Hot Iron # 106

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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)

<u>Complete Trasmitter & Antenna mechanical bits = £15.09</u>

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

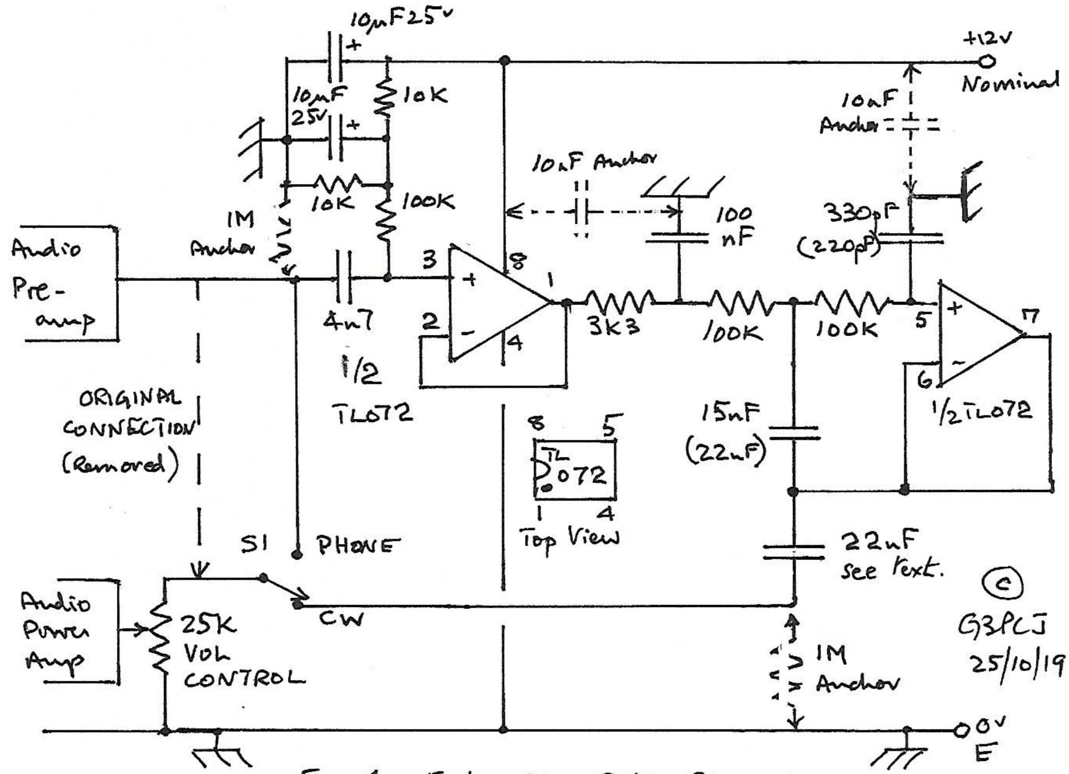


FIG 1: Extra CW Filter Circuit

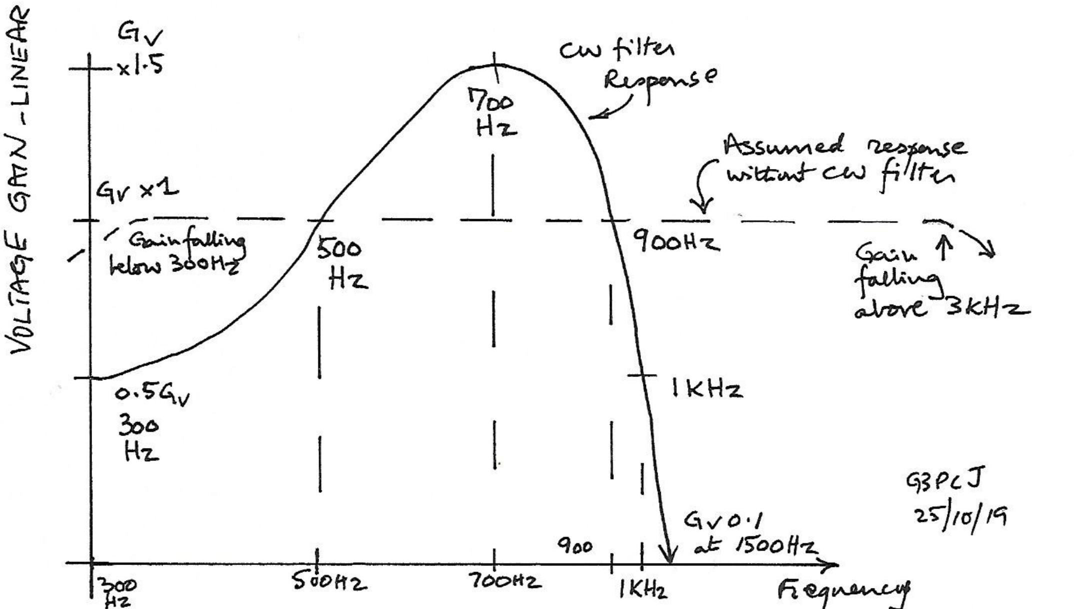
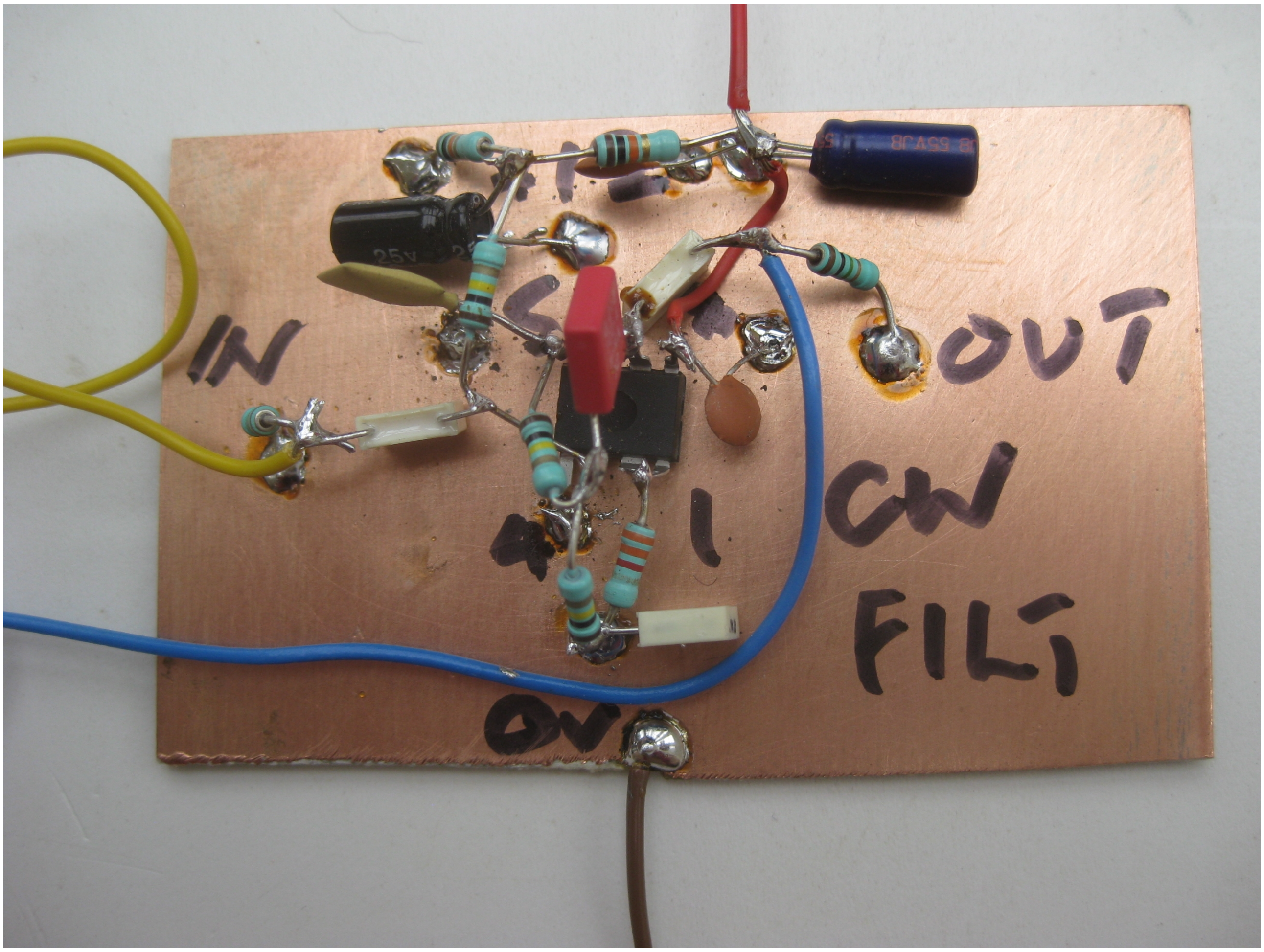


