Hot Iron #112

Table of Contents

CQ-CQ-CQ

Home Blues...

Ensconced in my new home in the mountains of West Wales, I now have a much better understanding of what my house here needs. Nobody sells a second hand Rolls Royce for Mini prices without good cause; now I know where my efforts (and money!) must go into my house in the near future.

For those who are familiar with roofing, I have two purlins with rotten ends, where previous owners have neglected basic and remedial roof maintenance and allowed water leaks from cracked lead flashing and slates to saturate the purlin ends in the supporting wall - consequently I either need to strip the entire roof to put new timbers in, or - and I think this is preferable - have the flashing, slates and flaunching repaired, then find a steel fabrication shop that can make me some 6 mm thick steel plate "U" sections, 2 metres long, to extend the existing purlins after chopping off the rotten ends, the steel to engage in the wall mortices and be through bolted into sound timber of the now (shortened) purlins.

There is a plus side to this: I have laid a floor in the loft, supported by new joists, for storage - and a dandy electronics bench will fit into the new space thus constructed. A bit draughty, mind; and quite a few existing tenants (with 8 legs...) will have to be evicted. I have nothing against spiders, mind you: but these are the size of wrens and don't run away when I prod them with a screwdriver blade! ardent wandering arachnid!

Correspondents write...

I am always very pleased to receive emails on any topic from Hot Iron readers, as I base items in each edition on the comments and ideas brought to light. The themes I have been asked about are most fascinating: they follow - loosely - common themes. Most are about receivers, how to make a 1µV capable, SSB / CW Dx receiver with one or two active devices that will run on simplest DC supplies, for a few ££'s.

The second topic is about antennas; how to make one that is invisible - a few metres long, typically - that will radiate 100 watts efficiently on any band between 135kHz and 50MHz at unity VSWR.

The third topic is winding inductors: quote: "I need 22µH, and I have a cardboard tube 2 inches diameter, how many turns of wire - and of what gauge - will I need, at what spacing?" is a typical (unanswerable!) request. Inductors, especially variable inductors for power RF, are rarer nowadays than hen's teeth: some do occasionally turn up on our favourite auction sites but alternative approaches are usually cheaper & more achievable. I consider the amateur who builds an antenna tuning device that eliminates the "roller coaster" to be a genius!

I strive to answer every request made to me via Hot Iron, but some, like the examples above, are just plain not possible. More to the point, surely, these questions illustrate a lack of electrical theory that studying for and passing the Radio Amateurs Examination is supposed to instil: how do licensed amateurs pass this examination, if they don't have basic electrical knowledge?

On basic safety grounds, if I'm asked to offer a design for a power supply that features voltages anywhere in it's construction above 50v AC rms or 70v DC then I have to refuse the request - I cannot encourage the unwary to use lethal voltages.

Amateurs who are unable to work confidently on anything running over 12 volts are (in my opinion) woefully lacking in education & confidence in their own abilities. Even on 12 volt DC supplies, a matching network with a decent loaded "Q" inductor running 100+ watts may well have RF voltages well over 500 volts swilling about; and an RF burn at these potentials is far worse than an AC or DC shock - RF arcs cause deep burns.

Hence this safety warning, which will be included in every edition of Hot Iron. I apologise to those who are entirely capable of complying with current safety requirements - but I must be sure those who don't are made aware that they are responsible for what they do, not me!

Circuits shown in Hot Iron may use potentially lethal voltages. It is your responsibility to ensure your own – and anybody else's – safety if you build or use equipment that employs hazardous voltages, currents or power. If in ANY doubt, you MUST get a competent person to check and approve the circuits, barriers and other provisions to avoid any injury and electric shock. You MUST comply with your local Electrical Regulations and Safety Regulations.

I cannot accept any liability for any damage or injury to you or any Third Party from any article or description in Hot Iron. It is your responsibility to ensure the safety and safe use of anything you build; I am not responsible for any errors or omissions in Hot Iron.

Unobtanium and Obsoletite

Many superb designs, both valve (tube) and solid state are from an age where components were of a different nature than those obtainable today. A couple of examples: the ubiquitous pie wound 2.5mH "RFC", and the darling of the mixer fraternity, the 40673 dual gate mosfet.

The 2.5mH RFC's were found by the hundreds in virtually every radio receiver or low power stages of transmitters, they were as cheap as chips and available from - well, anywhere that sold radio bits. Nowadays? You might find a few "NOS" ("new old stock"), or second hand of dubious parentage, but otherwise these chokes are as dinosaurs - gone from this earth.

Similarly the adored 40673 mosfet. You'll find "NOS" 40673's on auction sites, at serious money each - and one episode of rough handling (without static protection, typically) will have them shuffling off this mortal coil in a trice.

There are alternatives though, which breathe life into these old designs and make them a very viable proposition for the home constructor. I can't estimate the number of single tube receivers using a triode - pentode tube in various configurations, but where do you find, now the audiophools have hoovered up every available option, an ECL86? Or their kid brothers, the ECL84, '82 and '80? The RFC's are a different issue: in most instances they can be replaced by a resistor, but some designs will suffer with such substitutions. So how to proceed? Read this Hot Iron and see!

Tim's Topics

Transmit Receive changeover

It has been very busy these last few months - despite the Covid-19 virus – life on our farm has to carry on, which is why I missed a contribution to the last Hot Iron. I have several electronic projects on the go – in various stages of development. The most recent is the Queenie strong DC receiver for any band 20, 40 or 80m aimed at CW. It uses 4066 electronic switches for the product detector. Because that chip has a spare pair of switches, the RX has an optional simple add-on unit that gives single sideband CW reception by the phasing method. The matching transmitter is the Kingston which produces a nominal 5W on a 13.8v supply. To avoid chirp, this design triples from a low frequency VFO and then divides by 2 or 4 when 40 or 80m is desired; so it has coverage of the whole CW segment for whichever band is chosen and avoids the limitations of being 'rock bound'! The transmitter has full break-in TR changeover that often causes cause much design hassle to avoid nasty clicks or thumps that would be awful when using phones!

Aerial changeover using a relay is generally much easier even if the sequences and timing are somewhat slower. Clicks or thumps are usually caused by either or both of a) a change in internal supply line voltages or bias conditions when the key is closed/opened, or b) a transient of transmitted RF, or sudden change in bias voltages, that causes an audio filter to 'ring'. These effects occur as well as the need to prevent high levels of transmitter RF from damaging the RX front end! Using a relay to switch the aerial from the RX to the TX is seldom quick enough to hear the wanted station or other callers between morse characters, so modern rigs usually leave the aerial connected to the TX and have an electronic switch in series between aerial and RX input, sometimes also with another electronic switch across the RX input to reduce the transmitter attenuated RF applied to the RX even more!

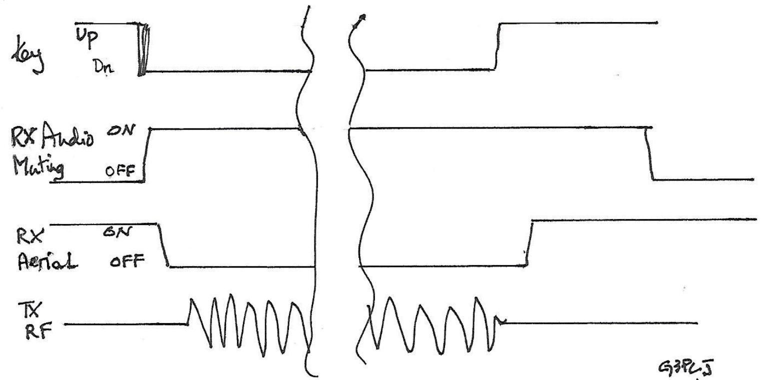
Avoiding changes in supply voltages is usually fairly simple using low power regulator ICs like the 78L05 series (for 5v up to 100 mA), or the 750L08 (for 8v up to 100 mA) for the bias controlling resistors or sensitive early stages in a RX. The 750 series are 'low drop-out' regulators so can be used for an 8v line with input down to near 8.5v! But they do need lots of decoupling to make their internal regulating control loop stable. The RX audio stages need to use op-amps and output power amps that are able to suppress/ignore the supply changes – eg TL072 and LM380. Following these principles usually avoids thumps due to bias changes. This leaves only the need for 'switches' of some sort for the signals. It is essential these 'switches' operate in a particular sequence. When the key is closed, the RX must first be muted very quickly (this is true for electronic TR and for relays), and then the RX aerial input disconnected before the transmitter RF is generated. After key up, the RF needs to stop quickly, reconnect the RX aerial and later unmute the RX when any filter or supply transients have settled out.

This sequence is key to avoiding or masking any unwanted noises – it is shown diagrammatically in the first part of the attached diagram. RX audio muting ought to occur within about 3 mS to be sure any transients due to relay currents are properly masked! The delay in activating the TX needs only to be long enough for the RX antenna switch to open – maybe 10 mS to allow for a relay but less for an electronic switch.

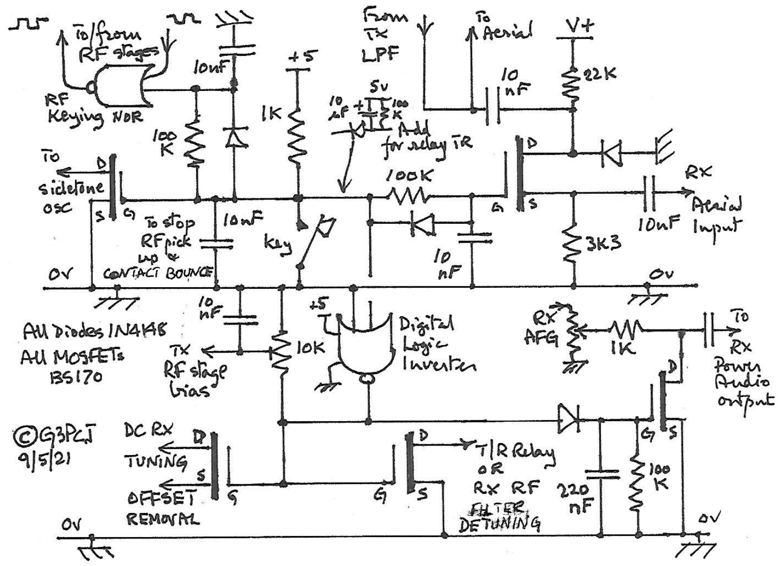
Removal of the RX muting usually needs to last much longer, either due to a relay operating or an audio filter settling after a burst of unwanted input signal. An audio muting on delay, or hold, of up to about 20 mS will often masks the worst effects while still being able to hear enough between fairly high speed morse key down periods.

It is not possible to give a simple universal circuit design to achieve these timings because of the interaction with the functional stages of the RX/TX. In my CW designs, the RF keying (or gating of the RF drive to the output stage) is done digitally in a CMOS digital NOR gate; for the series switch between aerial and RX input, I advocate a small MOSFET that can withstand the high voltages – the BS170s is cheap in quantity. I also use them for muting of the RX audio, and activation of the sidetone oscillator, when the key is down!

The inputs of digital NOR gates, and the control gate of the MOSFET, have a very high input impedance which allows simple CR circuits to be used to provide the proper sequence of actions to avoid the clicks and thumps. (The extra diodes control whether the long delay period occurs on the leading or trailing edge of the signal.) In some designs, it may be desirable to also 'shut down' the RX front end when RF is being generated; this can be done with another MOSFET that detunes the RF input bandpass filter by applying a short to the mid-tap of the resonant winding - the slight extra capacitance when it is off has a minimal effect on its tuning. The second part of the diagram shows a typical circuit which I hope is self-explanatory!
Tim Walford G3PCJ © May 9 2021



TRANSMIT RECEIVE SEQUENCIES



OUTLINE OF CW TX T/R CIRCUITS

Rx Topics

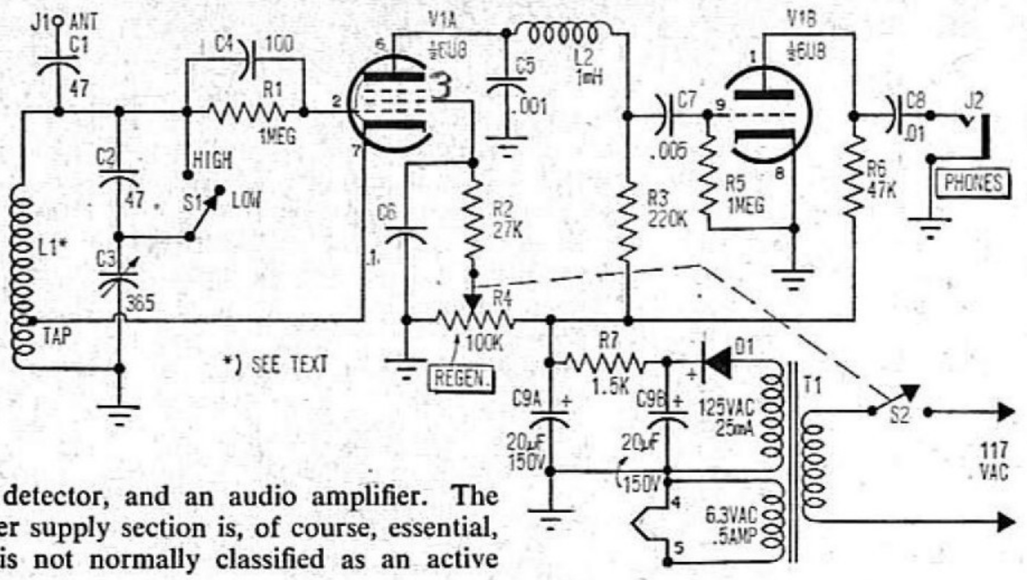
The ORIGINAL Neophyte receiver

In the next series of images is presented one of the most popular “generic” one valve receivers: the Neophyte. It is typical in every way; its components and construction are of its day and even though elderly, it can still put up a remarkably good performance if built robustly and operated by capable hands.

