Hot Iron 102

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CQ-CQ-CQ

Modules (# 1)

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

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

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

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

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

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

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

Modules (# 2)

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

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

Antennas and Interference

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

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

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

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

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

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Tim's Topics

Muting and avoiding clicks & thumps - from Tim G3PCJ

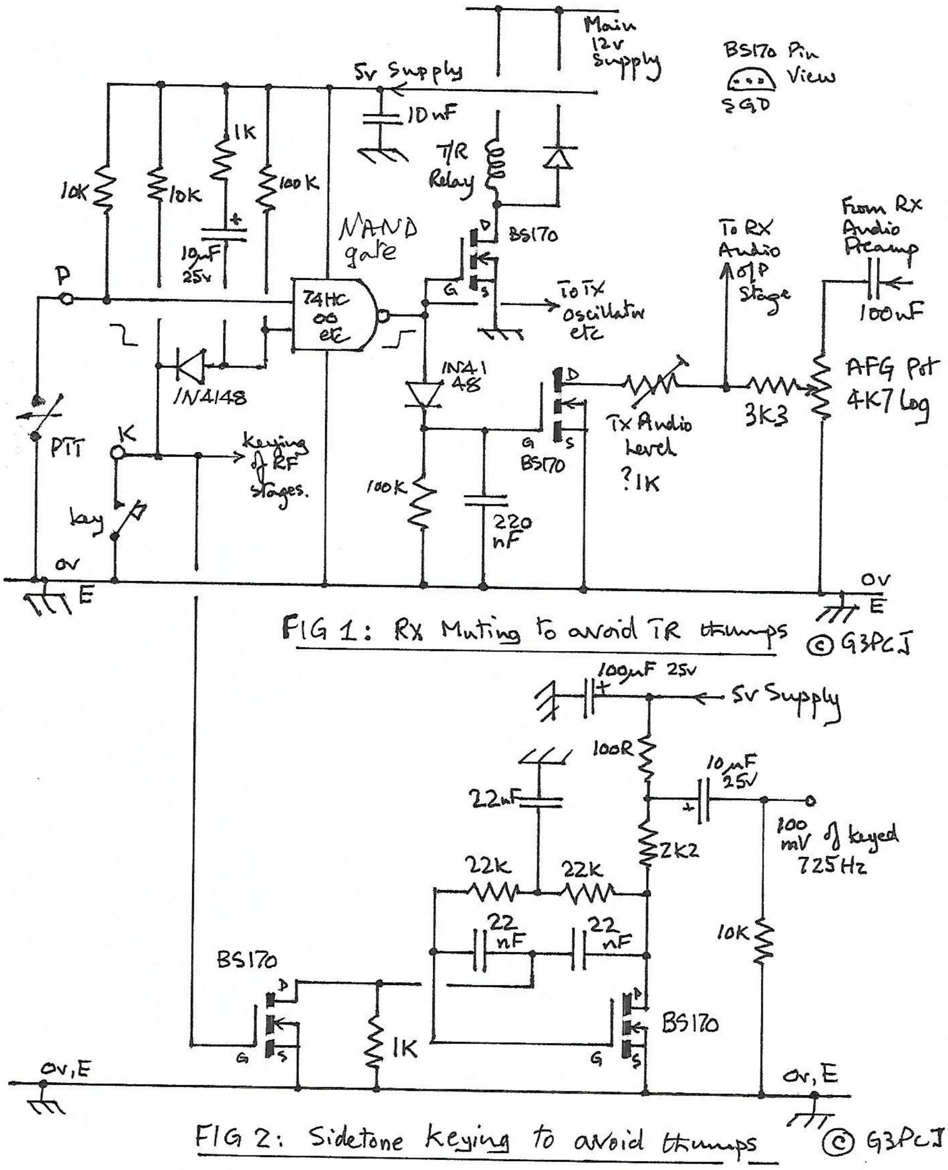


FIG 1: Rx Muting to avoid TR thumps © G3PCJ

FIG 2: Sidetone keying to avoid thumps © G3PCJ

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

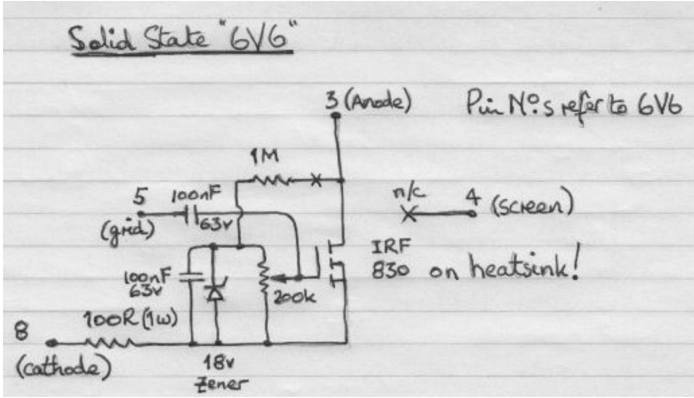
this makes the supply dip suddenly and translates through the early RX audio stages into a thump or splat in the phones. Because this is due to the relay current building up through its inductance over a few milli-seconds, the solution is to apply muting to the RX audio path before this relay current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

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

Radio Topics

Valve bits

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



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

Oscillators

LOCO and the Ceramic Resonators

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

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

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

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

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

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

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

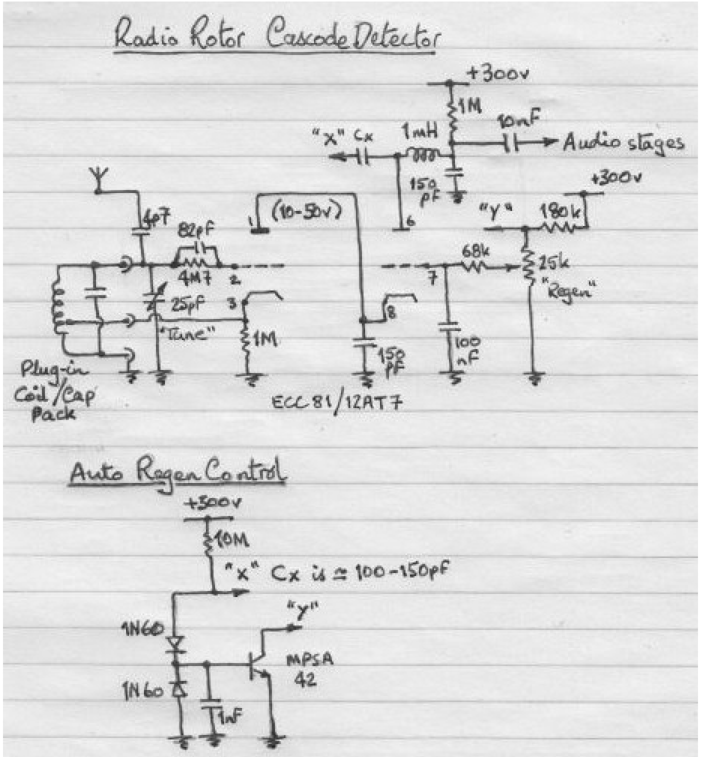
My advice: have another go at the PIC + DDS module approach. If you have the hex files and basic PIC blowing firmware from Terry’s (VK5TM) web pages, you have it sorted; but for those who defiantly eschew digital methods, then by all means try the “super VCO” crystal / ceramic resonator feeding a LOCO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

Rx’s

Hybrid TRF receiver...

