Hot Iron 103

Feb. / Mar. 2019

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CQ-CQ-CQ

SSB, AM and the end of “Amateur” Radio?

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

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

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

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

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

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

CW and my mobile phone

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

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

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

Noisy Neighbours?

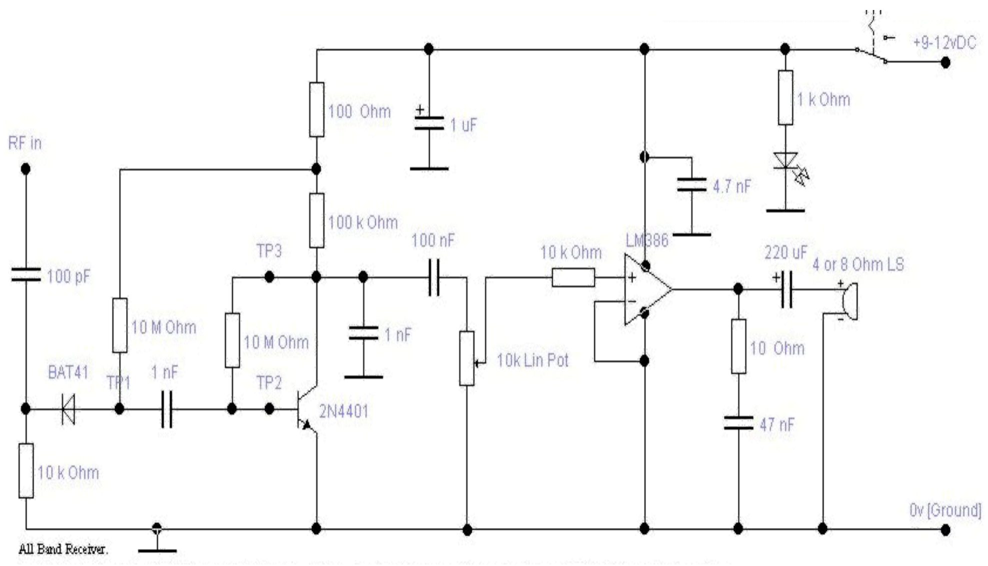
Reports of constant S8 / 9 background in urban areas are to be seen in various Amateur Radio orientated publications: this is a problem which causes blocking, obliterating and noise jamming of amateur signals. OFCOM take a stand well askance from amateurs, after all, we’re only “playing” radio seems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

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

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

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

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



Tim’s Topics

Dipole Dilemma!

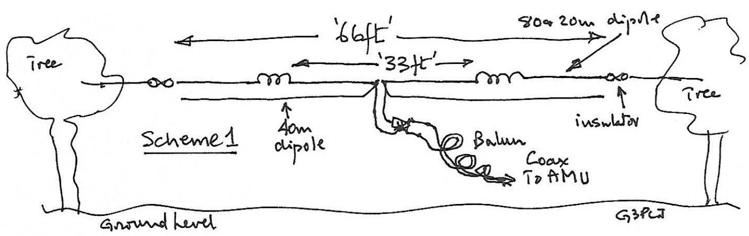
Many of you will know that we are a farming family, and have been in this part of Somerset for a long time! (See www.uptonbridgefarm.com for some amusement!) Our son is now doing most of the physical work so he needs to be living in the old Victorian farmhouse in the midst of all the farming activity!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

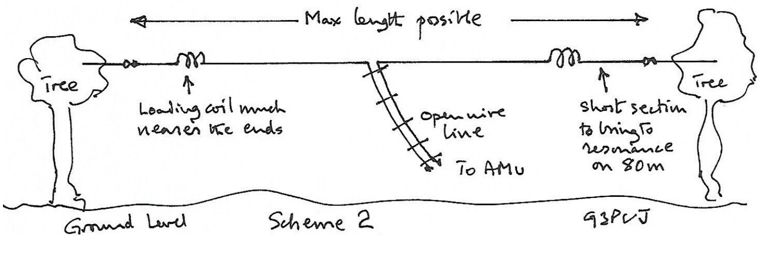
I want to be able to use at least 20, 40 and 80m; and there are two smallish trees about 70 ft (22m) apart some 30 ft (10m) from the house. Having nearly always used a balanced antenna system for serious contacts, I would much prefer that again. The gap between the trees might allow a quarterwave on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