The original article reproduced is from “Electronics Hobbyist”, the year and edition I don’t know, but I give my grateful thanks to the original article author (again, unknown) and the publishers.

It fascinates me why these oh-so-simple designs have no parallel in the solid state era: I have thought about building these circuits with “solid state tetrodes” - Fetrons and their kin - but experience, both mine personally and others, show the valve circuits far outshine the solid state versions in both performance and simplicity. The only snags are as far as I can see, are the HV power supply and overall receiver size - but for most users, these genuine distractions are easily overcome for portable service as you’ll see later in this edition of Hot Iron.

Schematic of Neophyte I shows conventional regenerative detector circuit followed by a stage of audio. Note how band is changed simply by switching capacitor C2 in and out of tuning circuit.



tive detector, and an audio amplifier. The power supply section is, of course, essential, but is not normally classified as an active stage.

The circuits are traditional. A regenerative-type detector, although no longer in use in commercial equipment, still finds plenty of applications where budget-minded experimenters and space requirements are involved.

The detector, besides extracting the audio from the carrier signal, also provides a considerable amount of audio amplification. It would certainly take more than half of one tube to do this using other conventional circuits.

The amplified signal from the detector is coupled to the audio amplifier stage where its level is increased still further to operate a pair of standard high-impedance headphones with adequate volume.

Wherewithal. Starting at the antenna jack in the schematic, you will notice a 47-pF capacitor (C1) connected between it and the tuned circuit. This capacitor prevents antenna loading effects and results in smoother operation of the regenerative feedback circuit.

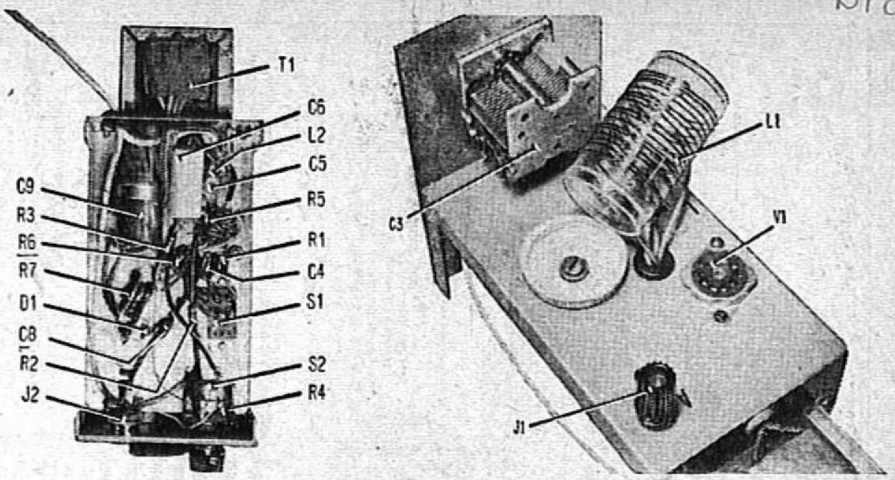
The tuned circuit consists of coil L1, tuning capacitor C3 and a fixed capacitor, C2. The single-pole-single-throw switch S1 shorts out C2 when closed and places C2 in series with the variable tuning capacitor C3 when it's open.

The closed position places more capacitance in the circuit and therefore tunes the receiver to a low frequency shortwave band. When the switch is open, total capacitance is less than 47 pF maximum (the value of

PARTS LIST

- C1, C2—47-pF disc ceramic capacitor
- C3—10 to 365- or 10 to 410-pF variable capacitor
- C4—100-pF disc ceramic capacitor
- C5—.001-uF disc ceramic capacitor
- C6—0.1-uF capacitor
- C7—.005-uF disc ceramic capacitor
- C8—.01-uF disc ceramic capacitor
- C9A, C9B—20-20-uF 150-VDC dual section electrolytic capacitor (Radio Shack 272-105 or equiv.)
- D1—400-piv., 200-ma or better silicon rectifier diode (Radio Shack 276-1126 or equiv.)
- J1—Insulated binding post (Radio Shack 274-736 or equiv.)
- J2—Headphone jack (Radio Shack 274-293 or equiv.)
- L1—Wound from #22 AWG enamel covered copper wire (see text)
- L2—1-mH radio frequency choke
- R1, R5—1,000,000-ohm, ½-watt resistor
- R2—27,000-ohm, ½-watt resistor
- R3—220,000-ohm, ½-watt resistor
- R4—100,000-ohm linear taper potentiometer with s.p.s.t. switch S2
- R6—47,000-ohm, ½-watt resistor
- R7—1500-ohm, 1-watt resistor
- S1—S.p.s.t. slide switch
- S2—Mounted on R4
- T1—Power transformer: 117-VAC pri., 125-VAC, 25-mA; 6.3-VAC, 0.3-A sec.
- V1A, V1B—6U8A vacuum tube
- 1—5¼ x 3 x 2⅛-in. aluminum minibox Radio Shack 77-0683 or equiv.)
- 1—High impedance (2000-ohm or more) headphones
- Misc.—9-pin tube socket, scrap aluminum for front panel, knobs, grommets, line cord and plug, terminal strips, screws and nuts, etc.

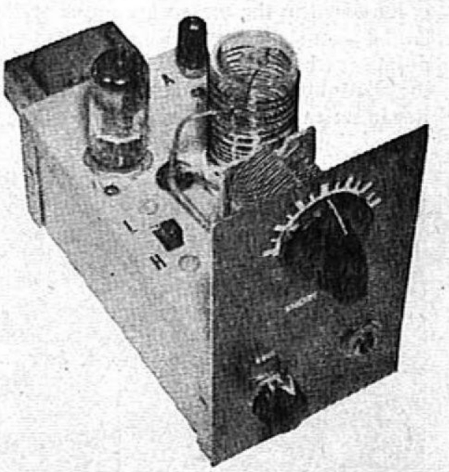
BUILT 8-16-93 NICE!



At left, parts arrangement in Neophyte is compact but uncluttered. Coil at right is wound on plastic pill bottle as shown.

C2) and this provides a second, higher frequency shortwave band. Using the specifications given for the coil and the capacitor values, Neophyte 1 covers from about 3 to 7 MHz on the low band, and from about 9 to 12 MHz on the high band. Other frequencies, higher or lower, may be covered by changing the value of C2 and the number of turns in L1. If you use variations, experimentation with the "tap" may be necessary.

Audio Extraction. As mentioned before, the first, or pentode section, of the dual section tube extracts the audio from the received signal and passes it to the triode audio amplifier stage. However, plenty of unwanted radio frequency signals also appear at the plate of the pentode section and they must be dispensed with for proper operation. The radio frequency choke L2 and bypass capacitor C5 are placed in the circuit for this purpose. The choke blocks or "chokes" higher frequencies, but allows lower audio frequencies to pass; conversely, the bypass capacitor blocks low frequencies and bypasses unwanted RF to ground. The result is a relatively clean audio signal appearing between the grid and cathode of the audio section for additional amplification.



Neophyte 1 will provide many hours of entertainment receiving the most active shortwave bands.

Regeneration. The current in the detector stage must flow through the lower portion of coil L1 and up to the cathode where it divides between the plate and the screen grid. The screen grid is connected to the positive (B+) supply through a limiting resistor and potentiometer R4. By changing the resistance of the pot, the screen voltage is varied and the tube current changes. The pot thereby varies the current through the tapped portion of the coil. The degree of current flow determines the amount of signal that is coupled to the upper portion of the coil which, in turn, determines the amount of feedback. The potentiometer is called a regeneration control, and it, as its name implies, controls the regeneration or feedback of the signal voltage.

Building Neophyte I. All parts mount on or in a 5¼ x 3 x 2⅛-in. aluminum minibox. A small piece of scrap aluminum measuring 3 x 4½-in. is used for the front panel. Follow the photos to locate mounting positions. *(Continued on page 104)*

Neophyte I

Continued from page 77

Start by cutting the large holes first, and finish up with all the small holes using the parts themselves for templates. The panel is secured to the box by the phone jack and regeneration control mounting hardware.

The power transformer T1 is mounted on the rear of the minibox. Two holes are made to pass the transformer leads inside the box for wiring. Make sure that all holes and mounting plans are such that the other half of the chassis box will fit in place without obstruction.

Cool Coil. A 1 x 2-in. long plastic pill vial is put to use as a coil form. The plastic cap of the vial serves as the coil form "socket" and is mounted on the chassis with a nut and bolt.

The coil consists of 17 turns of #22 AWG enamel-covered copper magnet wire. A tap is made 4 turns from the bottom or ground end of the coil.

The turns of the coil are spaced to cover approximately 1¼ inches. The #22 wire is stiff enough to be self-holding and cement is not needed. Minor frequency adjustments may be made later by adjusting the spacing between the turns.

Hookup wire brought through a grommet-protected hole in the minibox connects the coil to the proper circuit points. The band switch S1 is mounted on the top of the minibox, but a layout variation on the front panel will allow enough mounting space there.

When all components are wired in the circuit, make a careful check to insure that no short circuits exist and that there is proper clearance for the bottom of the chassis box.

Fire It Up. Turn Neophyte 1 on and check that the tube lights. Then make sure nothing is smoking or overheating. Connect an antenna to the jack and advance the regeneration control to a point just before the set breaks into oscillation. Turn the band switch to the high band and tune for a station. Readjust the regeneration control for best reception. Receiving conditions will be best after dark so don't be discouraged if you turn the little Hertz-grabber on during daylight hours and don't find much action. Try various inside antenna lengths and use the best one. A high outside antenna will be best for long-distance reception. ■

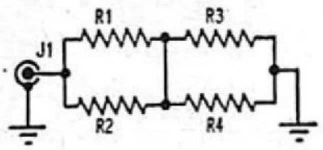
Scrooge Special

Continued from page 70

PARTS LIST

- **J1—RF connector, single hole mounting, type SO-239SH (Lafayette 42H6907 or equiv.)**
- **R1, R2, R3, R4—50-ohm, 100-watt, 1% non-inductive resistors (Corning Glass R-35* or equiv.)**
- **1—5x4x3-in. aluminum chassis box (Lafayette 12H8389 or equiv.)**
- **4—Rubber feet, ⅜-in. dia. (Lafayette 13H6035 or equiv.)**
- **1—Equipment handle (Allied Radio 42E8078 or equiv.)**
- **Misc.—Wire, solder, perforated aluminum, nuts, bolts, spray paint, insulated terminal lug, etc.**

***Available from John Mesha, Jr. Surplus, 19 Allerton St., Lynn, Mass. 01904**

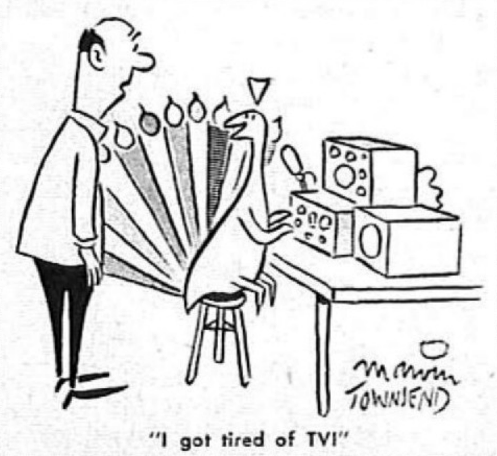


Wire resistors together as shown in schematic, then install in chassis box.

ground lug, and the insulated terminal post as shown in the photo.

Finishing Up. Carefully note the physical placement of the load resistors R1 through R4. These resistors are supported by the connecting wires to connector J1 and the ground lug on one side of the case, and to the insulated terminal lug on the other side. The sole purpose of the insulated terminal lug is to support the load resistors, no other wires or components are connected to it.

To speed construction, first wire the load resistors together per the schematic. After



"I got tired of TVI"

"An Improved Neophyte"

From W9BRD, Dave Newkirk, in http://theradioboard.com/rb/viewtopic.php?t=9345

To W9BRD, and all concerned at radioboard.com, I give my very grateful thanks. The ideas and improvements presented are an object lesson in how to adopt, adapt and improve an already good design. That's the mark of a genuine radio artificer!

