Hot Iron 108 May / June 2020

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A Thank You...

Tony Fishpool, G4WIF, emailed me about my including his work in Hot Iron #107:

"*Hi Peter*

Thanks for sending hot Iron. It is always a good read and I know from my years of involvement with Sprat that it takes a lot of work to produce.

I don't mind that you (or someone) lifted the entire page off my January 2017 blog for the comb generator article - but I do think it would have been nice to have asked me – or at least acknowledged my work - and all the text and photos and screen grabs and PCB artwork - which was also mine. I would certainly have given my blessing http://www.fishpool.org.uk/

I noted that you wrote on page 7 "I always credit the original author of any information or web page I reproduce in Hot Iron".

You said "please let me know and I'll happily correct the situation" so I have - and trust that you will.

72/3

Tony G4WIF"

I am more than pleased to include Tony's email in Hot Iron #108. I am most grateful for the articles on the Internet in the public domain as it is a wonderful source of information: I attempt in Hot Iron to illuminate the remarkable work of the authors.

Inbox Limits?

I am reducing the Mb size of Hot Iron as I get many "bounced" emails after every issue of Hot iron is mailed out - either "detected as Spam" , "exceeds Inbox limits", "recipients inbox is full" and similar. So, to reduce the time taken to sort out the mess (and clear my inbox!) I'm deliberately reducing the Mb's in each Hot Iron edition by giving links to relevant sources, rather than copying and pasting the bits I want to illuminate.

This has several advantages for all concerned: you don't inadvertently miss an issue; I don't spend a week sorting out "bounced" emails; you have the original article so can follow the references and associated links; it saves the formatting problems and strange issues the inclusion of pictures and image files in the midst of text files can create (don't ask...!).

I hope it will produce a streamlined yet informative Hot Iron; as ever I welcome your comments and thoughts on this and any other issues you might have or wish to be addressed in Hot Iron. My over-riding desire is to "keep it simple" for all concerned.

A good way to start...

Whilst Hot Iron is the Constructor's Club Journal, it's always an idea to keep an eye open on routes into radio construction that are of similar cost to making your own gear. For most amateurs of my vintage (don't ask...!) just starting out it in radio it was always "build your own" unless you got to hear of a bit of commercial kit going for a song: my first receiver that really shone was an AR88LF. I'd saved up for months to buy the beast from a Manchester Radio Club and it was a wondrous performer - and weighed more than I care to remember. Nowadays, a quality receiver, spanning 30kHz to 30MHz, can be found for far less (taking inflation into account) than the old AR88 by keeping an eye on "Marine Radio" or "Boat Accessories" equipment listed on our favourite on-line auction house; HF receivers / transceivers are particularly good value as most marine service communications are on VHF nowadays - and are usually ruggedised and tropicalised for service on the briny.

I picked up an HF marine service SSB / A.M. receiver for a song recently; I will be building an external audio filter to screw the bandwidth down from 3kHz (SSB, Usb & LSB on all frequencies) and 6kHz (A.M., all frequencies) for CW and RTTY. This, with an active (tuned pre-selector) antenna, will be a perfect companion for my "Pink Brazilian" 80m, 60m and 40m A.M. transmitter; as well as A.M. HF broadcasts, of which I'm a regular listener. The receiver has a switched antenna selector that in the "active" position, puts +12 volts DC onto the antenna jack via a choke; absolutely ideal for my home made active antenna using an LM733 balanced video amplifier without needing to modify the receiver or make a "hot" interconnect for the antenna jack.

I'm using a "security" (burglar alarm) power box for supply: it has a 4 Amp-Hour battery and a switch mode trickle charger. Thus when running the receiver, it's on a quality (and quiet!) voltage supply that will hold up for at least 12 hours, SMPS charger off, no mains connected. The cost of the security power box? A few ££'s, in a neat painted steel box, from my local security supplier. The batteries are available from our favourite on-line auction house, or my local security supplier again, to avoid the "heavy" postage and packing for a gel cell.

Most amateurs I know who build their own gear usually have a mixture of "bought" and "home made" - since a commercial product can't be as specialised as a specific amateur design - unless you're prepared to pay kilo-bucks for the "all bells and whistles" features you only use once every Preston Guild*. I'm looking at a home brewed Fliege audio filter for the audio processing as they are very easy to set up and adjust; the preselector will be a double tuned top coupled bandpass design switched to cover the three bands I'm interested in for A.M. service, and another three for the RTTY and digital modes I'm looking into for QRP purposes (yes; RTTY: I know, I know...!).

The whole assembly will give me good results for minimal outlay, by using my construction skills to adapt the marine receiver to my individual requirements - and I have a tunable "I.F." for down-converters to cover other frequencies I'm interested in. It's a modular approach, very easily adaptable and a lot of fun too.

*Preston Guild meetings are every 21 years.

Tim's Topics

I've not had any notes from Tim for this issue: I know he's rushed off his feet with many things presently, I'm sure he'll have plenty to say when he gets some time! As ever, I extend my very grateful thanks to Tim, he's always welcome to contribute, criticise and correct me!

Components

Back to Basics

I note from various places that some radio amateurs don't have a working grasp of the basics - the estimation of capacitance, inductance, and the like. Whilst you won't need this kind of information every day, it's still a basic requirement to building radio gear, especially if you're working on limited budgets or working from a modest "junque box". The simple basics are more than adequate for most jobs, the basic approximations with their magnificent calculations built in fit the bill without straining the grey cells too much.

Capacitance:

C = Eo.Er.A / D

where

Eo = 8.85 x 10-12 F/m (the Permittivity of free space);

Er = the Relative permittivity of the dielectric (i.e. what's between the capacitor plates)

For example, Air = 1; FR4 pcb board = 5; water = 80

A = area of the capacitor plates (in square metres)

D = the spacing between the plates (in metres)

OR... use http://www.66pacific.com/calculators/capacitor-calculator.aspx

Inductance

Of a single layer air cored solenoid = Radius^2 x Diameter^2 / 9xRadius x 10xLength

With dimensions all in inches OR centimetres

OR... use http://www.66pacific.com/calculators/coil-inductance-calculator.aspx

You can find the inductance of any toroid core here:

http://www.66pacific.com/calculators/toroid-coil-winding-calculator.aspx

OR

https://www.daycounter.com/Calculators/Air-Core-Inductor-Calculator.phtml

You can select the toroid material (iron powder for HF, ferrite for LF)

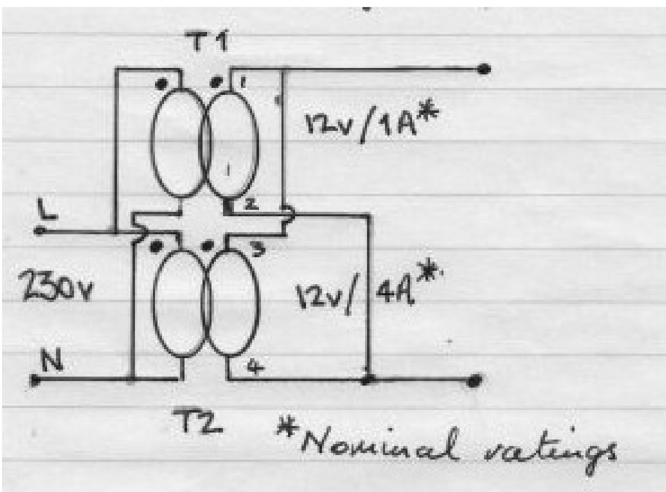
OR for air cored / non magnetic toriods μr = 1

https://www.easycalculation.com/engineering/electrical/toroid-inductance-calculator.php

Power Supplies

Albert's Power Supply

Albert had a conundrum. It had him flummoxed; his "dull lamp" safety device* (an incandescent lamp in series with the "live" line, as per Hot Iron # 101, pp28) lit up every time he tried his new power supply. He wanted to use two junque box transformers in his power supply: he needed 15v AC (rms) at 5 Amps. Albert had a chunky 4 Amp 15 volt transformer (T2) and a small 1 Amp 15 volt transformer (T1) so reasoned he could connect them in parallel to get his 5 Amps. Being a conscientious amateur, Albert tested stages as he wired them up to avoid having to modify his handiwork when all was built - so his AC power circuits, mains and low volts, were connected as he thought correct, and were the first to be checked, no load connected to the paralleled secondaries.



On went the AC mains; "all lit up" went his "dull lamp", indicating significant current demand! Albert then (logically) suspected one or even both his transformers might be faulty, he carefully removed T1 and T2 and tested them on his bench with his multimeter to see if any winding showed leakage to earth; to his surprise, all windings read clear, no shorts to the frame or core. Albert then wired each individual transformer to mains supply via his "dull lamp" with a few car lamp bulbs as a load - and both performed perfectly. Since no other components existed in Albert's power supply at this stage, it *had* to be - as per Sherlock Holmes - "with the impossible eliminated, what remains are the only possible solutions" - which leaves just the wiring? So Albert conscientiously checked, end to end, every wire in his power supply. Reconnected, to his dismay, on power up, he was greeted with his dull lamp once again "all lit up".

Albert, had learned from previous projects the sensible way to do things: he had wired his transformers to and from a screw terminal block*, so removal, rewiring or modification was simple and easy and they were tested in a jiffy. A multimeter ohms test of the windings showed the following results (having taken his multimeter lead resistances into account) when measuring the windings end-to-end:

T1 primary: 350 ohms; secondary: 0.2 ohms and labelled as 15v / 1A, 15VA

T2 primary: 110 ohms; secondary: 0.1 ohms and labelled as 15v / 4A, 60VA

Albert had already noted that his multimeter leads had a resistance of ~ 0.2 ohms, and so was reasonably confident his measurements were near as dammit - within the capabilities of his multimeter. Albert reconsidered: could it be the "phasing" of the windings, that funny stuff he'd heard about somewhere?

Albert sought advice, not being too confident and after all, this was mains powered stuff and he always erred on the side of caution - that's why he always used* his "dull lamp". Thus entered Stan the (Maintenance) Man, who, on seeing Albert's notes* asked Albert to measure the open circuit secondary volts of T1 and T2, "on no load, please, Albert". This Albert did, and with these results:

T1 o/c sec'y volts = 16.6v (RMS)

T2 o/c sec'y volts = 15.3v (RMS)

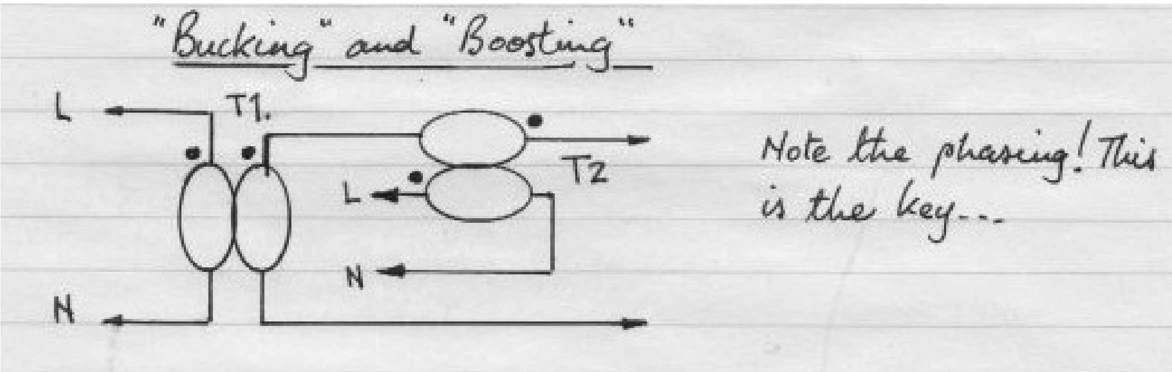
Stan had a probable solution: the transformer secondary voltages were unequal, which - assuming Albert had wired them in opposition (i.e. winding starts together, so the voltage of T1 opposed the voltage of T2) gives a potential difference of 1.3 volts around the paralleled secondaries (on no load, mind) resulting in a circulating current *with no load attached* - which was probably causing saturation in the iron core of T1.

As a rough approximation, not counting things like inductive reactance or leakage flux, the loop current will be roughly 1.3v through (0.2 ohm + 0.1 ohm) which is 1.3v / 0.3 ohms = 4.33 Amps. T1 being specified at 1 Amp (rms), was likely saturating it's core; thus the primary current in T1 was probably way too high.

Stan explained a few more transformer fundamentals to Albert, after Albert suggested paralleling the supplies after rectification and regulating. Stan had seen this tried; it inevitably ended, quoth Stan, “like marriage to the most beautiful girl in the village - heartbreak and tears”. Stan explained: “you’ll always end up with circulating currents in any circuit if you parallel low impedance supplies, be they AC, DC or anywhere in between; not always obvious but very likely”.

Stan went further: “on DC, paralleling ostensibly equal output 78XX three terminal regulators can cause problems: because the ‘common’ leads, if not earthed to a star point, can cause offsets in the multiple regulator’s output voltages, due to difference in volt drops in the common return lines: and there you go, one regulator - the one with the highest output volts - will end up driving all the load; the lower output regulators will contribute little or nothing. The lesson’s simple: don’t parallel power supplies.”

“One exception though, Albert: toroidal transformers - from the same maker, of identical ratings and of the same batch, can be paralleled: they are far better matched than traditional rectangular ‘E & I’ transformers and will parallel - usually - without trouble. Some amateurs use Buck or Boost connection to solve problems of not having the right transformer: by adding a second transformer



you can either throttle back a higher voltage transformer or increase the output volts by connecting in Buck or Boost, (diagram above) by observing the phasing. For instance, we had a job to replace a Radyne 150kW RF Generator filament transformer, rated 15 volts 160 Amps. We couldn’t get the manufacturer’s replacement for 6 weeks; so we had to improvise to get production running. A stud welding transformer rated at 20 volts 180 Amps and a 4.5v / 200 Amp electroplating transformer from the ‘Black Hole’ (the professional engineer’s equivalent of the amateur’s junque box...) and Bucked the 20v winding down to 15.5 volts by wiring the two transformers in opposition. We did this by wiring the secondary windings in series, and measuring the resultant voltage: it would be either 24.5 volts in “Boost” connection, or 15.5 volts in “Buck” connection. We got lucky, and got 15.5 volts first time; with unknown transformers this is the only sure way to find out the phasing. The only caveat on this job was to be sure both transformer secondary windings could carry the full 160 Amps, whether you Bucked or Boosted. We ran temporary wires to the filament in 6mm² cable, and got dead on 15 volts at the valve terminals, the 6mm² dropping a few hundred mV’s”.