FIG 2: Filter Response



Rx

From Harry Lythall's wonderful radio web pages, another of Harry's superbly simple yet devastatingly effective designs... my notes in *italics*.

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The easiest HF receiver ever

QUICK RECEIVER

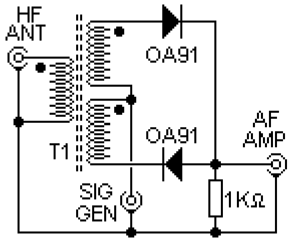
by Harry Lythall - SM0VPO

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.

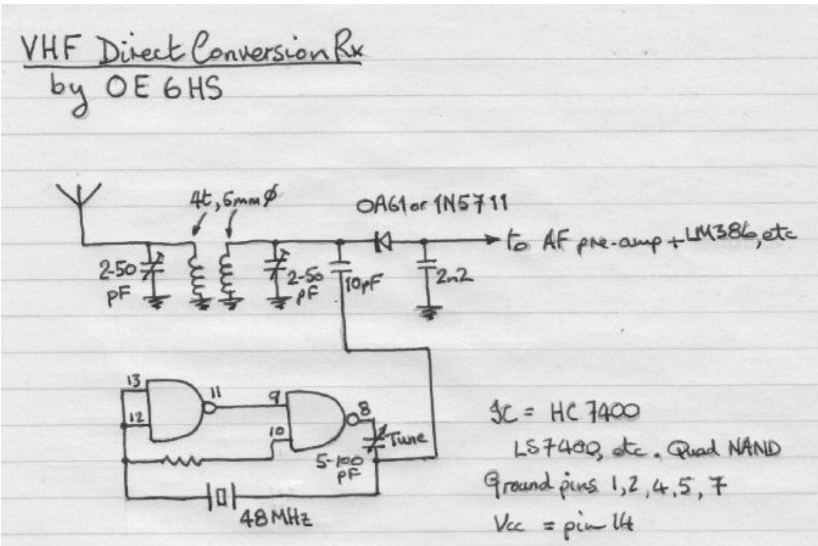


T1 is a Triflar wound component on a 1/2" ferrite ring (*a scrap one from a PC ATX power supply or similar would probably work...*). Twist together 3 lengths of thin enamelled wire and wind 17 turns on the ferrite ring. One winding is for the antenna and the other two are for the mixer. The black blobs 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.

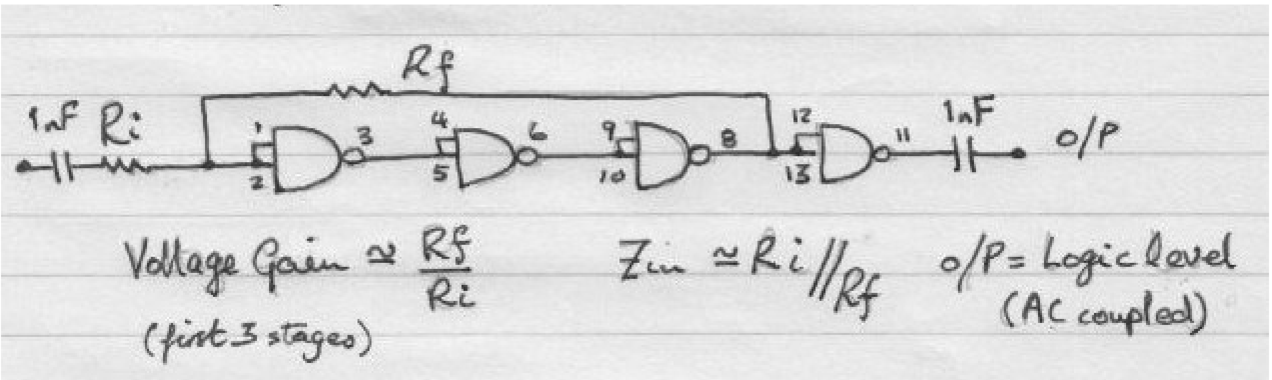
The final receiver is as stable as the RF Sig-gen and as sensitive as the AF Amplifier. A typical stereo amplifier will give out its full audio if there is one millivolt at the PHONO input. You can hear signals that are less than 1% of this (10uV).

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.

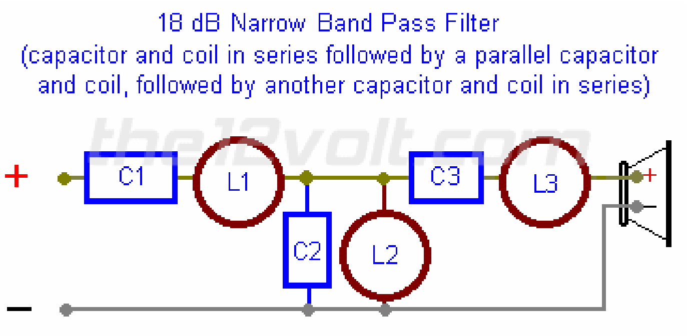
SSB converted to CW transmitter

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.