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"*I built one in about 1970 or so. It's just a simple 0-V-1, not too well understood by its author; it works well enough, as all simple regens do. But as with all simple regens, better performance awaits if you can break away from the circuit before you to some degree.*

So, some notes:

Band switch. The set's band switch isn't a band switch. All it does is put C in series with the tuning C. And all that really does is spread out part of the full coverage afforded by the tuning C on the "low" band, ever so slightly moving its upper limit slightly upward because of the C in series with the main tuning C's min C. So, like I said, it's not a band switch.

The AF stage needs cathode bias. Yes, it's a high-mu triode, but connecting the AF amp's cathode directly to common is benighted. If I remember right ~ ~ ~ use 2.7 kilohms, bypassed to common with a 10- to 25-uF electrolytic, positive toward the cathode.

Out with the RFC in the detector plate. A 47-kilohm resistor in series with the blocking C between the detector plate and AF amp grid will work as well, and only slightly tap the AF amp grid down on the detector output, like a turning down an AF GAIN pot just a bit and leaving it there. (0.001 uF for the detector plate bypass is a tad high for a pentode detector, as it will considerably roll off highs for those hoping to use the set for broadcast. Values that high generally come from those who don't grok the great difference in plate Z between triode and screen-grid detectors. I use 560 pF, and it works fine even at 1.7 MHz. All we're trying to do there is keep the RF level down at the AF grid; the RFC or series resistor toward the AF amp serves as the other part of that bypassing/decoupling function.) Maybe 220 kΩ for the detector plate load is a tad high. Nowadays I always use 150 kΩ for pentode-detector plate loads. (The plate circuit of a pentode detector is the equivalent of the plate circuit ofan RC-coupled AF voltage amplifier.)

Consider coupling the antenna to the detector cathode. Coupling the antenna to top of the detector tank is so 1930s wire-around-the-picture-molding-antenna-ish. Nowadays we generally use bigger, lower-Z antennas. (When I built mine, my dad suggested that I add a grounded-grid-triode input coupling tube (I used a 6C4), with the AC-coupled antenna input riding up and down on the wiper of the 1-kilohm pot that served as the g-g stage's cathode R. It worked fine with a low-Z antenna, and the pot allowed me to control the signal level presented to the detector to minimize pulling.

No, we do not use an interstage AF transformer between a screen-grid detector and the AF amp that follows it. That was for triode detectors, the plate Z of which suits using a 1:3 transformer. The plate Z of a pentode is on the order of hundreds of kilohms to a megohm, and no transformers are available with enough inductance to do 1:3 stepup based on that Z level.
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In the older days, a high-value AF choke (300 to 1080 H) was commonly used as the load for screen-grid detectors. Not only are such chokes pretty much Unobtainium nowadays, but they are unnecessary; an R between 120 k and 220 k works fine. Really.

If you haven't used (for CW communication) a high-C regen with its input level carefully adjusted to just overcome the detector's internal noise (for starters; more atten for stronger signals), you haven't heard how good a regen can sound on CW. Yes, that RC coupled input coupling tube is key; no need for an RFC-only load there, as we're out to add loss between the antenna and detector anyway. Regens work better on weaker input signals. Whatever regen circuit you use, keep the input level down as far as possible consistent with overcoming the detector's internal noise. Turning up regeneration to make the detector "oscillate harder" is not a substitute for input attenuation when one is using one's transmitting antenna for receiving with a regen.

Best regards,

Dave W9BRD"

A "Modern approach"
The Piglet receiver, by Forrest Cook, W0RIO, at:
[http://www.solorb.com/elect/hamcirc/pigletregen/index.html]

...is an example of how the "accepted" format of a triode / pentode valve in a regenerative receiver as in the Neophyte above can be reversed; you lose the first stage audio amplification, but gain the (huge) advantage of isolating the antenna from the detector, by using the triode as an isolation stage. This RF stage could be made selective if needs be; say for a specific band A.M. / NBFM slots for instance. Yes, you do need some extra audio amplification, but, as Forrest does here, it gives you chance to add a "modular" audio amplifier to do the job, and deliver speaker level output. Note: 6U8A = ECF82 (more or less) in European nomenclature; with heaters 16v, 300mA.

"TV" type tubes - typically the 300mA types designed for series connected TV heater chains - are readily available as "NOS", simply because the Audiophools can't use them as they won't plug-n-play in their amplifiers. We, as constructors, can cock a snook to all that: need 19 volts for heaters? Pah! Nae bother, laddie, we have many means to create such heater supplies as we can design and build to our needs, we have all sorts of transformers to hand and don't forget the new kids on the block: halogen lamp transformers, available at very low prices (compared to conventional transformers) and are physically very small. Two of these, secondaries in series, will give plenty of volts for TV type valve heaters at very economical prices. And keep to mind simple diode / electrolytic voltage multipliers: not only can you derive heater volts with these, but you can get useful HT rails too: parallel multiplier designs can be made to run efficiently with modern silicon diodes as octuplers!

The W0RIO Piglet 6U8A Regenerative Receiver

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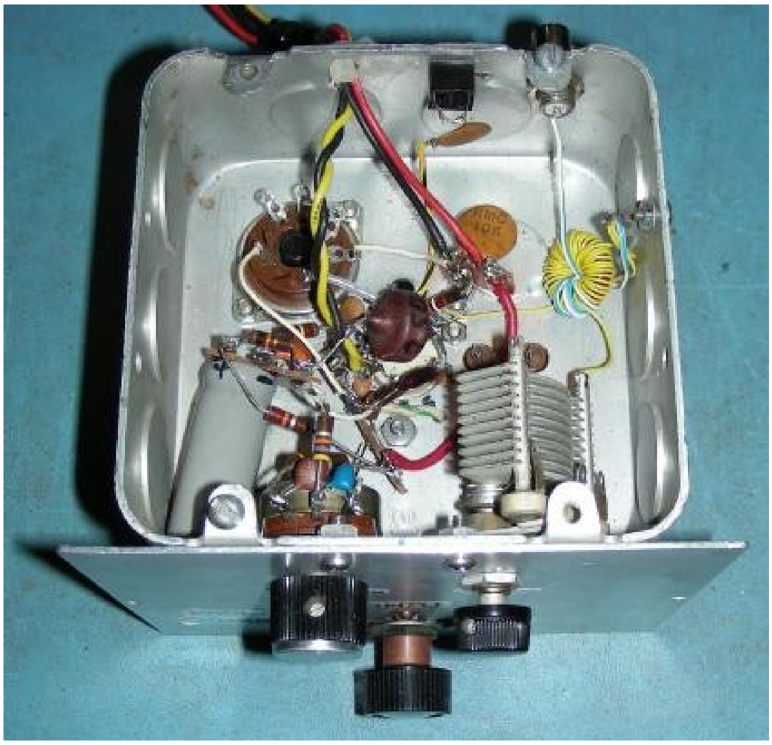
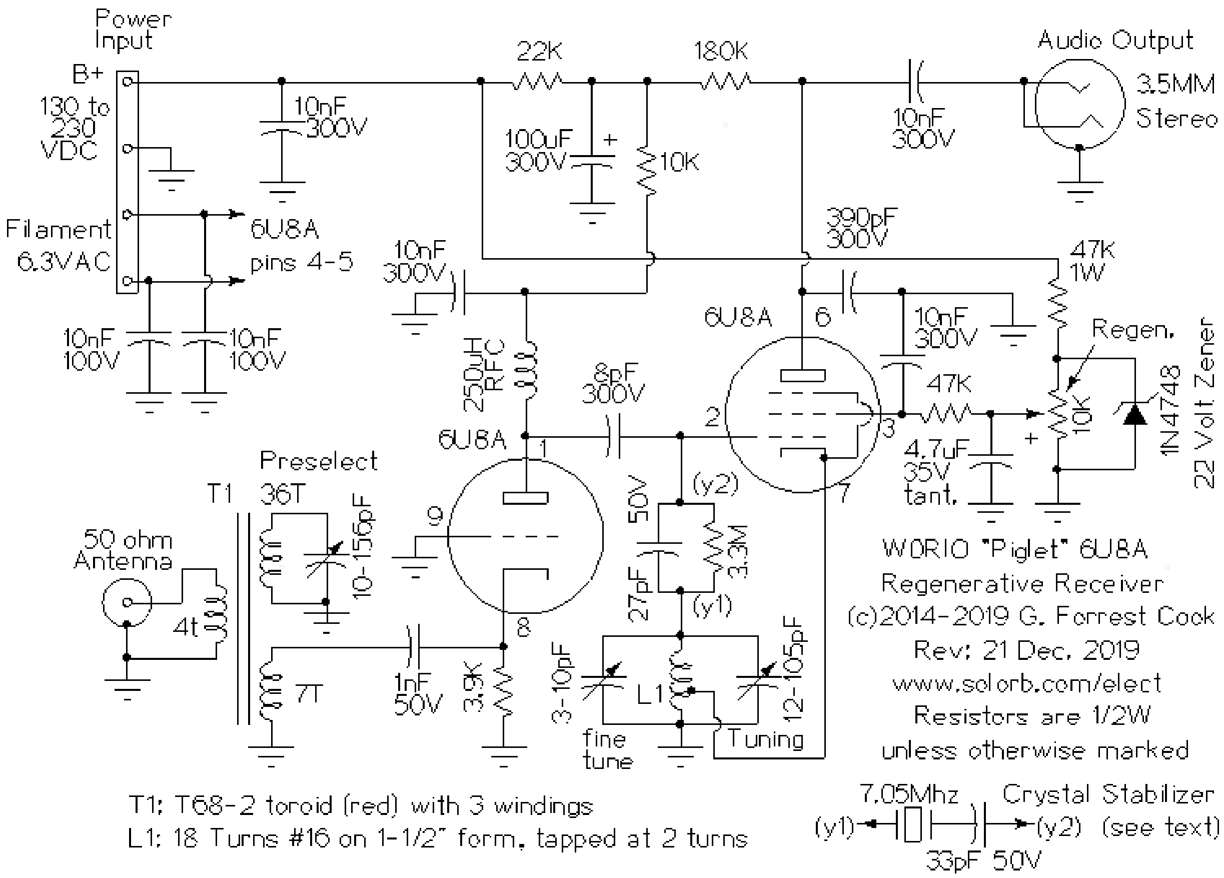




Introduction

This project is your author's first attempt at building a regenerative receiver, it has gone through several revisions. Thanks go to W9BRD, DF3DL and others for suggestions on how to improve the detector circuitry. The "Piglet" name comes from the squealing sounds that regenerative receivers can make when the regeneration control is adjusted. The receiver tunes from 5-10 MHz in the shortwave band and it can pick up foreign and domestic AM broadcast stations with ease. One of the design goals of the receiver was to be able to pick up both the 5Mhz and 10Mhz WWV time signals. When propagation conditions are good and the Piglet is connected to a good outdoor antenna, stations can be picked up across the entire tuning range of the receiver.

If the receiver is built with a narrow tuning range instead of the 5-10 MHz range, it can be used to receive SSB and CW radio signals in the 40 meter ham band. It could also be set up to cover just one shortwave broadcast segment. With a few minor coil adjustments, the receiver should also be able to work on the 80 and 30 meter ham bands.

Regens have always been very popular because they deliver a lot of performance from a small number of parts. Their disadvantages include being rather "tweaky" to adjust, de-tuning from wind on the antenna and a tendency to transmit RF from the receiving antenna while making tuning adjustments. This design fixes the second and third of those issues with a grounded-grid RF isolation amplifier.

The 6U8A tube includes a triode and a pentode in one 9 pin envelope. Most 6U8A regen designs use the pentode as the detector and the triode as an audio amp. This design uses the triode as a tuned grounded-grid RF amplifier ahead of the pentode detector section. This arrangement isolates the antenna from the detector stage and improves the front-end selectivity of the receiver. All of the audio amplfication is done outside of the Piglet.

The receiver can run on a wide span of B+ voltages, it works between 130VDC and 230VDC, allowing many power supply choices. I used my Power Supply for Vacuum Tube Experiments (set for either 160VDC or 260VDC) to power this project. When the supply is powering the Piglet and the V3 amp, the B+ loads down to either 130V or 230V. The higher supply voltages give the receiver more audio output and higher gain.

The supply is sufficient to power the Piglet and the Low Power 6U8A Vacuum Tube Audio Amp V3. If you don't want to build the outboard tube amplifier, a pair of stand-alone amplified computer speakers will also work.

Warning
This project involves the use of potentially lethal high voltages including 120 VAC and 160 VDC. The project should only be taken on by someone who has experience working with high voltage circuitry. The power supply should always be disconnected and the power supply capacitors should be discharged when working on the receiver.

Theory
A 10nF 200V bypass capacitor is wired across the B+ line and two 10nF bypass capacitors are wired to across filament pins, these parts bypass any extraneous RF that may be picked up on the power lines to ground.

The triode section of the 6U8A is wired in a tuned input grounded grid amplifier configuration. The 50 ohm antenna input is coupled via a 4 turn winding to the tuned input circuit's toroid coil. A 36 turn winding and a 10-156 pF variable capacitor form the resonant part of the tuned input circuit, it covers just beyond the 5-10 MHz tuning range of the detector. A 7 turn winding matches the input tuned circuit to the cathode of the grounded grid amplifier via a 1nF DC blocking capacitor. The 3.9K resistor sets the bias level of the grounded grid amplifier and the 250uH RF choke isolates the amplified RF input signal from the B+ supply. The 10K plate resistor and 10nF capacitor further isolates this stage from the detector circuitry.