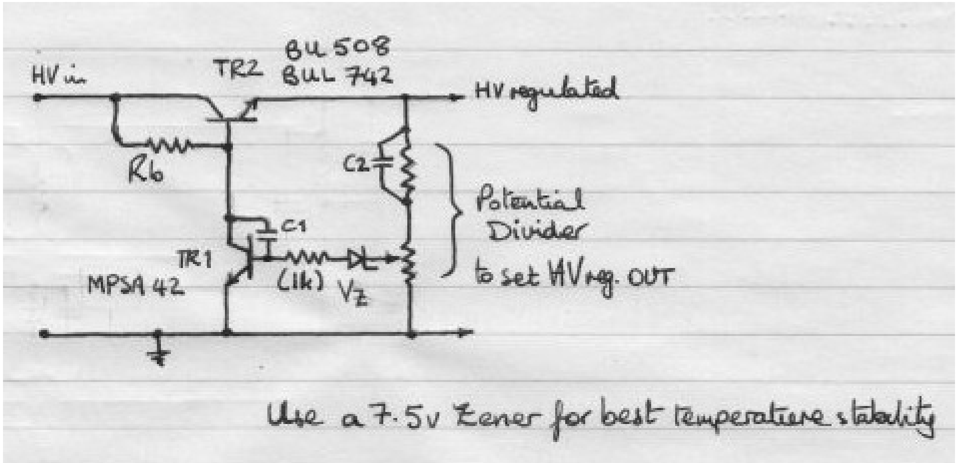
“The phasing of windings is the key: keep this simple rule to mind and you won’t go wrong. *Current entering a ‘dot’ will make all other magnetic coupled ‘dots’ positive*. A remarkable man called Augie Hand used just this method to identify the 9 (unmarked) leads of a USA dual voltage 3 phase induction motor - with nothing more than a 6 volt battery and an analogue multimeter. He's well worth a quick search on the Internet; these things are always useful to know...".

And I can state without doubt - that during one of those lonely12 hour night shifts - funny how you always end up working on your own when trouble strikes on a night shift - simple tests, like those Augie documented, applied to machinery designed for servicing*, is truly a blessing...!

* These are very sensible ideas, adopt them...!

HV regulated PSU's for pennies

Shown below is a simple HV regulator circuit that uses very cheap components - the HV bipolar transistors are very cheap, or free if you break open a dud LED or fluorescent lamp base. You'll find a handfull of goodies in there; in fact a useful 80m transmitter was created by that RF genius, Mike Rainey, AA1TJ, called "Das DereLicht", from a compact fluorescent lamp parts rip down.



The diagram has a couple of points worth noting. First is Rb, the base bias transistor for TR2. By making Rb a high value, the bias current into TR2 base can be limited: thus the emitter current (which is the output current) is limited to TR2's hfe (current gain) times the base current. This renders the output short circuit proof if Rb is chosen to be sufficient to feed your circuit(s), plus a little more for good measure; any further current demand is impossible as TR2 cannot pass any more current - a bit rough and ready, but it works. If you need an electrolytic across the output, this "built in" current limiting will allow controlled charging of the electrolytic, thus avoiding the surge of charging current that can pop upstream fuses.

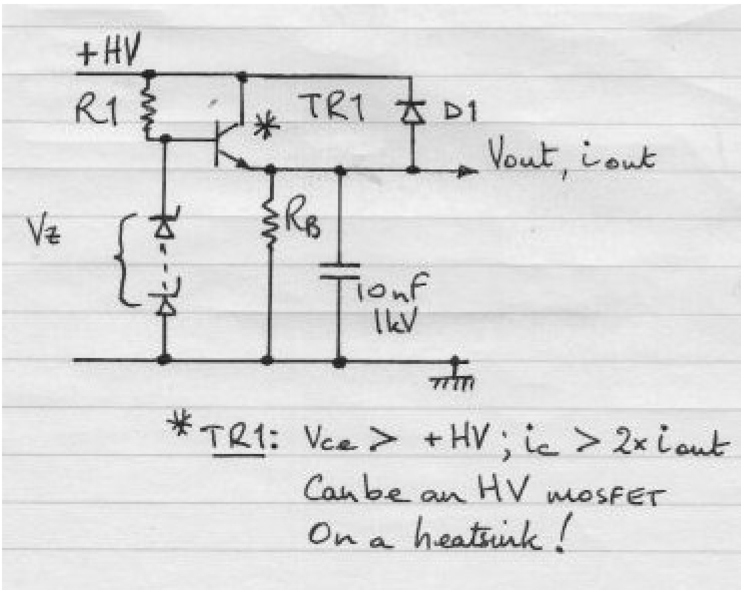
The BUL 742 is a monster of a transistor; but any NPN with sufficient Vce rating is good to go in this position but be aware a chunky series pass transistor is rugged - and experimental HV electronics can be somewhat destructive! Line output transistors (for those of you who remember TV's with cathode ray tubes) are an excellent choice here. For my money - and the umpteen car and motorbike electronic ignitions I've built with it - you'll find it damned hard to beat a BU508 transistor. Rugged, reliable, capable of gross overload, it's a superb workhorse in any rugged HV circuit. The BUL742 family are a modern device just as rugged, used in lamp ballasts running directly off the mains - so these babies have to be tough.

The potential divider reduces the output to an exact fraction of the main HV; this value is applied to zener diode Vz (7.5v nominally, but any between 4v7 and 12v will work fine) - the temperature co-efficient of a base emitter junction is -2mV / °C; the 7v5 zener is + 2.5mV / °C). If the output voltage rises for any reason, the zener breaks down and applies base current to TR1. TR1 collector sinks some of the base current applied to TR2, thus shutting off TR2, lowering the voltage out - compensating exactly the rise which originally overcame the zener barrier voltage. The potential divider also applies a ballast load to the regulator, ensuring that any current from the load (i.e. the screen grid of a tetrode, for instance, can *source* mA's as well as *sink* them) has a path to ground.

By it's very nature, a potential divider resistor dropping (say) +300v to less than +20v or so at the hot end of the potentiometer will be quite a high value; this means the stray capacitance around the base circuit of TR1 can form an RC low pass filter - sudden voltage changes or loading will not be compensated quickly. So C2 is shunted round this high value resistor so fast load changes are reflected into the error amplifier TR1 promptly. 470pF / 1kV is typical for C2. Note the gain of TR1 compensates for the loss of sensitivity created in potential dividing the HV output - in fact the voltage gain, with a high value for Rb, more than compensates for the potential divider losses. Thus C1 is a loop compensation capacitor; it effectively adds to the Miller capacitance of TR1 to roll off the HF response and stabilise the control loop. Typical values are 47pF / 1kV ceramic, but it's not always necessary if TR1 and TR2 are low Ft rated devices - which HV power transistors commonly are. It's a balancing act: C2 feeds the fast changes to TR1; C1 slows TR1 down a touch.

Simple HV Regulator

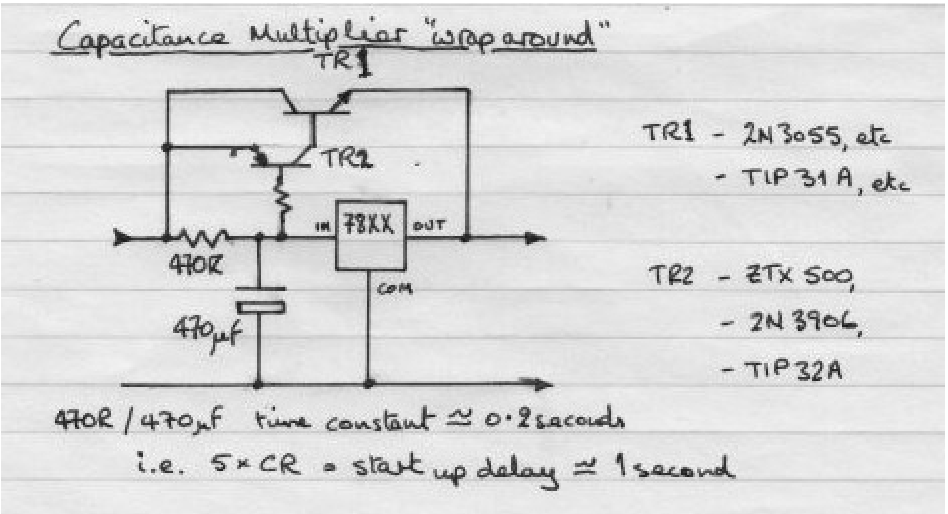
This circuit will give good results too, so long as you keep current demand low; and that goes for sinking current too - you need to scale resistor Rb appropriately. Diode D1, whilst looking somewhat redundant, is a safety measure, guarding against mains failure or upstream feed fuses blowing. The load may well have full charged HV electrolytics embedded: D1 shunts any back feeding voltage around TR1, preventing any damage to either junction. If you use a power MOSFET for TR1, you'll have the diode built in; it's part of the manufacturing process (though manufacturers will tell you it's an added feature...).



Capacitance multiplier & Sziklai complementary wrap around... two jobs in one

Most constructors consider integrated circuit voltage regulators (78XX types typically) as being a sort of electronic “guillotine”, in that they chop off the awkward bit at the top: if your DC feed to the regulator has ripple or noise, then a voltage regulator will surely “chop it off”, yes? Well, I hate to tell you... NO it won’t! The “Ripple Rejection” capabilities of most voltage regulators is not too good; sure they will cut it down, but certainly won’t yield that “flat as a millpond” DC level.

A way to get far better results from a simple 78XX regulator is to use a PNP / NPN wrap-around circuit detailed in previous Hot Iron #106, pp22, but add a *capacitance multiplier* to the input.



This circuit electronically “multiplies” a capacitor to be very much larger than the actual value: you don’t really get free µF’s, but the effect is the same. The diagram shows the added 470µF electrolytic, and the line resistor is a bit higher than you’d expect at 470 ohms; but this is how it works. You’ll see similar circuits in Direct Conversion receiver schematics, feeding the post mixer diplexer amplifier to guarantee low noise performance.

Basically, the base of a TR1 is slugged with a hefty electrolytic which means the emitter current is similarly slugged - but because the Hfe of TR1 multiplies the base current into the emitter - so the regulator and it’s wrap around are fed current derived from a very low frequency filter. With a 470 ohm sampling resistor and a 470 µF capacitor you have a time constant of ~ 0.2 seconds; resulting in a low pass frequency $\omega = 1/CR = 5$ rads/second, about 30Hz. Ripple from a full wave rectifier is 100Hz (in UK; 120Hz in USA) so the filter makes a good job of ripple reduction. The small resistor in TR1’s base is a 100 ohms or so; it’s a bit of protection for TR1’s base - emitter junction.

The only penalty is the start up time delay: you have to wait for the electrolytic capacitor to charge on power up. You could make the capacitor 1000 µF, the sampling resistor 1k, but you’d be waiting a while for the supply to run up: use 5 x CR as an estimate for start up time. As ever, it’s a trade off!

Compliance: constant amps and infinity gain amplifiers

Consider a power supply on your bench. You are wanting to pass a constant *current* through a load (maybe a NiCd battery to be charged; or a high power laser LED for that optical comms project) and you need a simple design. You look at some circuits for constant current generators, utilising maybe a 78XX regulator or a transistor or three, and you keep seeing the term "compliance". Just what is this "compliance"? Well, consider the following:

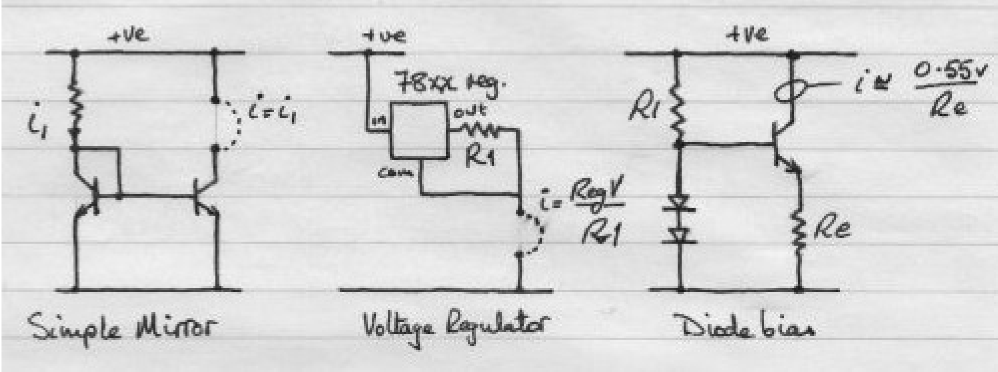
Supposing you want a fixed current of 1 Amp to flow in ANY load resistance you connect into your circuit - be it 1 ohm, 10 ohms, 100 ohms, whatever - the voltage across each of these loads would therefore be 1 volt, 10 volts, 100 volts. So for your circuit to work, assuming it needs a few volts extra to bias everything and run the clever bits, for the above you'd need a supply feeding your constant current generator of well over 100 volts. The "compliance" is the maximum voltage available to drive 1 Amp through any load: if the constant current generator is designed to drive 1 Amp, and has "compliance" of 100 volts, you can only connect a load up to 100 ohms, before the constant current generator "runs out of headroom" and doesn't have enough volts to drive 1 Amp through any load greater than 100 ohms.

All this leads to some strange territory for the circuit designer. As a theoretical example (not that I'd suggest you try this - but, if you must - on your own head be it...!) let's consider a 1kV DC power supply, with it's positive output feeding a load via a series connected 1 M-ohm resistor. If the load end of the 1 M-ohm resistor is shorted to the negative terminal of the power supply, the current flowing = 1 mA. Now, insert in series with the 1 M-ohm resistor a 1 k-ohm load resistor. The current will be 0.999 mA, near as makes no difference to 1 mA. Now remove the 1 k-ohm and replace it with a 10 k-ohm resistor in series with the 1 M-ohm: the current will be 0.9901 mA - still very close to 1 mA. Replace the 10 k-ohm with a 100 k-ohm, and the current is 0.909 mA, still not too far from 1 mA.

Now we shift up a gear, replace the 1 kV supply with a 10 kV supply; and replace the 1 M-ohm resistor with a 10 M-ohm, and repeat the previous test: with a 1 k-ohm in series with the 10 M-ohm, the current is 0.999900009 mA. Replace the 1 k-ohm with a 10 k-ohm current = 0.999000999mA; now the 100 k-ohm: current = 0. 99009901mA.

