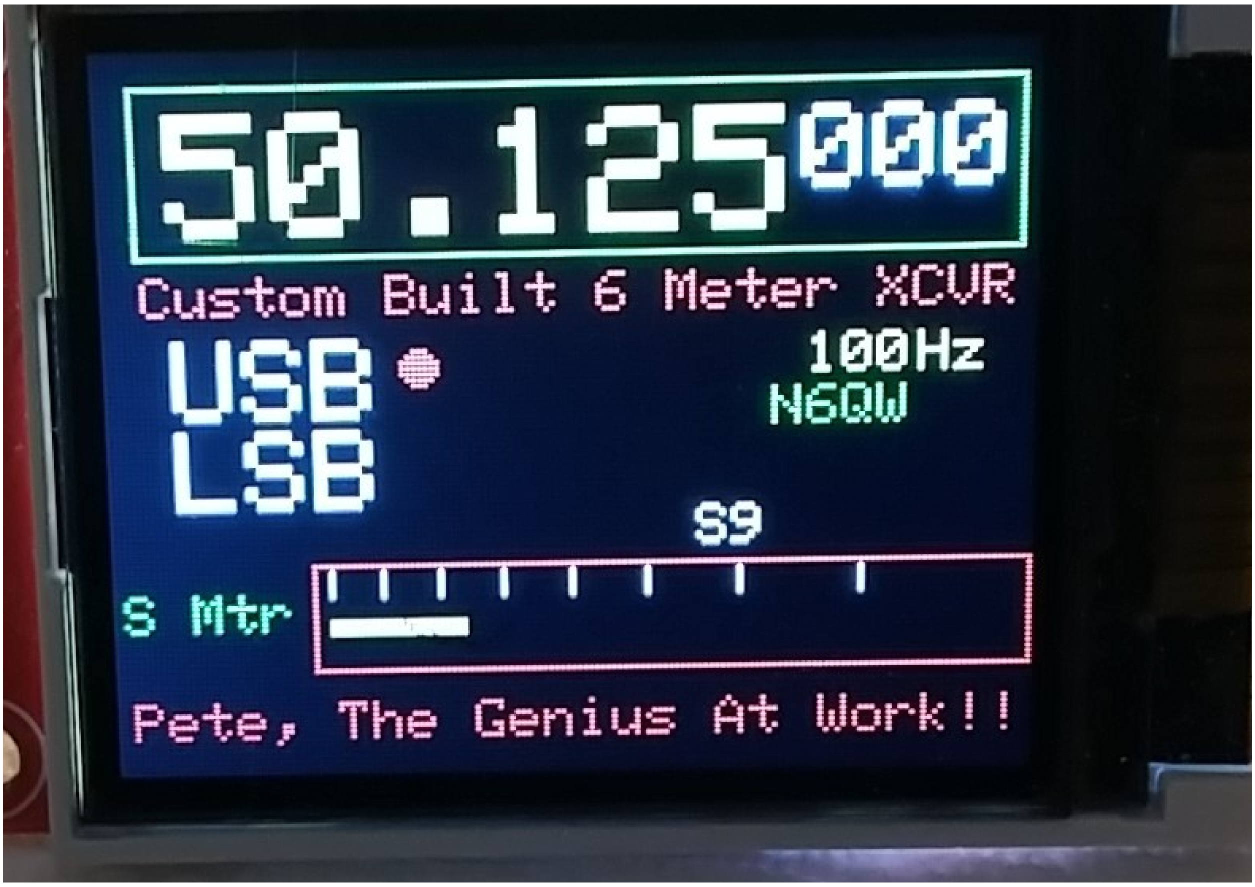
The code for the second meter is:

```
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.

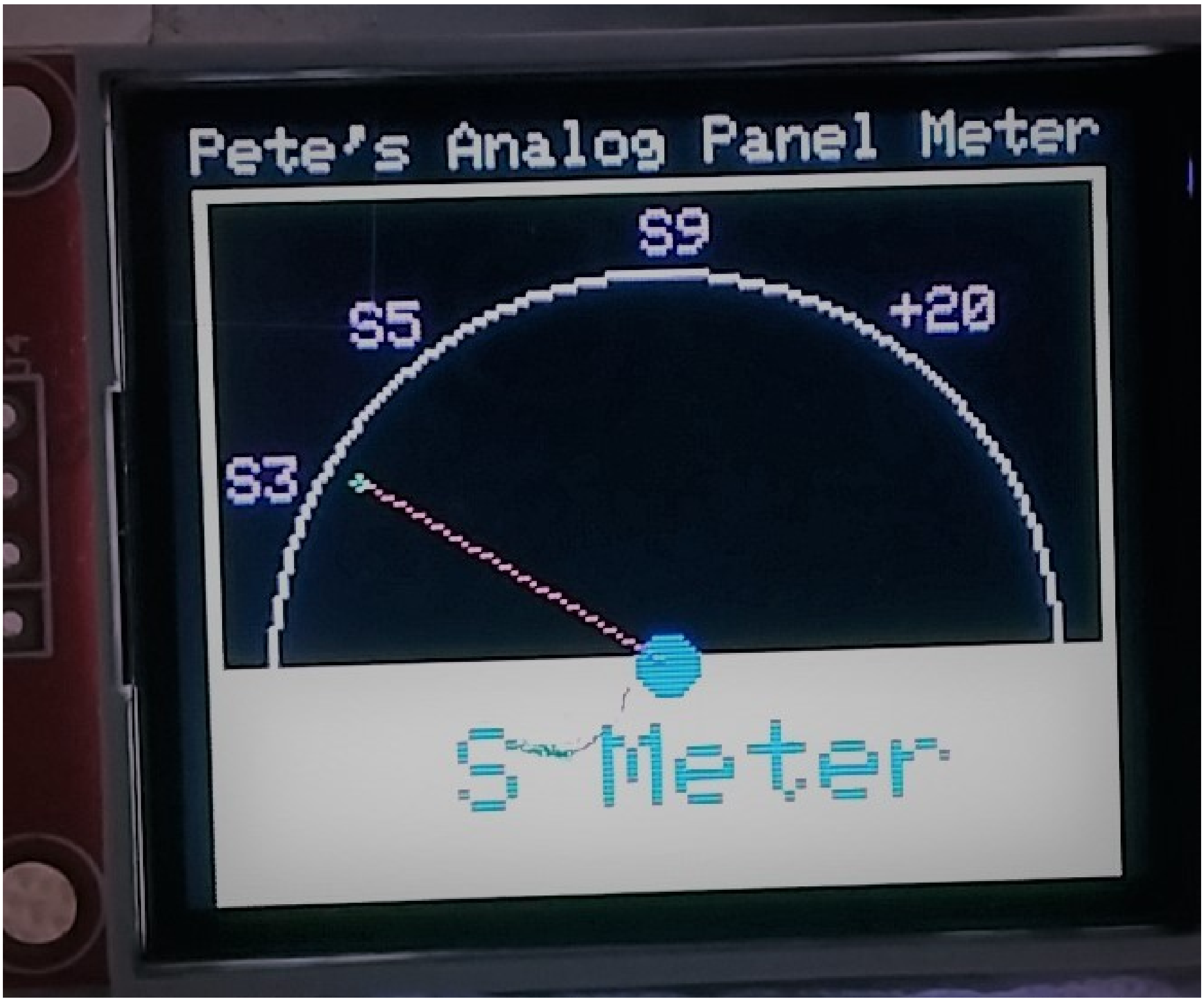


There is no sound basis for the code I am about to share, other than what is shown for the Tick marks “looks like” we see with S Meters. Since it too had to be non-linear I used a square root function with a multiplier. But there was also a visual trick at play here. In the case of our log scale the 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
```