The output of the RF amplifier is lightly coupled to the pentode detector stage via an 8pF capacitor. The detector's tuned circuit consists of a tapped solenoid coil in parallel with an 12-105pF tuning capacitor. The tap point on the L1 oscillator coil can be moved to change the behavior of the regeneration circuit. The tap at 6 turns can allow the circuit to oscillate at around 15Khz if the regeneration control is turned up, moving the tap down to 1 turn can reduce or eliminate this issue, but the gain is also reduced. Moving the tap to 2 turns provides a good compromise between sensitivity and stability.

A 3.3M grid leak resistor provides the grid bias and the 27pF capacitor couples the top of the tuning coil to the pentode's grid circuit. These values are not set in stone, but work well across the 5-10 MHz frequency range. The 27pF capacitor should be increased in value if the receiver is to be used at frequencies below 5MHz. The regeneration control provides a variable voltage to the 6U8A pentode's screen grid, it is used to keep the detector circuit at the point just at or slightly below the point of RF oscillation. The regeneration control's voltage is regulated by the 1N4748 22 Volt zener diode and filtered with a 4.7uF capacitor, this helps to stabilize the behavior of the circuit.

The plate circuit of the detector has the RF bypassed to ground via a 390pF capacitor. This capacitor also acts as an audio high-cut filter, the value can be adjusted for more or less treble. The audio output of the detector is fed to the output jack via a 10nF capacitor, where it is fed to a high-impedance audio amp.

The Regeneration circuit uses a 47K resistor and a 22V (or 24V) Zener diode to produce a regulated 22V supply. The 10K Regeneration potentiometer varies the pentode's screen grid voltage from 0-22V, which spans the region below and above the point of oscillation. The 4.7uF capacitor gives the Regeneration control a smoother response, the 47K resistor sets the screen current and the 10nF capacitor bypasses RF on the screen grid to ground.

Construction

The receiver was built into a 4-1/2"x4-1/2"x2" electrical utility box. An aluminum plate was mounted on the side of the box with some 6-32 screws to serve as the front panel. The 6U8A tube socket and the Octal coil form socket were installed into knockout holes on the top of the box. A solid box cover plate was used for the bottom of the box. Appropriate holes were drilled for the rest of the components. A number of multi-point terminal strips were installed inside the box and components were installed with the point-to-point wiring method. All RF wiring should be kept as short as possible.

The L1 mixer coil was wound onto a custom coil form. The form was made by gluing a section of plastic sink drain pipe to the base of an old octal tube. Small holes were drilled in the pipe to secure the ends of the wires. A matching octal tube socket was mounted to the chassis.

The L1 pluggable coil form was originally used with the intention of being able to use different coils for different bands. The circuit design changed during prototyping and the T1 tuned input circuit was added. Transformer T1 could also be bult as a pluggable coil if you want to be able to change bands. For single-band operation, L1 should be built without the plug and socket, this will help with the physical stability of the receiver.

In the first prototype version of the Piglet, the coil form was mounted too close to the 6U8A tube and undesired oscillations would occur with certain tubes. A grounded piece of printed circuit board material was added between the tube and the coil. A further modification of the receiver involved removing the circuit board shield and installing a metallic tube shield around the 6U8A.

Two copper braces were added to mechanically stabilize the front panel against the metal box. The brackets were made from 1/4" copper tubing, the ends were flattened in a vise and drilled to hold the mounting screws.

Parts Sources

A well-stocked junk box is the first place to start, your author scrounged most of the parts for this project from discarded electronics. The tuning capacitor came from an old radio and included a built-in gear-reduction drive. If you use a regular variable capacitor, a vernier dial is highly recommended. Tubes and sockets can be found at Antique Electrical Supply or on eBay. Home Depot, or any well-stocked hardware store will carry the electrical boxes and plumbing parts.

Use

Connect an antenna, power supply and audio amplifier or amplified computer speakers to the receiver. Be sure to ground the receiver chassis for safety and performance. A standard 40 meter ham radio dipole will work well with this receiver, a random longwire antenna will also be sufficient. Apply power to the receiver and let it warm up for a few minutes.

Adjust the Tuning control to a part of the band that you want to listen to. Set the Fine Tuning control to the center of its range. Adjust the Regeneration control until the receiver just starts to hiss. Adjust the Preselect control for the loudest signal, if the receiver starts to squeal, turn the Regen control down a bit. Adjust the Tuning control until you hear a station. Adjust the Fine Tuning control to zero in on the station. At the higher frequency end of the dial, the Fine Tuning control can be used to select individual stations across a small band segment.

All of the controls will interact with each other so it is a bit of an art form to get the receiver tuned to a station and peaked for the best signal. Once the controls are set correctly, the audio quality will be quite good. The Regeneration control will gradually need to be lowered as the Tuning control is changed to higher frequencies. If you tune to an active area on the shortwave band, multiple stations can be selected with just the Tuning control.

When the Regeneration control is adjusted too high, the 6U8A Pentode section has a tendency to break into oscillation at around 15Khz, not all regen circuits behave this way. Numerous changes were tried to eliminate this behavior, including removing the power and connections to the triode stage. Fortunately, this does not affect the receiver performance when it is adjusted correctly.

Circuit Variations

The initial design of this receiver covers 5-10 MHz, which includes several shortwave broadcast bands, the 40 meter ham radio band and the 5 and 10 MHz WWV time stations. With such a wide frequency range, the receiver tuning is very touchy, even with a vernier drive capacitor. If a narrower tuning range is desired, replace the tuning capacitor with a lower-capacitance part and add a fixed-value capacitor in parallel.

This design can be modified to receive frequencies from the AM broadcast band up to around 20 MHz by changing the resonant frequencies of the two tuned circuits.

The detector coil (L1) is already wound on a plug-in coil form. It would be relatively easy to construct other plug-in coils, just use a similar turns percentage (about 30% from the bottom) for locating the cathode tap. The extra pins on the coil socket could be used to connect the unused tuning capacitor sections for operation on lower frequencies. The preselector coil could also be built with a plug-in form, different types of toroid material and turn counts would be required for coverage of other frequency bands.

If the receiver is to be used to pick up ham radio signals, the tuning range should be reduced to cover a much smaller range, such as 6.9-7.4 MHz. This can be accomplished by replacing the tuning capacitor with a much smaller value variable capacitor and placing a fixed capacitor across the new tuning capacitor to set the range. It would be also be a good idea to use a gear reduction vernier dial on the tuning capacitor.

Crystal-Stabilizing the Piglet

An experimental crystal stabilizer was added to the regenerative feedback loop in an effort to stabilize the receiver over a narrow band of the radio spectrum. The results were quite impressive, when the receiver was tuned to near the crystal frequency it suddenly became more sensitive and also more stable. Morse code signals could be copied easily and could be listened to for many minutes without any significant drift.

A large FT-243 ham radio crystal with a nominal frequency of 7.05 MHz was used. With the crystal installed in the socket, the receiver can tune from about 7.03 to 7.05 MHz with the sensitivity dropping off on the edges of that range. When the tuning capacitor is adjusted so that the LC circuit resonates with the crystal, one can hear the crystal "pop in" to resonance and the received signals get much stronger. When the crystal is removed from the socket, the receiver goes back to its normal wide-band operation. For crystal-stabilized operation, the tuning capacitor configuration should be modified for single band operation (see above).

Other options for crystal stabilized tuning include adding a small coil in series with the crystal, using multiple crystals in parallel and using a ceramic resonator instead of a crystal. Ceramic resonators are known to have a wider pulling range than quartz crystals.

Hartley Regen receivers

The Hartley oscillator circuit, with the characteristic tapped inductor, is very common in regenerative receiver detectors: it offers a simple circuit that - from experience - wants to work even in rough, cobbled together formats. Sometimes though, if the gain stage, be it thermionic or solid state, has a bit too much gain, hfe or Gm, or perhaps you set the feedback tap a bit too “generous”, a shunt resistor in parallel with the feedback section of the winding will usually “soften” the beast, and yield a smoother slide into oscillatory autodyne mode for CW and SSB. So much so, the feedback function, rather than being solely applied to power volts or screen grids, can take the form of a pot. across the feedback section of the winding, so you have a “coarse” adjust on the screen grid, and a “fine” tweak pot in parallel across the feedback winding, making the adjustment far easier and repeatable whilst simultaneously softening the slide into oscillation.

I can’t give any guaranteed values for the softening resistor, it’s a “suck it and see” job - but you’ll very soon find a value that delivers better performance.

A different approach to 2m FM? - Take 2!

I had a number of emails about FM on Top Band, for which I thank all correspondents very much! More like that is very encouraging: FM on Top Band is a revelation, for local - and not so local - communications. Some correspondents told me of being threatened by other amateurs that “they were breaking the law” or “you’ll lose your licence because I’ll report you” by operating NBFM (narrow band frequency modulation) on Top Band. What absolute bigoted nonsense!

The uncalled for obstinacy of these “policemen” amateurs - and this is the sad bit - is woefully wrong, by not having a grasp of their licence as laid down by OFCOM and publicly demonstrating lack of understanding of their license conditions.

A glimpse at the OFCOM (UK) licence does NOT state specific frequency allocations within the amateur bands. OFCOM state categorically what *modes* may be used by amateurs but neither offer (or apply) any band *plans*. They DO, however, suggest the RSGB voluntary plans be used; but give no compulsion, legal or otherwise.

I am fully in favour of band plans in each amateur frequency allocation, where you’ll find an “All Modes” sector in each band and this is where NBFM could be used in full conformity with OFCOM and the voluntary RSGB band plans. The RSGB do a magnificent job in offering band plans that suit all current amateur modes - including NBFM in ANY band that has an “All Modes” sector. The steady carrier of FM sounds just like an unmodulated AM carrier, and will present a heterodyne whistle as the receiver tunes past the signal (assuming the BFO or Product Detector is running) - and if that’s acceptable for AM then there is no valid argument against NBFM.

The demodulation of FM is beautifully simple nowadays: complete IC intermediate frequency strips on a chip are available; there are Phase Locked Loop demodulators, even the LM567 tone decoder can be used as an add-on FM demodulator, which removes the ratio detector and discriminator alignment issues. The LM567 PLL gives superb results: limiting and auto frequency control come for free along with the 20dB+ noise reduction advantage NBFM offers over AM.

For a real “lateral thinking” experience, consider Nat Bradley’s (ZL3VN) discovery, who by introducing a pilot carrier from a local oscillator into the front end of a super regen receiver, demodulated NBFM perfectly by setting the pilot oscillator to exactly the quench frequency above or below the NBFM centre frequency.

This hints at some possibilities: make the pilot carrier oscillator variable, or - and this caught GW6NGR’s attention - make the quench oscillator variable. Thus you could adjust the quench oscillator to “tune in” the receiver. This also hints at multiple channels being available on one carrier frequency, by running several different quench frequencies! There MUST be a snag somewhere with this!

A guide to successful Regen Receivers...

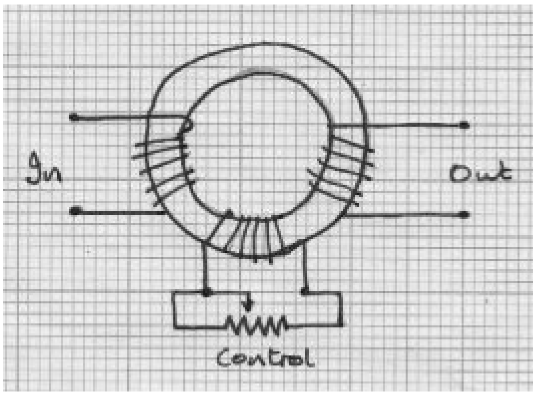
Once in a lifetime, an expert in regenerative receivers shows up. Dave Schmarder (N2DS) is one of these: his advice, designs and finished results are a credit to him and are a guide to all those interested in making a radio receiver that performs in the top notch category. You’ll find all the relevant information you'll ever need for reference in his pages http://makearadio.com/; I was intending to give a sample below of his guide to making a high performance regen receiver; but after trying for a week, trawling through all his web pages and references to find an email address to write to and ask his permission - I found nothing to help. I don't want to upset Dave in any way and understand why he might want to be "unobtanium", so if anybody does have a contact email for Dave Schmarder I'd very much like to ask his permission to use his regen guide.

In the meantime I suggest you check his website out; he's an amateur - N2DS - so he knows the score with HF receivers. If you know his email, please forward it to me at equieng@gmail.com .

The Cachia Attenuator

Here's an input attenuator that can be made from junque parts, no critical bits. Basically, it's a transformer with a third "load" winding - the input winding creates flux in the core which is "robbed" by the control winding and rheostat, before coupling to the output turns.