We therefore conclude that the higher the SOURCE RESISTANCE the more accurate is the circuit behaving as a CONSTANT CURRENT generator.

Not everybody has 10 kV power packs to play with, nor would relish working with source resistances of 10's of M-ohms; so we use semiconductors to simulate an infinite resistance, and create our constant current sources with them.



These are easily constructed constant current generators that are reliable and easy to set up or adjust - and, incredibly, within reasonable operating parameters, exhibit almost INFINITE source resistance, as the current is very nearly constant for any load - keeping ‘compliance’ in mind. So, let’s use this feature to make a very high gain amplifier, that can drive real loads.

Recall that as a rough approximation, the voltage gain of a bipolar transistor amplifier is proportional to the (hfe) x (collector load resistance). If the load resistance is INFINITY the voltage gain is also INFINITY! If we make the collector load a constant current generator, this simulates an INFINITE resistance and the gain is - well, so high, instability is almost guaranteed - unless the amplifier has lashings of negative feedback and sufficient roll-off to get the gain / phase inside the Nyquist -1,180° locus point.

You can see current mirror constant current generators in op-amp amplifiers at:
https://www.me.psu.edu/cimbala/me345/Lectures/Inside_the_741_Op_Amp.pdf

you’ll see “Current Mirror” constant current circuitry coloured red, acting as infinite impedance loads in the transistor collectors for input pins 2 and 3. The article describes the current mirror action far better than I can - but suffice to say that changing the bias on one transistor in a mirror causes an identical change in the other. These are precision constant current sources; for “odd job” roles like battery charging, and the like, a simple transistor or 78XX regulator will do the job nicely, and deliver a hefty current too.

The only downside to using a 78XX regulator as a constant current generator is the loss of compliance; a mirror or diode bias circuit has compliance equal to the supply voltage less collector to emitter volt drop - about 0.2 volts or so for a saturated silicon transistor. If you experiment with a mirror made from two discrete transistors, it’s a good idea to clamp the two devices together so they are thermally bonded; the current will track far more accurately in the mirror “halves”.

All these circuits can be “inverted” if you wish: simply replace all transistors with PNP types. If you prefer a voltage regulator circuit, exchange the 78XX positive type for a 79XX type.

Components...

Valve / Tube chassis holes...

I measured the bases I have and these are the sizes. No doubt there are dimension drawings and preferred hole sizes on the web somewhere; I'm happy with those listed below most of the time - but I have a dandy half round file in my tool kit, just in case.

The one thing I miss in my home building stocks are the once-common Octal plugs, which were a rugged, robust, reliable and cheap means of making power supply and module interconnecting cables. I uses DIN audio types nowadays, but they aren't a patch on the old Octal beasties.

Valve / Tube base	Hole diameter	Preferred metric size
B7G	15mm (½")	15mm
B9A	19mm (¾")	19mm
International Octal	28.3mm or 1⅛" *	29mm**

* Note: 5U4G (and many other) rectifiers fit "International Octal" sockets, but often, not all pins are implemented; the valve / tube is orientated correctly by the key on the octal base spigot.

** If you can find one on your locale, that is. I found one in the UK at:

https://www.toolstoday.co.uk/q-max-sheet-metal-punches-metric

...but for our non-UK readers it might be a bit of a tussle - but then again, you'll likely have the Imperial sizes available? Octal and other valve bases were specified in "feet and inches", so those of you fortunate enough not to have to deal with Metrication have a flying start.

Octal socket holes are "usually" 1⅛" diameter; but beware, some ceramic holders may need different sizes, to accommodate clamp rings and mounts.

Class X and Class Y capacitors... another aspect

I had some emails asking for clarification of "X" & "Y" class capacitor failure mechanisms; so from:

https://www.allaboutcircuits.com/technical-articles/safety-capacitor-class-x-and-class-y-capacitors/

below is an excerpt that will help clarify. In simple terms, a class X capacitor will fail SHORT CIRCUIT as it's meant to be connected line-to-line; the short will quickly blow the upstream fuses and clear the circuit. A class Y capacitor will fail OPEN CIRCUIT, as it's meant to be connected line-to-earth - which, if it failed short circuit, could make the earthed metal of a machine, tool, or equipment assume a high, possibly lethal, potential if the earth loop impedance is more than a few ohms. The passage below will explain better than I can:

"*Applications for Class-X and Class-Y Capacitors*

Subclass X2 and Y2 are the most commonly used safety-certified capacitors. Depending upon your own application and requirements, they are probably the ones you'll want to use. This is assumed because X2 and Y2 safety capacitors are used in common appliances that operate from ordinary household wall outlets. ***To be clear, you should select your Class-X and Class-Y capacitors according to your design's purpose and requirements.***

Whereas X2 and Y2 caps are appropriate for household applications, X1 and Y1 safety capacitors are used in industrial settings. As an example, a subclass X1 safety capacitor would be used for an industrial lighting ballast that is connected to a 3-phase line.

Of course, you could always use subclass X1 and Y1 in non-industrial applications, but you'll be spending more money and the larger sizes may prove inconvenient.

You might be asking, are X2 and Y2 safety capacitors interchangeable?

A Y2 capacitor can safely be used in place of an X2 capacitor, but an X2 capacitor should not be used in place of a Y2 capacitor. This is because, although an X2-type capacitor would work and filter noise sufficiently, it would not meet the line-to-ground safety standards. Y2 safety capacitors are more robust, are able to withstand higher peak impulse voltages, and are designed to fail ***open circuit*** *as opposed to failing short circuit.*

There are also safety caps that combine aspects of X and Y types, such that they have met both X and Y safety requirements and standards. So for an X1/Y1 combination, this simply means that the capacitor can be used either as an X1 capacitor in a line-to-line application or as a Y1 capacitor in a line-to-ground application. Examples include the following:

- *Vishay (PDF) offers their VY2 Class X1 (440 VAC) / Class Y2 (300 VAC) capacitor.*
- *Kemet (PDF) offers both X1/Y1 and X1/Y2 class combinations.*”

These capacitors are often seen in synchronous motor starters to give a phase shift voltage to a start winding. They can be very useful too as surge limiters in place of power resistors in HV power supplies, as described in Hot Iron #101, pp24; use class Y, to “fail open circuit” for safety.

Test Gear

Using a digital multimeter

For those who only have a digital multi-meter, rather than the much more friendly analogue instrument, trying to “peak” a circuit or tune an antenna you need to “de-jitter” those dancing digits with a simple low pass filter. LPF’s are especially useful (unlike those useless Digital bar-graph readouts) in circumstances where the readings are never *quite* settled.

Recall the input impedance of a digital multi-meter is often 10 meg-ohms or more - so the inclusion of a 10k - 100k ⅛watt series resistor in the positive lead, won’t make a ha’porth of difference; and a 100nF to 1µF HV capacitor to the negative lead completes the set-up. TV repair men in the halcyon CRT and PL504 “fizzing” pentode days had this little circuit built up on a bit of scrap PCB material, or perspex offcut, with 4mm plugs set 20 mm (¾”) apart to plug directly into their “digital dancer” -

thus removing the 15.625kHz line timebase crashing hash when peaking up a stage. I used 4mm brass nuts and bolts, 25mm long with solder tags to mount the resistor and capacitor rather than specific 4mm plugs; the current is very low so the threaded sections don't cause any trouble.

The inclusion of a small neon bulb across the disc ceramic also protects your nosebleed expensive Fluke or HP digital Wonder Wobbler (other makes are available) from the hefty ZAPP! from an inadvertent touch on a 2kV B++ line. Yes, I know digital multimeters are *supposed* to be protected, but....! The ⅛ watt series resistor doubles as low pass filter and safety fuse in the event of a misplaced "prod".

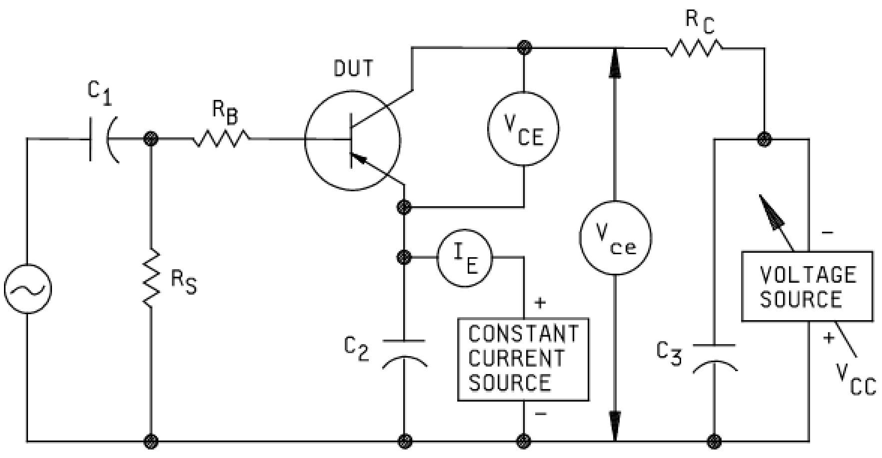
Measuring transistor ft (2)

I have had a few emails about my commenting on the method I used in Semiconductor Manufacturing for measuring Ft using the voltage gain and frequency method, outlined in the last Hot Iron. Of course, it IS possible to measure Ft via S parameters, network analysers and suchlike esoteric beasties: but when you've 7.5 million to test every 24 / 7 / 365, with fractions of a penny profit* on each device, time is of the essence; as is robust, rugged and reliable (simple and cheap!) test gear. Anything otherwise increases equipment set-up times, maintenance and operator fatigue which loses all the profit from the job. Of course, amateurs aren't concerned with this production trivia, but **are** concerned with paying no more than absolutely necessary for a 2N3904. It's canny production and test engineering why you pay only pennies for a 2N3904! Somebody in a factory somewhere has to make these little beggars and test them by the million to be certain you get exactly what you pay for.

* If you're lucky...

Below is an extract from the MIL-SPEC Transistor Test directory:

2. Test circuit. The circuit shown on figure 3306–1) and procedure in 3 are for common emitter configuration. For other parameters the circuit and procedure should be changed accordingly.



NOTE: The biasing circuit shown is for purpose of illustration only. Other stable biasing circuits may be used.

FIGURE 3306–1. Test circuit for small-signal, short-circuit forward-current transfer ratio.

3. Procedure. Capacitors C_1, C_2, and C_3 shall present short-circuits in order to effectively couple and bypass the test signal at the frequency of measurement. The value of R_B shall be sufficiently large to provide a constant current source. Resistor R_C shall be a short-circuit compared to the output impedance of the device. With the device removed from the circuit, a shorting link is placed between the base and collector and the output voltage of the signal generator is adjusted until a reading of one (in arbitrary units) is obtained on the high-impedance ac voltmeter, Vce. With the device in the circuit and biased as specified, the reading on voltmeter V_{CE} is now equal to the magnitude of (h_{fe}). (NOTE: Care must be taken to assure that the output signal is not clipped.)

HV diodes cheap!

https://www.ebay.co.uk/itm/5Pcs-CL01-12-Microwave-Oven-Induction-Cooker-High-Voltage-Diode-Rectifier-P-lq/123960643597?hash=item1cdca1500d:g:hfwAAOSw0GNbCMpP

These “diodes” are, in fact, stacks of silicon diodes - just the silicon dies, no wires or casings - electrically and mechanically bonded together in a series string. They are very conservatively rated in voltage terms; a typical domestic microwave oven transformer giving 1500 - 2500 volts AC on the secondary, and the silicon diode / capacitor network forming a voltage doubler using the magnetron as the second diode in a conventional doubler circuit makes about 5kV, but this doesn’t take in account the mismatch the magnetron faces with varying loads in the oven chamber; the HT can rise to very much more that 5kV sometimes.

As amateurs, if we need some hefty B++ volts for our 4CX250B linear, we’ll probably build our own series strings of 1N4007 diodes: in which case we can add 10M HV resistors and a 10nF HV disc ceramic capacitor in parallel with each 1N4007 to act as RF decouplers and voltage equalising resistors. If space is tight, however, CL01-12 diodes yield a big space saving - but keep in mind you can’t fit those (sometimes vital) parallel 10M //10nF, but **can** use strings of kV rated ceramic capacitors in parallel with CL01-12 diodes to shunt any RF.

R & D Dept.

This section is included as I’m still in mid house move and have no bench facilities to try anything or build test circuits. COVID-19 has kyboshed a lot of other activities, so I’ve listed a few of the thoughts that swill around the darker areas of my imagination for those more fortunate than I, who are not in the midst of the seething inactivity lawyers engage in regarding house sales - to have a go at and see if anything of interest emerges. I’d be most grateful if you have any ideas about these odd corners of amateur RF for inclusion in the next Hot Iron - no matter how “off the wall”, they might just have that touch of genius that moves our technology forward.

Compulsory Safety Note: *all that follows in this section of Hot Iron is EXPERIMENTAL. It’s not proven or assured designs or techniques! Enjoy experimenting, it’s great fun, but I’m not responsible in any way, shape or form for the bangs, whistles, burnt fingers or smoke that can (and probably will) occur if you push the boundaries of sensibility too far in a blasé fashion!*

In my semiconductor manufacturing days, “R&D” was that mysterious department behind the painted out windows where mysterious BANGS, occasional smoke and strange sizzling noises emanated. To that end, this section is presented with the philosophy “try it; never mind what the theory says”.

If you recall the theory that bumble bees shouldn’t fly, it dates back to the 1930s, when the French entomologist, August Magnan, stated that because of the haphazard way their wings flapped around they couldn’t possibly fly. The bees, however, not having known August Magnan’s theories, just flapped their wings, and fly they did. Just because it isn’t mainstream design and accepted principles, it doesn’t mean that it’s pointless. You might just discover “the next big thing” in your experiments - now that’s REAL amateur radio.

So, out with your soldering irons and junque boxes, and have at it with a will! Please let me know if you find any anomalies, mysterious behaviour and other “interesting” effects. I’ll very gladly publish your results!

- DC bias on Ceramic Resonators for accurate but small shift frequency shift keying / data modes
- Ditto on quartz crystals
- Ditto on ceramic capacitors
- Tx / Rx switching using pencil (“Sputnik”) tubes; switch the filaments on / off for easy and total isolation, they heat up in a second. Or using them as series / shunt switches?
- Crystal / ceramic resonators - limiting the dissipation by fitting the ceramic resonator between base and collector of a transistor with a 10M-ohm resistor in parallel and using the collector and emitter as the resonator’s “terminals” for valve or HV solid state roles

- 4 x crystal Colpitts a-la Peter Parker's VK3YE ideas... more than 4 = bigger stable frequency swings?
- If super vxco Ceramic Resonators / crystals are of different frequencies, what output frequency do you get?