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

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

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





Audio Topics

Microphones - common misconceptions & design notes

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

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

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

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

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

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

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

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

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

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

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

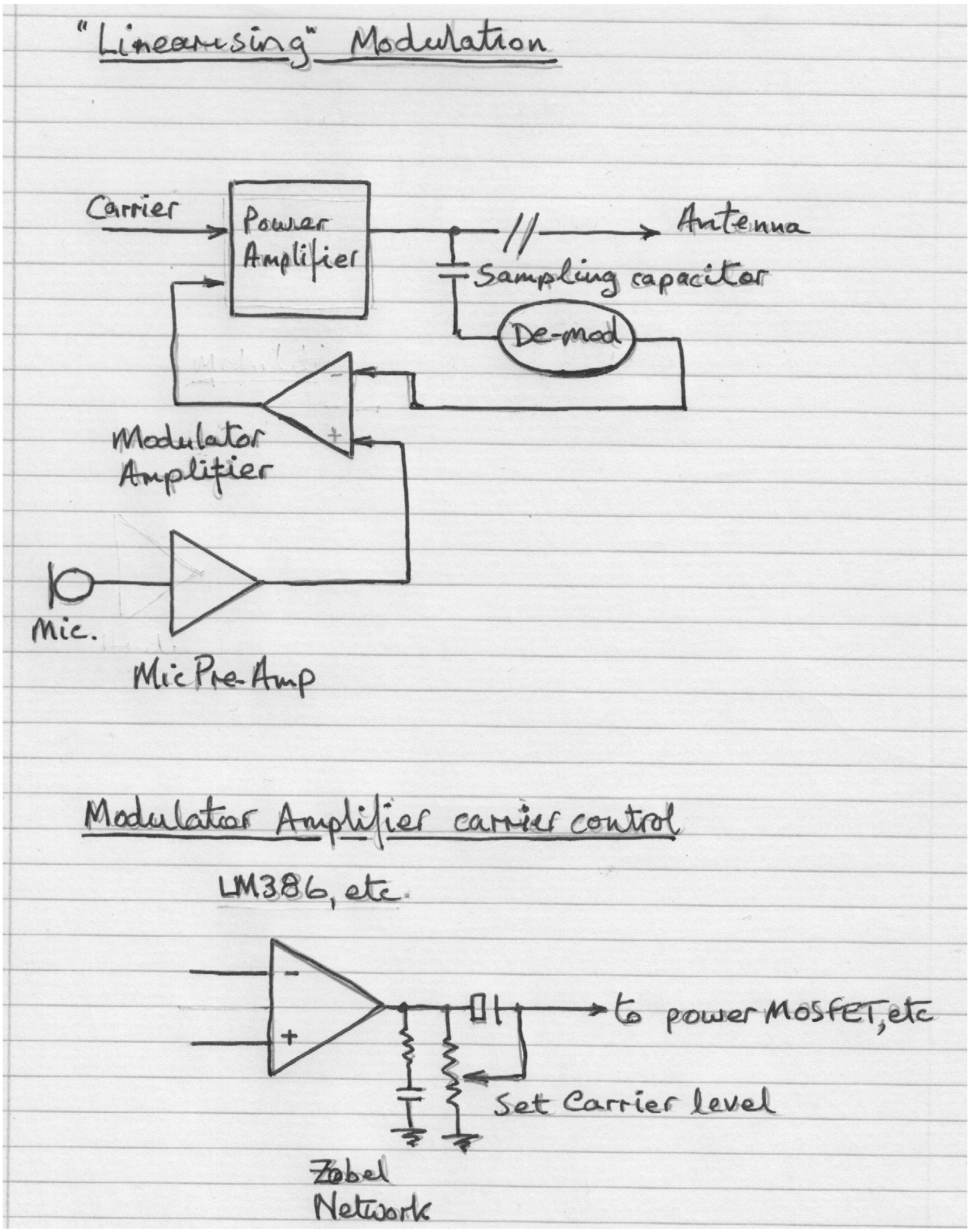
To use a low impedance broadcast type microphone requires a step up transformer. Typically these have an output impedance of somewhere around 50Kohm when connected to a 200 ohm source."