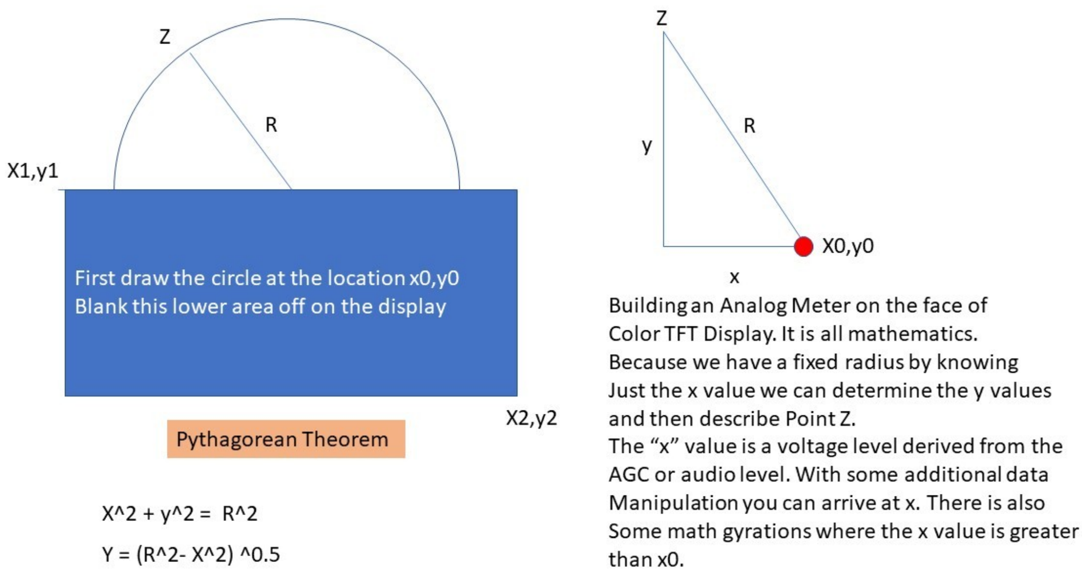
The important lines are the last two which shows that we will have 9 points and the second line shows the math equation that was pulled out of thin air. The 180 – (50*sqrt(1)) is the key.

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.

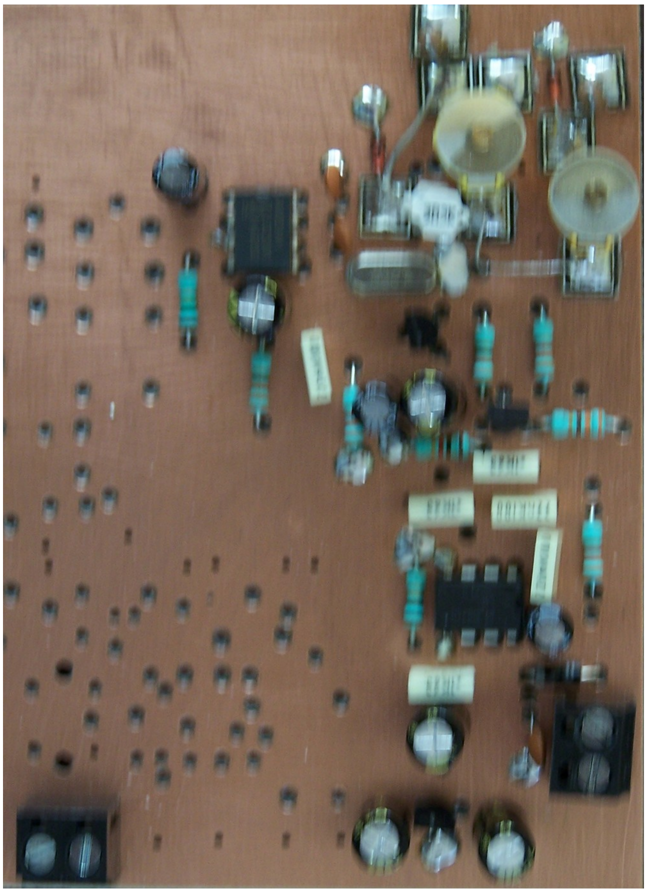
To increase the sound, connect a small loudspeaker with a capacitor in series across the normally closed contacts. The larger the capacitor, the louder the sound. Try a 47nF first and adjust as per requirements.

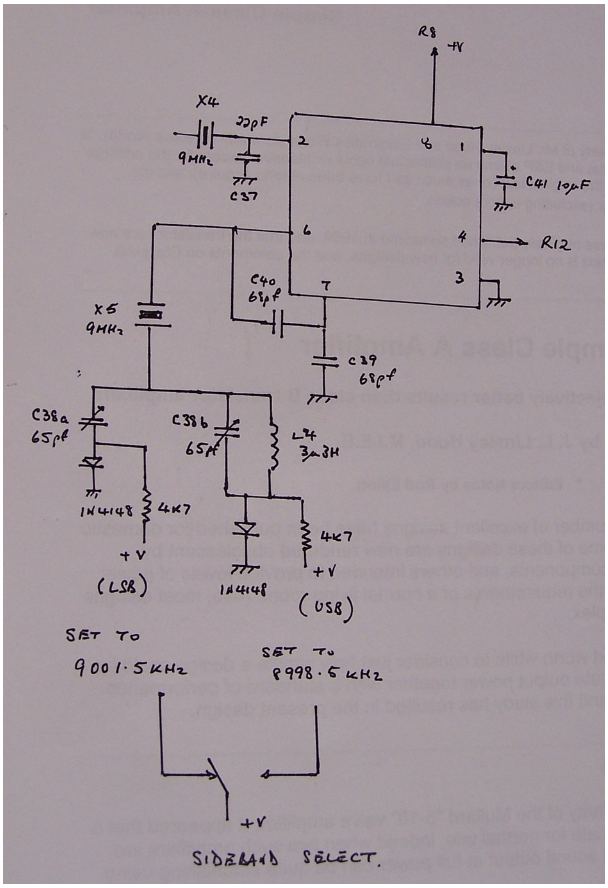
Rx’s

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.