Test Gear / Maintenance

Simplest ESR tester for electrolytics

Equivalent Series Resistance is a measure of the current capability and life left in an capacitor, oiled paper, ceramic, or electrolytic and is a "go-to" wonder for the service technician. You can buy hand held gizmos to do this... but we prefer to make our own from junque!

https://www.homemade-circuits.com/esr-meter-circuit/

I don't think I've seen a simpler method? Much to recommend it for high ripple rated power supply electrolytics removed from circuit for testing, but watch back-biasing electrolytics. I think I'd drop the transformer secondary to 3 volts or so to reduce the back stress on the electrolytic.

OR... https://ludens.cl/Electron/esr/esr.html which is an in-circuit tester using only a few hundred mV of drive applied to the capacitor. This is almost THE standard for bench ESR testing; most of the small gadget gizmos use this approach.

Oscillators...

The Resistance Stabilised Oscillator

Whilst this oscillator is commonly used for Audio and LF duty, there is no reason why the principle cannot be extended to crystal or ceramic resonator circuits; nor limited to valve technology. A jfet (with a gate diode for the "grid current" circuit) or indeed a bootstrapped bipolar gain stage (with a similar diode clamp) would most likely work equally well.

From: https://www.radiomuseum.org/forum/klirrarmer_oszillator.html

The resistance-stabilized oscillator is widely used for the generation of audio and low radio frequencies. Typical circuit arrangements are shown in Fig. 147 [Fig. 12-7 from 2nd ed.] and are seen to be conventional oscillator circuits with the addition of a "feed-back" resistance located between the plate of the oscillator tube and the tuned circuit.

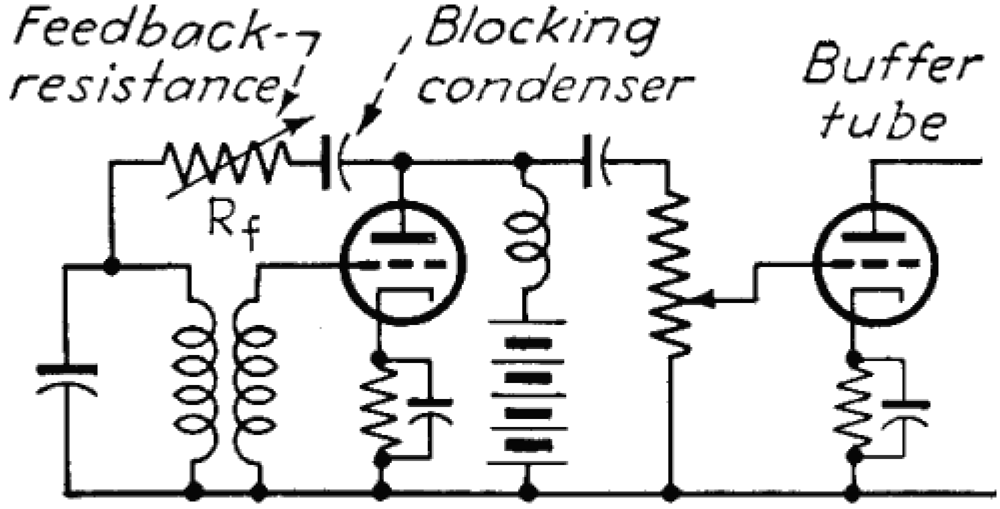


Fig. 12-7. Typical circuit diagram of resistance-stabilized oscillator.

This feed-back resistance must be high compared with the plate resistance of the tube and has two primary functions. First, it makes the resistance which the tuned circuit sees when looking toward the plate substantially independent of the electrode voltages; and, second, it provides a means for limiting the amplitude of oscillations to the straight line part of the tube characteristic.

The tube in a resistance-stabilized oscillator is adjusted to operate as a Class A amplifier, and the feed-back resistance is made so high that oscillations are just barely able to start. Under these conditions, oscillations start with minute amplitude and build up until there is grid current, which introduces additional losses that increase rapidly with further increase in amplitude. If the feed-back resistance is so high that oscillations are barely able to exist with no grid loss, an equilibrium will be reached at an amplitude which drives the grid only a few volts positive. It will be noted that a fixed grid bias such as obtained from a biasing resistance is necessary, and that the grid-leak bias arrangement commonly used with power oscillators is not permissible.

The wave form is determined by the linearity of the tube's dynamic characteristic over the range of voltage which the oscillations apply to the grid. It is apparent that for good wave form the tube when considered as an amplifier must be so adjusted that it will amplify without distortion an alternating-current voltage on the grid having a crest value slightly greater than the grid bias. This means that the oscillator tube should be operated at a grid bias that is slightly less than the bias that would be used for Class A amplifier operation at the same plate voltage.

Best results are obtained when attention is paid to certain circuit details. The circuit proportions should be such that the feed-back resistance required is at least twice, and preferably over five times, the plate resistance. The blocking condenser in series with the feed-back resistance must have a low reactance compared with this resistance in order to avoid phase shifts, while the shunt-feed choke should have a reactance that is high compared with the plate resistance of the tube for the same reason. The frequency stability is also helped greatly by making the coupling between plate and grid coils as close as possible. Two possible methods of connecting a buffer tube are shown in Fig. 148. The arrangement at Fig. 148a is usually preferred because it gives the best wave form, although the circuit of Fig. 148b has the advantage of developing greater output voltage.

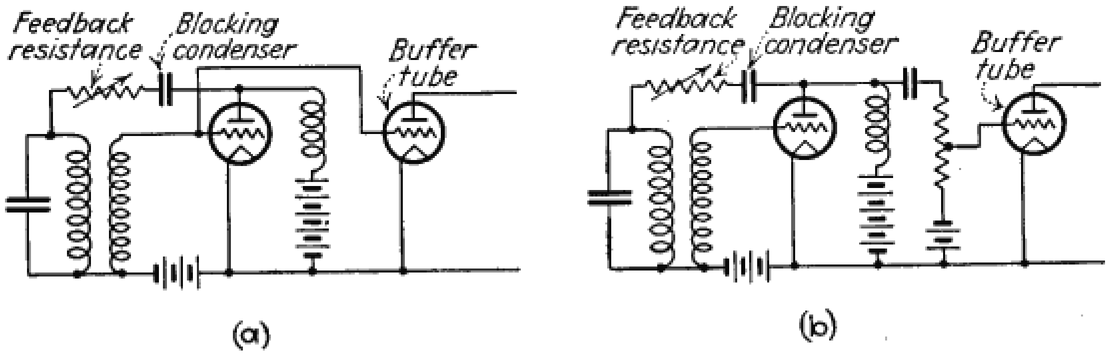


FIG. 148.—Methods of coupling a buffer tube to a resistance-stabilized oscillator.

The most satisfactory tubes for resistance-stabilized oscillators are those having amplification factors in the range of 4.5 to 8, together with the highest possible mutual conductance. With such tubes, the grid and plate coils should have approximately unity turn ratio.

Design of Resistance-stabilized Oscillators

When the characteristics of the resonant circuit are known, it is possible to lay out a resistance stabilized oscillator on paper and predict accurately the amplitude of oscillations and the circuit conditions required for proper operation. For example, assume that it is desired to set up an oscillator employing a tuned circuit that develops a parallel-resonant impedance between plate and filament taps of 50,000 ohms. Assume further that the ratio between plate and grid coils is 1 to 1, that a Type 89 tube operated as a Class A triode amplifier is to be employed, and that an amplitude of oscillations of 10 volts crest is desired. The first step is to select a grid bias that will be 2 to 3 volts less than the crest amplitude, so that 7.5 volts bias will be satisfactory. The plate voltage is now chosen so that the operating region is located on a straight-line part of the tube characteristic. This calls for the highest plate voltage that will not give excessive plate current with the grid bias, which for this case is about 110 volts.

The feed-back resistance that will just barely enable oscillations to start has a value such that, when 1 volt is applied to the grid of the tube, exactly 1 volt will be developed across the tuned circuit by amplifier operation. If the impedance of the shunt-feed choke is very high compared with the plate resistance of the tube, the feed-back resistance at which oscillations will just start is given by the formula

Starting feed-back resistance = $R_L(\mu - 1) - R_p$

where R_p is the plate resistance of the tube, R_L the load resistance offered by the tuned circuit, and μ the amplification factor of the tube. In the case at hand $R_L = 50{,}000\ \Omega$, while reference to a tube chart shows $\mu = 4.7$ and $R_p = 3000\ \Omega$. The critical feed-back resistance hence works out to be

182,000 ohms, and the value actually employed should be 5 to 15 per cent less, or roughly 165,000 ohms. In practice the resistance is usually adjusted experimentally by setting it at a value about 10 per cent less than that at which oscillations start, but calculations such as have been outlined are of considerable aid in establishing the limiting values that will be needed.

From Eq. (59) it will be noted that the feed-back resistance that is required will be nearly proportional to the tuned-circuit resistance RL, and this fixes limits to the allowable L/C ratio in the tuned circuit since RL is proportional to sqrt(L/C) when the circuit Q is constant. It is undesirable to use feed-back resistances higher than about 500,000 ohms at audio frequencies, and higher than 50,000 to 100,000 ohms at the lower radio frequencies. At the same time, the L/C ratio must not be too low, since it is desirable that the feed-back resistance be at least twice, and preferably over five times, the plate resistance of the tube. The most suitable values of tuned-circuit resistance are in the range 10,000 to 50,000 ohms.

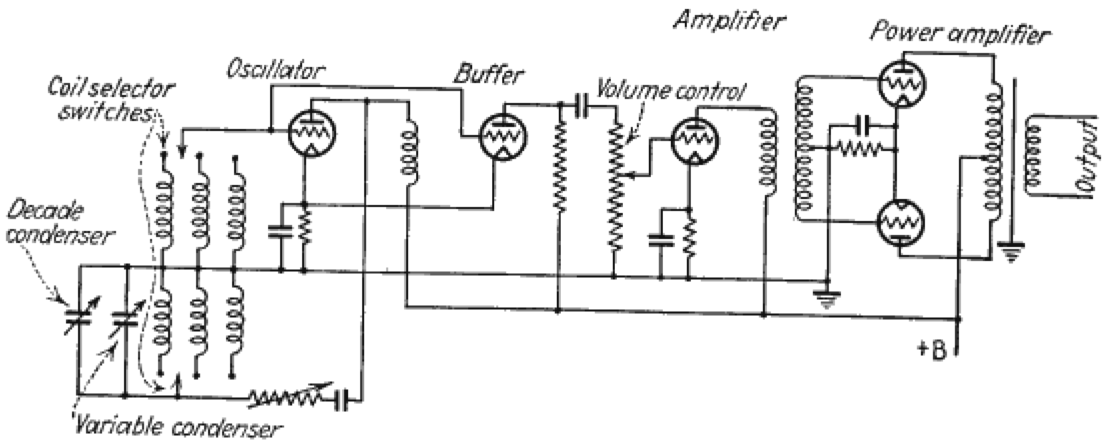


FIG. 149.—Circuit diagram of typical resistance-stabilized oscillator for covering the audio-frequency range.

A complete circuit diagram of a resistance-stabilized oscillator for generating audio and carrier frequencies to be used in laboratory measurements is shown in Fig. 149. Continuous variation of frequency is obtainable by using a continuously variable tuning condenser consisting of a decade condenser supplemented by a variable air condenser to interpolate between the smallest steps, together with provision for switching various coils in and out of the circuit. The feedback resistance can be a tapped or adjustable commercial wire-wound resistance arranged with a tap switch so that the feed-back resistance can be varied in increments of about 10 per cent. The proper setting of the feedback resistance will depend upon the frequency and can be given on the frequency-calibration chart.

The resistance-stabilized oscillator is the most satisfactory type of tuned circuit oscillator available for generating audio frequencies in the laboratory. The amplitude of oscillations is constant over the entire frequency band (assuming the feed-back resistance is readjusted as necessary), the wave form is practically perfect except for distortion that may be introduced by the output amplifier, and the frequency is practically independent of tube voltages and tube replacements. Resistance-stabilized oscillators are also simple to build and easy to adjust. They are used primarily for audio and carrier frequencies and can be employed up to 100 to 200 kc. At frequencies higher than this, stray capacities tend to by-pass the feed-back resistance and thereby nullify the advantages of the circuit.

“Pulling” and “Pushing” Crystal oscillators

Whilst most of us have probably heard of adjusting the frequency of a crystal oscillator - oft referred to as “pulling” the frequency - there are techniques not often mentioned in literature that can help us build an effective “VXO”, namely “**pulling**” a crystal oscillator (NOT tweaking the crystal with a series capacitor or inductor combination) or “**pushing**” a crystal oscillator. What’s all this about, and is it any use for amateur service?

Well, from https://www.w4npn.net/wp-content/uploads/2020/01/Pushing-and-Pulling.pdf, you’ll find Pushing and Pulling crystal oscillators described in depth!

“Pulling” the oscillator is the amount the frequency shifts according to the load presented to the oscillator; a slugging resistor to alter the load is a way to do this, but to be honest I’ve never come across this technique in my working (or amateur) life. The point is though, it should be a way to shift the crystal oscillator’s frequency in a controlled manner.

“Pushing” by oscillator supply voltage control is a technique I have seen used in film thickness monitoring in high vacuum metal evaporators and sputterers, used to create metal interconnects on silicon (and other) semiconductor materials. It enables frequency control without adding L or C in the crystal circuit.

To “push” a crystal oscillator the supply voltage is varied - a variable voltage regulator is ideal. Please note, however, the amount and direction depends on the oscillator configuration; but keep it in mind as an extra tweak to get that few kHz from a “conventionally” shifted L/C VXO that can’t quite get you to the “sweet spot”.

Receiver Topics...