My grateful thanks to Richard Knoppow for these notes.

RF demodulation feedback

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

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

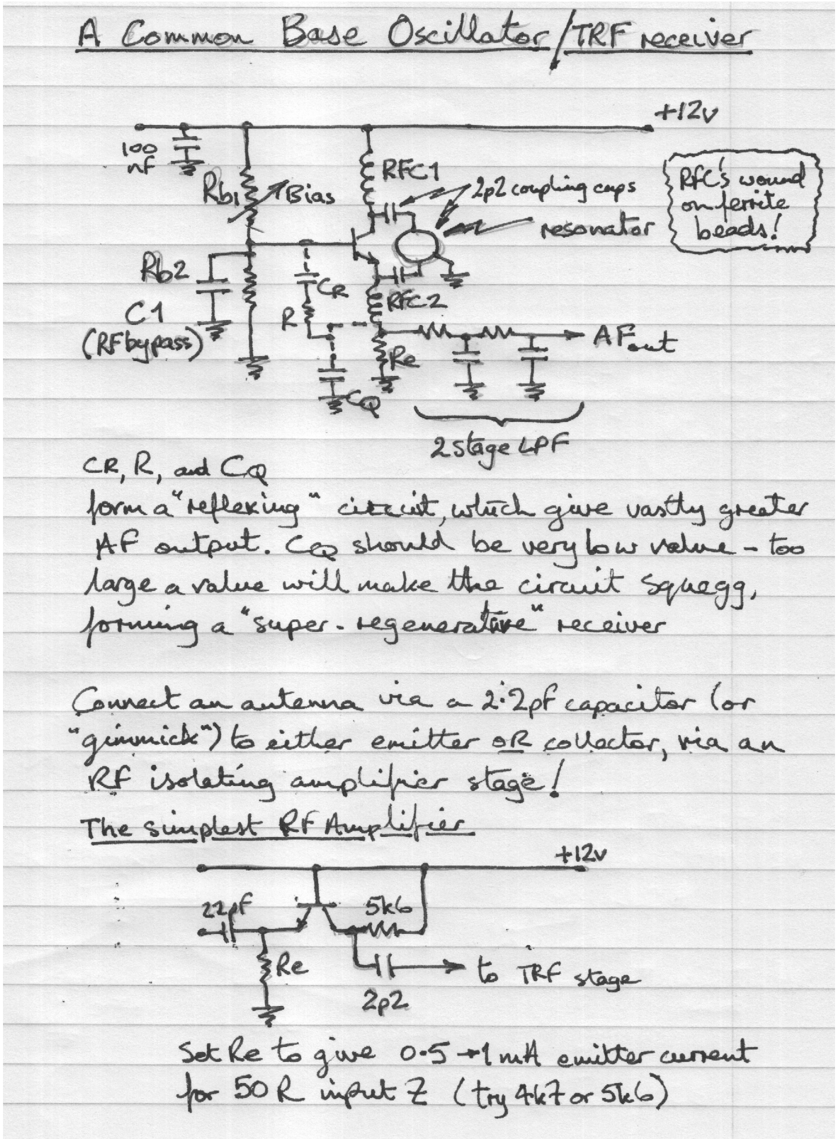


Rx's

VHF / UHF Coffee Cans...

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

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



Using SLAB’s for noise free Rx power

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

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

Humbuckers...

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

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

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

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

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

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

Tx's

Peter Parker's AMOXO

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

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

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

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

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

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

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

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

FT241/3 & HC6-U crystals...