Any ferrite ring will (probably) do; make two identical "signal" windings, and add a third "control" winding to connect to the rheostat. You will need to cut and try; as a start I usually try 3 x 10 turns, and a 100K - 1k (not *too* critical...!) carbon track potentiometer on VERY SHORT leads to the control winding. If you have a signal generator, you can try the attenuator by tuning your signal generator and receiver together, then inserting the Cachia attenuator in the line and check the effect. Not bad for a few junque parts! Make it up in a neat box when you've got the optimum performance with handy plugs and sockets for quick deployment.



Direct conversion receivers & SSB - the 4th. Method?

A novel approach to SSB - The 4th. method? See:

https://sites.google.com/site/vk3bhr/home/ssb-by-the-4th-method

I particularly like the blend of standard value phasing network with digital quadrature signal generation. Probably not the simplest method; but likely the easiest using commonly available (& therefore cheap...) parts: it's well worth a shot if you're an SSB aficionado!

Tx Topics

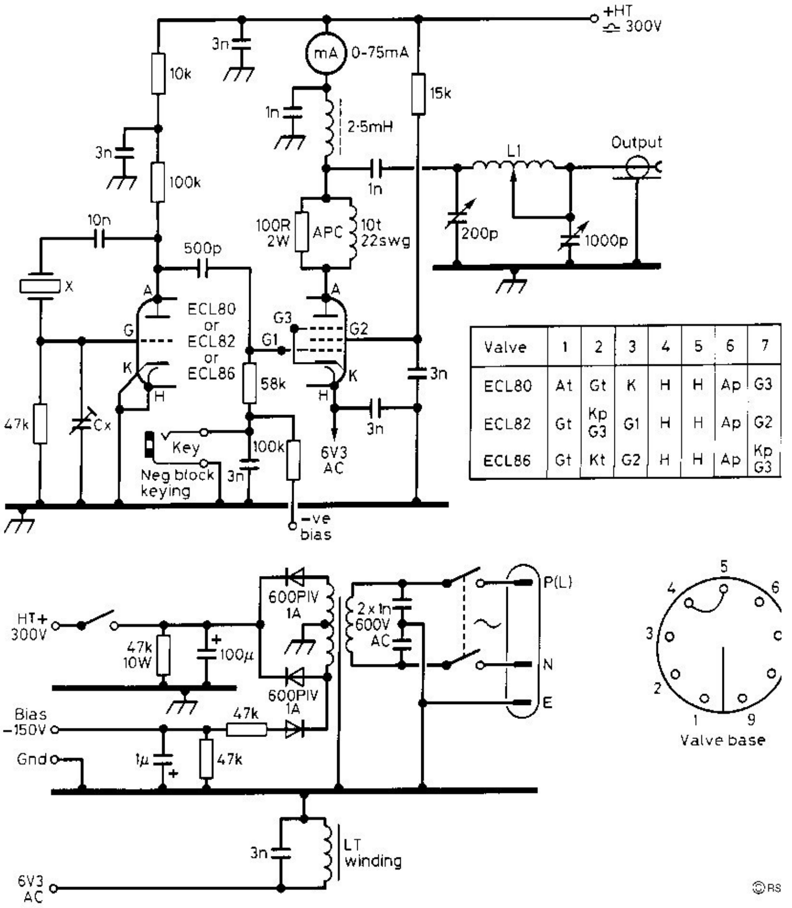
ECL 86 transmitter by G4VAM

How simple can it be? Bombproof, too! Knock this up with an el-cheapo PCL86 TV tube for a really nice home brew transmitter. The anode meter can be replaced with a filament lamp; 12v at 120mA would be about right, fitted with a “tune / run” shorting switch for those extra mW’s.

For the filament supply, 13.3v at 300 mA, use the 6.3v winding and a voltage doubler, then add a series ohm or two to get bang on. It’s not unknown for “enthusiastic” amateurs to push this valve to 13.5v on the heaters; and 350v (or more) on the anode. Just remember to back off a bit when the anode glows cherry red...!

A.M. enthusiasts could try “cathode modulation” for with a mosfet in the cathode to ground link: adjust the mosfet gate bias for 50% carrier output with key down and no audio applied to the mosfet gate. You’ll need some RFC’s and decoupling capacitors to keep the RF out the audio section.

The 14GW8 tube, perhaps more common than the PCL86 in the USA, and maybe cheaper too - is a direct substitute for the PCL86, but I’ve been told the pinout can be different so double check. You can usually spot the anode connections coming down through the base, and the filament leads - these in the “right” place should tell you if you’ve got a plug-n-play substitute.



Valve	1	2	3	4	5	6	7
ECL80	At	Gt	K	H	H	Ap	G3
ECL82	Gt	Kp G3	G1	H	H	Ap	G2
ECL86	Gt	Kt	G2	H	H	Ap	Kp G3

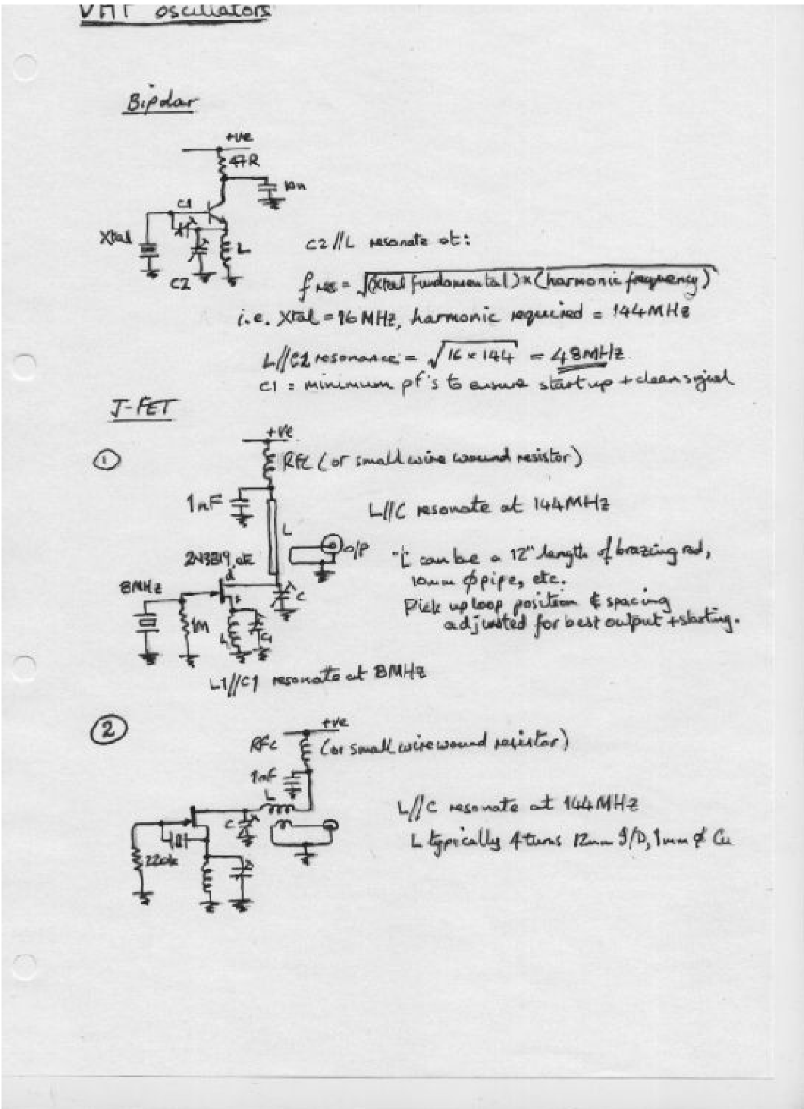
A QRPP 2m transmitter

It’s a very handy device to have around, if you’re into VHF: a local signal source to test your designs. I use a Trio Grid Dip Oscillator, but is afflicted by quite severe “driftitis”, a nasty feature of simple oscillators running at these frequencies - but for quick resonance checks and similar GDO jobs, quite adequate. So, 8 MHz crystal from the junque box, a crystal oscillator cobbled together, and lo! I had a stable, reliable signal source for Rx test. Pete Insley, who ran a radio and TV repair shop, put me onto these circuits, he used them as alignment aids for his VHF radio repairs by substituting crystal to hit 90MHz output. Of course you can substitute crystals and resonant elements for 4m or 6m bands, whatever you have to hand or prefer.

Below are a few VHF crystal oscillators, all of which use resonant harmonic multiplication and make dinky QRPP transmitters, when matched into a half decent Yagi antenna.

Tune the oscillator L & C for a dip in supply current, as per usual practice, you can detect output level with a simple Germanium diode probe - “tune for maximum smoke” as Stan used to tell me!

(Apologies for the reproduction quality; the original was a rather old piece of paper. Use “zoom in” to see in detail).



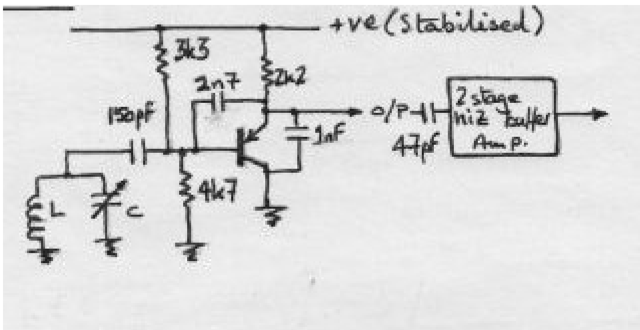
Oscillator Topics

The Synthetic Rock

I had a request for my "favourite" VFO circuit, meaning an L / C oscillator rather than a PLL / DDS, for 5MHz. For decent results you MUST use a good quality tuning capacitor(s), and a rock solid inductor wound on a decent former. These are not easy components to procure nowadays: a handy trick is to get a good example and design your VFO's to use an "outboard" tuning capacitor and inductor combination. The power supply is critical too: double stabilisation, via two monolithic regulator chips is a good way to go: initially to (say) 8 volts from +12v DC, then to 5v DC to feed the oscillator. The lower the voltage to the oscillator, the less the elements in the circuit heat up: running your oscillators on as low a voltage as you can is therefore a good idea. You might need a couple of buffer amplifiers to get the drive you need; but buffer amplifiers, if well away from the L / C, don't contribute to drift.

A diecast box for your superb L & C parts, with wide strips of pcb material to make the connecting jumpers inside (some oscillator circuits need parallel, some series, L / C combinations) is a good idea. Make the external interconnection a short length of screened cable, no longer than absolutely necessary; or make it a BNC socket on each and a "back-to-back" BNC adapter to connect them. The earthing of the L / C parts allows this and it makes for a very stable secure connection; as a series connected L / C oscillator doesn't care which component is earthed.

This circuit is a Seiler; it dates to 1963, and is the famed solid state "synthetic rock". It will, after a little warm up, hold zero beat with a crystal if reasonably steady temperatures are maintained - I've been tempted to try a Huff-n-Puff stabiliser on it, which would probably yield a good (low cost and easy!) substitute for a DDS / PLL, as it doesn't have the spurs and noise of digital controls.

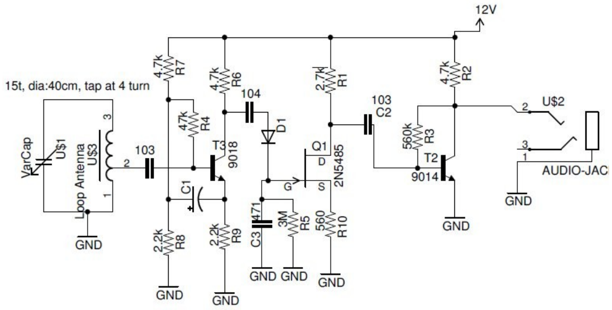


Purists will note the huge capacitances wrapped around the transistor: this is the key to good performance, as the any temperature shift in the transistor parameters and internal capacitances is swamped by the huge chunks of pF's wrapped around each terminal. Make the capacitors with NP0 dielectric, it's an idea to substitute the tuning capacitor(s) with a fixed NP0 capacitor, and note the drift after an hour - the fixed NP0 capacitor shows you the drift attributable to the inductor and the construction, so you can use a different ceramic dielectric capacitor to correct the drift. A useful reference is:

https://forum.digikey.com/t/understanding-ceramic-capacitor-temp-coefficients/727 .

 The PNP design also allows earthing the collector, a great aid to stability and heat sinking, a heatsink on the transistor will help stability in most cases.

The 150pF base capacitor “unloads” the tuned circuit; another idea was active bootstrapping the base bias point - as in the circuit below, which is a simple bootstrapped TRF receiver, to illustrate bootstrapping an L / C resonant circuit:



(I don’t have the original reference for this circuit - if you recognise it please let me know).

The positive feedback via C1 creates >1Mohm input impedance, relieving the tuned circuit of virtually all loading, increasing the tuned circuit “Q” without using “traditional” regeneration. The bootstrap principle can be readily adapted to oscillators, amplifiers and any other application requiring high AC signal input impedances. For a more comprehensive reference about bootstrapping, see http://www.keith-snook.info/wireless-world-magazine/Wireless-World-1968/High%20Input-Impedance%20Amplifier%20Circuits.pdf .