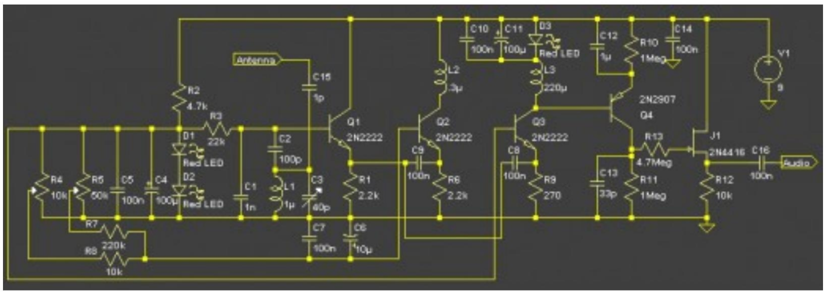
A Regenerative receiver that does not “block” on strong signals

I have often wondered if the gain compression ability of a long-tail pair connection (a differential amplifier) could be used to create a regenerative receiver that, on receiving a strong signal, didn’t block: the higher the input signal, the lower the gain of a long-tail pair (it’s actually a shift in transconductance, but amounts to the same thing). I have reproduced some pages with my grateful thanks below so you can see what all this is about.

from https://hubpages.com/technology/The-TriStar-Regenerative-Receiver

As a further evolution of the differential regenerative receiver the TriStar design improves a number of issues. Careful consideration and testing points toward using a high impedance AM detector and asymmetrical collector currents for better stability and control.

The TriStar circuit



The TriStar regenerative receiver circuit.

Circuit description

L1, C2 and C3 are the main frequency determining components in the circuit. The ratio of C1 to C2 is important as it creates an impedance transformation from the high impedance resonant circuit to the relatively low input impedance of Q1. The 10 to 1 ratio is enough to prevent damping of the resonant circuit and provide maximum selectivity. You can alter the values of L1 and C3 to change the frequency range of the receiver. The transistor Q1 works in differential mode versus both Q2 and Q3. When the collector current of Q1 is increasing the collector currents of both Q2 and Q3 are decreasing. When the collector current of Q1 is decreasing the collector currents of both Q2 and Q3 are increasing. Also the emitters of both Q2 and Q3 present a low impedance (of a few ohms) to the emitter of Q1 via both C8 and C9.

This allows Q1 to have much higher gain that if it was working through the emitter resistor R1 alone. In fact the low impedance created is not exactly constant with signal level giving the circuit a compressive open loop gain characteristic. This is vital to smooth control of regeneration. In particular the asymmetry in the collector currents of Q1 and Q3 allows for very smooth control of regeneration and helps stabilize the circuit greatly. L2 is the so called tickler coil which provides positive feedback (regeneration) when wound on the same former as L1. If L2 is connected the wrong way around it will instead cause negative feedback and the radio will not work. The exact number of turns required for L2 is best determined by experimentation. The higher tap ratio makes the circuit more linear. This narrows the the transition zone between the non-oscillating and oscillating state making the circuit more sensitive to supply line noise and stray pickup of hum etc.

Conclusion

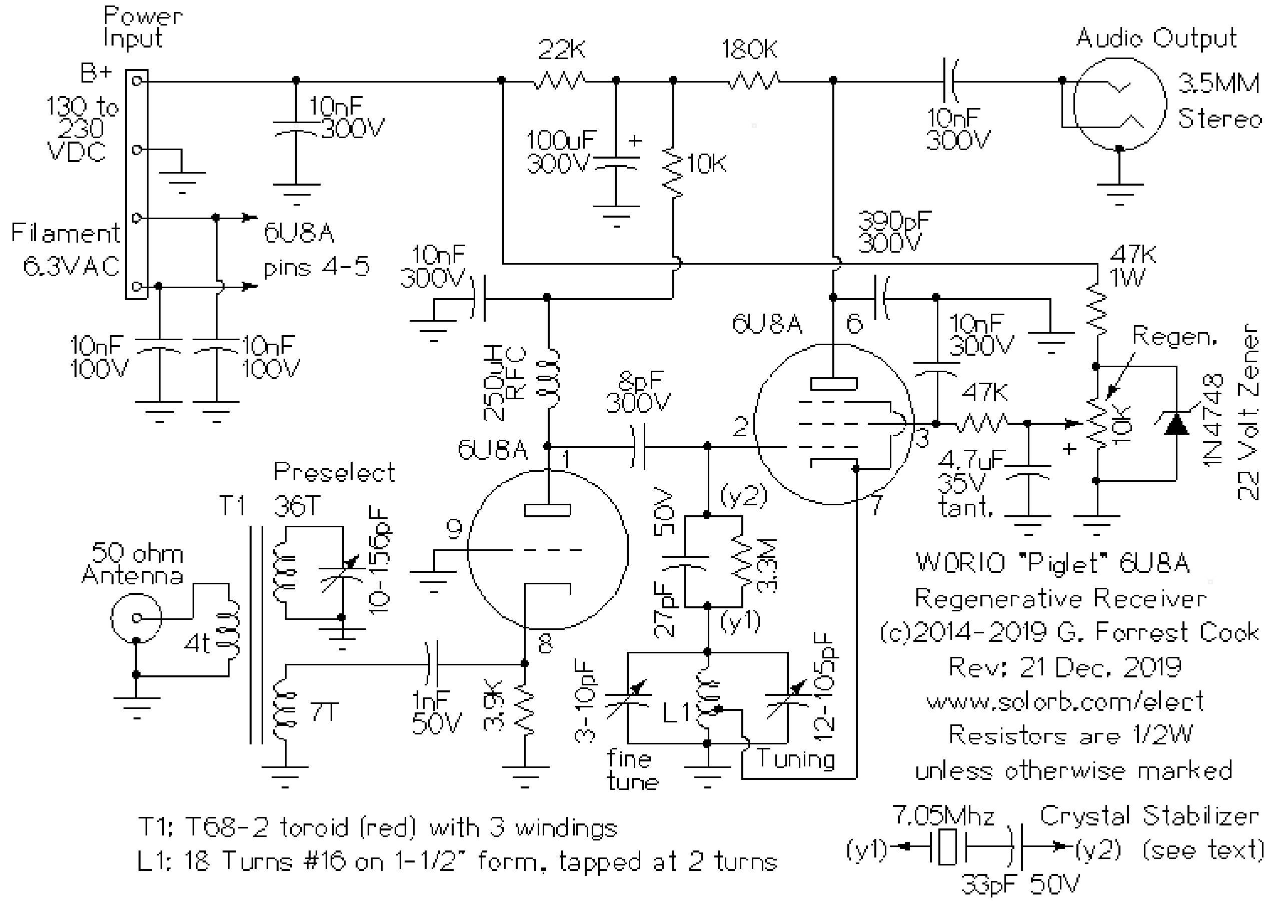
The further refinements in circuit design and component values continues to provide marked improvements in the performance and stability of the differential regenerative receiver. Hopefully you will find this circuit useful and a good basis for both experimentation and creating practical radio receivers.

The Piglet - a superb (and simple) receiver

Probably the best “simple” regenerative receiver ever designed - my thanks to W0RIO, G. Forrest Cook for his permission to reproduce his article. It clearly illustrates the vastly simpler construction and excellent performance valves / tubes offer the amateur constructor.

The design shows how a crystal or ceramic resonator can be connected in parallel with the grid resistor / capacitor combination (see the points labelled Y1 and Y2 in the diagram): this gives crystal control of the receiver, a method reminiscent to the “Goyder Lock” technique, oft employed in early crystal controlled transmitters.

Schematic:



Note points y1 & y2, shunting the 27pF // 3.3Meg RC network for grid leak biasing. Forrest connects, in shunt, a crystal: and this becomes the defining “tuned circuit” for reception. The original L // C components are now effectively in series with the crystal, and “pull” the crystal for a slight amount. Those of you who have seen the “super VXO” principle - using several crystals of the same frequency in parallel - will be able to try such ideas in this circuit; as will those who favour ceramic resonators, which will yield much wider (but perhaps less stable?) frequency swings.

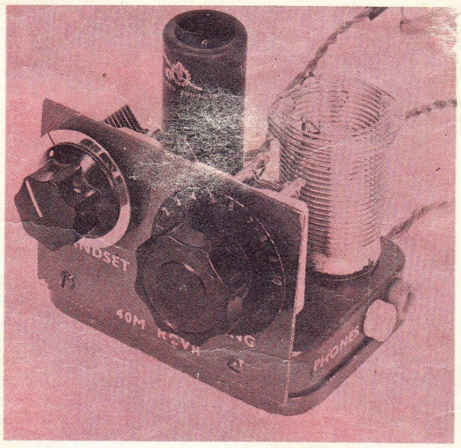
Some years ago I tried the “super VXO” idea with multiple ceramic resonators, and achieved enormous (in crystal frequency shift terms, that is) reasonably stable frequencies and this would make the Piglet a very potent receiver - especially so if it was the detector core of a “tunable IF” receiver, with a down converter(s) for the band(s) required. Choose an IF frequency using easily available and cheap ceramic resonators, for decent portions of any HF band and the frequency stability derived from the regulated screen supply would make the Piglet really shine.

The WeeCeiver - a hybrid design that has much to recommend it

I don’t know the original source of this dinky receiver, but if anybody can enlighten me I’d very much appreciate it! I like this design as it illustrates the simplicity of valve design for simple receivers, with a solid state “impedance transformer” to drive the ‘phones. I would guess that some high voltage NPN transistor(s) - MPSA42 and their like - would work very nicely in this position, and eliminate the need for a separate “audio” supply; low current high voltage mosfets could be used too. If two such devices were wired as a two stage audio feedback amplifier, you could drive (hi-Z) ‘phones (or an output transformer for a loudspeaker) quite nicely.

The design would transfer to “Sputnik” tubes easily I think, and yield a very neat, portable, yet rugged design if the tubes are mounted carefully - with the added plus of battery operation being very easily arranged with four PP9 batteries clipped together. An added RF stage would make for sensitivity and isolation - and yield opportunities for reflexing to squeeze the last drop out of the design.

I apologise for the image size and quality; images and text are not good bedfellows in my word processor! Use your “zoom” control to help.



Front view of the 40 meter QRP receiver shows the coil mounted on the stand-off insulator and the 3V4 to the left, under the shield. The bandset capacitor is on the left and the bandspread capacitor (two stator and one rotor plates) provides smooth tuning requiring no vernier dial. Phone jacks are on the side of the Sucrets chassis.

A 40 METER "WEE-CEIVER"

BY BYRON C. WEAVER,* WB2HAL

This 40 meter QRP receiver, the "Wee-Ceiver," is battery operated and built into a Sucrets box. It is a regenerative job that tunes from 5.5 to 12.5 mc and is ideal for Field Day or emergency work.

WAIT! Don't let my size and simplicity fool ya! I'll pull in a signal loud enough to make your eyes squint, tune 5.5 mc to 12.5 mc, operate over 100 hours continuous on inexpensive batteries, won't cost ya a fortune to build, and because of my size you'll want to take me with you on a field trip or just a picnic outing!

Having promised myself and others many times that I would write on some of my small projects, I've finally brought myself up to it. The receiver shown in the pictures is simple to construct, utilizes a Sucrets pill box for the chassis and is very comparable in signal reception to the "Novice Special" [1] without taking up the room, expense, or the current. Although primarily designed for 40 meters, it should not be difficult to change the coil for other bands.

The receiver performs extremely well even though no vernier dial is used and the

*15 Lake Ave., Hazlet, New Jersey 07730.

[1] Mix, D., "The Novice Special," *QST*, June 1956, p. 34.

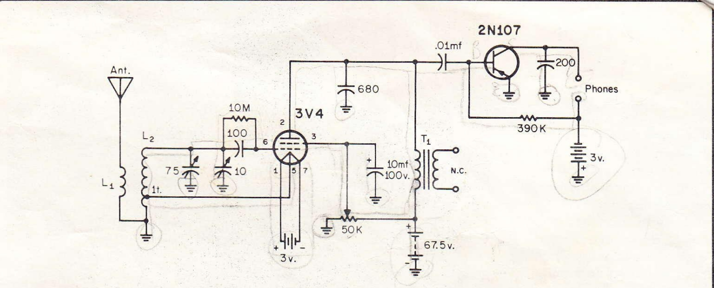
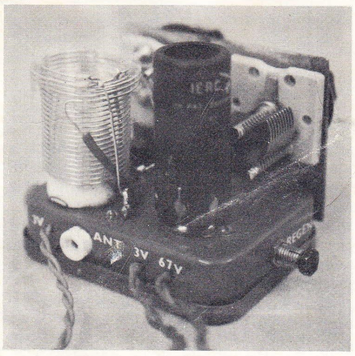


Fig. 1—Circuit of the QRP 40 meter receiver. Transformer T_1 is a miniature unit with a 15K primary (UTC 0-5 or equivalent). The coil construction is described in the text. All capacitors are in mmf unless otherwise noted and all resistors are ¼ watt.

antenna wire is only 18 feet long. There are no effects of hand capacity and the stability is very good if the antenna is unable to swing. Microphonics have not been noticed. There is ample room in the chassis so that with suitable parts even the beginner should encounter little or no difficulty in building the receiver.

Circuit

Looking at the schematic, a 3V4 is used as the regenerative detector because of its low current drain and power output capabilities. Two regular size flashlight batteries in series will heat it for well over 50 hours and by using four, and paralleling two, well over 100 hours continuous operation can be

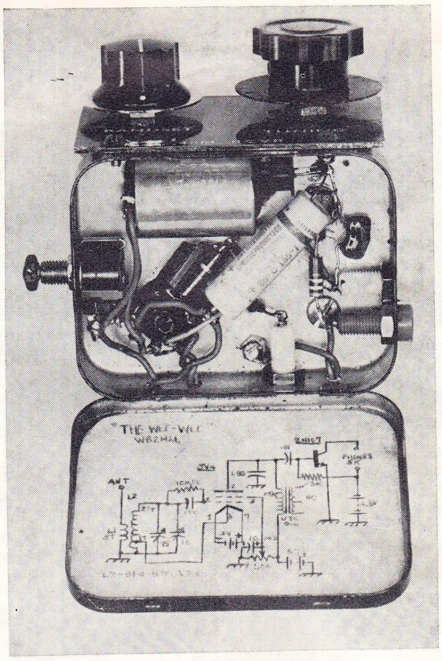


Rear view of the receiver.

expected. Burgess battery No. XX45 is used for the plate supply although any battery between 45 and 90 volts will work well. The tube draws only about 4 ma depending on the point of regeneration. A 2N107 is used as an audio amplifier and draws 0.5 ma from two flashlight batteries in series. A 4.5 volt battery has been used with the 2N107 with no appreciable gain in audio output. A battery pack can be made taping the batteries together which takes up a minimum amount of room.