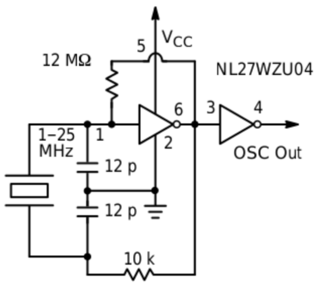


Figure 2. Complete Crystal Oscillator Circuit

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.

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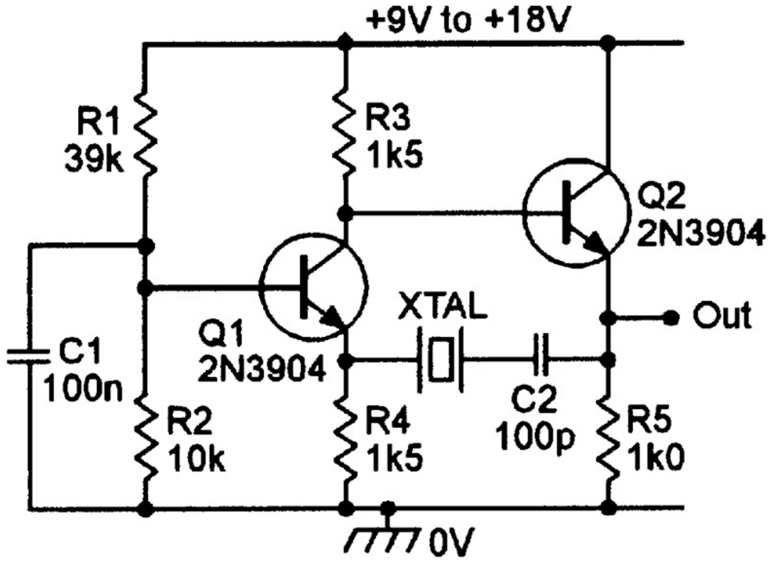
The Peltz, Zachary, Franklin and Butler Oscillators

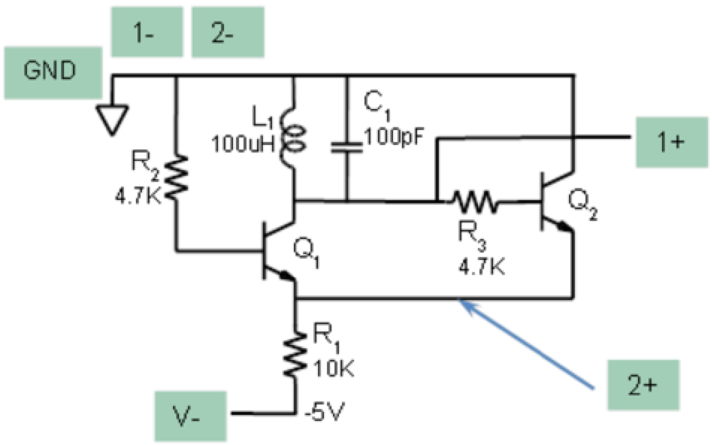
In looking for oscillators for test gear projects, I found some very useful oscillator circuits not in general circulation which have many advantages compared to the “standard” circuits usually specified. I didn’t need the complexity of a DDS / PLL set-up, but a reasonably stable oscillator that could 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:

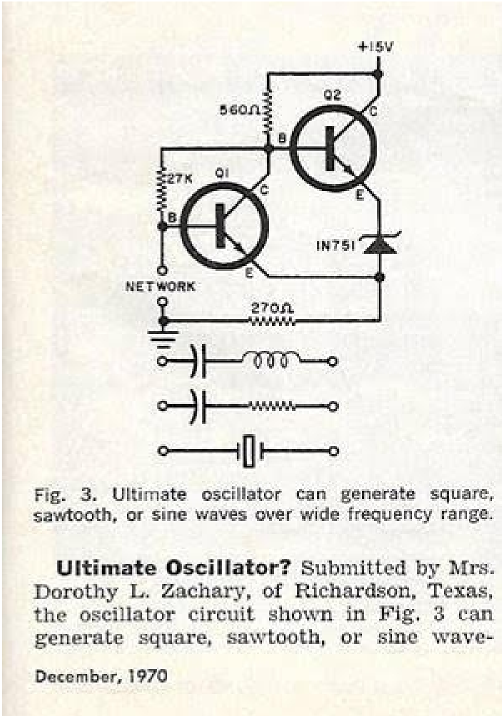


Fig. 3. Ultimate oscillator can generate square, sawtooth, or sine waves over wide frequency range.

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

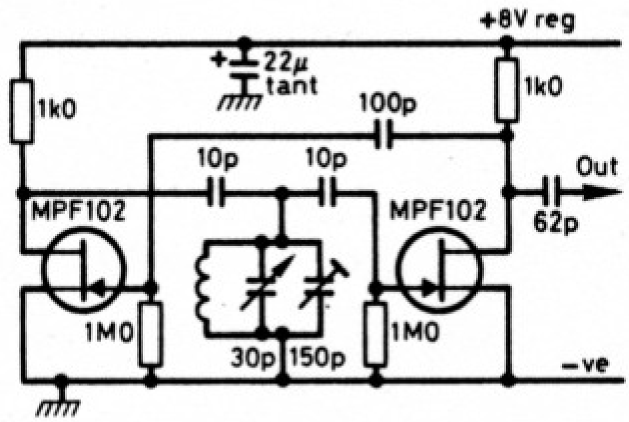
A close relative of the Peltz; but simpler: and illustrates the useful different outputs available with alternative resonator networks. I don't know where the original image of December 1970 is from; but give my thanks to Mrs. Zachary and her erstwhile publisher!

From his excellent page: https://www.robkalmeijer.nl/techniek/electronica/radiotechniek/hambladen/radcom/1990/02/page32/index.html, we find...

Franklyn:

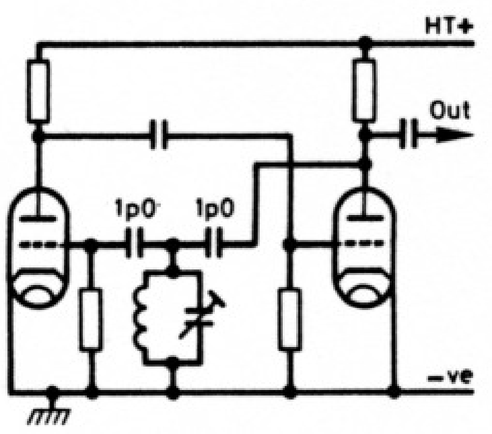
A close relative of the Eccles-Jordan astable multivibrator - note the tiny value (10pF) coupling capacitors - after a short warm-up period, this oscillator can stay zero beat with a crystal oscillator for hours. Makes a superb VFO (in non DDS / PLL terms) using decent components in the tank circuit, and kept well away from heat in the thermionic version.

jfet devices:



Twin triode version:

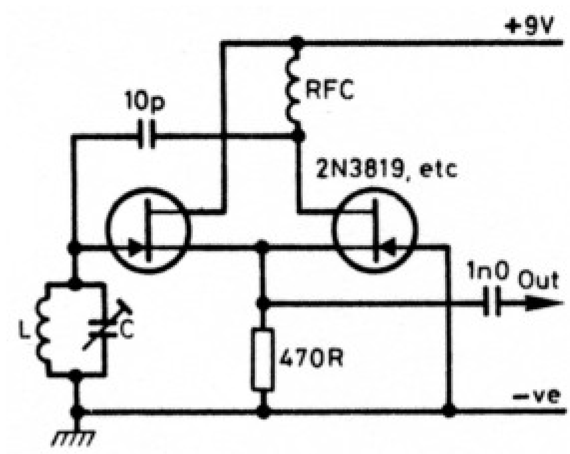
No mistaking the ultra-low coupling capacitors in this design!