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

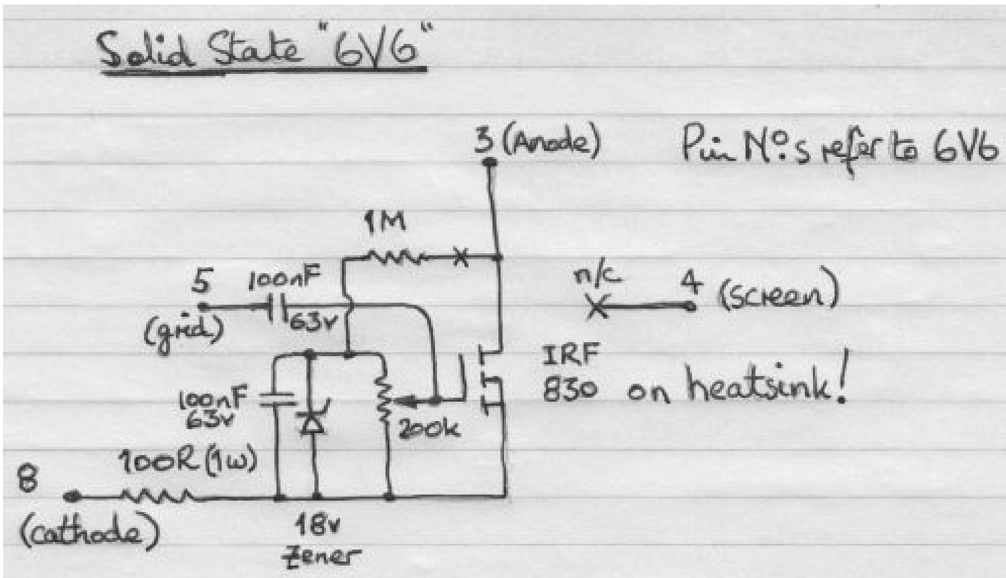
“*Wire Pins 1, 2, 5 and 6 are connected together and connect to one side of the crystal; pins 3, 4, 7 and 8 are connected together and go to the other side of the crystal. Now plug an FT-243, FT-241 or HC6-U into the octal socket, in any position that takes the crystal's pins without any strain or bending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

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

(As seen on a web page by N2EY)

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

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



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

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

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

A Rig in a Bottle

Pete Juliano n6qwham@gmail.com

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

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

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

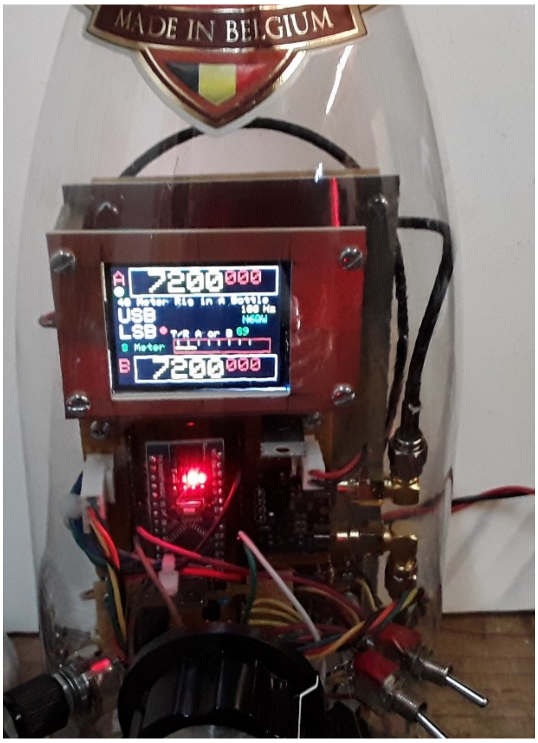
The rig itself uses a 9 MHz four pole filter from INRAD and it is a bilateral design employing the Plessey amps as Found in EMRFD. The Microphone amp is a single 2N3904 and the Audio amp is a 2N3904 driving a LM386. For the RxTx Mixer and the Product Detector/Balanced Modulator we have the TUF-1 at both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

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

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

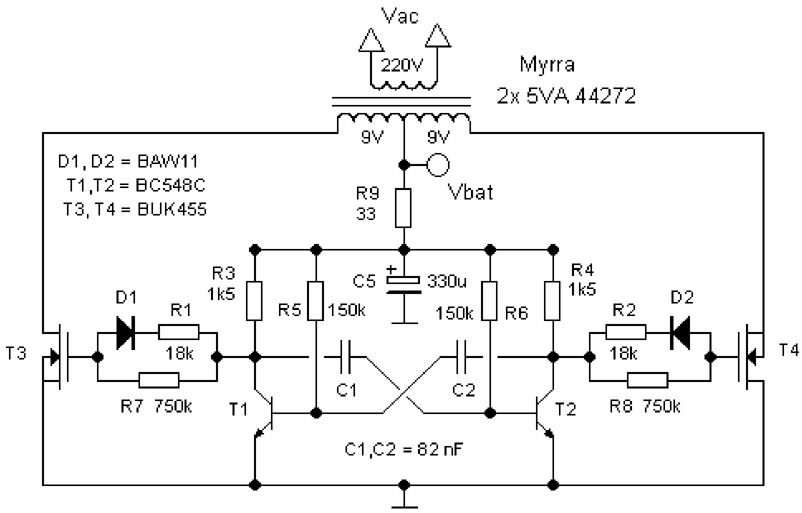
Keep an open mind for possible rig enclosures.