Inductor L_2 is 22 turns of B&W coil stock #3015 (1" dia., 16 tpi). To make L_1, proceed as follows: Assuming you had a 3 inch length of coil to start with, strip off about 8 turns of wire from the left-over portion of the remaining coil stock after making L_2. Cut off the four plastic support strips you have just removed the wire from and glue them to L_2 as shown in the photographs. Next, straighten the wire that you have striped off the coil and rewind 3 turns on the glued strips of plastic, placing a coat of glue on top of the strips, after you have wound L_2, to hold it in place. Coils L_1 and L_2 are mounted on a stand off insulator but could be modified for plug-in coils if preferred. The tap for the cathode is one turn from the ground side (top in photo) of L_2. (The top of both coils are ground as shown in the photograph.)

The 75 mmf bandset capacitor was originally 100 mmf with several rotors and stators removed until it fitted in place without hitting the tube behind it. The tuning capacitor is only about 10 mmf (two



Bottom view of the receiver shows the regeneration control on the left and transformer T_1 up at the top. A spare transistor is taped to the end of T_1.

stators and a rotor) and spreads so well that no vernier drive is used. Small size components were used throughout.

A large value resistor (10 meg) is used in the grid for a noticeable increase in sensitivity. The signal handling capabilities for strong signals could be improved by a smaller value resistor but I am interested in receiving the weaker signals (QRP stations) anyway.

The transformer, in the plate circuit of the 3V4, was originally an 18K ohm resistor which worked fine but I decided to try the small transformer that I had in my junk box. This increased the output so much that I decided to mount the transformer underneath the chassis, cutting a hole large enough to permit it to protrude through the top of the chassis. This component is quite expensive ($6.50) but was given to me in some surplus equipment. It has a primary impedance of 15K, and therefore any small transformer or audio choke with a high audio reactance should work equally well. The secondary is not used.

Operation

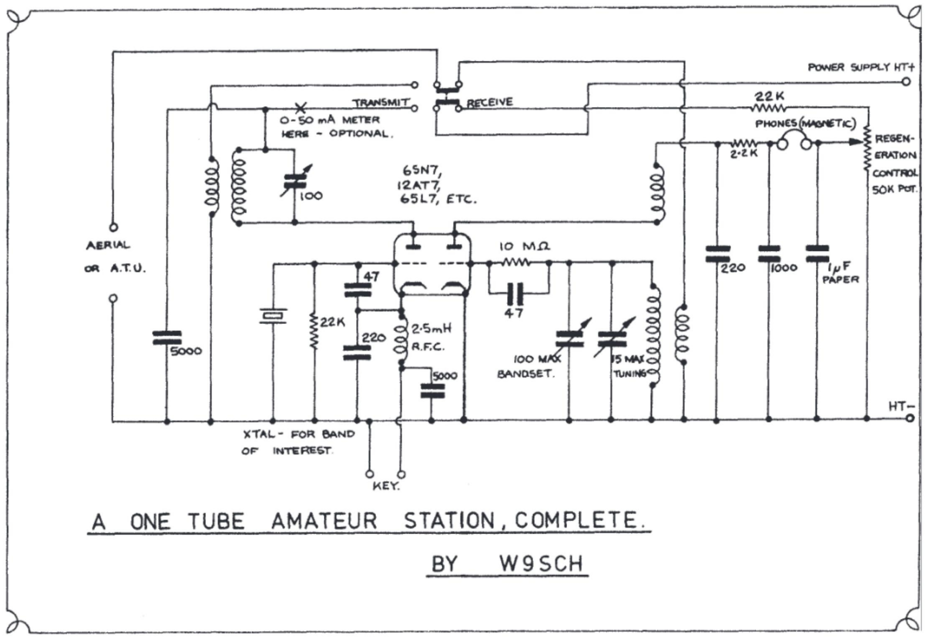
Any high impedance magnetic earphones may be used, the author using a pair with a 5K ohm impedance. An earth ground connection may be made at the negative side of the 67½ volt battery or to the positive side of the transistor battery. Small alligator clips are connected to all external leads for convenience in making connections. The other construction details can be seen in the photographs.

Needless to say, I am very satisfied with the receiver and it was well worth the time to build. It is also ideal for foreign broadcast reception (loud!), the traveling bag, or as a portable receiver for the home station. Although it appears a novelty, the Wee-Ceiver performance will definitely surprise you. ■

PLEASE USE YOUR ZIP CODE NUMBER ON ALL CORRESPONDENCE

One Valve Amateur Stations

These are presented as basic building blocks: the theme has been taken up using single transistor designs like the Pixie, OXO, and the like; but for my money the valve circuits, whilst needing a heftier power supply, are far better performers. Alternatively, try some Sputnik tubes: a really neat and miniature station could be built. Try some and see!



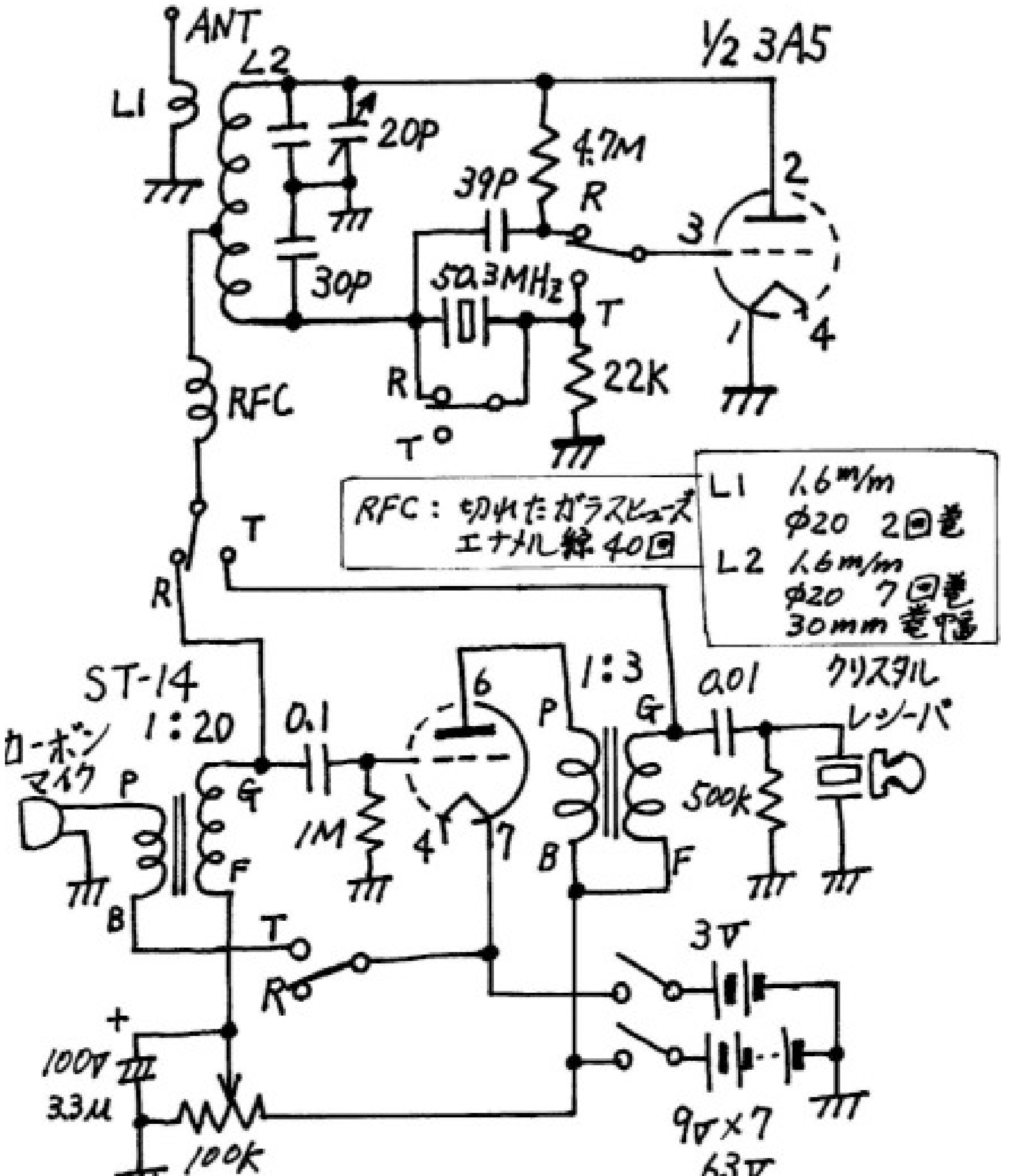
A ONE TUBE AMATEUR STATION, COMPLETE.

BY W9SCH

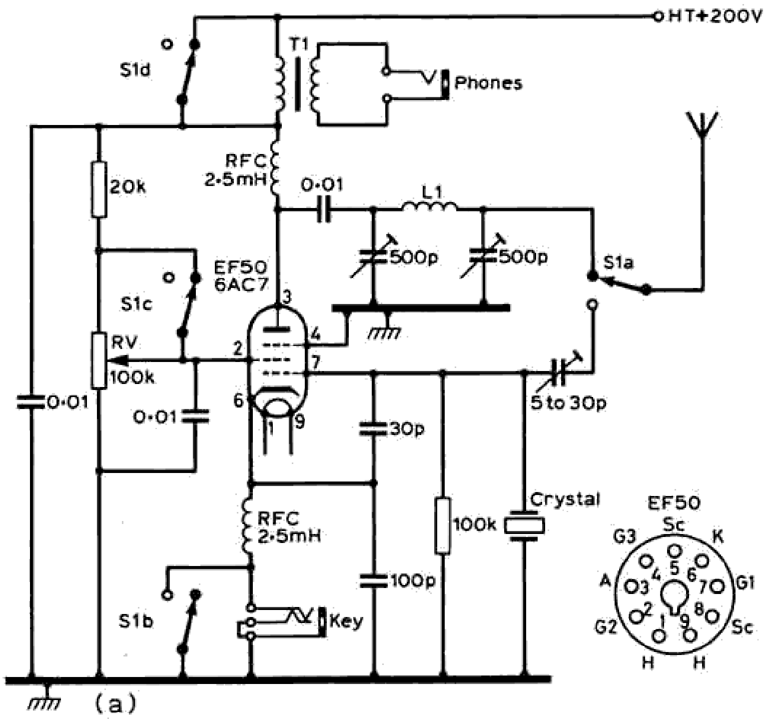
This circuit is from Chas. Rockey W9SCH and was published in SPRAT #7, the GQRP club's magazine with details of the coils and general construction. It's of more or less generic design; not too critical in any way, but, with good construction and high Q coils, will perform admirably.

Use a 12AT7, and adapt for HF / VHF band(s) of your choice in the A.M. slots. With a 12AT7 it is a very capable and reliable design; up the HT to 250v but watch that crystal current! A tiny "pee-wee" incandescent bulb (from an old Christmas tree light set perhaps?) in series with the crystal will indicate drive level and (to some extent) loading and tuning.

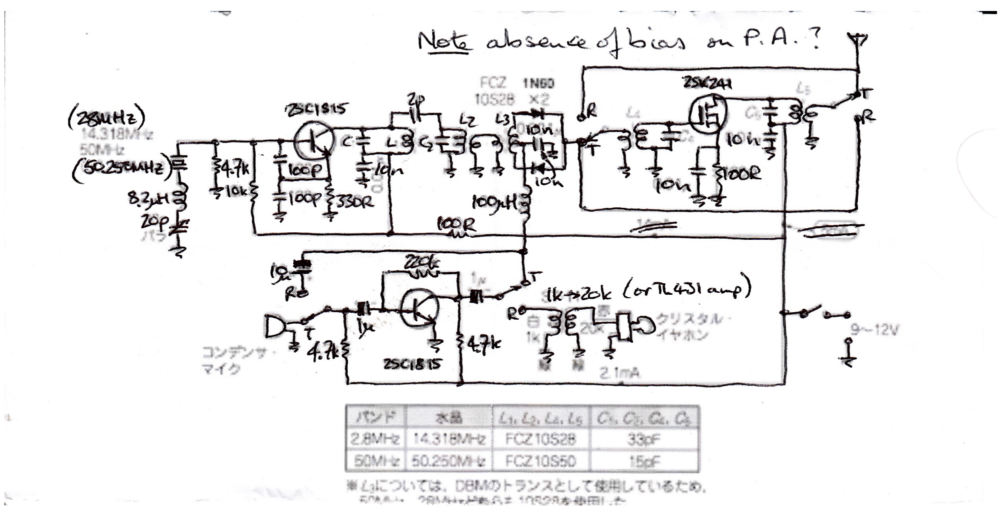
This next transceiver was shown in Hot Iron #107 as an indicator of bidirectional design; here it's shown to demonstrate simplicity. I'm not sure where the design comes from but suffice to say it is very reminiscent of the "walky-talky" mobile transceivers from WW2. It's a crystal oscillator / carbon microphone modulated transmitter and a super-regen receiver, and is typical of valve designs - simple & capable. You might consider a "solid state" replacement for a carbon mic, though.


ANT
L1
L2
20P
4.7M
1/2 3A5
39P
R
2
3
30P
50.3MHz
T
4
22K
RFC
RFC：切れたガラスヒューズ
エナメル線 40回
L1 1.6m/m
φ20 2回巻
L2 1.6m/m
φ20 7回巻
30mm 巻幅
ST-14
1:20
カーボンマイク
P
G
F
B
0.1
1M
6
4
7
1:3
0.01
クリスタルレシーバ
500k
3V
100V
3.3μ
100k
9V×7
63V

This is a design I saw in Pat Hawker's (G3VA) "Amateur Radio Techniques"; it will modulate very nicely with a carbon microphone (substitute circuit) in the "key" jack. Expect at least 3 watts out, it's a very reliable circuit. Any of the "EF" range of Octal or B9A pentodes will run sweetly in this circuit with a bit of tweaking.



To finish off, here is a design using (alright, I admit it - TWO devices) semiconductors; I've built it from junque - and it works just fine. From that Japanese marvel JF10ZL - his web pages are a veritable goldmine of elegant and simple RF technology - and please forgive my scribbled notes on the diagram! Substitute with transistors and mosfets you have to hand.



バンド	水晶	L1, L2, L4, L5	C1, C2, C4, C5
2.8MHz	14.318MHz	FCZ10S28	33pF
50MHz	50.250MHz	FCZ10S50	15pF

Antenna Topics

PA0RDT Mini-Whips and all that

An active receiving antenna can be a saviour in some circumstances. For those with extremely constrained areas for antennas, some form of "active antenna" for receiving can be the only hope. The well-known Mini-Whip, first shown by PA0RDT many years ago, is a reliable performer for reception, equalling or better than long wires - which, of course, capture every sparkle of noise that's going!