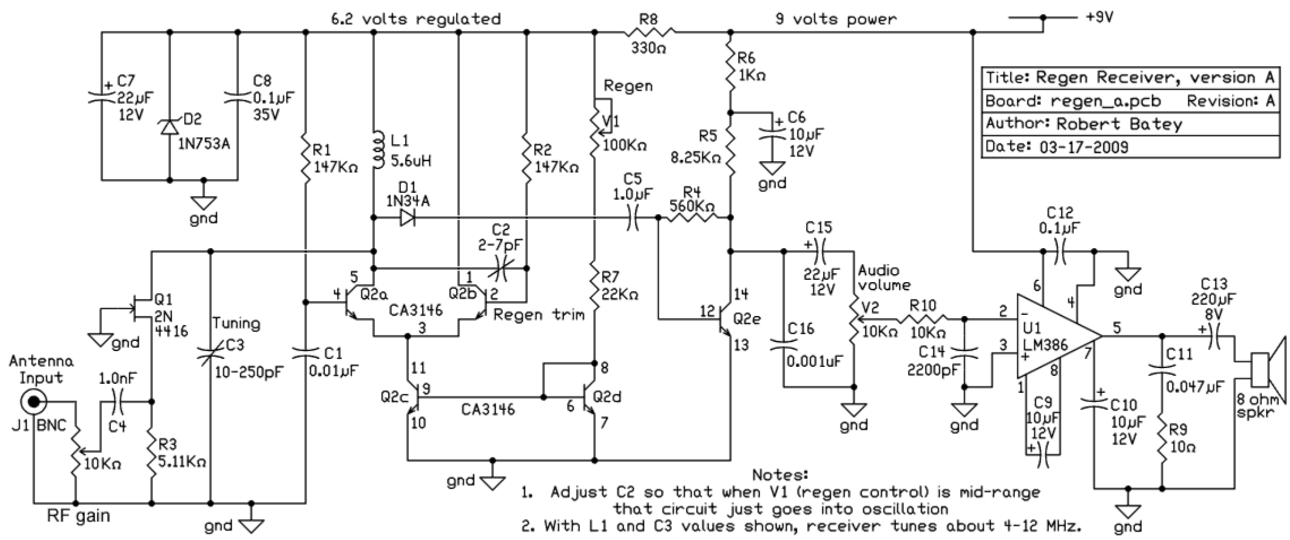


A very well behaved TRF receiver...

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

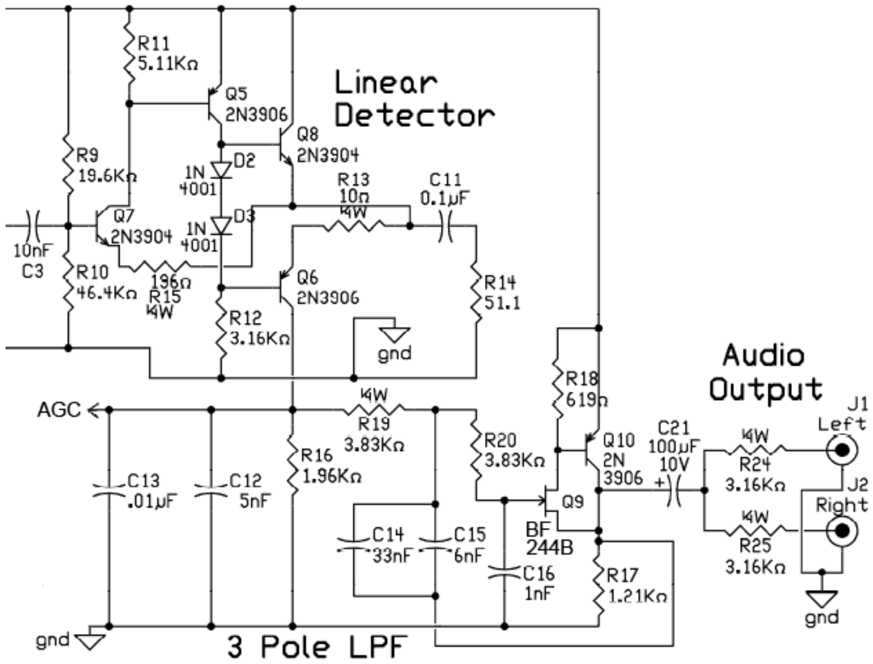
This receiver is an example of good design, as it eliminates a lot of the problems found in simpler designs yet retains easy construction and straightforward circuitry. The main problem with a simple regenerative receiver is the “hysteresis” in the regeneration control, the control having being been 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".

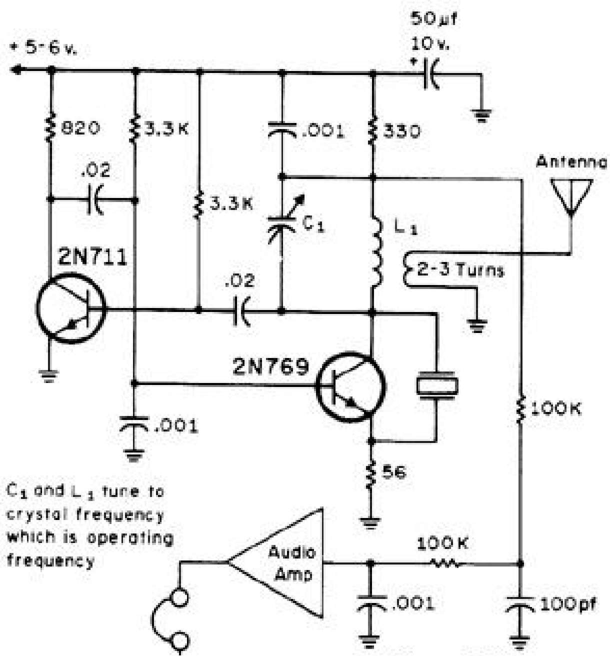
Super-Regens on HF...?

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...