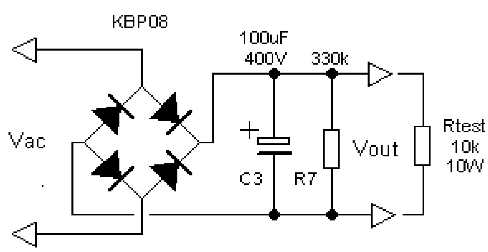
73’s
Pete N6QW



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

Power Supplies





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

Testing an unknown transformer

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

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

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

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

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

Kindest regards, Peter Thornton, G6NGR"

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

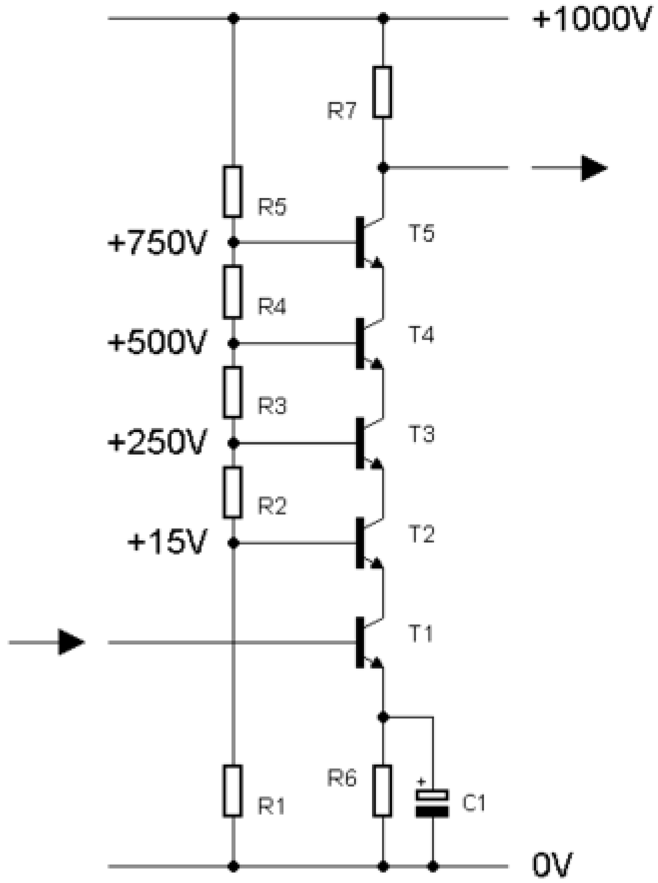
The Cascode (2)

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

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

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

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



(Diagram from
Wikipedia, for which many thanks)

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

Test Equipment & Fault Finding

Dim lamp [3]

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

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

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

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

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

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

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

<u>Answers</u>

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

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

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

(4) Self explanatory!