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

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



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

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

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

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

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

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

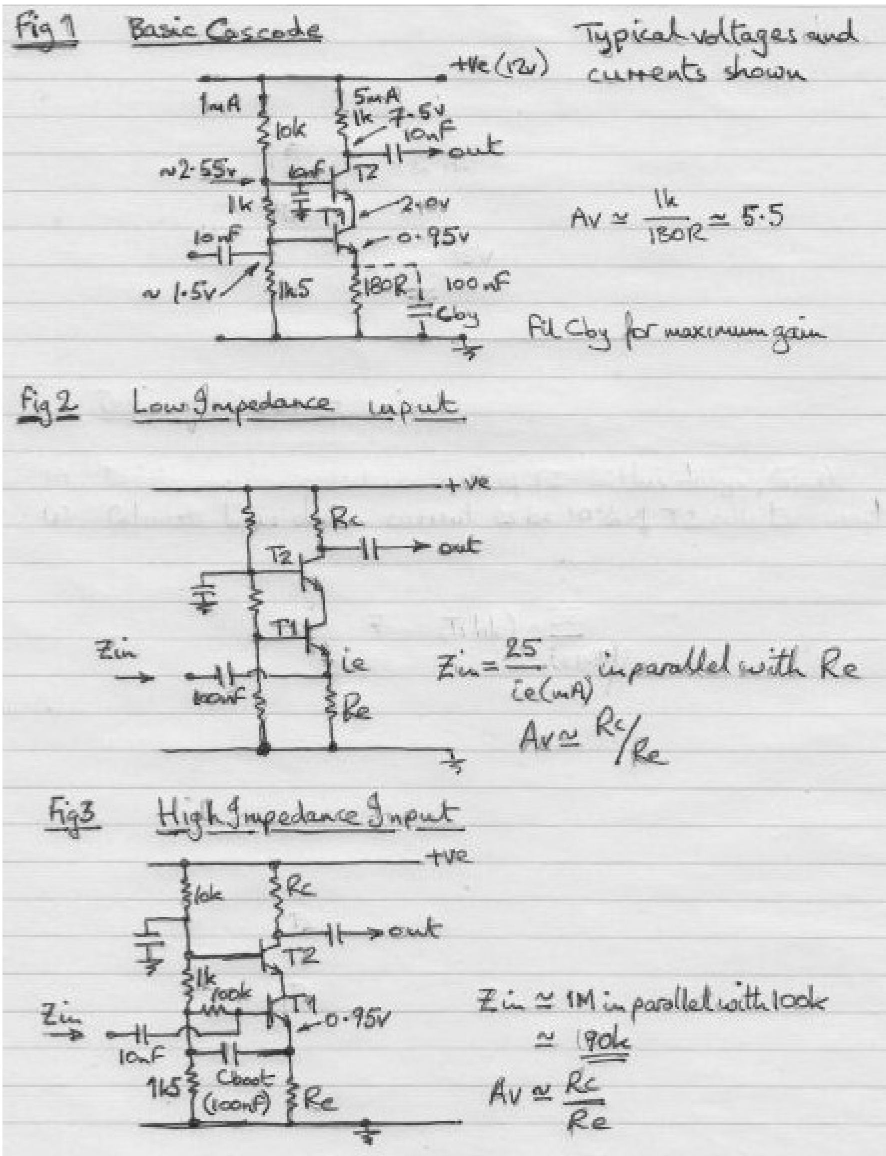
The Cascode [1]

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

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

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

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



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

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

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

Tx's

A Digital Interface

By Pete Juliano, N6QW n6qwham@gmail.com

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

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

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

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

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

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

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

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

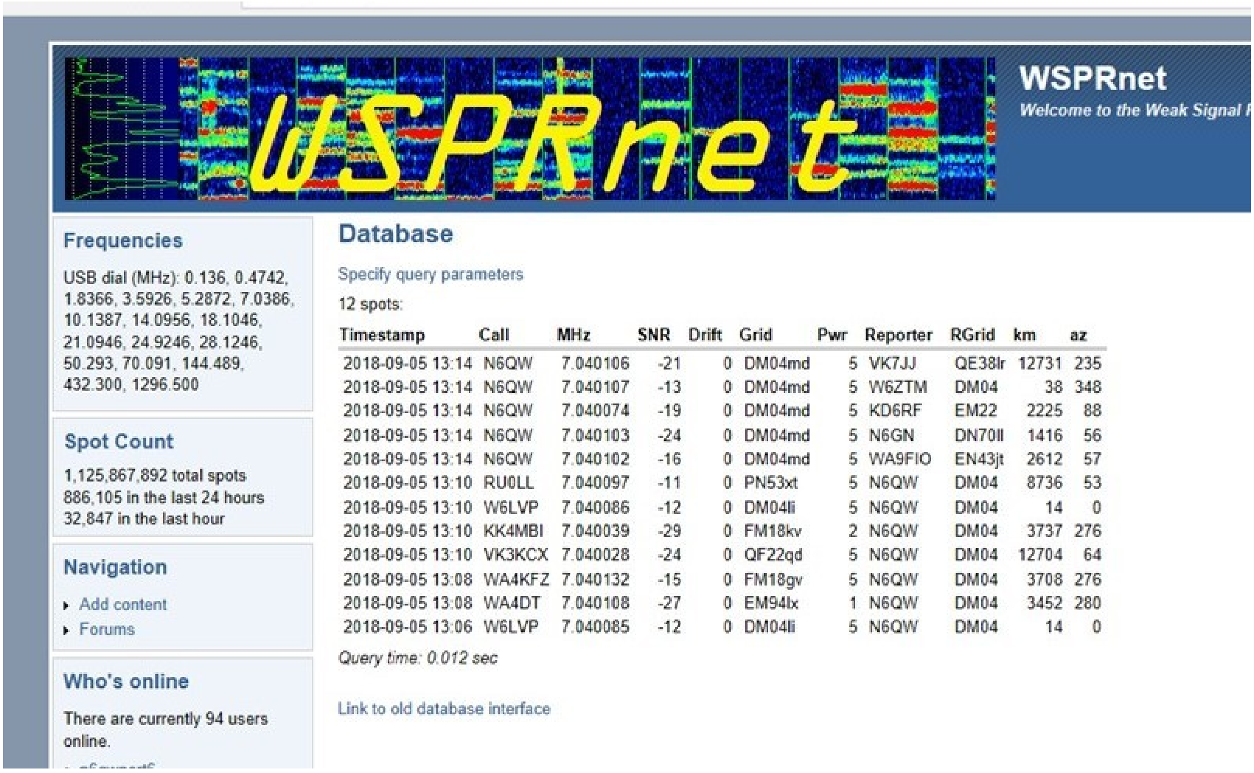
The WSJT-X has a settings tab that requires you to enter your call sign, grid square and the method of keying (RTS) and the COM Port to be used. There are some other items that require checking the block, like double click to automatically respond to a CQ and to disengage the transmitter once your computer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

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

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

73's
Pete N6QW

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



Frequencies

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

Spot Count

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

Navigation

- Add content
- Forums

Who's online

There are currently 94 users online.