Audio Topics

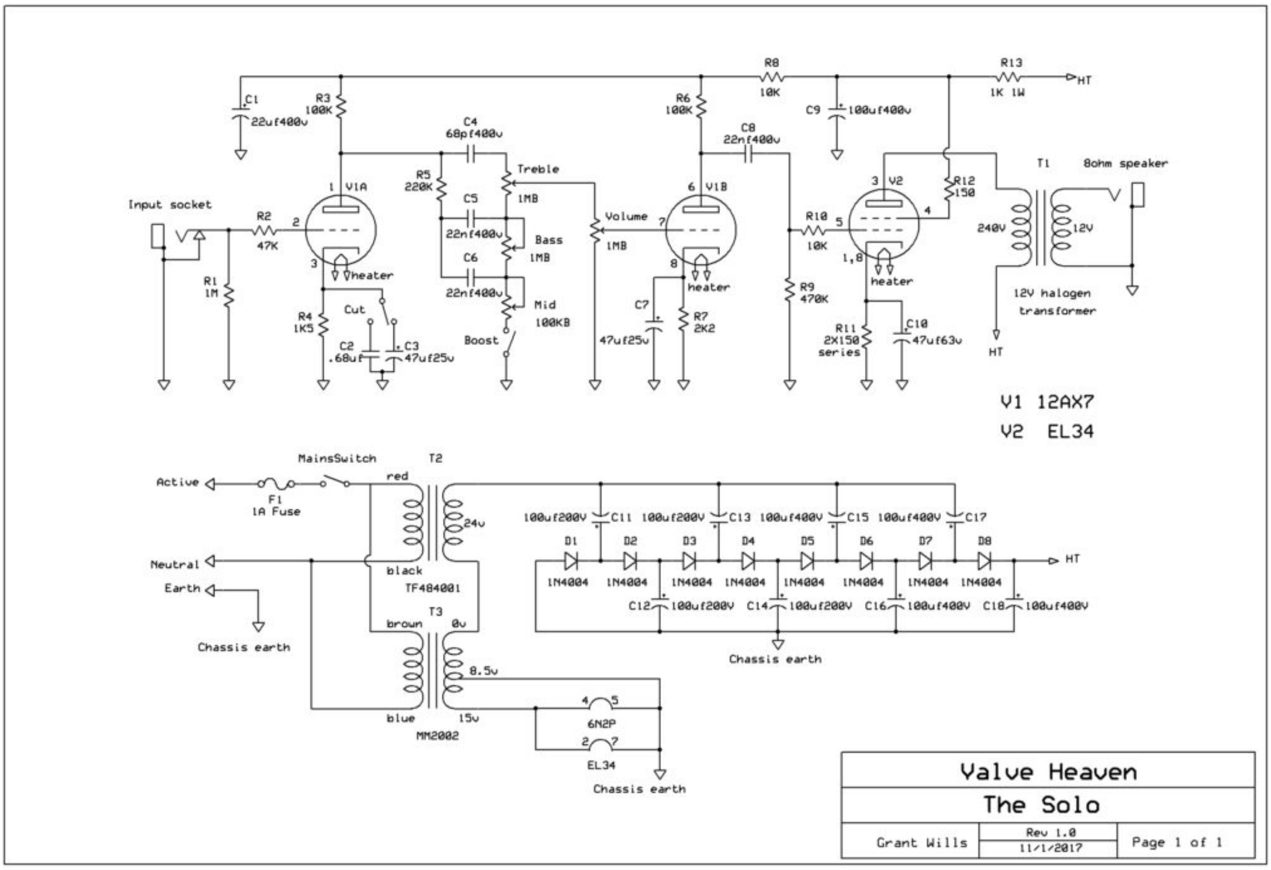
Valve Heaven

Working as I did in a factory with an applications lab that had several audio amplifier geniuses creating phonic sonic miracles it was guaranteed some audio appreciation rubbed off on me! One particular design was a 150 watt A.F. slave amplifier, based on a ZN424 gated op-amp. I would give a great deal to see that circuit again!

One major point though: to get really linear, low distortion amplifiers capable of driving cathode ray tube scan coils - a more or less identical job to driving loudspeakers - you need a complex circuit, and, in some instances, matched pairs or quads - whereas older hands who had been brought up with “Williamson” valve amplifiers loved the valve circuit simplicity (derived primarily from canny output transformer screen grid taps) generally disliked the feedback and bootstrapping in silicon designs.

The arguments for and against solid state vs. thermionic amplifiers still rages today: neither will win, it’s so subjective. But experience points toward the inherent simplicity of tube designs, delivering reliable watts of “good-to-the-ear” audio. The commercial music industry like tubed amplifiers: there’s a damn good reason for that, and it’s not nostalgia!

In hunting around for active, practical designs for “TV” type tubes with “odd” heater voltages - thus still obtainable at penny prices (well, nearly...) as “NOS” - I came across Grant’s web pages [https://valveheaven.com] and lo! There was the answer to my prayers: take a look, read slowly and absorb the wisdom. You won’t be disappointed! Below is Grant’s design of a simple 10 watt valve amplifier, using common tubes.



Take a look at that power supply: I've not seen a parallel voltage octupler circuit driving real mA's for many a year. Note that the diodes are rated at comparatively low voltages; the electrolytics step up in voltage rating, unlike the diodes, as in the usual "series" connected multipliers. Note too the heater voltages - Grant is a lover of TV tubes and halogen lamp transformers. He uses, in some instances, these low cost transformers as valve output transformers, the turns ratio of roughly 20 to 1 (240v in, ~12v out) giving an impedance ratio of 400 to 1 - an 8 ohms load = 3k2 in the anode, far cheaper and vastly more available than many other "audio transformer" solutions.

He's not over driving the heaters using an 8.5 volt tapping: the wiring combined with transformer regulation means he gets 6.3v delivered right at the valve base terminals.

Would you like to check out those junk box tubes you have never used? Try Grant's Tube Tester, so simple, so straightforward. Take a look at:

http://www.valveheaven.com/2015/03/an-inexpensive-easy-to-build-diy-valvetube-tester/

A different "TV tubes" amplifier is at: https://valveheaven.com/2019/11/another-tv-special-amp/ which illustrates a simple "doubler and dropper" set up to get the heater voltages spot on.

Power Supply Topics

The "ideal" HV power supply & some Notes on Safety Earthing

From: https://www.angelfire.com/electronic/funwithtubes/Com_Rcvr-E.html I read what follows; & I agree entirely!

Safety Grounding.

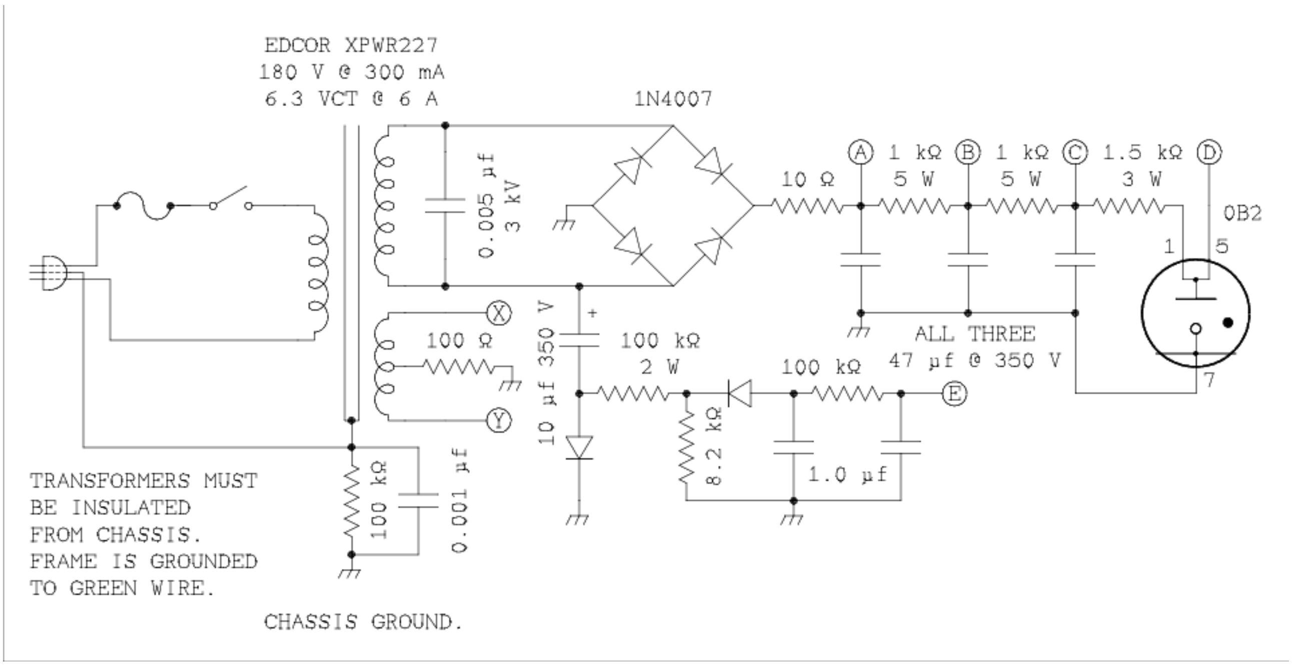
Electrical safety has been taken to the extreme of forcing new construction to use spark detecting circuit breakers that will be tripped by a sparking thermostat in a hair dryer or an electric drill with a sparking commutator. I have to advise you to be safe so you can't say I didn't warn you! A ham station is one of the safest things around because it is connected to an antenna earth / ground that in most cases is better than the one the power company put in when the house was built; however that's not enough for some safety fanatics. Here is my advice and it's up to you to take it or leave it.

Insulate the power transformer from the chassis and connect it to the third wire ground which is usually a green wire in power cords with molded plugs or a green screw in a plug you attach to the cord yourself. If a fault develops in the power transformer the fault current will go back to the power ground as intended. The power on/off switch should be similarly isolated from chassis and connected to the power safety ground. No metal that is part of the switch should be located where the operator can come in contact with it.

"*The secondary is connected to the chassis which is the common return for the rest of the receiver. Just in case the receiver is operated away from the ham station ground there is a resistor capacitor parallel combination connected from the power safety ground to the chassis.*

The reason the two grounds are not connected together is 60 Hz hum. When an independent ground is connected to the power ground, such as the TV cable or a ham station, relatively large current flows because there is a small potential difference between the two grounds. Although the voltage is small, so is the impedance so the current is relatively large. This will induce hum into everything including your transmitted signal. If your station happens to be located right next to the main electrical panel you may want to try using the power ground as your station ground. This may or may not work. Be prepared to sink your own ground if it does not."

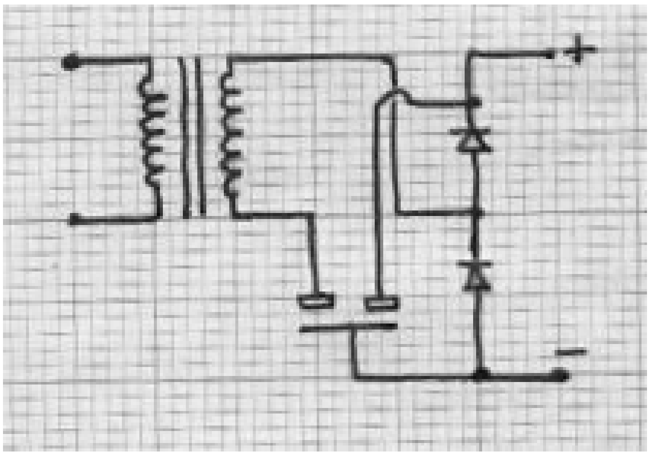
He shows the following diagram to illustrate:



__The Dinky Doubler__

Years ago double or twin electrolytics in one canister were common: you got reservoir and smoothing capacitors all in one, with a common negative terminal (the metal case). The addition of a choke or low ohms power resistor between the two positive terminals gave you a complete power supply in very small space for tube electronics. Nowadays these are rarely seen; but the circuit is still of interest as it's so simple and effective, and the insulating sleeves on HV electrolytics are well capable of service in this application. Below is a full voltage doubler using a twin common -ve electrolytic.

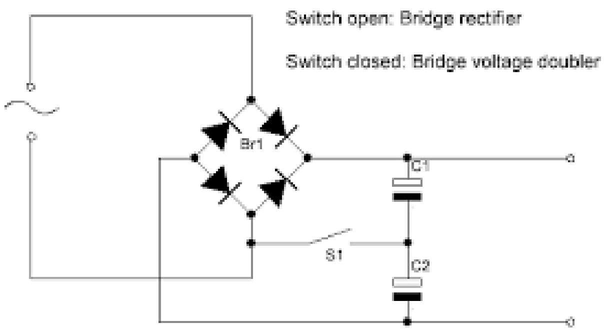
It's also a note to those of us who service tube gear of any sort: those old boys certainly knew their onions when it came to economical and elegant design, something seemingly forgotten in this day and age where the ease of bunging in another dozen or two active devices renders modern designers somewhat lacking in the wonderful (read "reliable") simplicity of economical design!