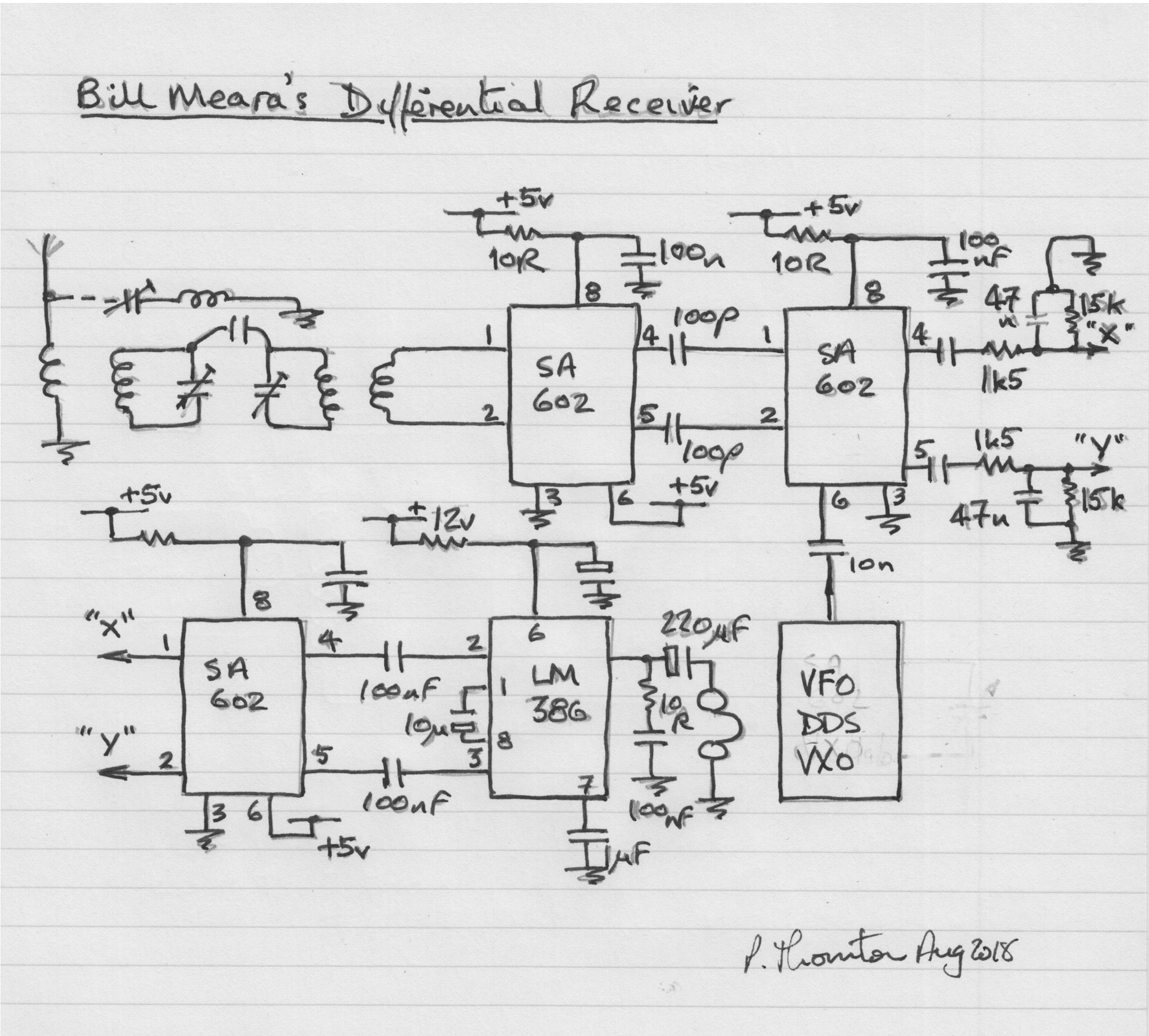
As you will have probably gathered, I’m often found wandering in the more curious corners of RF. One of the most interesting RF explorers I’ve come across is Harry Lythall, SM0VPO, who has hundreds of wonderful RF projects on his web pages. One which caught my eye when designing transistor Ft test rigs 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).

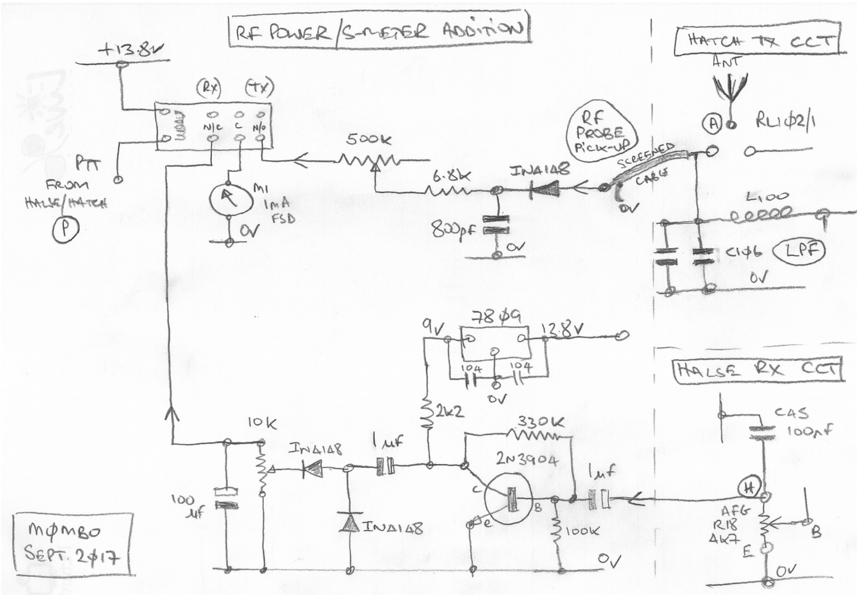
The local oscillator isn't shown – you can use any oscillator you want, so long as it can drive 300mV or more into pin 6 of the mixer. Needless to say, the local oscillator can be an SA602/612, if you like!

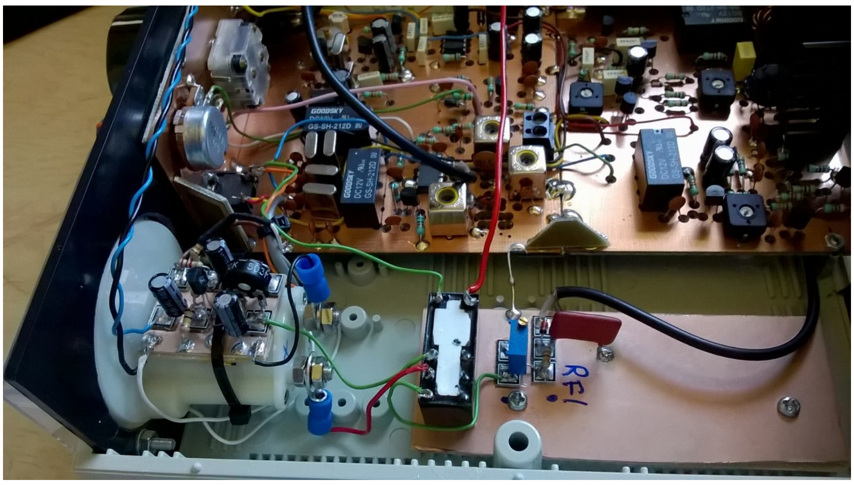


Pin 4, LM386 = ground, pin 5 = output. All supply resistors are 10R, capacitors 100nF/10µF.

Tx's

Hatch SSB transceiver mods by M0MBO....

