HOT IRON

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CQ-CQ-CQ

More and more people are finding that buying a modern, all singing, all dancing gizmo (be it a camera, radio, or anything whatsoever) holds no long term satisfaction as compared with something you have to *learn a skill* for good results. That's why home-made regenerative receivers, simple transmitters and other miscellaneous radio gear are becoming more popular by the day. Of course, your home-made 1V2 regen Rx can't compete with a £1000+ transceiver - but **you** made it. **You** made it work. **You** created it on your kitchen table, or on your "radio" bench under the stairs, which **you** probably made yourself.

Creativity is one of mankind's basic satisfactions: be it art, photography, writing, studying Nature, whatever. The principle that gives lasting satisfaction is that **you** made it happen **your** way, in **your** time, to suit **your** desires. No Japanese mass-produced "black box" radio transceiver can come within a million miles of that; **you** are individual: each and every one of us are different.

When you are looking to finance buying the latest "wonder" Transceiver keep to mind that next year, after the marketing and advertising men get to work, your current "wonder" transceiver will be "obsolete" and worth a piddling fraction of what you paid for it when you part exchange it for the next "wonder +1" model you *simply* must have, if you believe the B/S the advertising and marketing swindlers peddle. Don't be taken in; year after year the reviews, the performance testing, don't tell you the simple truth that no matter how good a performer that wonder receiver is, or however potent at sending out a signal that transmitter is, it's whoever's operating it and the antenna it's connected to that makes the difference between success and failure - whatever they are, in your context! No mass produced item fits all people; the marketing men want **you** to fit **their** device. Reverse the equation: make your radio equipment fit **you**.

Vive la home built - **always** better than shop bought.

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Seen recently a comment that the ONLY acceptable telephony mode for RESPONSIBLE users of HF bands phone is SSB, quoting that "DSB will disrupt adjacent traffic". What about the distinct A.M. slots on the HF bands? The author of this wondrous missive has obviously not read her License; I can only comment on the UK / OFCOM License, but CW, A.M., FM and a few data modes are specifically allowed; the parts of the band where these modes are allowed aren't mentioned - you could, without breaking any of your UK license conditions, use A.M. or any other mode allowed, anywhere within the bands - with due regard to the transmitted signal's bandwidth near the band edges.

As a gesture of goodwill, we stick to the band plans put forward by the (purely voluntary, with NO official authority or sanction) RSGB. The UK license does not in any way insist on SSB for phone, and those misinformed individuals who think that SSB is the only "responsible" mode ought to read their UK licenses fully and not decry any licensed user who sticks to them.

Those suggesting that A.M or DSB is in some way irresponsible or unlawful are acting in a very irresponsible manner themselves. Whilst A.M. might not (quite reasonably) use the whole width of an HF band due to the bandwidth of the signal emitted, ALL band plans are voluntary in the UK. Indeed, the A.M. spot frequencies prove a most useful means of enjoying A.M. amateur radio operation, and are an excellent way to attract newcomers to amateur radio telephony as construction of A.M. transmitters and receivers is simple, being tuned to a single frequency, and affords a vastly cheaper entry to the bands where A.M. slots exist for those who can't or don't want to blow several £k's to become Black Box operators and not have the ultimate pleasure of building their own station from scratch.

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RF Basics

A very useful description and source of information for all radio nuts:

https://www.ti.com/lit/ml/slap127/slap127.pdf

Well worth a look for all would be amateur radio operators and designers. No matter what your experience or skill level, it does no harm to review and look at the fundamentals of our hobby. It gives a good starting point if you're asked about Radio, or need "Elmer" skills.

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"Filling the Vacuum"

From Grayson Evans, TA2ZGE / K7UM:

My thanks to Grayson for his pointing me to this publication: and I'm very happy to let Hot Iron readers know about it. I'm sure we all wish the Museum well!