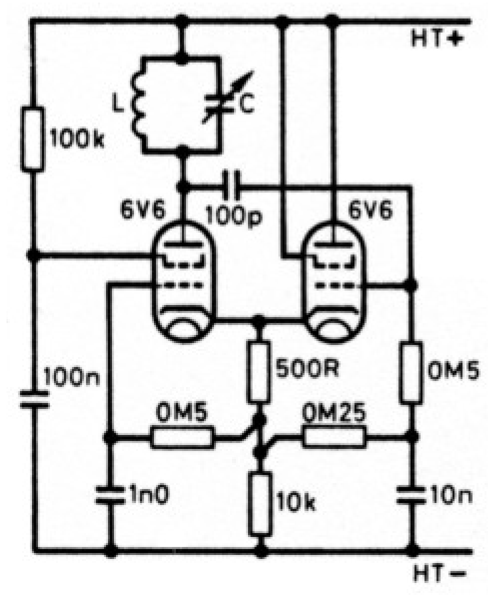
I'm tempted to try a double triode Franklyn with the L/C's isolated in a small die cast box, mounted underside the chassis to avoid the valve heat, to test the warm-up time and long term stability.

Butler:

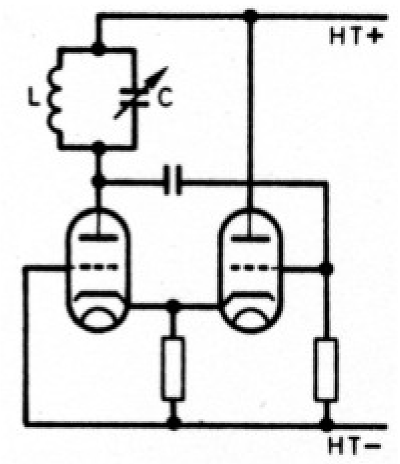
jfet devices:



Valves:



This is the generic circuit, use twin triodes:



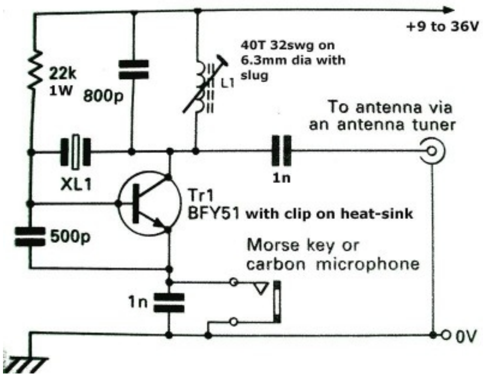
The differential “long tailed pair” topography is very obvious in the Butler design; and as an added advantage, yields superb overtone oscillators for VHF / UHF jobs - replace the anode to grid coupling capacitor with a crystal and set the tuned circuit to the overtone required.

9th. overtones are possible with particularly lively crystals, but can be prone to mode skipping and spurious oscillation unrelated to the original crystal cut.

Tx

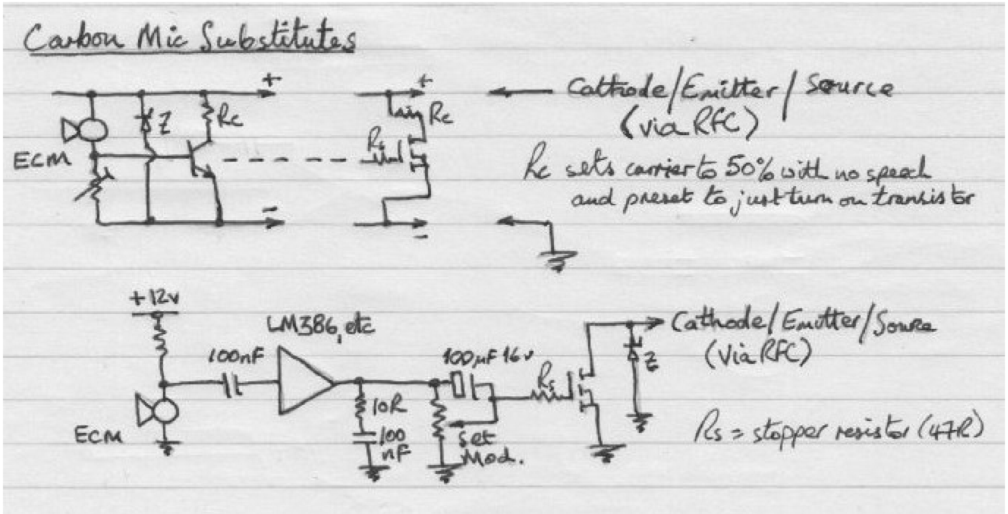
I’ve always had a fascination for single valve or transistor transmitters: add a simple low pass filter and you’ve a neat low power (and not-so-low-power) CW transmitter. With me being an A.M. enthusiast, I look for designs that I can easily modulate: the Michigan Mighty Mite is a champion little transmitter 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.

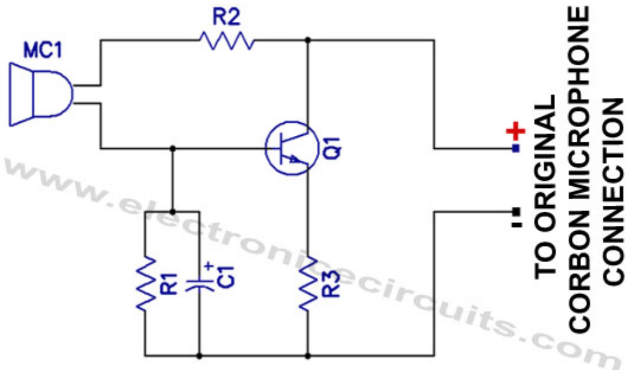
First, a single transistor transmitter that can certainly do the business: feel free to substitute other transistors or jig up a bias scheme for a power mosfet version.



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.