The Mini-Whip has some very interesting (and strange!) properties, as shown by Peter Parker, VK3YE in a video at:

https://www.youtube.com/watch?v=MTkVGN9tgQg&feature=youtu.be

Some of his performance checks - practical as ever - show some distinct anomalies. The received signal is markedly improved as the Mini-Whip is lowered to ground level - near concrete paving flags, immersed into shrubbery, and held in near contact with his ground cover plants (species unknown!). Peter shows how the "sampling" of the electric field with a Mini-Whip high above ground level collects more noise, thus degrading the S/N ratio and readability.

One section of Peter's video especially caught my eye. Many years ago I in my employment I often had to work with low-level signals buried in noise. Stan, my mentor, emphasised that it's as much about selecting and enhancing the signal you want, whilst rejecting the others you don't want (i.e. noise!). In other words, a preselector always helps in reception.

In Peter's video he holds his Mini-Whip in close proximity to a tuned loop - the improvement in S/N ratio is outstanding! A preselector, especially of the larger area of a MW / LF loop, can capture and select the frequency desired, and delivers many more "clean" µV's than the unadorned Mini-Whip.

Others have worked with very low (in height) antennas; in some cases **negative** heights! Roger Lapthorn, G3XBM, at:

https://sites.google.com/site/g3xbmqrp3/antennas/earth-electrode-antennas

has shown some remarkable results on LF / VLF; which should (in theory...!) be transposable to HF: 160m / 80m / 60m / 40m are likely candidates for experiment. Roger has had remarkable reception results right down to 8kHz with his "E-Field" antenna; and, indeed, by driving RF into two spaced ground electrodes - the multiple ground paths between two electrodes form an infinite number of conductor paths, in theory creating parallel multiple "conductors" much akin to the strands in a multi-cored cable. Though predominantly aimed at VLF / ELF service, the Wikipedia article:

https://en.wikipedia.org/wiki/Ground_dipole#Receiving_antennas

gives excellent descriptions of the principles involved.

From Martin Ehrenfried, G8JNJ, is an excellent and comprehensive article about common forms of active antennas:

https://www.g8jnj.net/activeantennas.htm

which is a valuable "go-to" source for active antenna designs; including "improved" Mini-Whip designs. Martin's article covers monopole collectors, dipoles and loops, with the pro's and con's of each design commented on. One item Martin commented on that I have had personal experience using is the "dipole" type collector, feeding a VHF / Video differential amplifier. Martin comments that the short dipole must be balanced; this includes stray capacitance thus predicating a wide open spaces Mount - you can't expect a short dipole to be balanced if it's near (i.e. within a few metres) of a building, gutter, roof, or whatever constitutes an electrical influence; it has to be high wide and handsome for good results.

The "dipole" active antenna design by Marco Eleuteri, IK0VSV, published in SPRAT (GQRP Journal) issue #101, pp14, which uses an LM733 differential video amplifier fed via a high pass filter to eliminate strong / local MW signals entering the amplifier (the "preselector" principle scores again..!). Marco describes using "North - South" and "East - West" orientated dipoles, switched for best reception. The LM733 is a very capable device, and can give good results from kHz to 50MHz and possibly more.

Below the surface...?

The transmission of radio waves through the Earth has long been though a practical means of communications, but no real effort has been given to the topic professionally (as far as I know, which isn't a lot). Amateurs however have been driving amps of RF into the Earth with some success: as mentioned above, that master of the art, Roger Lapthorne, G3XBM has done some experiments in this quarter with good success. I came across an article whilst researching how to construct a good "radio earth" - which makes me think that the success Peter Parker found (above) might well be an example of signals coming from below, not above: the corresponding earth currents from our antennas have got to go somewhere! The article at:

https://nvlpubs.nist.gov/nistpubs/jres/65D/jresv65Dn2p189_A1b.pdf

I found fascinating; I wonder if there is a radio "Whispering Gallery" right below our feet? This is an area amateur radio experimenters might be able to make significant strides forward, where the "professionals" have no time or enthusiasm. Recall that amateurs were once granted all those "useless" wavelengths below 200 metres?!

Do I really NEED and antenna analyser?

"*I've been a ham since 1963 and have built all my own antennas. Yagi beams—wire beams—loops —verts, etc. Back in those days all you had was a SWR bridge and maybe a grid dip meter. The most important thing, I think, is a booklet or some kind of articles on antenna design. They will give you accurate lengths and feed line info that should get you up and running in no time. There's plenty of info on the internet, although my personal favorite source is Bill Orr, W6SAI; his antenna books and very entertaining antenna articles in CQ magazine circa 1970's are great.*

My first antenna was made of electric fence wire and a second hand hunk of RG-58 in an inverted vee configuration. It is supremely simple to build. One support pole, one hunk of 50 ohm coax, balun or not, 120 degree spread between the legs, gives you 50 ohms. Make it about three feet longer than formula and trim it to resonance using an el cheapo used ($10) SWR bridge.

A used grid dip meter ($30.00) will let you get the resonant frequency—not necessary here—and a used ($30.00) noise bridge will let you deal with impedance issues, but is not necessary with simple antennas like this. Simple antennas are easy to build and work well. Height is a big plus. Just get in there and klutz around until it works. You can build anything easily with the three pieces of test gear mentioned here and they will do a lot more things than help set up antennas. Simplicity is bliss.

WB0SNF"

A different approach

Here's an old fashioned way to tune an antenna; you might have seen previously in "Parasets", or Chas. Rockey's W9SCH small "soup loop lamp" to indicate RF current? Well, there is a way you can "modernise" this approach, yet maintain the functional efficiency and ease of construction a lamp RF indicator offers: build an RF ammeter with a difference, it barely loads or wastes power (as a directly inserted panel lamp does).

First, find a **ferrite** toroid core. I use a salvaged ring from an ex-PC power supply - then wind on it about 5 - 10 turns of enamelled copper wire, stiff enough to hold it's shape. On the end of the winding, solder a 4 volt 25mA pee-wee incandescent bulb, or similar: the voltage isn't critical but it must be low current (check your favourite on-line auction house: they have plenty). You can use an ordinary LED here if you wish, polarity doesn't matter, but go easy on the transmitter power when you key! You might like to look at Peter Parker's video at: https://www.youtube.com/watch?v=NjHyXi1SrZs

or, a similar idea, but clip-on style by AC2RJ at:

https://www.youtube.com/watch?v=ltZLxdEteBY

The theory bit: the ferrite toroid forms a current transformer, the primary is a single antenna feed wire through the centre; the secondary is your winding. The resistance inserted in the feed line is proportional to the square root of the turns ratio multiplied by the secondary load resistance: i.e. a 100 ohm bulb, and 5 turns of secondary = 4 ohms added to the feedline. 10 turns would be 1 ohm inserted into the feedline, and so on. Somewhere between 5 and 15 turns on the secondary winding is about right, and is relatively non-critical. A LED, being a (non-linear) diode, might - but I don't know this for sure - create some low level harmonics in the output, but it's a lower loading on the feedline needing only a couple of mA's to illuminate - hence the warning above to go easy on the wampum you bung up the spout! Some toroid RF ammeter designs also use a diode rectifier to drive a meter; these might be studied for low level harmonics too. If anybody has any definitive results re. harmonics from the LED or diode versions, please let me know.

Fit the toroid onto the "hot" feed (or co-ax centre conductor) to your antenna, between the antenna tuning unit ("ATU") and the antenna - and key your transmitter. Adjust the antenna tuning unit for maximum brightness, which indicates maximum RF amps into the antenna - the best match / lowest SWR with your transmitter and feedline system at that frequency. Job done!

Baluns and losses

Much is written about these little beasties, and I'm not going to spend too much time on them as many yards of text are already swilling about on the Internet; and I apologise if you're a dedicated QRP(P) man, the following might not be up your street. Suffice to say, the "acid test" is to observe the balun's temperature after a transmission: if it's lossy, it'll be warm (and that's an understatement if you're a QRO operator).

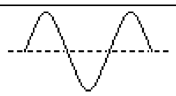
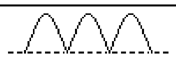
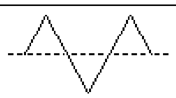
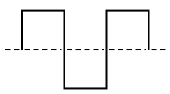
That's physics; it tells the truth, no matter what the gadgets and gizmos you put so much faith in might tell you. Run plenty of power up the spout for 10 minutes, then nip out and check the balun. Cold = Good; Hot = Lossy!

Data and Information

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

Basic AC Relationships

Crest Factor for varuous waves. www.turneraudio.com.au

Wave type	Wave form	Mean magnitude (rectified)	Wave form Factor	RMS value	Crest Factor	Crest Factor
DC		1.00		1.00	1.00	0.0dB
Sine wave		$\frac{2}{\pi} \approx 0.6363$	$\frac{\pi}{2\sqrt{2}} \approx 1.1112$	$\frac{1}{\sqrt{2}} \approx 0.7071$	$\sqrt{2} \approx 1.4142$	3.01dB
Full-wave rectified sine wave		$\frac{2}{\pi} \approx 0.6363$	$\frac{\pi}{2\sqrt{2}} \approx 1.1112$	$\frac{1}{\sqrt{2}} \approx 0.7071$	$\sqrt{2} \approx 1.4142$	3.01dB
Half-wave rectified sine wave		$\frac{1}{\pi} \approx 0.3182$	$\frac{\pi}{2} \approx 1.5714$	$\frac{1}{2} = 0.50$	2.000	6.02dB
Triangle wave		$\frac{1.00}{2} = 0.50$	$\frac{2}{\sqrt{3}} \approx 1.1547$	$\frac{1}{\sqrt{3}} \approx 0.5773$	$\sqrt{3} \approx 1.7320$	4.77dB
Square wave		1.00	1.00	1.00	1.00	0.0dB

π = greek letter pye, = 22 / 7 = 3.142857134..... and is a mysterious and significant mathematical figure used in countless equations. $\approx$ = symbol for "approximately equal to".

The Unobtanium & Obsoletite files...

A list of those solid state parts made from Unobtainium and Obsoletite - please let me know your alternatives! **Note:** when Unobtainium and Obsoletite parts are overheated, over-volted or over-amped, the rare elements used inside the plastic / metal packaging react violently, emitting the "magic smoke" which renders any solid state device instantly useless. In a Yocto-second, no less.

Useful cross-reference web pages:

https://english.electronica-pt.com/components-cross-reference?ref=

https://archive.org/details/TowersInternationalTransistorSelector

For Solid State fans...

These are more or less equal equivalents, use in both directions i.e. BFY90 = 2N5178. Any more that have been proven in actual circuits, please let me know: the supplies of Unobtanium and Obsoletite is getting harder and harder to find, any help is always welcome.

2N5179	BFY90	½ watt VHF NPN
2N3866	BFY90	½ watt VHF NPN
2N4427	BFR91	1 watt VHF / UHF NPN
ZTX300	BCY70	0.3 watt HF NPN
OA91	1N60/61	Ge signal diode, 50v, 50 mA

Alternatives to ZN414 = MK484, YS414, TA7642, UTC7642, LMF501T, LA1050.
For Valve / Tube fans...

https://en.wikipedia.org/wiki/List_of_Mullard%E2%80%93Philips_vacuum_tubes

(Well, you *did* ask...)

http://www.angelfire.com/electronic/funwithtubes/tube_select_guide.html

(THE 'Magnum Opus' of bottle lists)

https://frank.pocnet.net/sheets5.html

(Is the broadest range of data sheets I've ever used, very helpful in finding usable alternatives)

Some not very obvious alternatives:

ECL 82 is an audio triode / pentode, much beloved in vintage radios, economy audio amps and the like. However... if you have 12v. ac heater volts available (or higher) then the bottles following can be useful with a dropper resistor to tweak the heater volts down (and get long heater life too). Don't forget that half wave rectified 12v. r.m.s. = 6v. r.m.s.; near enough for 6.3v. heaters; or strap two 6.3v. bottles in series if their heater currents are near equal, to run on 12v. AC - or a car battery.

ECL82 = LCL82 (10.7v heaters) = 11BM8 (10.7v heaters) or PCL82(16v) / UCL82(50v) / XCL 82(8.2v). There are dozens of equivalent or similar electrode structures but with different heaters.

For instance: PCL82 = 16A8 = 30PL12 = 16TP12 = 16TP6 = 16Ф3П Different heater volts = 8B8 (8.3v ac)

Check the web page: https://www.radiomuseum.org/dsp_searchtubes.cfm where you can search for many different tubes, characteristics and equivalents. For instance, web searching for an ECL84 equivalent - typically LCL84 - yields dozens of hits. If you want an ECL84, which are as rare as hen's teeth nowadays because Audiophools buy them at nosebleed prices, try the different heater volts equivalents and alter the heater supply appropriately.

Keep to mind that 5v or 6.3 v AC heater supplies, if doubled or trebled, will yield higher heater volts if you don't want to modify an existing or historically important piece of kit - but take great care not over volt filaments / heaters! A true RMS multimeter is handy for this job.

HF & VHF Output Types:

6146B = 8298A = S2001; or nearly so, YL1370 = 6146 = 6146A = 6146W

807 = VT-100 = QE06/50 = Г-807 = GL807 = RK-807 = A4051I = ZA3496 = CV124 = 5S1 = 4Y25N = VT199_GPO = 5B/250A = CNU-807; nearly so = 10E/11441 ; 4Y25 ; ATS25 ; ATS25A ; ATS25N ; CV1364 ; CV1374 ; FU-7 ; HY61 ; QV05-25 ; RK39 ; VT60 ; VT60A

Audio valves; useful for low band RF:

From an article by Robert H. Levi

"My Favorite Tubes"
by Robert H. Levi

Small Signal Tubes:

12AX7

Substitutes: ECC83, 12AX7A, 12AX7WA, 7025, 5761, 6057, 6681, 7494, 7729, 7025#, ECC83#, 6L13, 12DF7, 12DT7, 5751, 7025A, B339, B759, CV4004, E83CC, ECC803, M8137

The GE 5751 is a bargain basement musical giant! The Mullard CV4004 is still King of the Hill.

12AU7

Substitutes: 12AU7A, ECC82, 5814, 5814A, 5814WA, 6189, 6680, CV4003, E82CC, ECC186, ECC802, ECC802S, M8136, 7025#, ECC83#, B749, 6067, 6670, 7730, B329, 5963, 7316, 7489

I discovered the 5814A from RCA is a bargain and the best sounding 12AU7 made in the USA!