Database

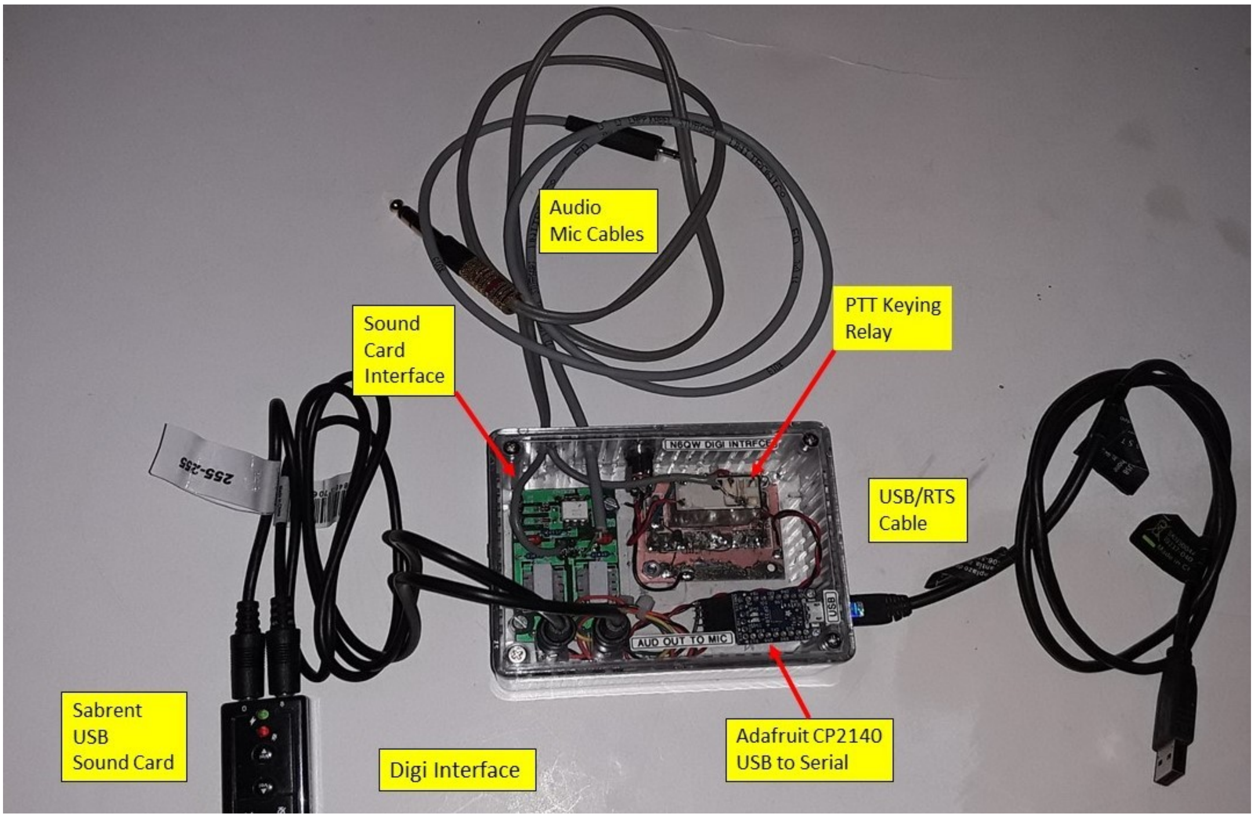
Specify query parameters

12 spots:

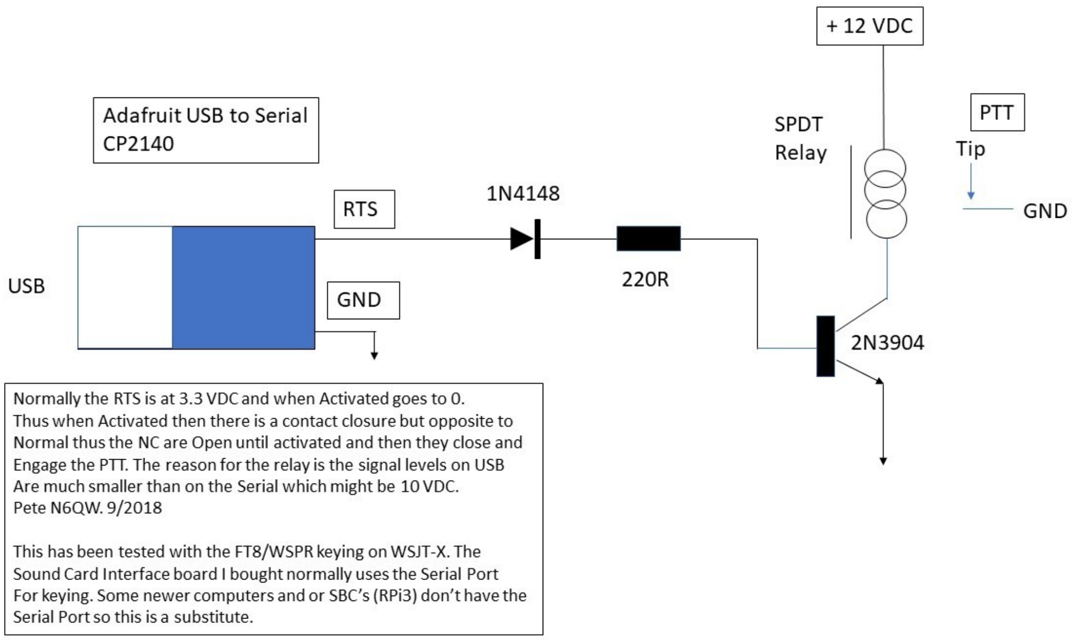
Timestamp	Call	MHz	SNR	Drift	Grid	Pwr	Reporter	RGrid	km	az
2018-09-05 13:14	N6QW	7.040106	-21	0	DM04md	5	VK7JJ	QE38lr	12731	235
2018-09-05 13:14	N6QW	7.040107	-13	0	DM04md	5	W6ZTM	DM04	38	348
2018-09-05 13:14	N6QW	7.040074	-19	0	DM04md	5	KD6RF	EM22	2225	88
2018-09-05 13:14	N6QW	7.040103	-24	0	DM04md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

Query time: 0.012 sec

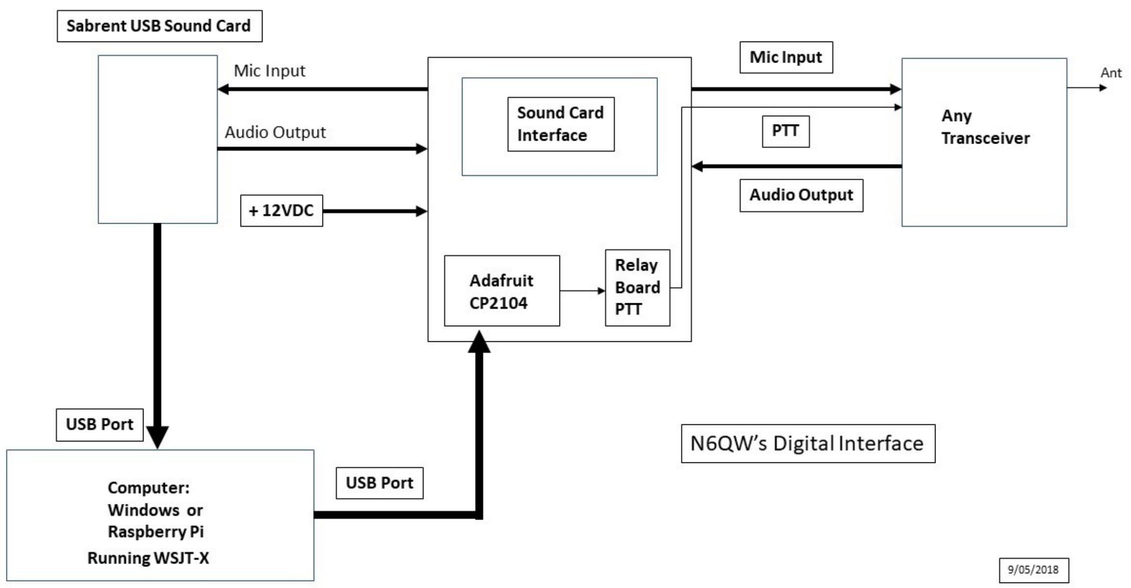
Link to old database interface



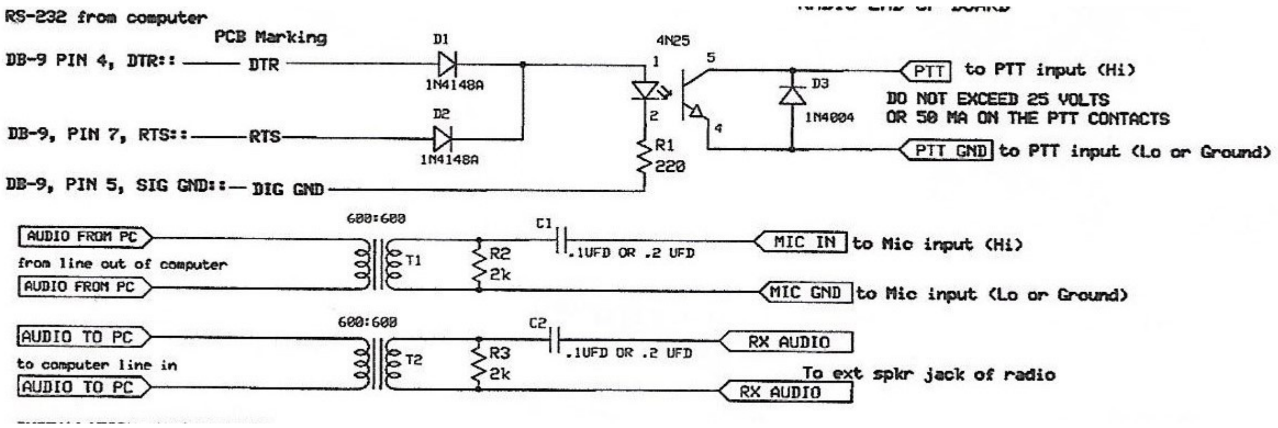
This is the modification to the Adafruit CP2140 to key the PTT on the transceiver



Below is a pictorial of the component/board interconnects.