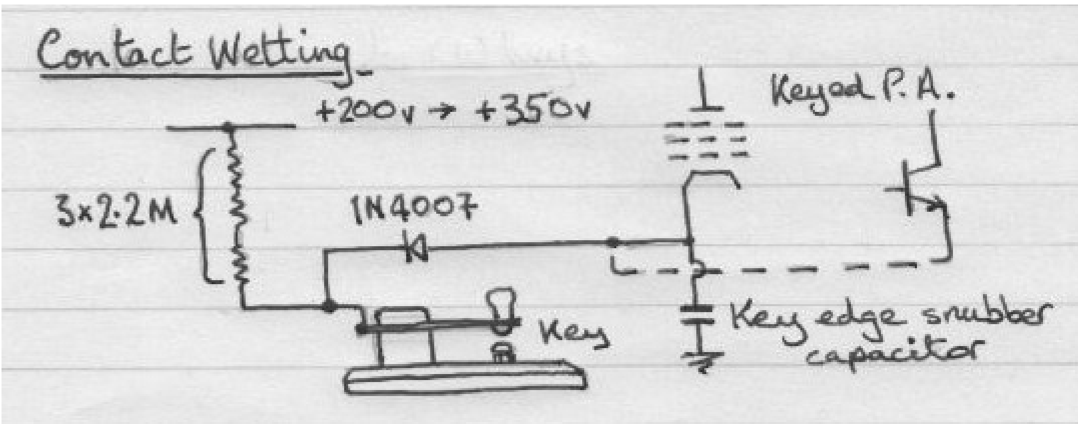
One nifty trick I learned as an apprentice is that decent ½” or ¾” (13mm / 20mm) hardwood ply can be tapped to take a thread - and thus the bottom “fixed” contact is a brass dome or cheese head bolt, screwed into a tapped hole in the plywood base; fitted with a (gap adjusting) nut and washer, a solder 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

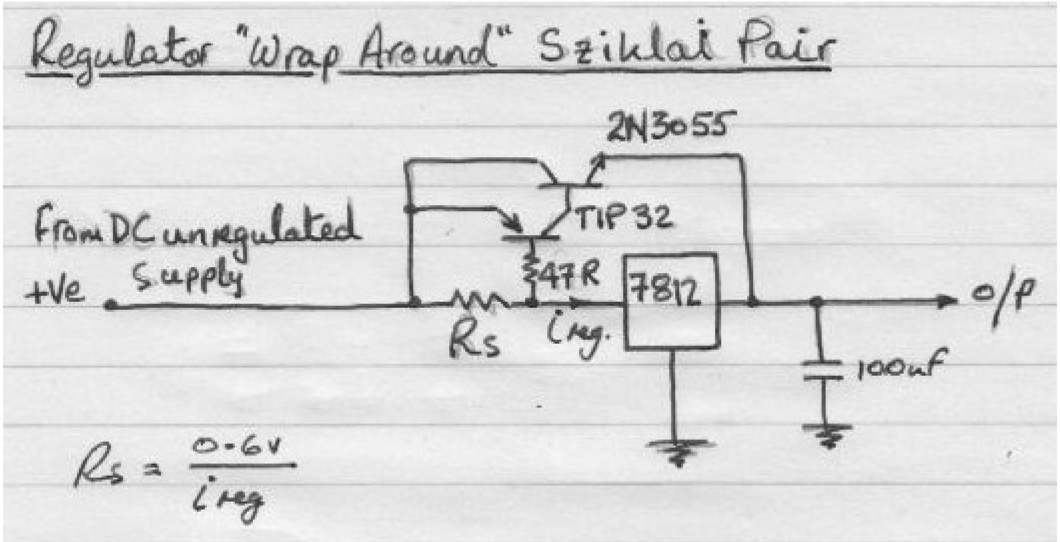
I maintained silicon epitaxy reactors for a living a few years ago, which used high power (500kW) RF to heat a process chamber to 1270°C - with a hydrogen atmosphere inside. It was an “interesting” few minutes after servicing the process chamber when the RF was applied - any air leaks and the whole thing 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.

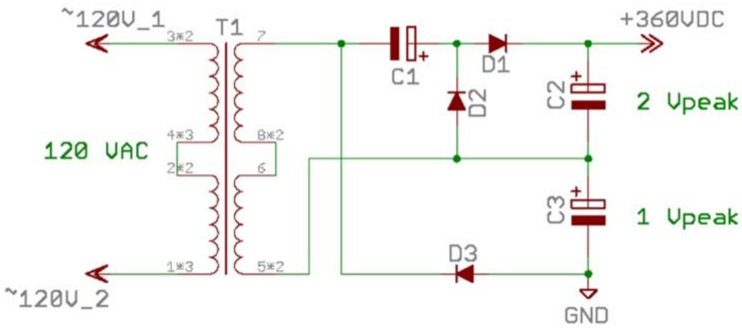
This circuit, whilst similar to the conventional PNP power "wrap-around" regulator booster, allows far more common NPN power devices to do the job. The Sziklai pair is named after the Czech engineer who first described it, and offers the advantage of having an overall volt drop in saturation of one Vbe, 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!).

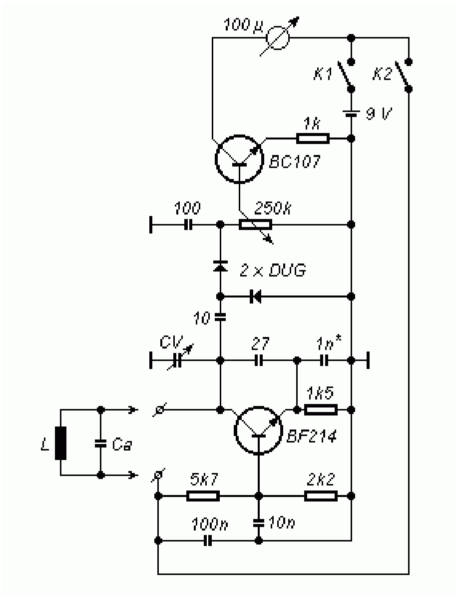
The basic principle of Grid Dip Oscillator is to induce RF into a resonant circuit, be this a tank L / C circuit, antenna, ½ λ or ¼ λ section of co-ax or anything else that might be reasonably suspected of having resonant properties, and noting the level of oscillation in the instrument. Using a valve / 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").