__QRP or QRO?__

Here's a wonderfully simple design, that's adaptable to either tube or solid state jobs: it's a voltage doubler with TWO massive advantages. It uses a cheap and readily available bridge rectifier and it can provide either "QRP" output volts or... for QRO operators who want all the RF watts they can get (think RTTY and the like), a doubled output - at the flick of a switch. Neat, eh? Using a common 120v to 230v transformer - or back-to-back halogen lamp transformers to get 230v AC, this circuit gives ~ 310v or ~ 620v.

Might be usefully used for the PCL86 transmitter, for instance, if fed with 110v AC?



My thanks to the author of this diagram - not given on the image. Please let me know if it's yours and I'll credit you in the next edition.

Component Topics

Home made RF chokes

RFC’s can be made cheaply and easily by adopting, adapting and improving other technologies - in this instance, sewing machines! Nowadays the once common 2.5mH RFC’s are rare, if not “Unobtanium” - so here’s a good substitute.

To make your own RFC’s, you need a few items, as well as the enamelled copper wire for the winding. First, from our favourite auction house, you need “Universal Sewing Bobbins”: typically https://www.ebay.co.uk/itm/262670781164?hash=item3d28660aec:g:afwAAOSwZmdgeEHi . Then, by watching your local rummage sales, junk shops and such like, procure a small hand drill, as per:

To mount the drill, you’ll need a small vice - the suction based type is good - and this holds the hand drill by gripping the body beneath the large pinion wheel, thus putting the drill in a horizontal position. Some M4 steel bolts, 30mm long or more, with some M4 washers and an M4 wing nut for easy mounting of the sewing machine plastic bobbins in the chuck of the hand drill are used to grip and turn the bobbins.

The spool of enamelled copper wire is held on a bit of dowel (or even a pencil!) fitted vertically into an offcut of timber, weighted down or clamped to a table top; the friction to tension the wire as it’s wound is created by packing some kitchen tissue packed into the centre of the wire spool to bind gently on the vertical dowel. Mount the sewing machine bobbin on the 4mm diameter bolt, and lock into the drill chuck. Mount the spool of wire and friction dowel roughly in line with the bobbin in the drill chuck and clamp or weight it to maintain its position.

Now it’s time to wind the choke. Feed some wire through a convenient hole in the sewing machine bobbin; they are usually moulded in. Feed through the hole roughly 100mm of enamelled copper wire and secure with super glue or hot melt glue.

Start rotating the hand drill handle, guiding the wire with the free hand; the friction on the wire spool sets the tension and is maintained as long as you keep a little pressure on the drill handle. Fill the inner diameter of the sewing machine bobbin evenly until you reach the opposite cheek; a touch of super glue secures. Now, and this is an important point, bring the now secured wire back across the first layer of turns to the start cheek, in just one turn - this minimises the capacitance between the layers - and secure with super glue. Wind the second layer, exactly above the first layer, and return to the start end cheek once again when the second layer is complete. Fill the bobbin keeping the windings neat and tidy, always returning to the start end cheek after every each complete layer and using super glue to keep the windings secure. Keep a tally of the completed layers for reference.

For the low bands, say below 20m, fill the bobbin, keeping pressure on the end cheeks to a minimum. For the higher frequencies, you'll need fewer layers: at 10m probably a single layer will do fine. Check the inductance thus created with a home made Maxwell bridge, or direct reading instrument. My first attempt was ~ 2.0mH with 38 swg enamelled copper wire and a full-ish bobbin, with soft iron pins packed into the core of the inductor, measured on my home made bridge. Bear in mind too, the bobbin can be anchored with a screw through the centre hole very easily.

The layers of windings tally can be used to scale up or down your inductors; the multiplication ratio makes the winding job a doddle. Always remember to keep some friction pressure on the wire spool; some people use springs and cotton pads, weights on top of the spool - in fact anything to stop the wire spool spinning freely and preventing the wire from springing off the spool and unravelling. I've even used spring clothes pegs, a lump of rock off the beach with a hole drilled in - you name it, it will probably work.

Low Ohms "resistors"?
Need an ohm or two for a filament dropper? Use a length of wire, neatly coiled up for the job. Got a bit of ribbon cable? Join alternate ends to form a series chain, and you've got a yard or two of thin wire in a neat package that's low inductance too, should the job need that.

Fault Finding without a Schematic: COLD TESTING

WARNING: **On an unknown pcb or circuit you must exercise due caution at all times: all mains power MUST be removed and an "Earth Hook" fitted to short incoming mains terminal(s) to Earth; capacitors must be discharged via a 240 volt 10 watt lamp in series with a 3k9 / 10 watt resistor on INSULATED clip leads (which has saved my life more than once - if the lamp doesn't dim after a few moments consider that terminal as continuously LIVE). ALWAYS cold test as far as possible before testing powered up. This applies to ANY supply voltage or system.**

Ask the user...
When faced with a "dud", find out as much as possible what happened at the last attempt to run the circuit / system. Typically "it was running fine, but then made a funny noise and then nothing", "it wouldn't switch on", "it's not run for a year or two (for which read 20 or more!)".

All these (and a hundred more, all of similar features) point towards a fault based on different prognoses, as below.

Description given	Probable fault symptom
Running then stopped	Sudden failure: something's blown or died the death.
Won't start up but was running OK yesterdayS	Start up surge and / or start resistor(s) blown; no mains fuse, on/off switch jammed / welded off,

Description given	Probable fault symptom
	look for mechanical problems, broken wire(s) inside sheaths, unplugged loose plugs / sockets.
Not run for a while	Electrolytics! Or vermin, damp rot, physical damage, perished insulation, resistors open circuit, relays jammed, connectors rotted, wires snapped... plus all the above.

Fault categories (1) & (2) call for immediate physical inspection; fault category (3), get ready for a long slog! All this assumes that some daft Herbert hasn't been in and radically altered the original (functioning!) design. I often wonder what these bumblers are trying to achieve: they make changes and alterations without any notes, get deep into a non-functioning mire, then go on chopping and changing until eventually wrecking the whole thing.

The only hope here is a rebuild (possibly from archive libraries or other on-line sources to original circuit and components (or substitutes that are very close to original) then repair the mechanical mayhem these clowns have created. As you might gather, I've been in this situation before - and the wreaker of all this havoc usually denies all responsibility, even though he bought it from new and nobody else has ever been in there.

Don't always believe the symptoms of failure you're told: "oh, it just won't start..." can really mean "I've been in there and randomly changed everything I could find, then plugged it in but it blew the mains and internal fuses so I tried 13 amp plug top fuses instead of 2 amp and then tried 30 amp car fuses...". Yes, it's happened to me when taking on a repair for an (erstwhile) friend.

First Moves

Open all the covers to physically inspect the circuit / system. Look for components with burns, damage or fractures. Simply replacing a burnt out component (including fuses!) is pointless: the original died for a reason, and you must resolve this before replacement. Look too for lead wires fractured right next to the component or just above the pcb; resistors burnt; capacitors swollen or distorted; tracks blown out; pcb scorched; wire insulation melted or burned. Use all your senses: gently tug and stress test connection wires, components, plugs and sockets, IC's in sockets (always a favourite candidate for "weird" faults); trapped or crushed wires / coax. You can sometimes smell "burn out" faults, see the leakage of electrolyte from electrolytic capacitors bulging cases, discoloured pins or nearby pcb tracks on connectors.

Cold Testing common semiconductors

Cold Testing means, in most instances, looking for short circuits with your multimeter. Not just low resistances, this means dead shorts, and you might need to take into account your meter's test lead resistances if the instrument can't compensate for these.

Test every semiconductor device with your multimeter set on "OHMS / Diode Test" (or, if you're using an analogue meter, the readings with a known good diode). Note many analogue meters REVERSE the probe polarity on OHMS test, black becoming "+ve" and RED "-ve". Checking your meter's reading on a known good diode proves the polarity of the test probes and gives a "good" reading for you to refer to during fault finding.

I keep a set of known good semiconductor devices to check my instruments at the start of each shift, and after break time - it's not unknown for your "mates" to "borrow" the battery from your multimeter whilst you're away from your bench!

Check each transistor / diode for short circuits, from every pin to every other. Next identify the diodes that make bipolar transistors / jfet's / mosfet's - but be aware that not all mosfets have diodes from Source to Drain; nor are all mosfets N channel with the protection diode cathode connected to Drain: P Channel mosfets reverse this.

Any bipolar transistor will test as two back-to-back diodes on OHMS test, the BASE terminal being the centre connection of two diodes. For NPN, base terminal is +ve probe, diode reading with -ve probe to the other two pins. For PNP reverse this: base = -ve, collector & emitter = diode.

For a jfet, you can find the gate similarly, using one probe to drain or source, the other probe to gate = diode. Note that drain to source will read some (high-ish) resistance, unlike bipolar transistors.

Many power mosfets show a diode from Drain to Source; but small signal mosfets (2N7000, &c.) don't always have this diode: it depends on the manufacturing technologies used. A sneaky test for mosfet functioning is to clip your meter on "OHMS" +ve probe to drain and -ve probe to source, then touch the gate terminal with a graphite pencil tip. Usually the mosfet turns "on", giving a low OHMS reading on the meter. You might need to reverse your meter probes for this to work, it depends on the mosfet polarity, P or N channel. +ve probe to Drain = N channel; -ve probe to Drain = P channel.

Cold Testing Passive Components

Resistors...

...Are where you look for open circuits: a resistor should have some electrical path through them! Check each resistor for a reading on your multimeter when set on OHMS. Resistors can go high with age: this often used to be carbon composition types on screen grid feeds, but nowadays, even quality metal oxide resistors suffer from old age. Any resistor (usually) above a few k-ohms is suspect - why this is, I don't know - but 47k and up are good candidates for going high or open. When testing any resistor in circuit, you should read something equal or lower than the rated value as there must be circuitry around it in parallel! Try reversing your test probes; this might give you a better indication, as it's common for a diode to be fitted reverse polarity in the power supply to catch any inductive backwash which can cause odd readings.

Note too that mains input filters often contain high value resistors to bleed the capacitors down in high power filters. These bleed resistors, failed open circuit, can leave hefty µF capacitors charged up to mains peak volts and capable of giving a very nasty "bite". Your 10 Watt lamp in series with a 3k9 power resistor should be used every time a filter is suspected to discharge all pins to each other, then leave shorting croc clip lead shorting the capacitor terminals together.

On systems where you can't be alongside the mains power source switch, lock out the switch (if possible) and put an "earth hook" onto the live incoming terminal of the equipment. This is a hook, lug or similar fits onto the live incoming termination; the other end is fastened to a solid Earth terminal. Any attempt to power up the circuit immediately blows the upstream fuse, protecting the fault finder from a dangerous situation.

Capacitors...
Of all electronic components, the most likely candidate for old age infirmity is the electrolytic capacitor! You'll fix many electronic faults by simply changing all the electrolytics, lock stock and barrel. If you're a purist, remove every electrolytic and test its ESR with a suitable instrument (an AC OHMS meter in effect). Several circuits have featured in Hot Iron and simple bench test gizmos are available if you're wanting to take up electronic fault finding for professional reasons.

Capacitors in mains AC service - filters and the like - are specially rated for continuous AC mains service. DON'T substitute any other, it's dangerous and false economy. Class X and Y are the ones to go for: https://www.allaboutcircuits.com/technical-articles/safety-capacitor-class-x-and-class-y-capacitors/ has an excellent description and pictures. Basically, Class X are for Line to Line; Class Y are for Line to Neutral. They make superb RF coupling capacitors: just watch the DC levels and voltage ratings, you might need to put a few in series to stand off the volts when used as kV anode couplings.

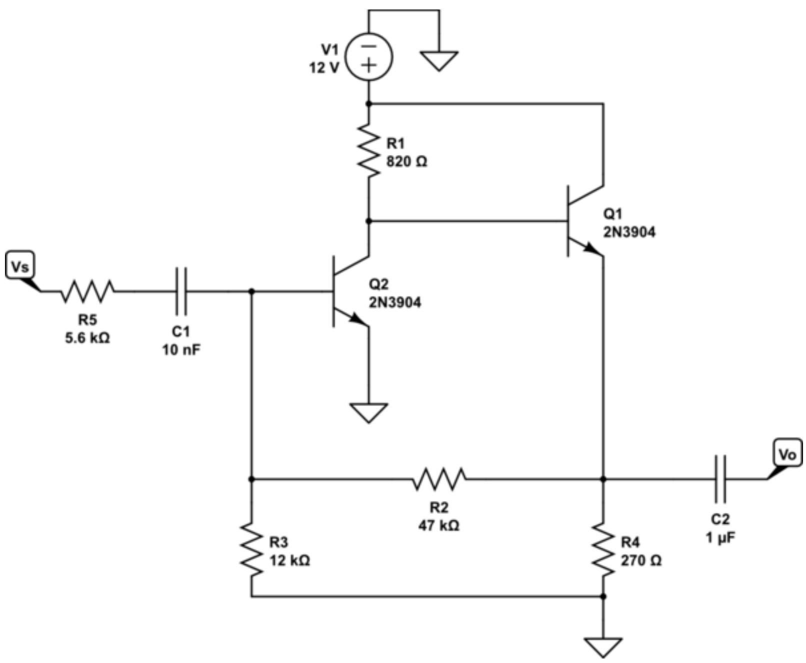
Smaller film capacitors, used all through RF applications, are pretty tough; failures will generally show as two bits of wire with an exploded mess in the middle. What some amateurs forget is the peak RF volts add to the standing DC bias: under high VSWR conditions blown capacitors can indicate an intermittent antenna, dodgy counterpoise or earth mat connection.