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



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

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

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

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

Zener Clamps and mosfet Gate - Source charge storage

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

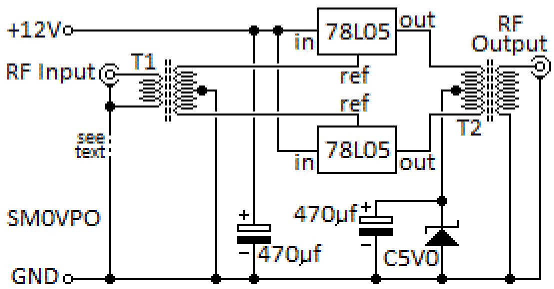
A simple answer is to add a fast (silicon) signal diode in series with each zener, in such a way the zener action isn’t blocked by the signal diode. Result: the capacitance of the signal diode is far lower than the zener diode, so represents the effective capacitance of that leg of the clamp, when back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

Push-Pull Voltage Regulator Amplifier

by Harry Lythall - SM0VPO

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

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



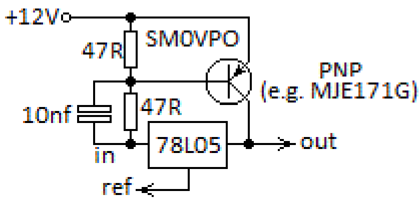
The 5V regulators each deliver +5V, which is fed though the output transformer T2, with the centre-tap connected to a 5V Zener Diode. The Zener will not conduct (much) until the voltage rises above +5V DC. The two +5V out pins of the regulators are modulated with the input waveform, so either side of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

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

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

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

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



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

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

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

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

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

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

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

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

Transformer T2 (2.5-Watts)

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

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

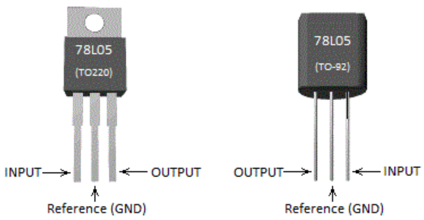
You could alternatively stack 2 + 2 of them, using glue, to make what looks like a pair of mini spectacles: one turn is in one ring and out through the other. You can get 2-hole ferrites ready made from Maplins, Mouser or Conrad, if you do not want to go to the trouble of making then with cheap rings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

Ready-made 2-hole ferite

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

78L02 Pin-outs

Here are the pin connections to the 78L05:



Device pin-outs

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

Stability

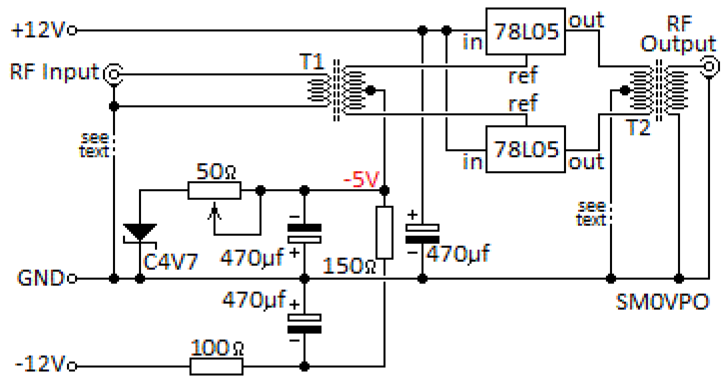
If you intend to use this project as an RF power amplifier then I strongly suggest you:

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

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

Biasing

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



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

The benefits of this method are:

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

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

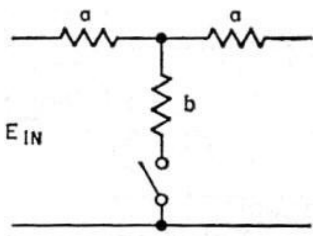
I never cease to be amazed by the ingenuity and diversity of Harry's designs! G6NGR

Audio Topics

Quality, or the lack of it - Soft Limiters

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

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



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

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

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

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

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

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

(Z is the characteristic impedance of the attenuator).

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

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

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

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

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

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

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

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

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

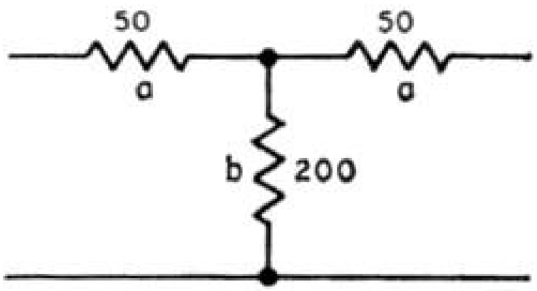


Fig. 5 - Attenuator used as an example for calculation as described in the Appendix.

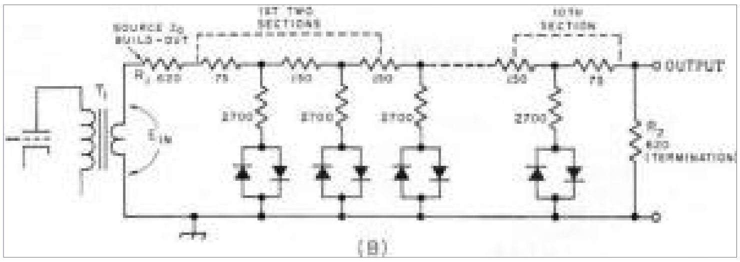
A single attenuator section of 150 ohms impedance and 6 db. loss is shown in Fig. 5 (above).

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

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

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

W9NLT shows a series attenuator:



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

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

Sub-Audio control?

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

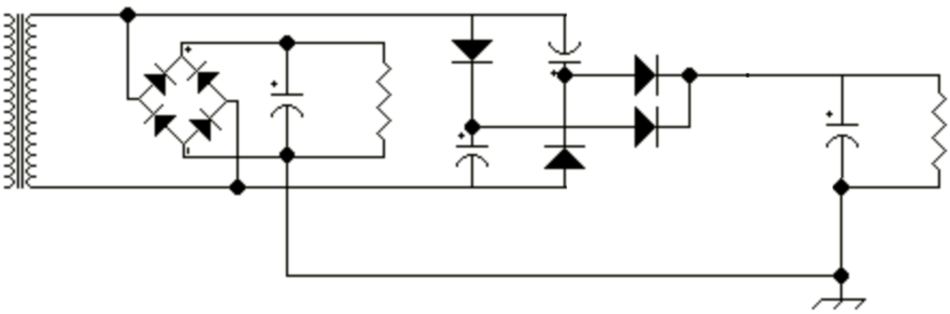
The proposition is this, consider the CW first. If the monotonic carrier is 20% amplitude modulated with a sub 10Hz tone, two sidebands, a 10 Hz displaced from the carrier will be present in the received signal during every key “down”. The carrier will be dominant by a factor of 4 (standard AM carrier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

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

Power Supplies

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

The Pink Brazilian - the doubler / rectifier



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

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

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

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

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

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

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

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

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

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

"Hi Peter

Good to hear from you.