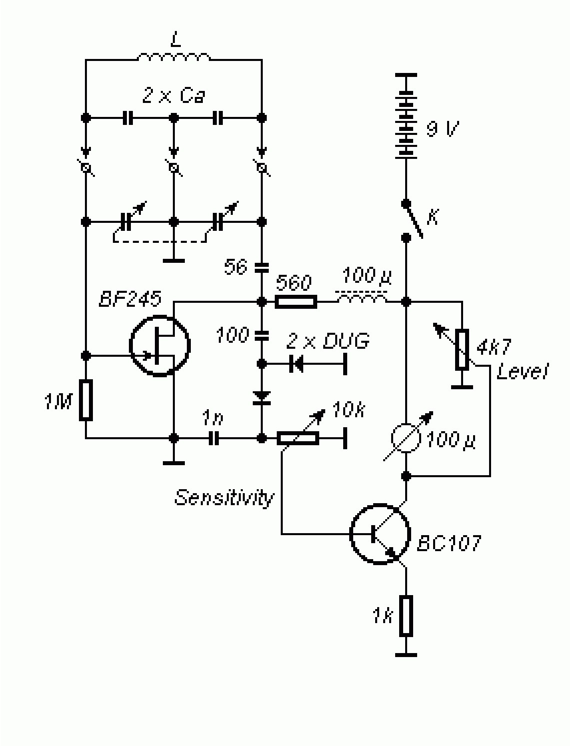
Using Bipolars:



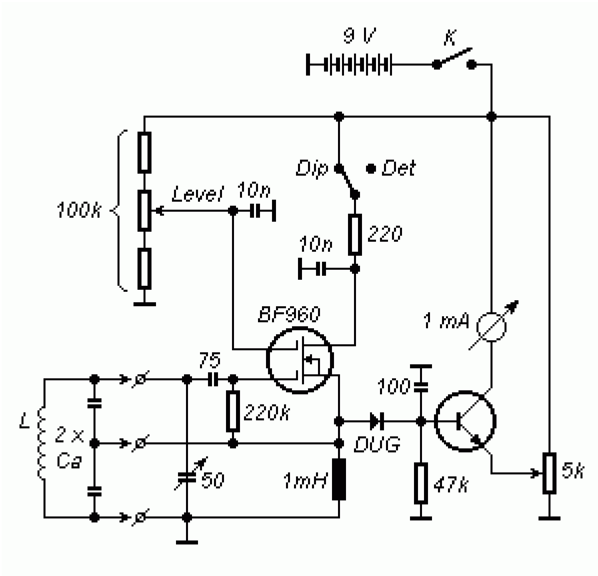
A BF199 should work well in this circuit.

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:

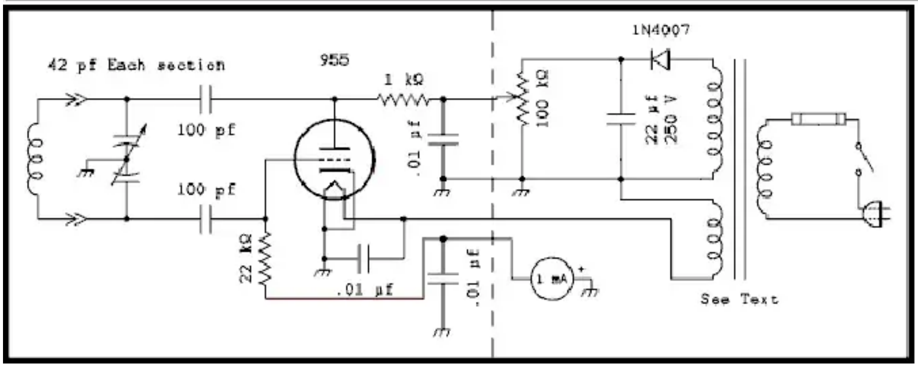


Diagram courtesy https://www.scribd.com/document/268728159/Tube-Grid-Dip-Meter

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.

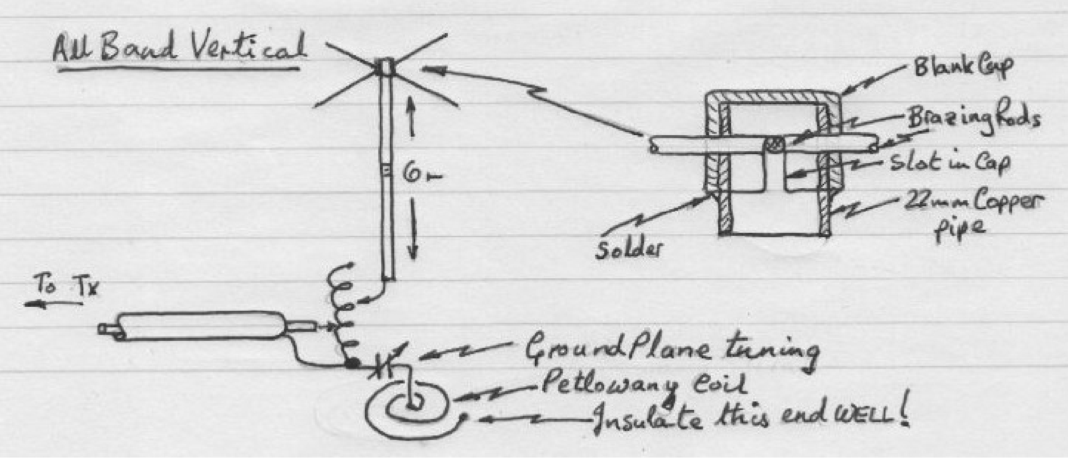
There are ways of helping the ground plane too: you can resonate the ground plane to simulate a ¼ λ set of wires for any frequency - you use series tuning to resonate the entire ground plane at the frequency you want to run, and then you don't have to bother cutting and trimming ground plane wires, laying 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 - - - -"