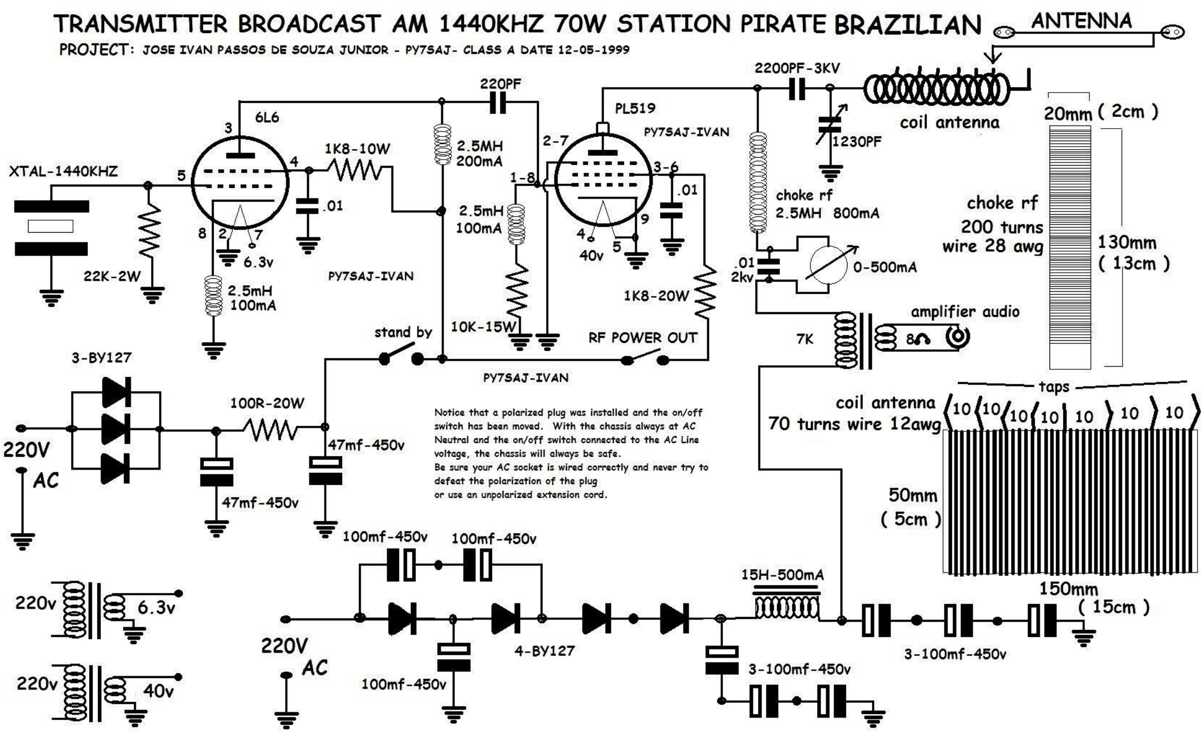




Here's a very neat mod to the "Hatch" transceiver by M0MBO to add an RF power and "S" meter circuit. You can see the neat way the space has been adapted, and the effective installation. A good job well done!

The Pink Brazilian...

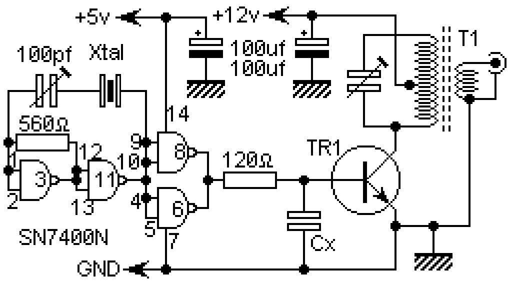
Here's a design from Ivan PY7 SAJ, which illustrates the simplicity of valve circuits (for purposes I cannot condone). I intend to modify it for CW (cathode keying) and A.M. (plug-in MOSFET cathode modulator). I'll be using a 6146B valve for the final, and high voltage transistors for the oscillator; 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...

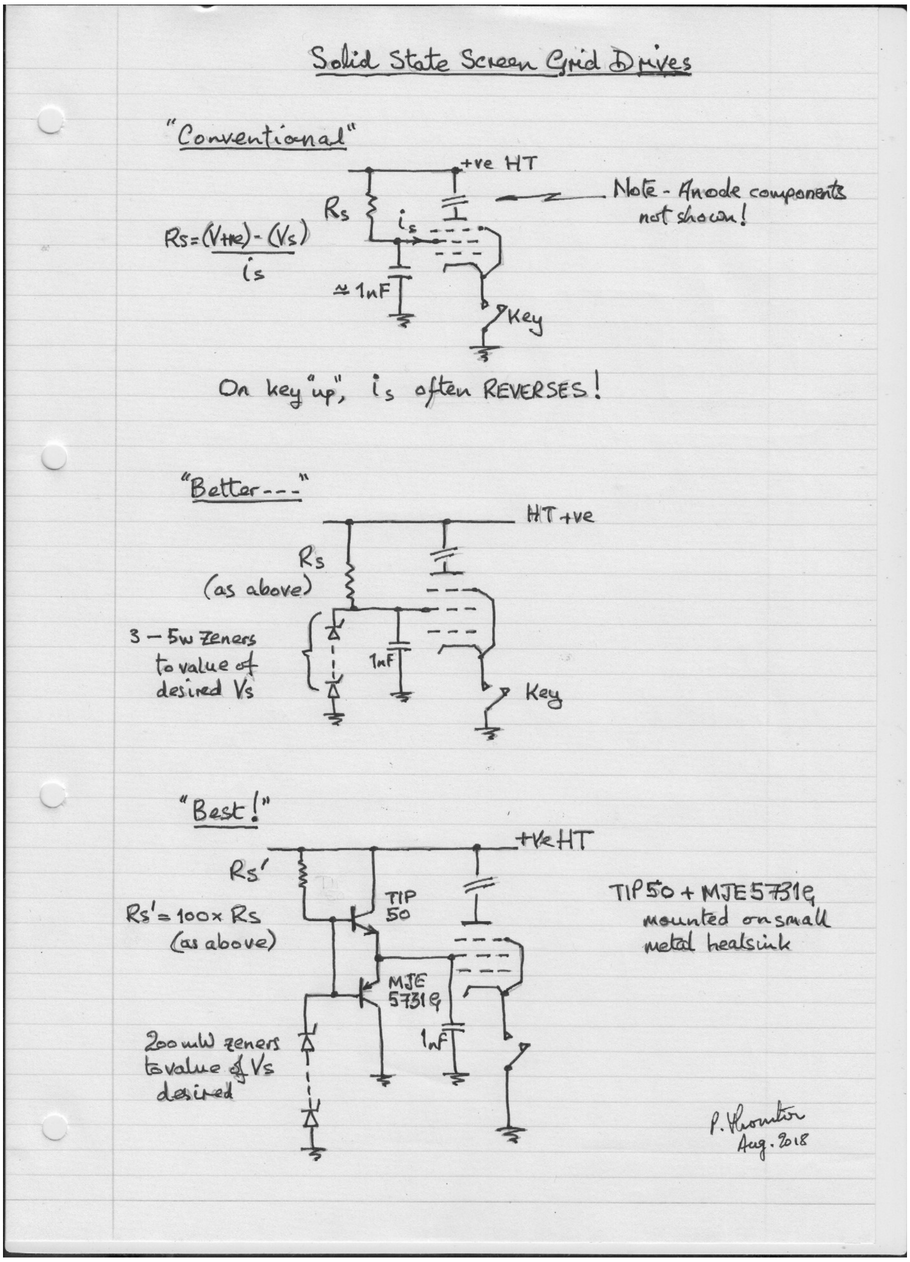
Microwave oven transformers are big chunky beasts, crying out for radio amateurs to use them in power supplies. They have an easily adaptable filament winding that can be tailored to requirements; they are tough as old boots and can be made more efficient by smacking out the magnetic shunts. These are 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.