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

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

Around 6% for a 200VA unit.

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

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

I hope that helps.

Best Regards

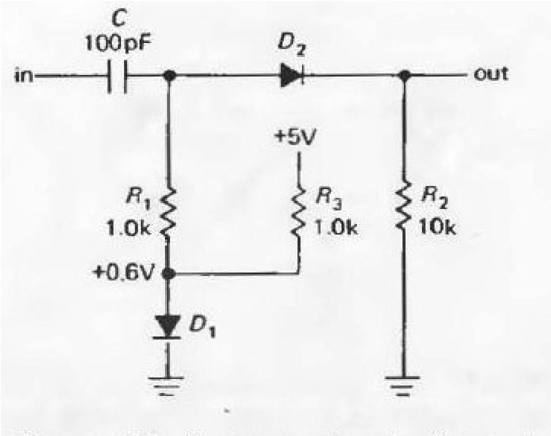
Martin Boardman"

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

Test Gear & Fault-Finding

RF Probe WITHOUT diode offset voltage [# 2]

Another biased diode RF probe:



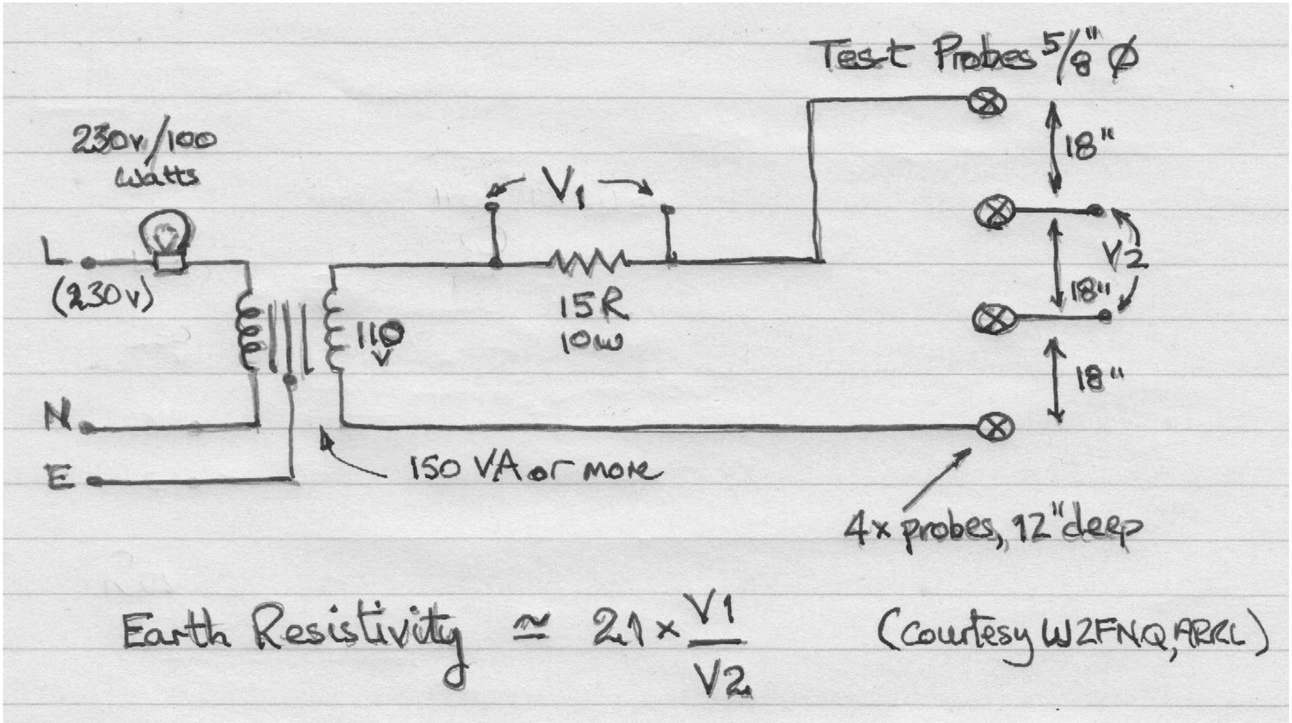
This is from a diagram in “The Art of Electronics” by Horowitz & Hill; one of the “Bibles” no professional Industrial Electronics Engineer should be without. You can modify the values up or down as you like. The only drawback is the need for a bias supply; but almost any voltage above a 1.5 volts will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

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

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

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

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



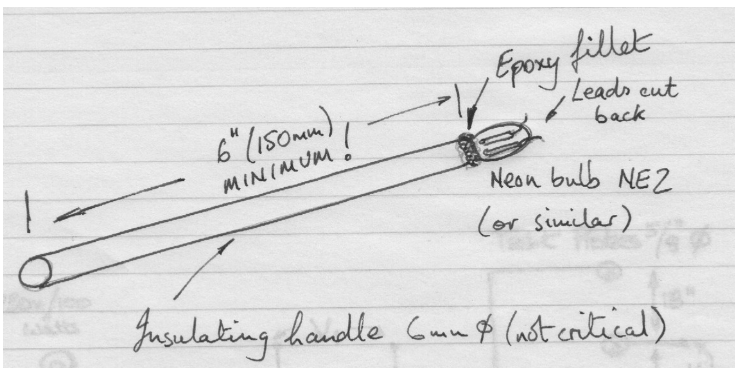
The 100W incandescent lamp limits the applied power; V1 is proportional to the current flowing and V2 is the generated voltage measured in the earth. By using the dimensions shown, the maths simplifies to 21 x V1/V2, approximately.

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

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

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

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



Signal tracers

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

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

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

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

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

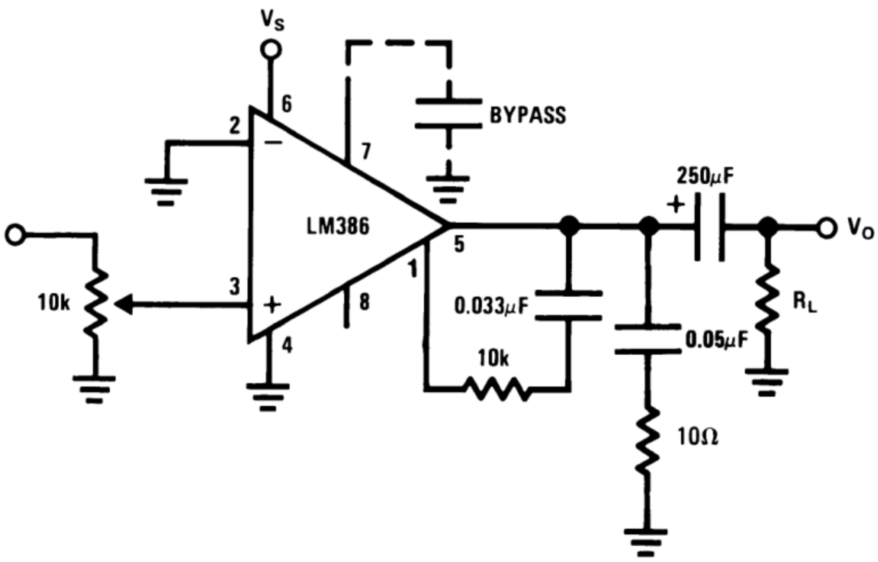
In short, you’ll find the section of a “deaf” receiver that is giving trouble very quickly and easily, as most receivers can be split into sub-systems and then divided further as the results become known. Typically the sequence of sub-systems in a receiver is: RF amp → Mixer → IF amp → Product detector/BFO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