Relays
These are often used for Rx / Tx switch-over duty - and if you're a break-in CW operator you're going to need a good supply of spare relays! In basic terms anything that has bearings and contacts will wear out at exactly the wrong moment. Bearings wear; contacts burn. Anything that moves or is subject to mechanical movement like connectors and sockets are other likely candidates for going open circuit when the power is running flat out. Why this should be I don't know: but do it, it does, so be ready! Think "MMS" - "Micro Mechanical Systems" are a million times more unreliable than a hefty diode electronic switch.

Hot testing - measure the volts at every node

Locate the power supply tracks from the smoothing capacitors or voltage regulators on the pcb: these are usually bellwethers to guide you into the circuit. "Common" rails can soon be found with OHMS tests; usually they are the NEGATIVE supply connection - but NOT always. POSITIVE supply tracks can be found from voltage regulator output pin "cold ohms" test to tracks.

Consider the circuit below:



Here is a quick analysis to illustrate fault finding. We don't have a circuit diagram, but we can see the wider common ground tracks on the PCB so it's a good guess that's the point for our negative probe of our multimeter. Similarly, we know the +ve. supply from "cold ohms" testing from regulator chip output pins to various heavy tracks on the circuit board. Watch for components in the common lead of three terminal regulators: often used for auxiliary functions and "jacking up" the output volts.

Let's look at transistor Q2 using a voltmeter (an analogue multimeter for preference). We don't know (or can't find) any information about the transistor; we don't know if it's a jfet, bipolar, or mosfet. It has 3 pins.

Q2 Pin	Voltage to common / gnd.	Probable terminal
1	0.55v.	Base
2	5.5v.	Collector
3	0.0v.	Emitter

It's a good guess the transistor is an NPN bipolar from these results: we know from "cold test ohms" it read as two diodes and an "o/c" across the diode cathode ends. If it was depletion jfet, you would have picked up ONE diode, the gate - and an equal (high-ish) resistance reading either way between the other two terminals, probably the drain and source, which are (usually) interchangeable.

In circuit, volts "on", a j-fet is identified by the source being more +ve than the gate (n channel, the most common type). We can use similar logic on Q1: the chart would look like below.

Q1 Pin	Voltage to common / gnd.	Probable terminal
1	4.9v.	Emitter
2	12.0v	Collector
3	5.5v.	Base

If you look at pin 3 and pin 1 voltages above, you'll spot a silicon diode forward volt drop: the dead give-away. One terminal is at supply rail, or nearly so, and one terminal is at identical voltage to the previous test result chart: they are indeed directly connected, as found by a "cold ohms" test to double check.

You can now, with the aid of the charts, "cold ohms" checks, and physical layout, sketch the circuit and thus see it's function: it's at two stage buffer amplifier, with voltage gain (Av) of 47k divided by12k = 3.92

A "logical" approach
You will see in many fault finding guides the term "...using a logical approach...". The authors rarely, if ever, tell you what that is! At Hot Iron, we take a far more practical viewpoint: below is a technique taught to me by Stan, my mentor all those years ago, when I was a green as grass and hadn't seen the millions of circuit failures Stan had. I was faced with a Cathode Ray Tube scan coil test unit, used in testing radar cathode ray tubes. It generated ramp currents that were applied to the X and Y deflection coils, to create a spiral sweeping the electron spot from the dead centre to the outer periphery, then back to the centre during flyback blanking and off again on its perpetual (or not so perpetual, as it had ceased to function!) journey round and round.

I'd "cold ohms" checked, and found a dud output transistor, short circuit, every terminal to every other. I had the chart below from Stan's guidance:

Reading between every terminal	Probable cause
Dead Short between all terminals	Over-voltage or reverse polarity "punch through" of the internal junctions.
Open Circuit between all terminals	Over-current blown the bond wires.
Ohms between all terminals, tested both directions	Long term overload has melted the silicon die.

A Logical Approach: Artificially duplicate the problem
So, what had blown the transistor? Where had the short circuit come from? Probably - from the chart - over-voltage. Stan came, out as ever, with a golden phrase that still echoes from all those years ago: "what would you have to do to make this circuit create these voltages?". Or, "what voltages would I see if the transistor was collector to emitter short? (or open?)" In this instance, I needed to find where a high or reverse polarity voltage could have come from.

This is the trick Stan taught me: at each stage in a circuit, how would you (mentally!) artificially duplicate the fault conditions you see? Stan gave these examples: "if you find a collector at a very low voltage above ground, you could duplicate that fault with a short, collector to ground, yes? Or driving permanent base current? If the collector was at full rail volts, you could duplicate that fault by open circuiting the collector bond wire inside the transistor? Or shorting the collector load out? Or open circuiting the base bias?”

I saw the point he was making. How could you make this circuit create the situation you’re seeing with some artificial means - because those are the probable cause(s) of the fault you’re seeing, and now you know what and where to test.

I knew over-voltage was the likely cause; the load was inductive (scan coils round a CRT) so where was the backwash (Lenz’s law) back emf protection? A quick search showed, on cold OHMS, a open circuit diode - soldered to the scan coil binding post terminals inside the test gear - the anode connected to the collector, the cathode to the HV positive rail, in reverse parallel with the scan coil on test. Stan reckoned it had been fitted to cope with possible open circuits in the coil wires, and fitted right on the binding posts to stop transients entering the test gear. The diode was quickly replaced; a new drive transistor fitted and a scan coil connected and tested OK. I did notice one of the binding posts slipped round a little as I tightened up the securing nuts...

Ask ‘Why?’ five times...
Stan wasn’t happy. The cause of the O/C diode was not an electrical fault: on close inspection, one binding post had lost its locating key, and was move slightly when the operator tightened up the binding post. The original backwash diode, fitted directly to the binding post terminals, had sheared a “leg”, and this was the source of the open circuit and consequent damaged transistor.

Stan recommended I replace the binding post and apply hefty dose of epoxy resin as double indemnity: then he played a simple but effective master stroke. “Critical components like this diode should always have some redundancy both electrically and mechanically. These binding posts get a right heave-ho hundreds of times a week, every time a coil goes on test. Fit the new diode on flying leads, if the binding post locating key fails again, the diode won’t be damaged”. I made up a pair of flying leads by winding wire round my screwdriver blade to make a simple “spring”, and re-fitted the diode with heat shrink to cover the diode lead wires and solder joints.

“Always consider the cause of the fault, and keep backtracking to find the root cause. You might have to ask ‘why?’ five times as you backtrack to get the real source of trouble! Don’t just bung another component in - it will fail again sooner or later”.

Thank you, Stan: the radar scan coil test gear flew like a bird for years, no more problems.

Construction Topics

Lighting - spot lamps vs flood lights
Modern LED bench lights are a godsend in some cases. Years ago we had halogen lamp spotlights (as used on microscopes and the like) for close bench work; the modern single, ultra-bright LED type, on a long flexible chrome “bendy stalk” is a modern alternative that can throw a bright light just where you want it, stays cools so you don’t burn your fingers, and can get right in to see awkward spots. They do have a problem, though, just as the old halogen lights did: they cast very intense shadows, the brightness of the illuminated spot swamping any peripheral view, and causing some quite severe eye strain, especially in those who wear glasses.

An easy solution is to also use an old fashioned bench (or machine tool) incandescent work light, set a bit higher up; it's more red biased tungsten filament illumination dispels deep shadows and allows much longer on the bench without consequent eye strain. A 40 watt incandescent lamp is perfectly adequate for most purposes, but do keep to mind the shades run HOT! Try by all means an LED equivalent: they run cool and give very even illumination.

Test Gear Topics

Why Moving coil meters aren't dead

My "go to" instrument for most purposes is my elderly AVO Model 7 - it dates from 1947 - and is about as robust as they come, with diecast casing and screw clamp binding post terminals. It's been overloaded, dropped, suffered years of abuse, yet still does the job superbly. As most battle hardened electrical / electronic engineers know, those digits a'dancing on a digital meter just don't reflect reality; they lead to a false sense of accuracy and are generally hopeless at finding peaks or minima in tuning circuits. Yes, digital meters only lightly load, agreed, but I'd bank on my old AVO in the rough and tumble of industrial grade kV's, MHz, and kA's.

To that effect, you might like to read the following: it makes my old heart sing to see this sort of thing. See what you think!

https://hackaday.com/2017/11/08/why-you-shouldnt-quite-forget-the-moving-coil-multimeter/

Antenna Topics

Active Antenna co-ax outer noise

If you consider the modern home with its plethora of switching power supplies, digital noise generators and TV electronics all spewing out broadband RF, any adjacent - and not so adjacent - conductor will intercept the radiated hash, and this includes the outside of the OUTER screen of co-ax: your prized antenna lead-in. For those of us with limited "real estate" to assemble our antennas often turn to active receiving antennas, and these, though excellent, can be badly disturbed with the onslaught of noise from household appliance power supplies and the like. This, on the outer of the co-ax coupling line to the receiver, walks into the active antenna amplifier via earth / common power supply lines and apparently "grounded" enclosures.

This is a job for those chunky ferrite tubes, or similar, to catch those outer screen interference currents. Consider too, for a quick fix, wrapping your active antenna downlead around a ferrite rod - or even a taped together bunch of iron nails. This will give you a quick means of checking if outer screen currents are really the problem with your "noisy" antenna.

Put the ferrite or iron chokes very close to the antenna amplifier module if you can; this can be a bit of a problem in some installations - so try several smaller chokes along the downlead. It is, as always, a very good idea to use a "braid-breaker" transformer or link coupling into a pre-selector tuned circuit, to reject as much unwanted mush entering your receiver as possible. A simple LC tuned circuit, followed by a high input impedance unity gain buffer (or even below unity gain, creating an active attenuator) a-la bootstrapping as shown earlier in this edition of Hot Iron should be of benefit.

You won't do any harm using those big ferrite sleeve cores on any coa-ax antenna lead: current on the outside of the screen are trouble, whatever the cause - so if a ferrite sleeve on the outer makes a difference, you need to investigate further!

Impedance Matching made easy

From Tom McKee K4ZAD I have the following, and as a lover of simplicity, I admire his obvious choice and design!

"*An Antenna Impedance Matching Tale* *Tom K4ZAD*

A neighbor recently got re-licensed after being off the air for almost 60 years. He wanted to use CW as he did as a teenager via a 20 Meter 5 W QRP rig. Our neighborhood's antenna restrictions prohibited an outdoor antenna so he installed a 20 M dipole in his attic and trimmed it to resonance at 14.08 MHz. Unfortunately, and possibly due to nearby wiring and heating/AC gear, its impedance was 84 Ohms, almost pure resistance with some inconsequential C, as measured through a Balun at the antenna. Not really a terrible match.

But, unhappy with the mismatch to his 50 Ohm coax feed line and the line match to the rig, and not wanting to use an ATU just for single-band CW operation, he talked with me about what else might be done to get a more-perfect match. We discussed the, "quarter-waves transform and half-waves repeat," phenomenon and he tried a couple of short random lengths of coax added to the feed-line but neither alone, or both in series, made the match at the rig satisfactory. Besides, I knew that the problem was best corrected at the antenna.

A quarter-wave length of 72 Ohm coax installed at the antenna could transform the impedance to 60 Ohms. That was a bulky solution needing a velocity-factor correction and only partially correcting the problem. Then I remembered the simple, three-element, Pi-network, lumped-constant equivalents of quarter-wave coax-line transformers that I occasionally used years ago in my work with General Electric's (USA) mobile-radio business. Five Watts wouldn't stress one of those. I could build a 67 Ohm one and it would transform the 84 Ohms to 50 Ohms. Digging through some old notes produced the design equations.

The input and output capacitors: $C = 1/(2 \pi f Z)$ The series inductor: $L = Z/(2 \pi f)$

Where Z is the desired transformer impedance in Ohms, C is in Farads, L is in Henrys and f is in Hertz.

Putting 67 Ohms and 14.08 MHz into the equations yielded 169 microFarads for the 2 capacitors and 0.758 microHenrys for the series inductor. The capacitor value was achieved by paralleling capacitors from my mica capacitor box and the inductor was custom wound on a 6.8 MegaOhm resistor.

The resulting network is shown in the photo. With the network installed at the antenna the impedance there, and at the rig, was now 50 Ohms resistive with some inconsequential L. He is pleased that his antenna is now optimally (SWR 1:1.1) matched, and is happily making North American and European contacts with his QRP rig".

How simple and straightforward is that? An excellent solution!

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Hot Iron 112 Peter Thornton June 1st 2021
equieng@gmail.com