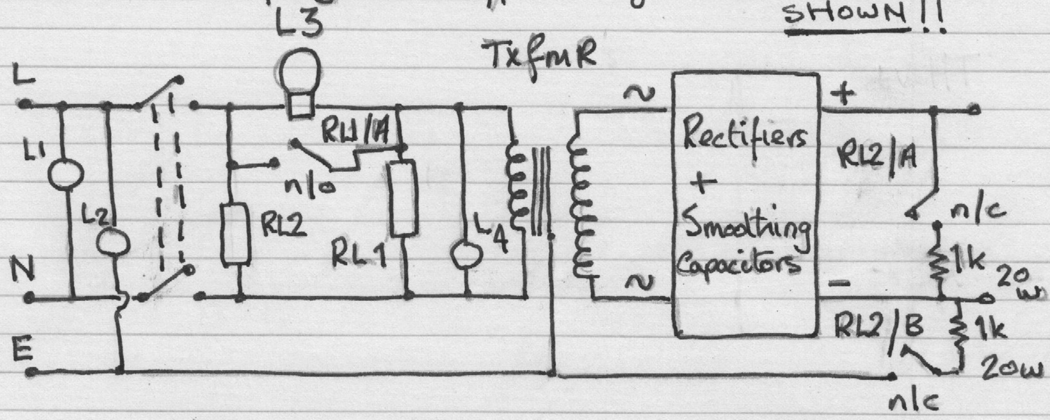
Lamps L1 and L2, rated at 240v rms for UK use, merit some explanation, as does L4.

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.

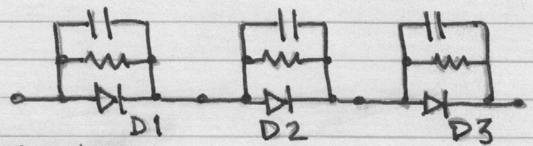
RL2 earths both sides of the smoothing capacitor’s charge immediately power is shut off: normally closed contacts short the HV output to ground via 1k power resistors, and open the instant power is applied to the primary. RL2/B isn’t always necessary if the negative output of the bridge is grounded; 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 –

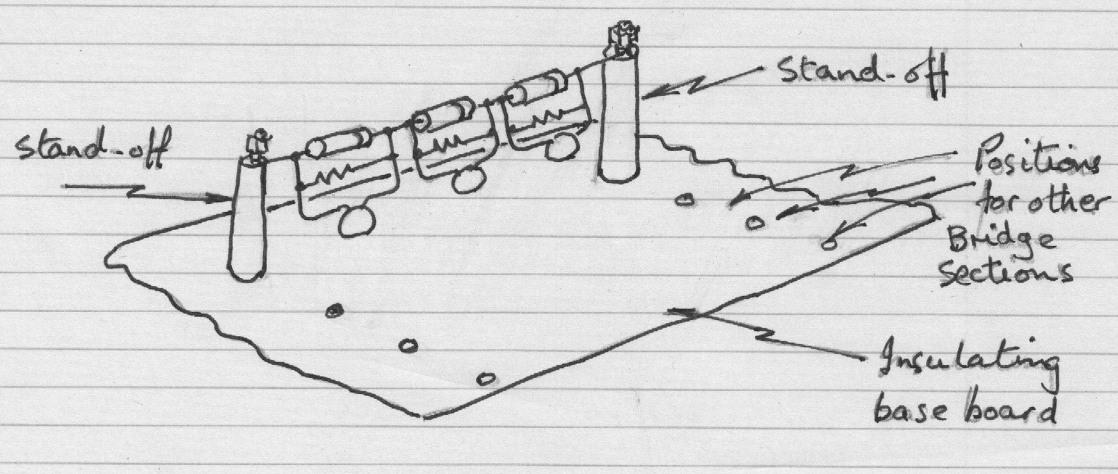


C = 10nF 1kV
R = 1MΩ 2 watt
D1-3 = 1kV, 1A
(1N4007)