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

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

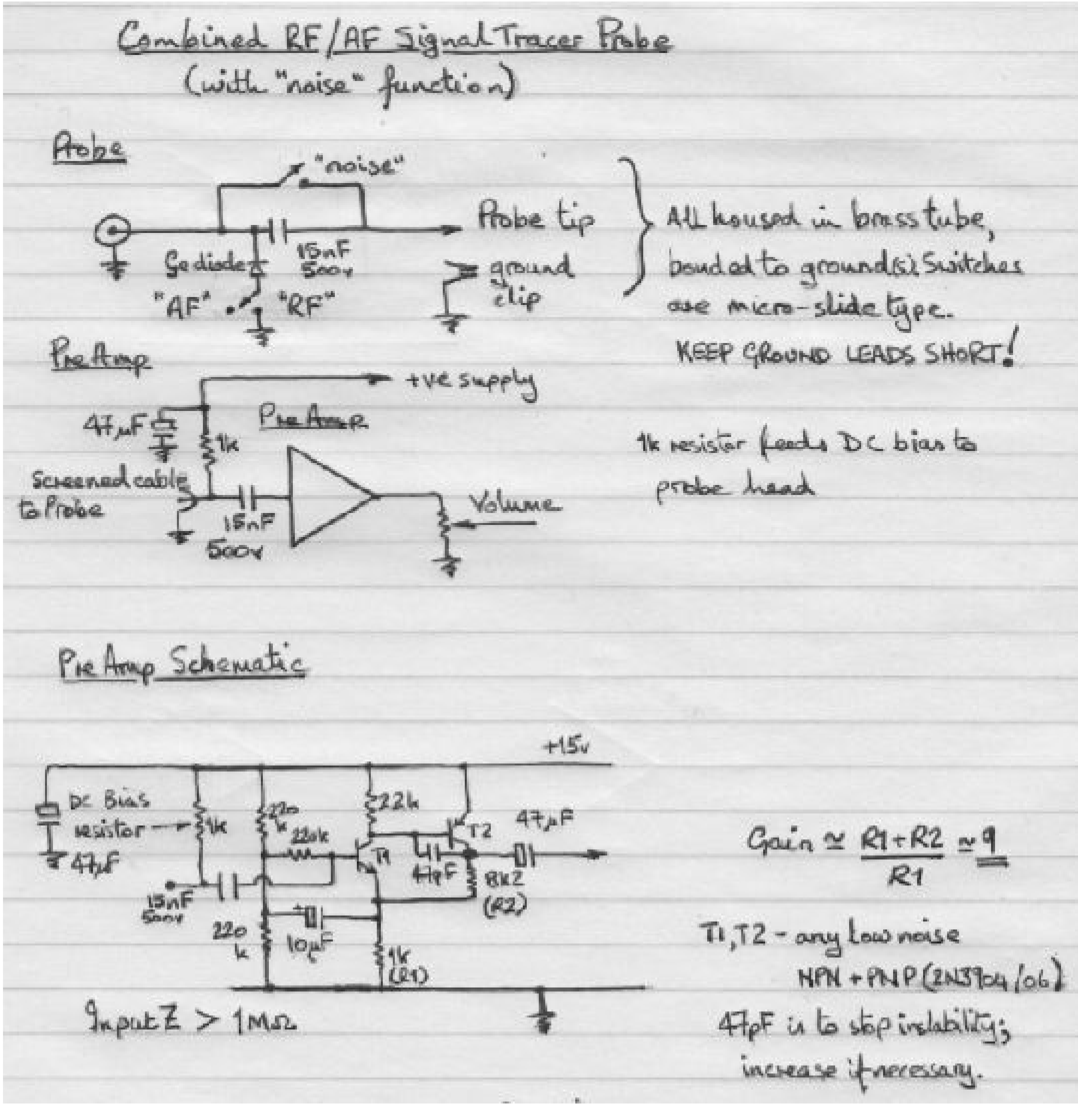
The pre-amplifier I prefer is “bootstrapped” bipolar transistors, to gain very high (>1M ohm) input impedance to eliminate loading effects on the circuit being tested. You could use a j-fet or mosfet, but I prefer the repeatability and robust performance bipolar silicon transistors offer; especially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

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



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

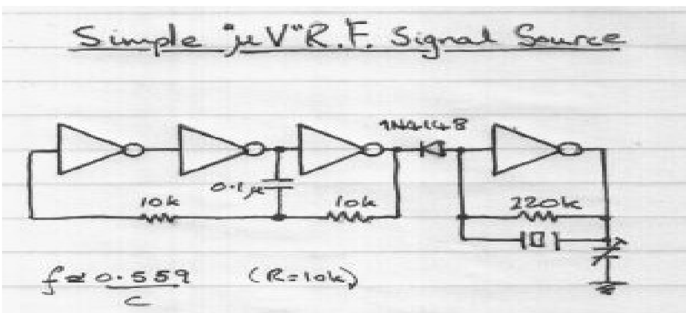
The RF probe with switched RF / AF function and “Noise” setting is shown below. I personally use the standard “shunt diode” RF probe for most functions; it works just as well on AF as far as I’m concerned, for most jobs and means I can use it for metering purposes too, indicating peak RF.



A modulated µV RF signal source

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

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



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

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

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

Components

Electrolytics – again...

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

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

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

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

“Real or Fake”, the curse of Scam devices

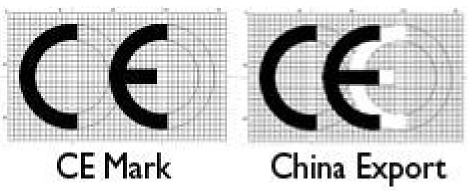
Terry, VK5TM, gave some advice recently about scam devices for sale on our favourite on-line auction house; it’s a sensible check and test method, and I recommend it. Terry says:

* “*Always assume they are fake (they are more often than not).*
  Doesn't help when you need some for a project/job I know, but the majority of RF transistors for sale on the auction sites haven't been made for quite some time now.
* *Do a photo search using the photo's from the ad, quite often the same picture will show from multiple sellers, usually a sign of no good.*
* *If the price seems too good to be real - well, you know the saying.*
* *Search using the sellers name to see if there has been any comments outside the eBay system, good or bad, about the products from that particular seller.*

Terry VK5TM”