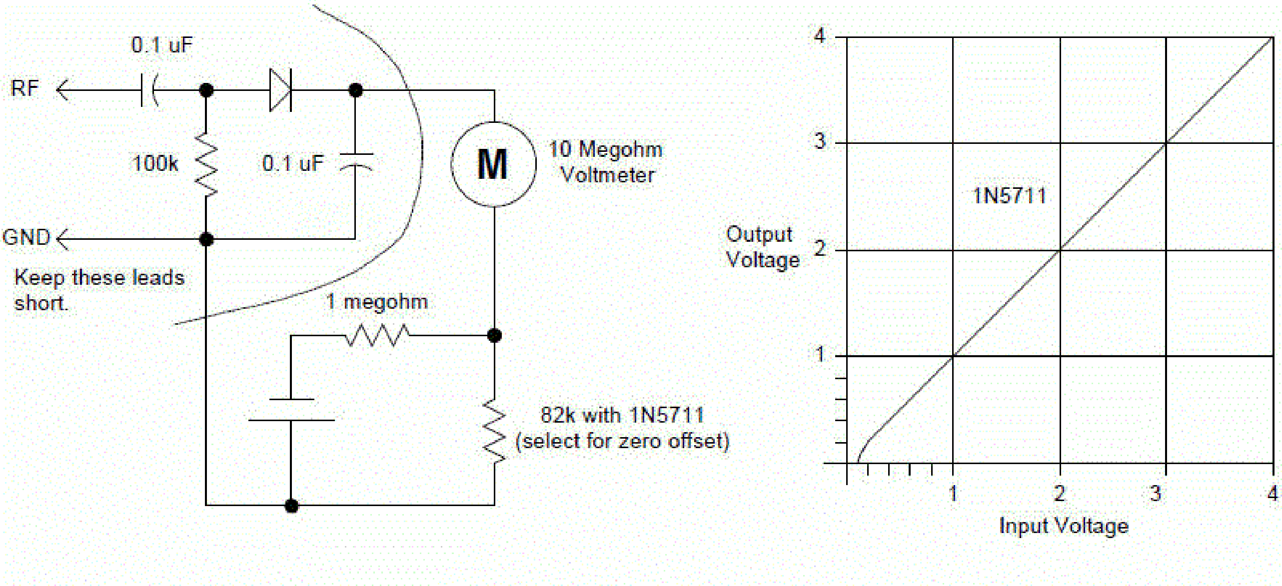


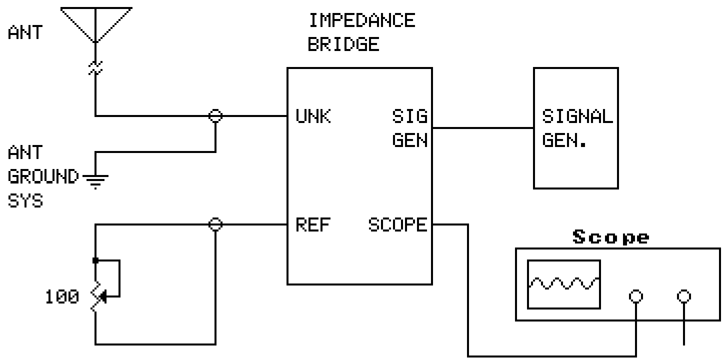
Figure 2: Series detector with offset correction. The 82k resistor may be varied for best results with different diode types.

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 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.

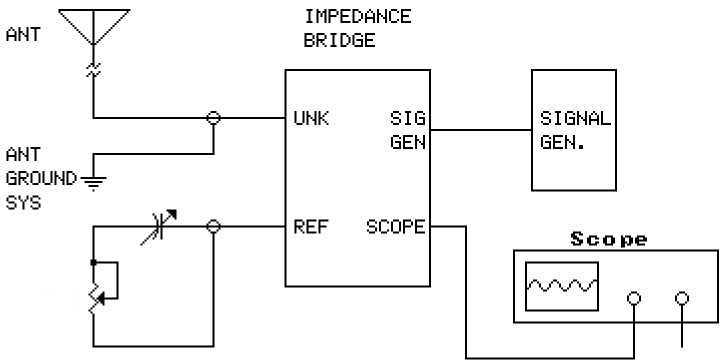
"Flatline" refers to a complete nulling of the test signal's *fundamental* frequency. Residual harmonic content from the signal generator may be evident in the scope trace after nulling, depending on how clean the generator signal is. Also, interfering signals from local transmitters may be present.

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.

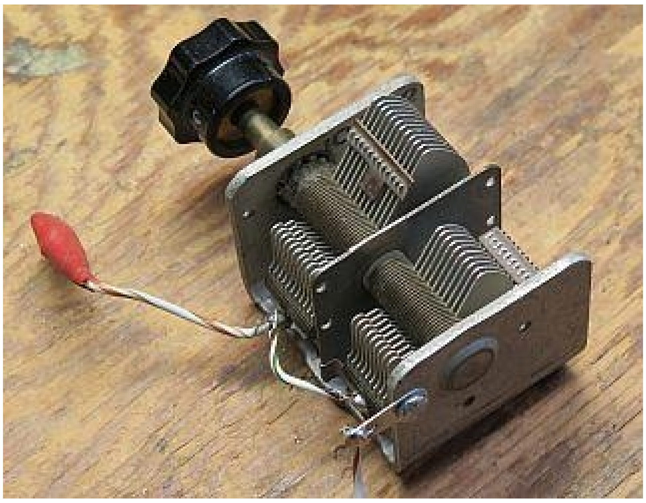
Second Pass - find the reactive component (capacitive)

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:

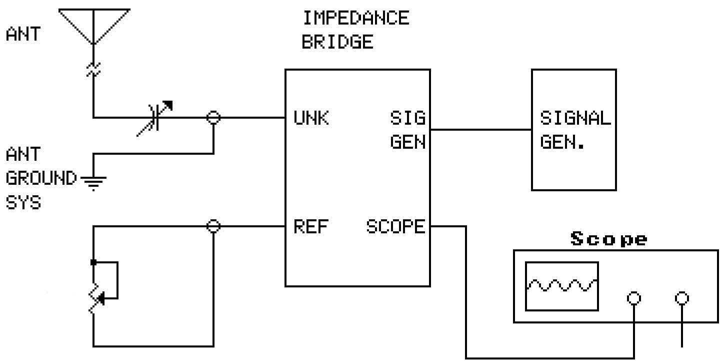
X_L is the inductive reactance in ohms, [L= X_L / 2πF in Henries]
F is the operating frequency in Hz, and
C is the measured capacitance in farads.

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):



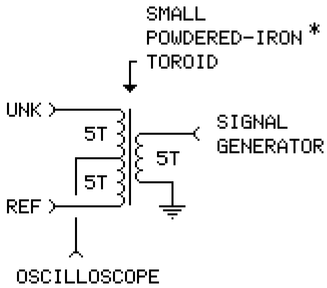
•Adjust the test capacitor to obtain the deepest null. You may have to slightly readjust the potentiometer.
•If you obtain a flatline, the antenna impedance is inductive. Measure the potentiometer to obtain the resistive component. Measure the test capacitor to obtain the capacitance [*this is the pF's 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