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

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

Simplest Audio / RF sig gen

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

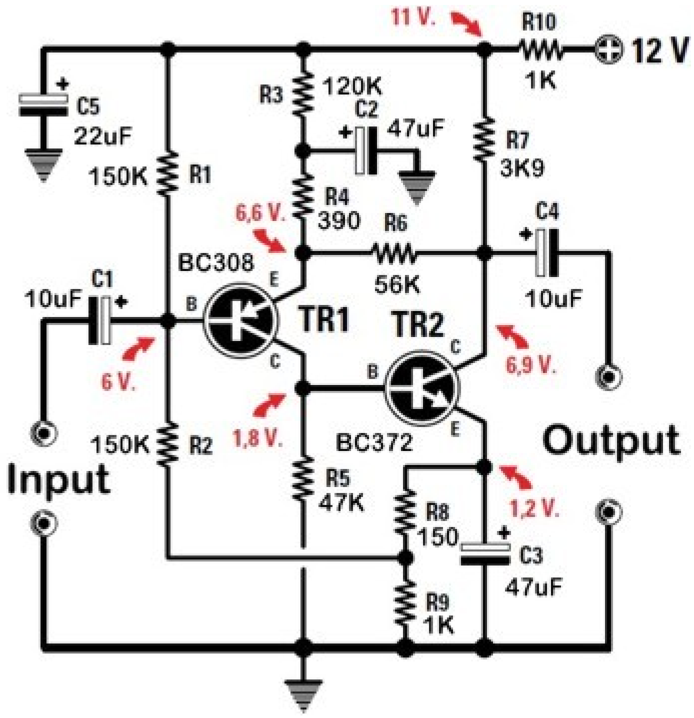
You could use a single series resistor feeding a shunt capacitor as a one section low pass filter; but far better - and easily lashed up - is multiple R-C low pass filters cascaded in series. You then have a choice of taps down the cascaded low pass filter sections, for different output voltage levels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

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

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

Pre-amp for signal tracer, more gain required?

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



Restarting / Using old electrolytics...

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

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

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

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

Servicing without a schematic diagram

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

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

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

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

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

Now try it again in service!