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

Chinese companies printing close replica of European standards logo on products



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

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

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

Ft measurements for the amateur

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

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

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

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

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

Antennas & ATU's

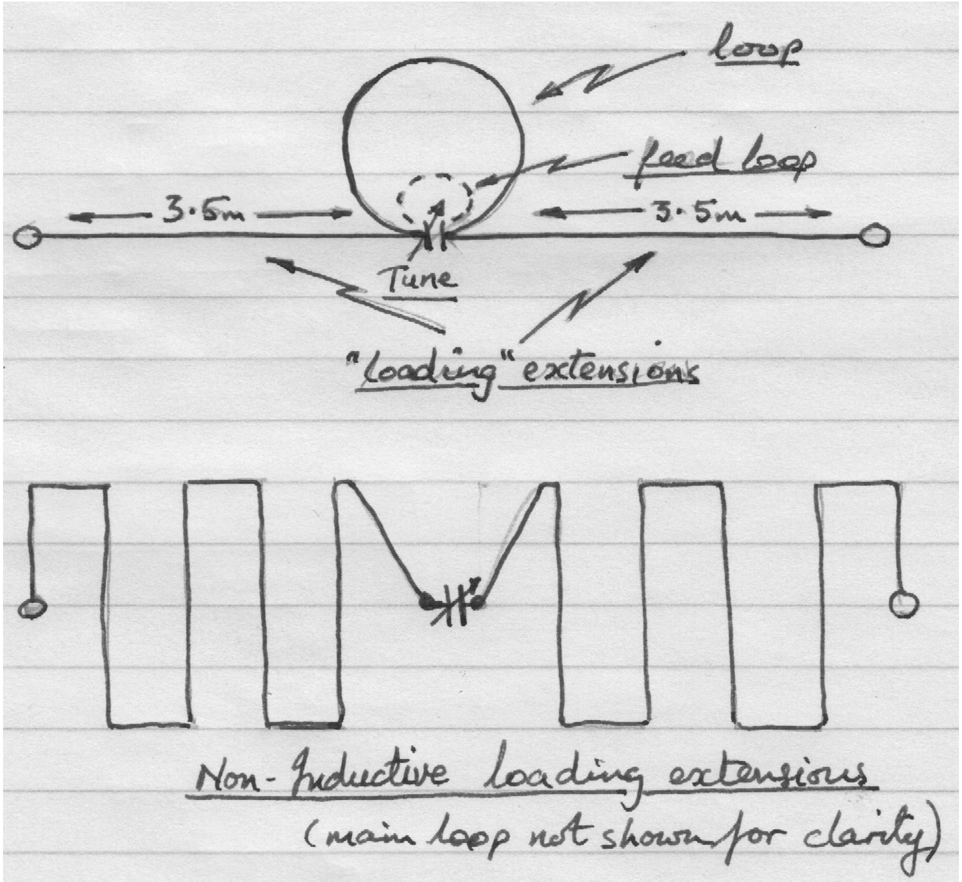
A Mag Loop – with a difference

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

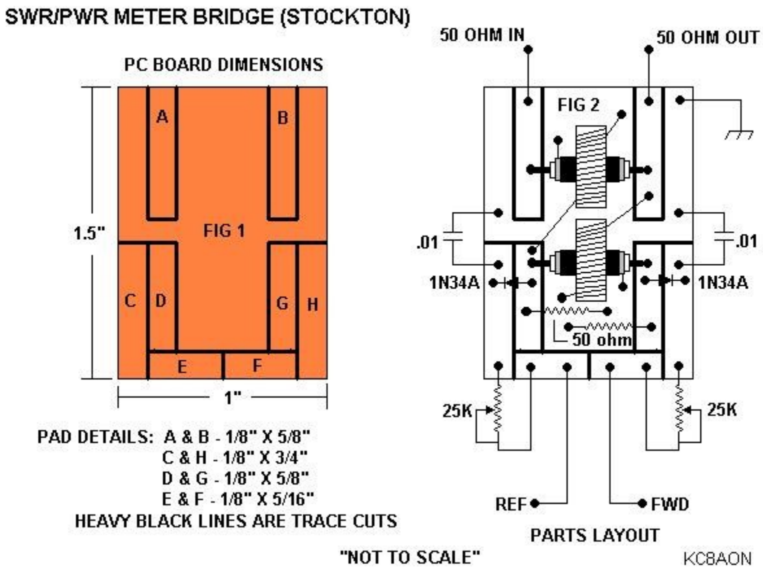
UA6AGW has found a potential answer to this "elephant" in the form of a standard antenna technique that is simple and well proven: capacitive loading.

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

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



SWR measurement without tears



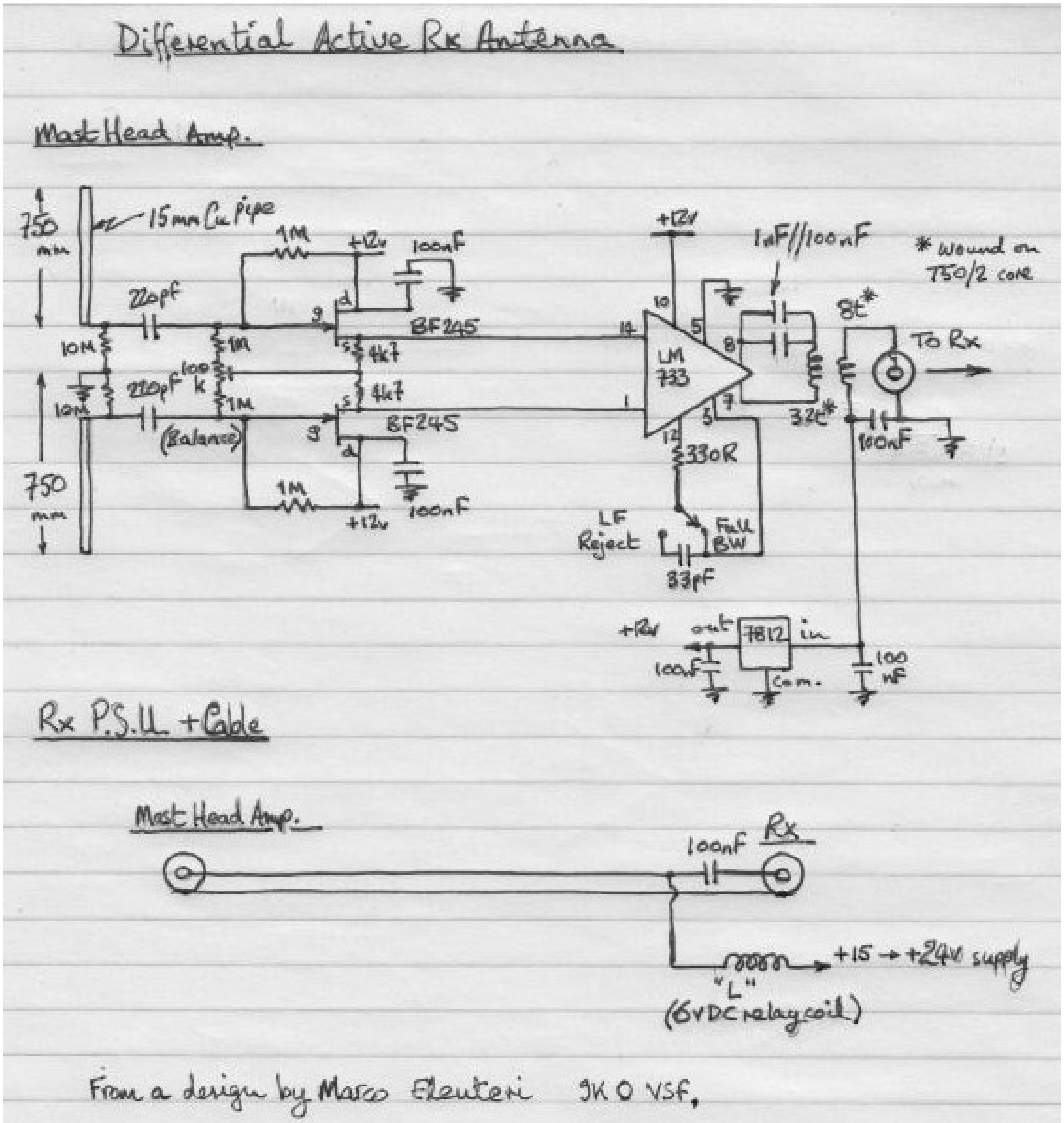
This is a simple PCB for the ever-popular Stockton SWR Bridge, by Richard S. McKee, KC8AON, with this superb layout that I saw recently. What attracted my attention was the symmetrical layout Richard has achieved: this is the key to measurements like this, maintaining balance and minimising stray capacitances.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

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

An Active Antenna for Dx

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

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



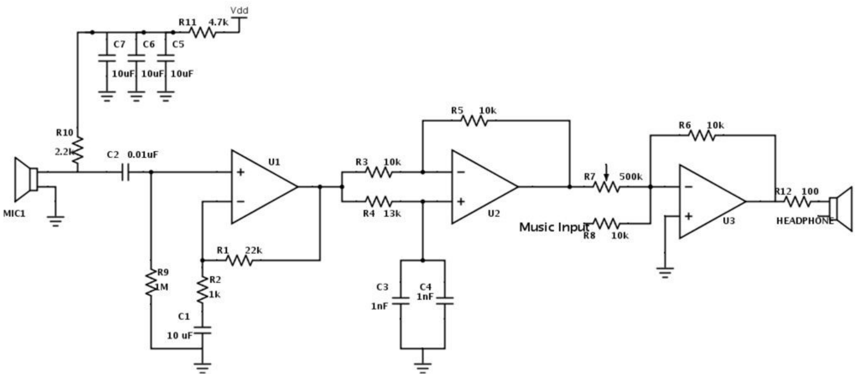
Allied to this antenna, the schematic following is an “noise cancelling” audio section, designed for “noise cancelling” headphones comprising buffer amplifier, an all-pass filter section (for delay / phase adjustment) and a summing amplifier for cancellation. Noise cancelling at RF is not at all easy;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