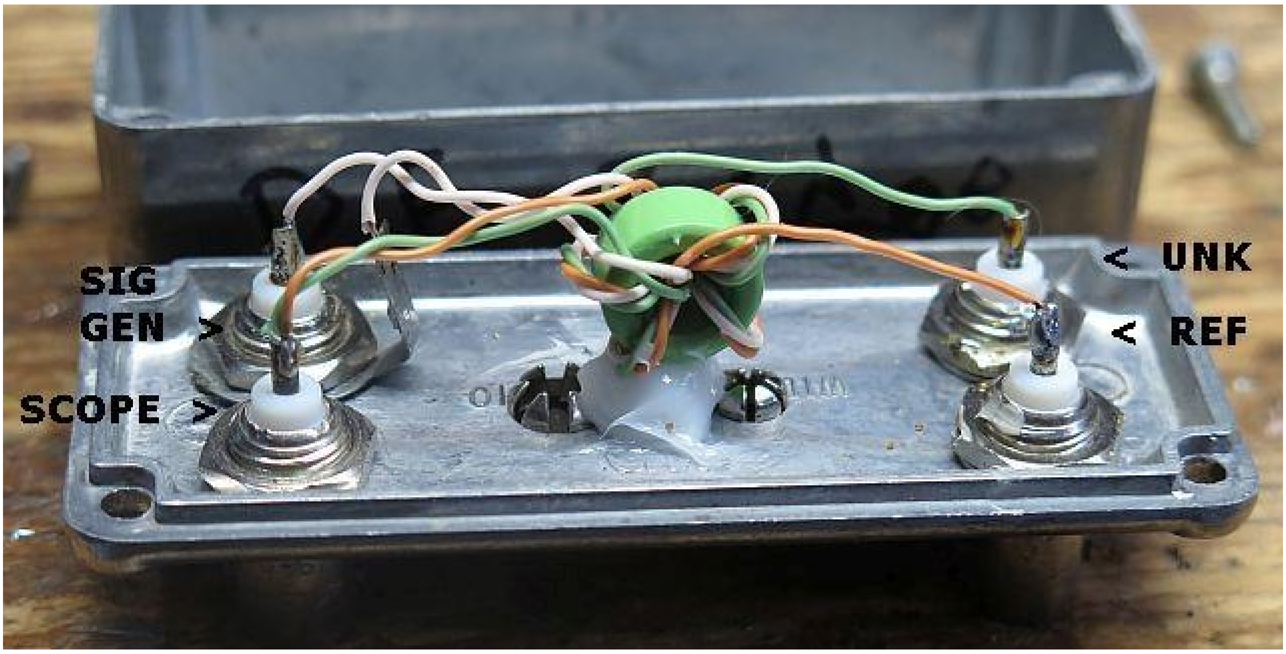
Building an Impedance Bridge

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.

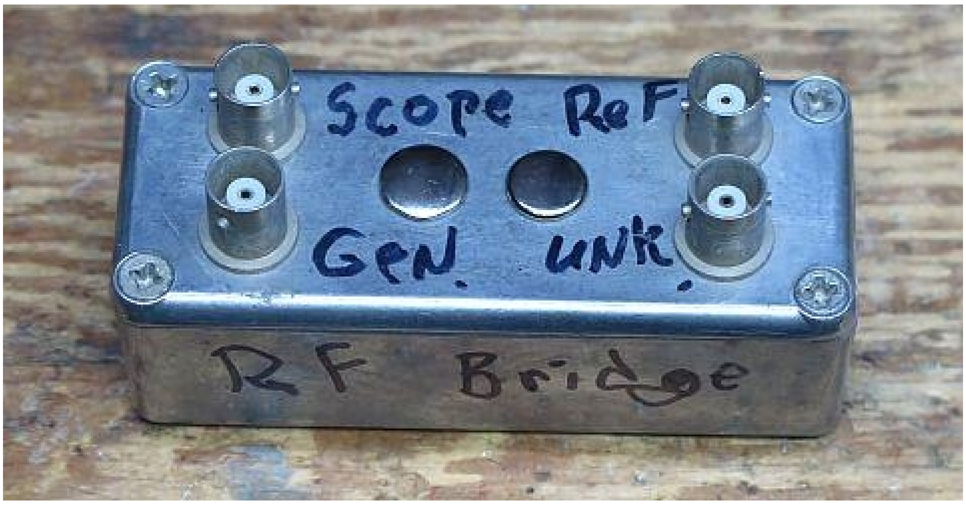
Bridge Inside



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



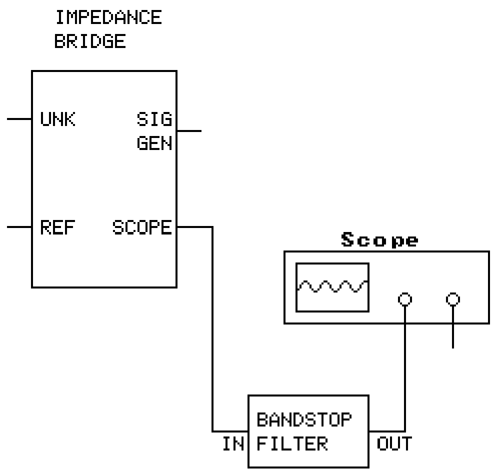
Equipment grounds are interconnected via the common case.

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.

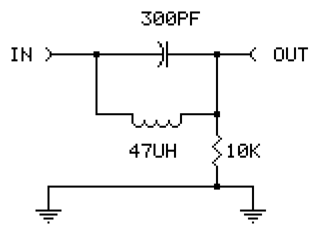
Optional Notch (Bandstop) Filter

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

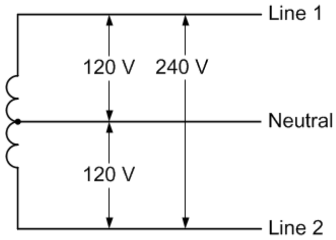
3615 Khz	Saturday AM net 08:30 – 10:30
3615 Khz	Wednesday USB net for military equipment 20:00 – 21:00
3615 Khz	Friday LSB net 19:30 – 20:30
3615 Khz	Regular informal net from around 07:30 - 08:30
3577 Khz	Regular Sunday CW net 09:00
5317 Khz	Regular AM QSO’s, usually late afternoon
7073 Khz	Wednesday 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

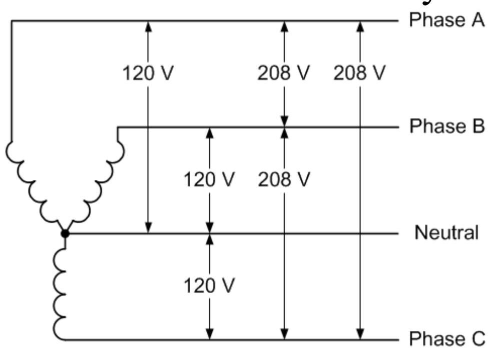
In the following drawings, the coil symbols represent the secondary winding of a utility service transformer or other step down transformer. Electrical code regulations in most jurisdictions require that the neutral conductor be bonded (connected) to the earth safety ground at the electrical service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

Single Phase Three Wire



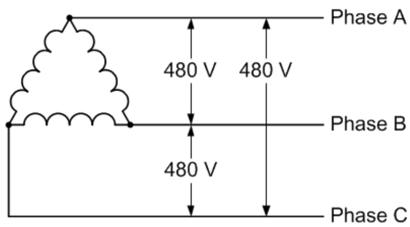
Also known as an Edison system, split-phase or centre-tapped neutral. This is the most common residential service in North America. Line 1 to neutral and Line 2 to neutral are used to power 120 volt lighting and plug loads. Line 1 to Line 2 is used to power 240 volt single phase loads such as a water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

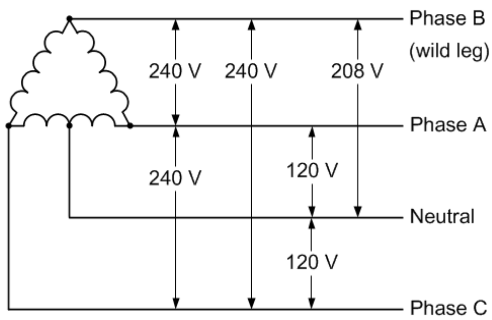
Three Phase Three Wire Delta



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.

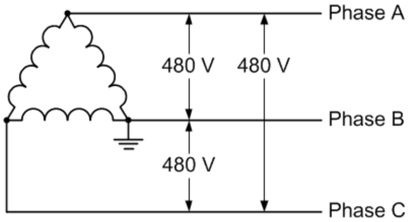
Uncommon Electrical Services

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.