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

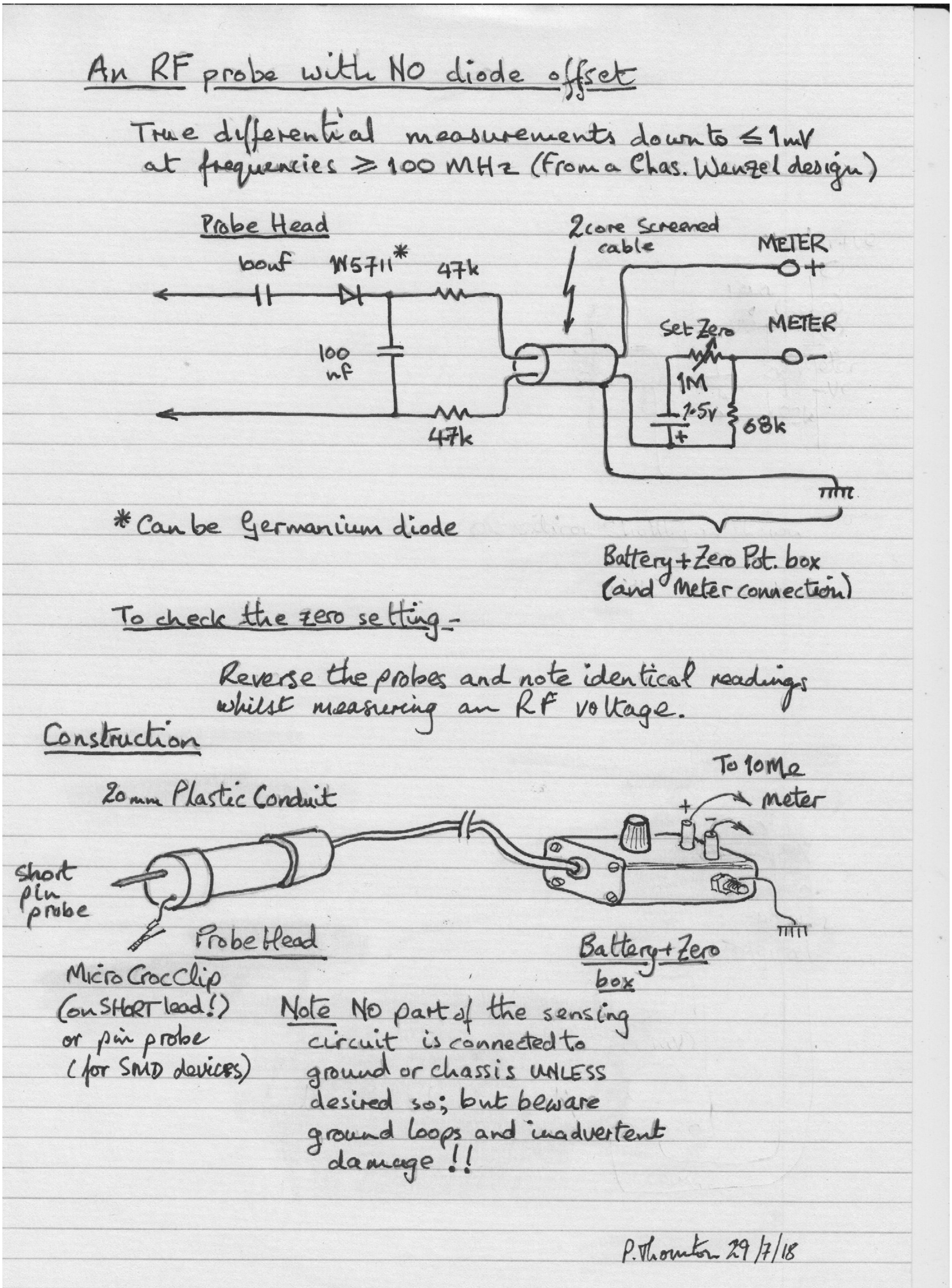


P. Thornton July 2018

Test Gear & Fault-Finding

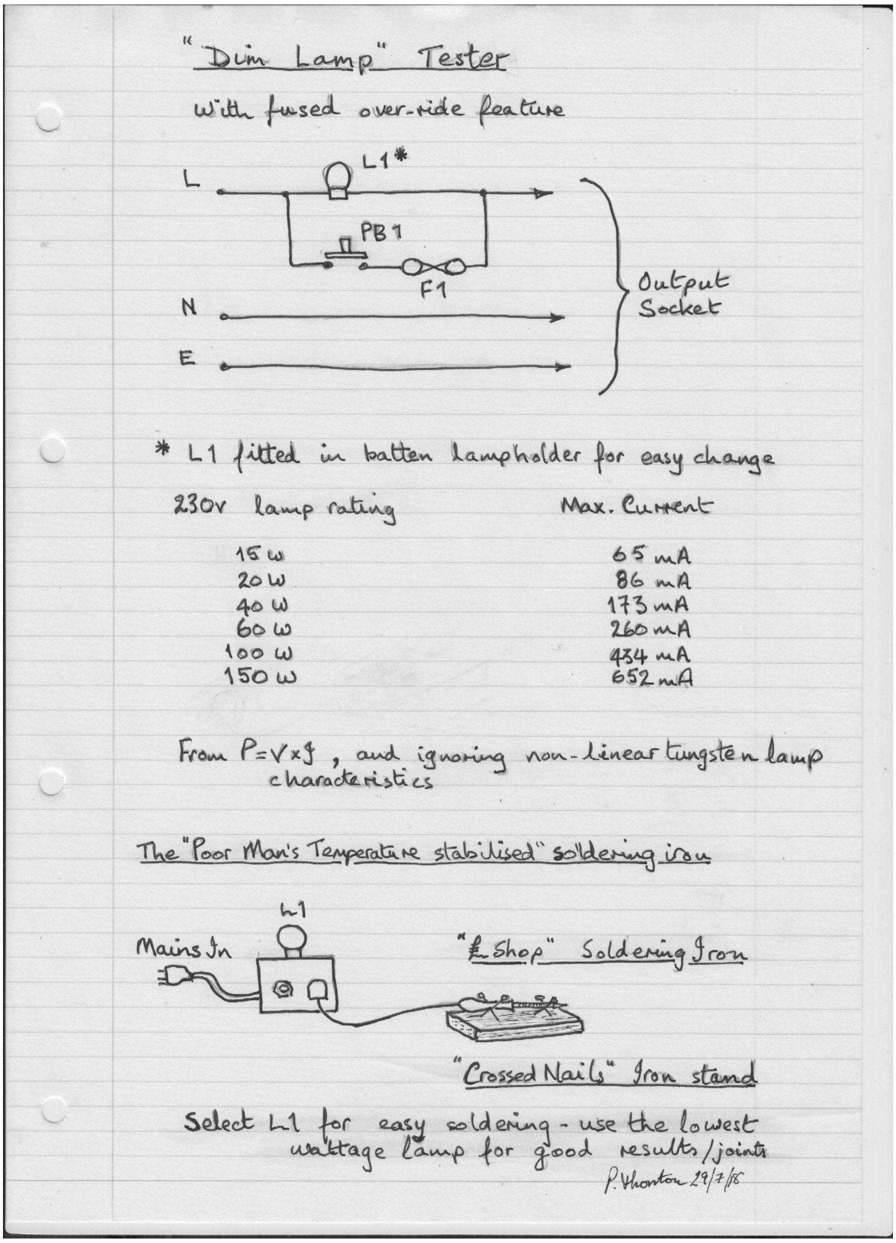
RF Probe WITHOUT diode offset voltage...?

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!



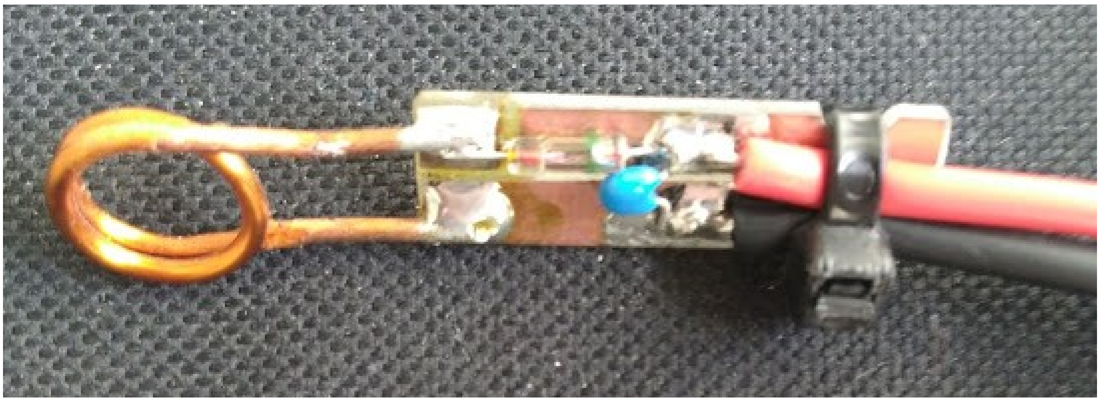
The iron's temperature is partially regulated by the non-linear resistance of the lamp filament: the lamp is working as a baretter, a non linear device used to stabilise current. Push button PB1 delivers 100% mains volts for fast warm-up: MUST momentary, NOT toggled!