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

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

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

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



Mechanical & Construction

Earth plane construction

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

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

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

Letters

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

~~~~~~

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

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

73,
Paul Smith, G4BJG

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

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

Kindest regards, Peter Thornton G6NGR

~~~~~~

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

~~~~~~

Hello, Peter--

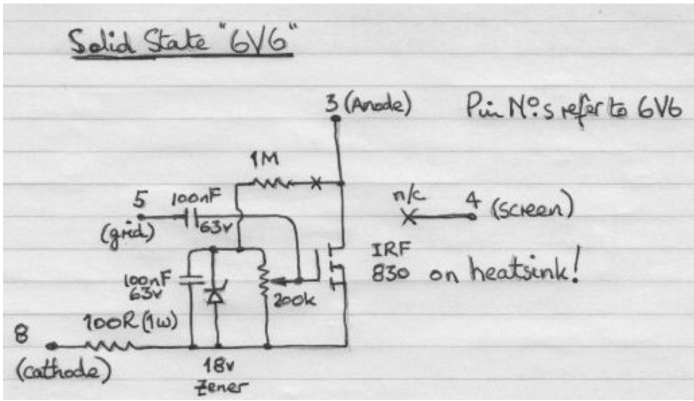
Thank you for the FETRON circuit-- I'm unfamiliar with the BF459, but I looked it up on line. That device might make a good QRP final amplifier transformer since its fT is reasonably high and the breakdown voltage rating *might* make it somewhat resistant to unpleasant loads.

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

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

Thanks again, and 73--

Brad AA1IP



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

(Handwaving mode OFF)

Thanks again, and 73--

Brad AA1IP

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

~~~~~~

Hi Peter,

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

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

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

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

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

Regards,
Richard Fearnley

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

P.Th. G6NGR

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Data and Information

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

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

Wire Information...

AWG Table

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

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

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

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

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

Wire Gauge Resistance per foot

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

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

Current ratings

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

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

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

Resistivities at room temp:

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

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

Thermal conductivity at room temperature

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

diamond	0.24
bismuth	0.084
iodine	43.5E-4

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

Copper wire resistance table

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

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

Wire current handling capacity values

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

Mains wiring current ratings

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

Cross-section Overload current

CSA / area rating

0.5mm²	3A
0.75mm²	6A
1mm²	10A
1.25mm²	13A
1.5mm²	16A

Typical current ratings for mains wiring

Inside wall

mm^2	Amps
1.5	10
2.5	16

Equipment wires

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

Wire sizes used in USA inside wall

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

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

PCB track widths

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

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

Equipment wires in Europe

3 core equipment mains cable

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

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

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

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

Common Cable colour Codes

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

•**Ground wires:** green, green with a yellow stripe, or bare copper

•**Neutral wires:** white or gray

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

•**Single phase live wires:** black (or red for a second "hot" wire)

•**3-phase live wires:** black, red and blue for 208 VAC; brown, yellow, purple for 480 VAC

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

•**Earth wires** (called ground wires in the U.S. and Canada): green with a yellow stripe

•**Neutral wires:** blue

•**Single phase live wires:** brown

•**3-phase live wires:** brown, black and gray

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

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

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

A.M. Frequency slots in Amateur HF Bands

All Frequencies in MHz

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

1.850 (W. Europe)

1.933, 1.963 (UK)

1.843 (Australia)

80 Metres: 3.530, 3650 (South America)

3615, 3625 (in the UK)

3705 (W. Europe)

3.690 (AM Calling Frequency, Australia)

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

60 Metres : 5.317

40 Metres: 7.070 (Southern Europe)

7.120, 7.300 (South America)

7.175, 7.290, 7.295 (USA)

7.143, 7.159 (UK)

7.146 (AM Calling, Australia)

20 Metres: 14.286

17 Metres: 18.150

15 Metres: 21.285, 21.425

10 Metres: 29.000-29.200

6 Metres: 50.4 (generally), 50.250 Northern CO

2 Metres: 144.4 (Northwest)

144.425 (Massachusetts)

144.28 (NYC-Long Island)

144.45 (California)

144.265 (Los Angeles, CA)

Other AM Activity Frequencies

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

FM Frequencies

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

VMARS RECOMMENDED FREQUENCIES

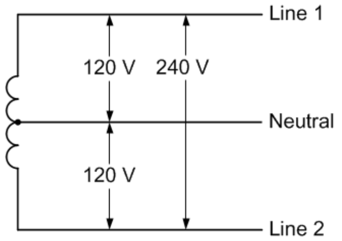
3615 Khz	Saturday AM net 08:30 – 10:30
3615 Khz	Wednesday USB net for military equipment 20:00 – 21:00
3615 Khz	Friday LSB net 19:30 – 20:30
3615 Khz	Regular informal net from around 07:30 - 08:30
3577 Khz	Regular Sunday CW net 09:00
5317 Khz	Regular AM QSO's, usually late afternoon
7073 Khz	Wednesday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

Electrical Supplies - Courtesy LEGRAND equipment

Common Electrical Services & Loads

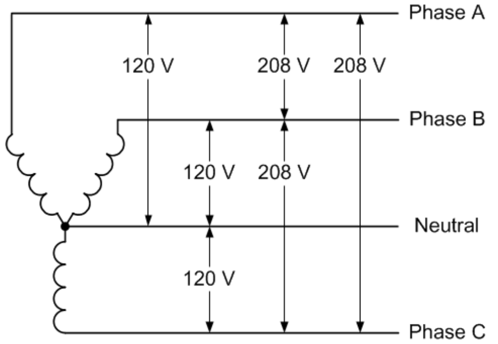
In the following drawings, the coil symbols represent the secondary winding of a utility service transformer or other step down transformer. Electrical code regulations in most jurisdictions require that the neutral conductor be bonded (connected) to the earth safety ground at the electrical service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

Single Phase Three Wire



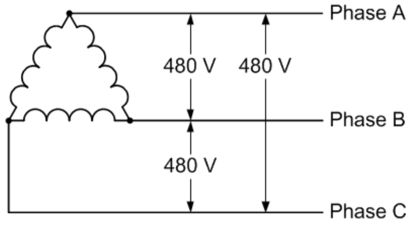
Also known as an Edison system, split-phase or centre-tapped neutral. This is the most common residential service in North America. Line 1 to neutral and Line 2 to neutral are used to power 120 volt lighting and plug loads. Line 1 to Line 2 is used to power 240 volt single phase loads such as a water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

Three Phase Four Wire Wye



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

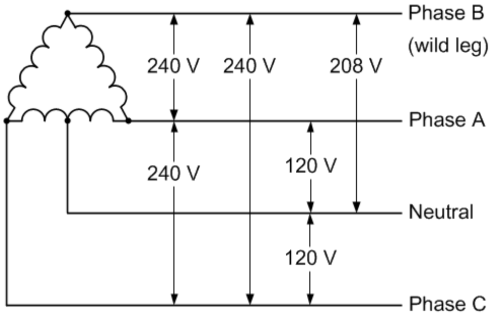
Three Phase Three Wire Delta



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

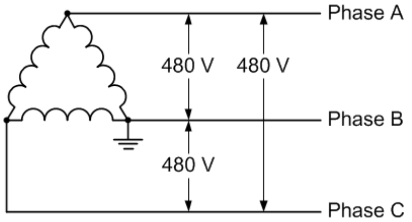
Uncommon Electrical Services

Three Phase Four Wire Delta



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

Three Phase Two Wire Corner-Grounded Delta



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

International Electrical Distribution Systems

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

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

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