Components & Construction

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

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

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

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

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

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

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

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

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6BA screws

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

UNC - Unified Coarse Threads

Major Diameter *(in)*	**Threads per inch**	**Major Diameter *(in)***	**Major Diameter *(mm)***	**Tap Drill Size *(mm)***	**Pitch *(mm)***
#1 - 64	64	0.073	1.854	1.50	0.397
#2 - 56	56	0.086	2.184	1.80	0.453
#3 - 48	48	0.099	2.515	2.10	0.529
#4 - 40	40	0.112	2.845	2.35	0.635
#5 - 40	40	0.125	3.175	2.65	0.635
#6 - 32	32	0.138	3.505	2.85	0.794
#8 - 32	32	0.164	4.166	3.50	0.794
#10 - 24	24	0.190	4.826	4.00	1.058
#12 - 24	24	0.216	5.486	4.65	1.058
1/4" - 20	20	0.250	6.350	5.35	1.270
5/16" - 18	18	0.313	7.938	6.80	1.411
3/8" - 16	16	0.375	9.525	8.25	1.587
7/16" - 14	14	0.438	11.112	9.65	1.814
~~~~~~

Major Diameter *(in)*	Threads per inch	Major Diameter *(in)*	Major Diameter *(mm)*	Tap Drill Size *(mm)*	Pitch *(mm)*
1/2" - 13	13	0.500	12.700	11.15	1.954
9/16" - 12	12	0.563	14.288	12.60	2.117
5/8" - 11	11	0.625	15.875	14.05	2.309
3/4" - 10	10	0.750	19.050	17.00	2.540
7/8" - 9	9	0.875	22.225	20.00	2.822
1" - 8	8	1.000	25.400	22.85	3.175
1 1/8" - 7	7	1.125	28.575	25.65	3.628
1 1/4" - 7	7	1.250	31.750	28.85	3.628
1 3/8" - 6	6	1.375	43.925	31.55	4.233
1 1/2" - 6	6	1.500	38.100	34.70	4.233
1 3/4" - 5	5	1.750	44.450	40.40	5.080
2" - 4 1/2	4 1/2	2.000	50.800	46.30	5.644
2 1/4" - 4 1/2	4 1/2	2.250	57.150	52.65	5.644
2 1/2" - 4	4	2.500	63.500	58.50	6.350
2 3/4" - 4	4	2.750	69.850	64.75	6.350
3" - 4	4	3.000	76.200	71.10	6.350
3 1/4" - 4	4	3.250	82.550	77.45	6.350
3 1/2" - 4	4	3.500	88.900	83.80	6.350
3 3/4" - 4	4	3.750	95.250	90.15	6.350
4" - 4	4	4.000	101.600	96.50	6.350

UNF - Unified National Fine Threads

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

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

Antennas

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

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

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

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

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

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

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

3/8ths wave monopole

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

Tx/Rx auto changeovers...

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

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

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

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

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

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

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

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

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

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

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

An interesting Web article by Peter Hand....

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

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

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

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

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

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

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

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

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

Types of Transient Suppression Utilized with Relays

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

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

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

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

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

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

F. A reversed-biased rectifier diode.

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

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

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

Effects of Coil Suppression on Relay Dynamics and Life

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

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

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

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

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

R = V peak /I coil   where;

R = resistor value in Ohms

V peak = peak transient voltage permitted

I coil = steady-state relay coil current

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

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

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

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

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

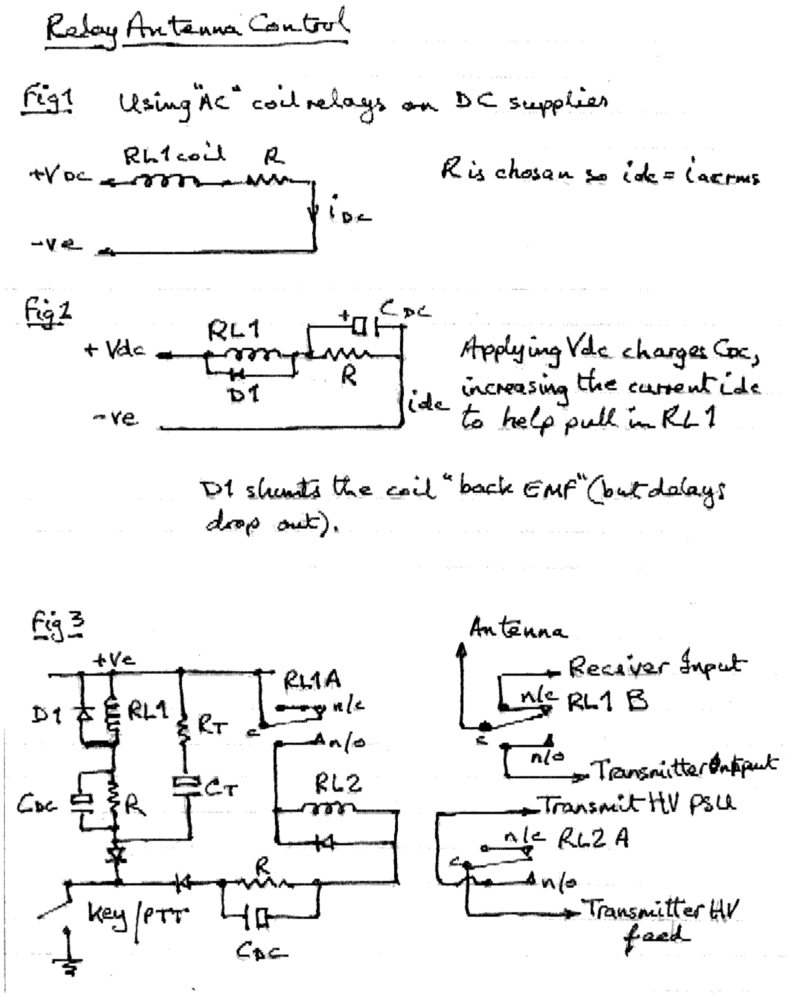
220Ω Resistor	3.2	-81
100Ω Resistor	3.7	-54
82Ω Resistor	4.0	-37.1
70Ω Resistor	6.1	-20.1
Diode & series 24v zener	5.5	-24.6
Diode	**9.8**	-0.8

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

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

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

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



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

Reflections...

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