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

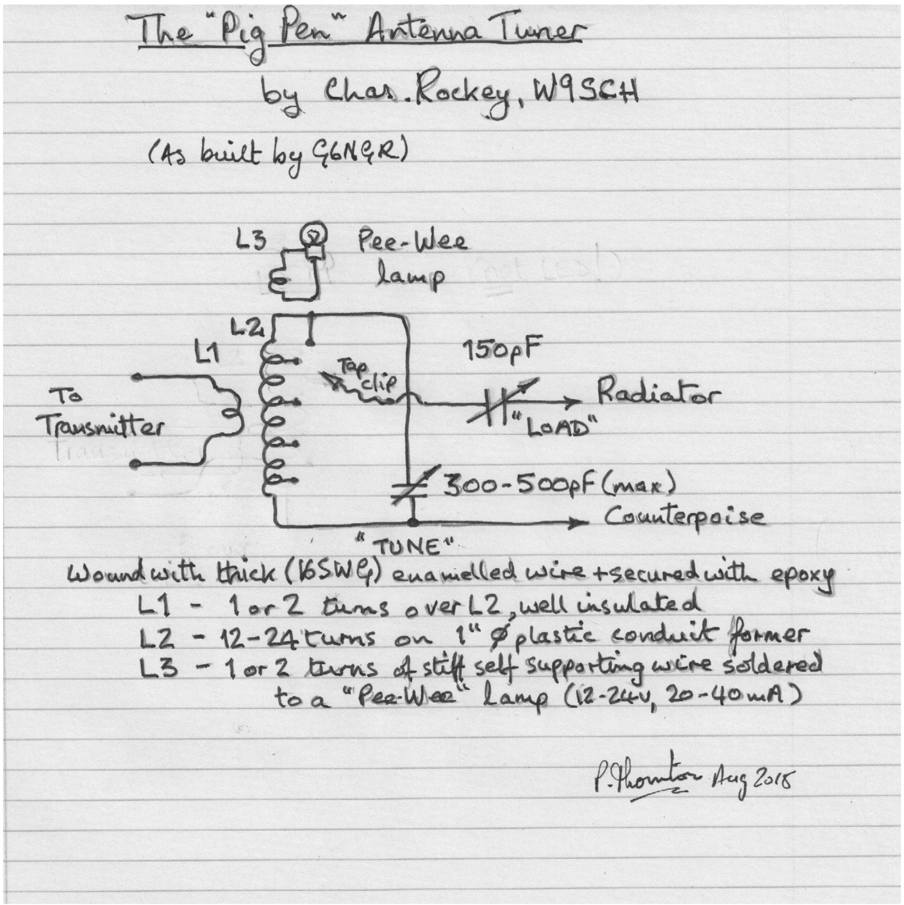
It's not always possible to have a monster antenna, or even a dipole: but if you get as much wire "up and out" for the radiating element, and a "counterpoise" of some sort, draped near or on the ground then you'll be able to get something out. Sure, a cut-to-resonance dipole, or multi-element beam, mounted 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:

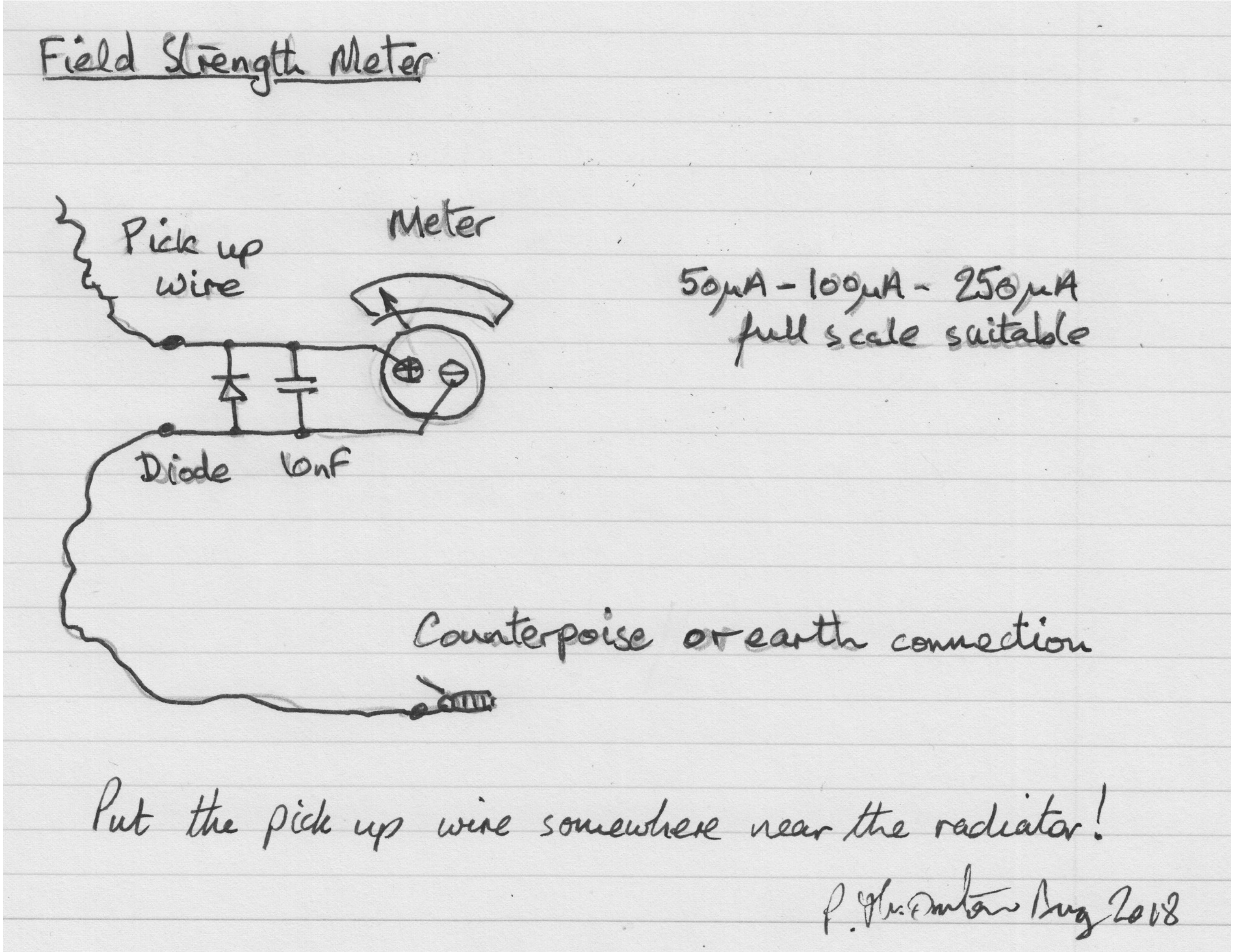
1. Connect the diode with 10nF in parallel to the analogue meter terminals – the "bar" end (cathode) to the meter +ve terminal, and the other (anode) end to the -ve terminal.
2. Connect a short (300mm?) length of wire as the "pick up" to the analogue meter +ve terminal, and a 2 metre length of wire to 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

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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
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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:

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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,
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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.

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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
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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
0.5mm²	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
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