The Mullard CV4003 is still fairly cheap, plentiful, and magnificent.

12AT7

Substitutes: 6201,6679, ECC81, 12AT7WA, 12AT7WB, 6060, 6201, 6671, 6679, 7492, 7728, A2900, 8152, B309, B739, CV4024, E81CC, ECC801, ECC801S, M8162, QA2406, QB309

As good as the GE and RCA are, the Mullard CV4024 is not pricey and totally glorious.

6DJ8

Substitutes: ECC88, 6ES8#, 6ES8, ECC189, ECC189#, 6FW8, 6KN8, 6922, E88CC, CV2492

The bargain priced PCC88, the 7 volt version of this tube, works nicely in the vast majority of 6 volt applications. I use them in a cocktail with their 6 volt brethren all the time for top results. You can still actually afford the Telefunken, Dutch Amperex, and Siemens versions of the PCC88!"

Rectifier Tube:

5AR4

Substitutes: GZ34, 52KU, 53KU, 54KU,GZ30, GZ32, GZ33, GZ37, R52, U54, U77, 5R4GYS (from Philips) The Mullard GZ34 is King of the Hill. Buy it used, but checked, if necessary. The Philips 5R4GYS is a recent find by Upscale Audio in Upland. A killer tube, but huge and requires lots of space (bigger than a KT88.)

Other Dual Triode Tubes:

6SN7

Substitutions: 6SN7A, 6SN7GT, 6SN7GTA, 6SN7GTB, 6SN7W, 6SN7WGT, 65W7, 5692, B65, ECC33, 6SN7L, 13D2, B65, 6SN7GTY, 6SN7WGTA

The vintage GE and RCA are very fine if hand selected. The Electro Harmonix is very good, too.

6SL7

Substitutions: 5691, 6SL7W, 6SL7WGT, 6113, ECC35, 6SL7GT, 6SL7L

Same comment as 6SN7 type.

Output Tubes:

EL84

Substitutes: 6BQ5, 6P15, 6267, 7189, 7189A, 7320, E84L, EL84L, N709, Z729, 6BQ5WA, EL84M
I have had little use for these. Am told the NOS Mullard prices are strong, but worth it.

EL34

Substitutes: 6CA7, 7D11, 12E13, KT77

Lots to choose from. Usually your manufacturer tuned the gear to a certain brand of these. Be mindful of that before you spend tons of money on vintage NOS versions that end up not sounding as good.

6550

Substitutes: 7D11, 12E13, 6550A, 7027A#, KT88, KT90 Type 2 or 3, KT99, KT100, KT120/KT150 (only if sufficient bias is present) Unless forbidden by your manufacturer, I would try some of the high powered goodies on the market to boost performance. The EH KT90 or the new KT120 may be astounding in your amp. At least try KT88s!

6L6

Substitutes: KT66, 5881, 6L6S, 6L6G, 6L6GA, 6L6GAY, 6L6WA, 6L6WGA, 6L6WGB, 6L6WGC, 6L6WGT, 6L6GB, 6L6GC, 6L6GT, 6L6GX, 6L6Y, 1622, 5932, 7581, 7581A, WT6, EL37

Same comment as EL34 type.

KT88

Substitutes: 6550, 6550A, KT90 Type 2 or 3, KT99, KT100, KT12O/KT150 (only if sufficient bias is present) Though your manufacturer may have settled on a certain brand of these, the hunt for cool NOS types may be sonically worthwhile, or try switching to EH KT90s or bigger for more impact. I would!

Wire Information...

As used in Test Gear Maintenance at a factory I worked at:
Green (or green & yellow stripe) - Earths, Chassis connection

Blue	A.C. power lines (N, single Φ, inside machinery)
Brown	A.C. power lines (L, single Φ, inside machinery)

Note: 3Φ supplies external to machinery or distribution systems may use some of these colours; check, check and check again what the wiring is!

NEVER, NEVER, assume a blue wire is a neutral; you may have an old 3Φ installation which ran colours as follows:

Red	Phase 1
Yellow	Phase 2
Blue	Phase 3
Black	Neutral

Valve Electrode wiring:

Gray	heaters or filaments
Red	DC power supply positives (numbered sleeves indicating voltage)
Black	returns, commons, NOT grounded
Orange	screen grids

Yellow	cathodes
Pink	control grids
White	anodes
Violet	AC / DC control signals (AGC, etc.)

From Kevin, VK3DAP / ZL2DAP seen on a web page recently, is another wiring code - last seen in a Savage 5kW audio amplifier driving a vibration table for semiconductor testing:

Valve Electrodes:

Anode	Blue
Cathode	Yellow
Control grid	Green
Screen Grid	Orange
Suppressor	Grey

DC Supplies:

Chassis / Ground	Black
Positive to Chassis	Red
Negative to Chassis	Violet

Miscellaneous Wiring (control signals & the like):

White or mauve

AC Supplies (modern UK &European):

Active or Phase	Brown
Neutral	Blue
Earth	Green/Yellow stripe

AWG Table

1 AWG is 289.3 thousandths of an inch

2 AWG is 257.6 thousandths of an inch

5 AWG is 181.9 thousandths of an inch

10 AWG is 101.9 thousandths of an inch

20 AWG is 32.0 thousandths of an inch

30 AWG is 10.0 thousandths of an inch

40 AWG is 3.1 thousandths of an inch

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

There's several handy tricks:

Solid wire diameters increases/decreases by a factor of 2 every 6 gauges,

" " " " " 3 every 10 gauges,

" " " " " 4 every 12 gauges,

" " " " " 5 every 14 gauges,

" " " " " 10 every 20 gauges,

" " " " " 100 every 40 gauges,

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

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

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

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

The wire gauge is a logarithmic scale base on the cross sectional area of the wire. Each 3-gauge step in size corresponds to a doubling or halving of the cross sectional area. For example, going from 20 gauge to 17 gauge doubles the cross sectional area (which, by the way, halves the DC resistance).

So, one simple result of this is that if you take two strands the same gauge, it's the equivalent of a single wire that's 3 gauges lower. So two 20 gauge strands is equivalent to 1 17 gauge.

Wire Gauge Resistance per foot

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

Current ratings

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

AWG	dia	circ	open	cable	ft/lb	ohms/1000’
	mils	mils	air Amp	Amp	bare	

10	101.9	10380	55	33	31.82	1.018
12	80.8	6530	41	23	50.59	1.619
14	64.1	4107	32	17	80.44	2.575

Mils are .001". "open air A" is a continuous rating for a single conductor with insulation in open air.

"cable amp" is for in multiple conductor cables. Disregard the amperage ratings for household use.

To calculate voltage drop, plug in the values:

V = DIR/1000

Where I is the amperage, R is from the ohms/1000' column above, and D is the total distance the current travels (don't forget to add the length of the neutral and live together - ie: usually double cable length). Design rules call for a maximum voltage drop of 6% (7V on 120V circuit).

Resistivities at room temp:

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

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

Thermal conductivity at room temperature

	W/cm²/°C
silver	4.08
copper	3.94
gold	2.96
platinum	0.69
diamond	0.24

bismuth	0.084
iodine	43.5E-4

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

Copper wire resistance table

AWG	Feet/Ohm	Ohms/100ft	Ampacity	(mm2)	Meters/Ohm	Ohms/100M
10	490.2	.204	30	2.588	149.5	.669
12	308.7	.324	20	2.053	94.1	1.06
14	193.8	.516	15	1.628	59.1	1.69
16	122.3	.818	10	1.291	37.3	2.68
18	76.8	1.30	5	1.024	23.4	4.27
20	48.1	2.08	3.3	0.812	14.7	6.82
22	30.3	3.30	2.1	0.644	9.24	10.8
24	19.1	5.24	1.3	0.511	5.82	17.2
26	12.0	8.32	0.8	0.405	3.66	27.3
28	7.55	13.2	0.5	0.321	2.30	43.4

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

Wire current handling capacity values

mm2	R/m-ohm/m	I/A
6	3.0	55
10	1.8	76
16	1.1	105
25	0.73	140
35	0.52	173

50	0.38	205
70	0.27	265

Mains wiring current ratings

In mains wiring there are two considerations, voltage drop and heat build up. The smaller the wire is, the higher the resistance is. When the resistance is higher, the wire heats up more, and there is more voltage drop in the wiring. The former is why you need higher-temperature insulation and/or bigger wires for use in conduit; the latter is why you should use larger wire for long runs. Neither effect is very significant over very short distances. There are some very specific exceptions, where use of smaller wire is allowed. The obvious one is the line cord on most lamps. Don't try this unless you're certain that your use fits one of those exceptions; you can’t go wrong using larger wire. This is a table apparently from BS6500, reproduced in the IEE Wiring Regs which describes the maximum fuse sizes for different conductor sizes:

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

Typical current ratings for mains wiring

Inside wall

mm^2	Amps
1.5	10
2.5	16

Equipment wires

mm2	A
0.5	3

0.75	6
1.0	10
1.5	16
2.5	25

Wire sizes used in USA inside wall

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

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

PCB track widths

For a 10 degree C temp rise, minimum track widths on 1 oz. copper are:

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

Equipment wires in Europe

3 core equipment mains cable

Current	3A	6A	10A	13A	16A
Conductor size (mm)	16*0.2	24*0.2	32*0.2	40*0.2	48*0.2
Copper area (mm2)	0.5	0.75	1.0	1.25	1.5

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

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

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

U.S.A. Common Cable colour Codes

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

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

•**Neutral wires:** white or grey

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

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

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

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

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

•**Neutral wires:** blue

•**Single phase live wires:** brown

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

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

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

•**Neutral wires:** white

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

•**3-phase live wires:** red, black and blue

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

A.M. Frequency slots in Amateur HF Bands

All Frequencies in MHz

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

1.850 (W. Europe)

1.933, 1.963 (UK)

1.825 (Australia - daytime)

1.850 (Australia - evening)

80 Metres: 3.530, 3650 (South America)

3615, 3625 (in the UK)

3705 (W. Europe)

3.670 & 3.690 (popular AM frequencies, Australia)

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

60 Metres : 5.317

40 Metres: 7.070 (Southern Europe)

7.120, 7.300 (South America)

7.175, 7.290, 7.295 (USA)

7.143, 7.159 (UK)

7.125 (Primary AM Calling, Australia)

7.146 (Secondary and WIA Sunday morning Broadcast, Australia)

20 Metres: 14.286

17 Metres: 18.150

15 Metres: 21.285, 21.425

10 Metres: 29.000-29.200

6 Metres: 50.4 (generally), 50.250 Northern CO

2 Metres: 144.4 (Northwest)

144.425 (Massachusetts)

144.28 (NYC-Long Island)

144.45 (California)

144.265 (Los Angeles, CA)

Other AM Activity Frequencies

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

FM Frequencies

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

VMARS RECOMMENDED FREQUENCIES

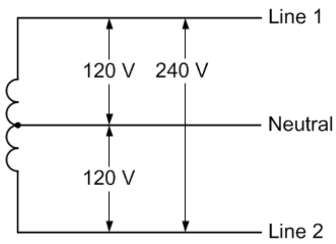
3615 Khz	*Saturday AM net 08:30 – 10:30*
3615 Khz	*Wednesday USB net for military equipment 20:00 – 21:00*
3615 Khz	*Friday LSB net 19:30 – 20:30*
3615 Khz	*Regular informal net from around 07:30 - 08:30*
3577 Khz	*Regular Sunday CW net 09:00*
5317 Khz	*Regular AM QSO's, usually late afternoon*
7073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

Electrical Supplies - Courtesy LEGRAND equipment

Common Electrical Services & Loads

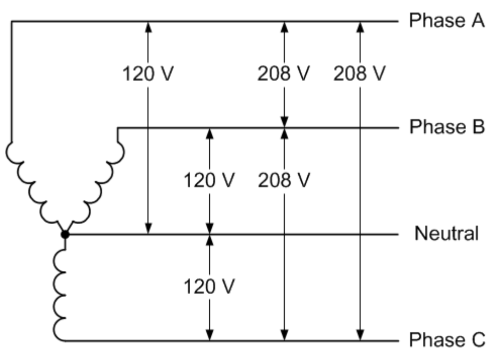
In the following drawings, the coil symbols represent the secondary winding of a utility service transformer or other step down transformer. Electrical code regulations in most jurisdictions require that the neutral conductor be bonded (connected) to the earth safety ground at the electrical service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

Single Phase Three Wire



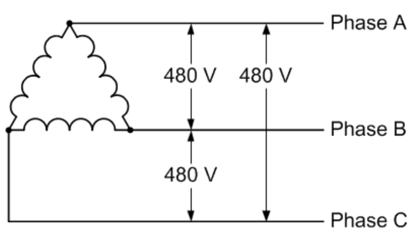
Also known as an Edison system, split-phase or centre-tapped neutral. This is the most common residential service in North America. Line 1 to neutral and Line 2 to neutral are used to power 120 volt lighting and plug loads. Line 1 to Line 2 is used to power 240 volt single phase loads such as a water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

Three Phase Four Wire Wye



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

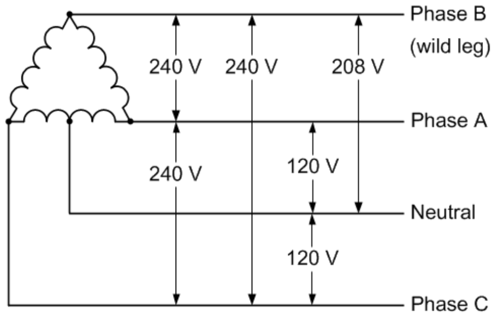
Three Phase Three Wire Delta



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

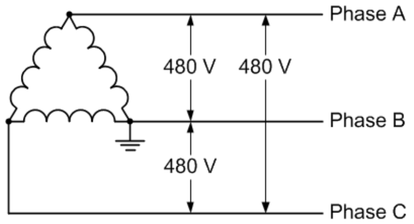
Uncommon Electrical Services

Three Phase Four Wire Delta



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

Three Phase Two Wire Corner-Grounded Delta



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

International Electrical Distribution Systems

Description	L–N Vac	L–L Vac	Countries
1-Phase, 2-Wire 120 V with neutral	120	–	US
1-Phase, 2-Wire 230 V with neutral	230	–	EU, UK, Scandinavia
1-Phase, 2-Wire 208 V (No neutral)	–	208	US
1-Phase, 2-Wire 240 V (No neutral)	–	240	US
1-Phase, 3-Wire 120/240 V	120	240	US

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

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