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

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

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

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

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

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

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

A selection of Ivor Catt’s work include:

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

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

Data and Information

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

Wire Information...

AWG Table

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

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

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

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

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

Wire Gauge Resistance per foot

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

Current ratings

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

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

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

Resistivities at room temp:

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

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

Thermal conductivity at room temperature

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

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

Copper wire resistance table

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

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

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

Wire current handling capacity values

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

Mains wiring current ratings

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

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

Typical current ratings for mains wiring

Inside wall

mm^2	Amps
1.5	10
2.5	16

Equipment wires

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

2.5	25

Wire sizes used in USA inside wall

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

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

PCB track widths

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

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

Equipment wires in Europe

3 core equipment mains cable

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

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

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

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

Common Cable colour Codes

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

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

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

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

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

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

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

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

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

A.M. Frequency slots in Amateur HF Bands

All Frequencies in MHz

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

1.850 (W. Europe)

1.933, 1.963 (UK)

1.843 (Australia)

80 Metres: 3.530, 3650 (South America)

3615, 3625 (in the UK)

3705 (W. Europe)

3.690 (AM Calling Frequency, Australia)

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

60 Metres : 5.317

40 Metres: 7.070 (Southern Europe)

7.120, 7.300 (South America)

7.175, 7.290, 7.295 (USA)

7.143, 7.159 (UK)

7.146 (AM Calling, Australia)

20 Metres: 14.286

17 Metres: 18.150

15 Metres: 21.285, 21.425

10 Metres: 29.000-29.200

6 Metres: 50.4 (generally), 50.250 Northern CO

2 Metres: 144.4 (Northwest)

144.425 (Massachusetts)

144.28 (NYC-Long Island)

144.45 (California)

144.265 (Los Angeles, CA)

Other AM Activity Frequencies

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

FM Frequencies

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

VMARS RECOMMENDED FREQUENCIES

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

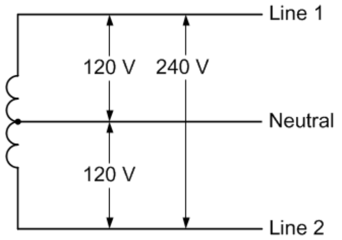
70.425 MHz VMARS FM operating frequency, also rallies and events

Electrical Supplies - Courtesy LEGRAND equipment

Common Electrical Services & Loads

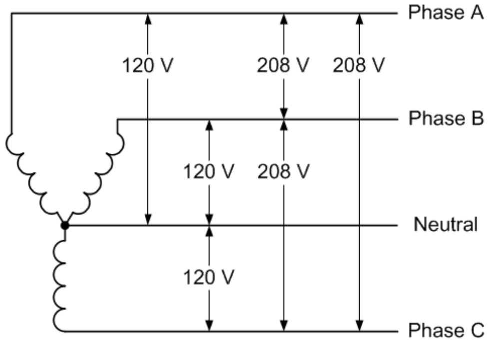
In the following drawings, the coil symbols represent the secondary winding of a utility service transformer or other step down transformer. Electrical code regulations in most jurisdictions require that the neutral conductor be bonded (connected) to the earth safety ground at the electrical service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

Single Phase Three Wire



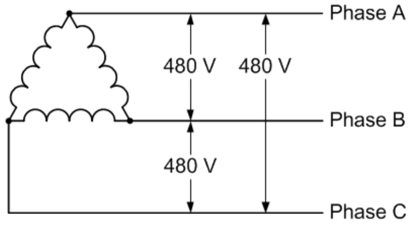
Also known as an Edison system, split-phase or centre-tapped neutral. This is the most common residential service in North America. Line 1 to neutral and Line 2 to neutral are used to power 120 volt lighting and plug loads. Line 1 to Line 2 is used to power 240 volt single phase loads such as a water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

Three Phase Four Wire Wye



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

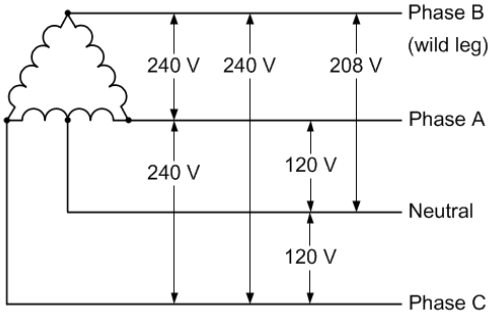
Three Phase Three Wire Delta



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

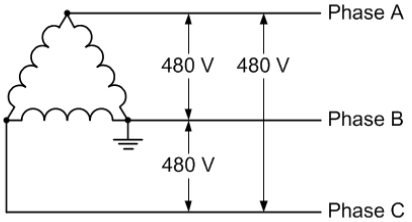
Uncommon Electrical Services

Three Phase Four Wire Delta



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

Three Phase Two Wire Corner-Grounded Delta



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

International Electrical Distribution Systems

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

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