You can find more at: https://themuseums.org/international-vacuum-tube-museum/

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From Terry Mowles, VK5TM:

This was prompted by my suggesting that the stability and controllability of DDS / PLL oscillators would allow effective demodulation of Double Sideband Suppressed Carrier A.M.

Re. the DDS phase comments (pages 11 & 12 in Hot Iron #106), a lot of DDS chips can have their output phase controlled in software, although I'm wondering if in fact it might just be simpler to adjust the phase of the incoming signal, capacitors and inductors are good at that sort of thing. The atmosphere has already done a lot of phase shifting of the signal before it reaches you, so a bit more isn't going to make much difference, just a thought.

(I note that apparently I have moved to Victoria by the change in my call sign hihi! Funnily enough, even Google thinks that's where I am at the moment, must look outside and see what's changed).

On Page 16 (Hot Iron #106) and the Zachary Oscillator, the full article (well paragraph in another article), is in Poptronics, page 85 of the December 1970 issue, available on the American Radio History site.

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From John Kirk, VK4TJ (1):

Get The "H" Out of Here

My ancestors have been known to squeeze a quid so hard that it screams, so it's no wonder I can be found on certain far-eastern auction sites, picking up "bargains" on certain electronic components. "Bargains" in quotes, as some things are clearly not what they seem.

I was first alerted to a potential problem by one of my Foundation licence graduates – his uBITX was not behaving as it it should, and he thought his LM338KC regulator might be suspect. "C'mon, Mike", I thought, "It's only got 3 legs – how can you stuff that up?". This guy sand-casts his own heatsinks(!), so is no stranger to "sweat equity" in rigs.

As it happened, I had purchased a handful of the same chip from the same, or at least a very similar source. Sure enough – the chip behaves perfectly until the very final "brick on the key" test (You do perform those, don't you?). It is at this point that the internal pass transistor departs this earthly vale of tears with alacrity, fortunately in an open state, rather than the more often seen "Let's dump the entire job lot of unregulated DC into the gozouta" state I am familiar with.

We expanded our field of research to include additional suppliers, as well as similar 78H05 & 78H12 regulators. Not a one was found to be what it said on the tin!

Fortunately, they have not found it cost-beneficial to counterfeit 2N3055 & MJ2955 transistors (yet!), so make yourself a nice cup of tea and re-read Hot Iron 106, where Peter discusses "wraparounds". No, not the sunglasses, nor the skirts your YL used to favour back when granny glasses were de rigueur, but ways of extending the current capacity of the lowly 1-amp 3-legged regulators.

VK4TJ

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From Tim Walford, G3PJC (1)

A quick comment on that simple gate oscillator (Hot Iron #106) with 10K in the feedback path – I suspect that most modern gate family equivalents will not work with this circuit because the loop gain will be too low due to low 'gain' in the gate part of modern gate families. Somewhere in my deep memory I think most modern gate families have a voltage gain of about 10 when biased in their linear region – so 10K in the feedback path is too much for oscillation. Typical circuits now use about 1 to 3K in series.

(That also reminds me that the three gates in series biased in their linear region for linear amplification are quite often prone to oscillation unless they are very fast gates. You can of course put a CR network in the feedback path to shunt that route for AC signals!)

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From John Kirk VK4TJ (2):

I know you were half-joking about cheap equivalents to the 4CX250B, but I have been having great fun with Russian Gi-6B's as a "functional" equivalent @ 7USD. No socket really required - spring steel tool clips from the hardware store work just fine. Yes, they are a triode, not a tetrode, but, at that price, can we really afford to be so choosy? There is an ancient article on my blog on how to hose one up for HF:

https://vk4tj.blogspot.com/

You are welcome to it if it fits the general tone of "Hot Iron", but might need a bit of editorial dusting off & updating.

Many thanks John; your G1-6B blog article appears in the Transmitter section of this issue of Hot Iron.

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From Tim Walford, G3PCJ (2)

….after some thoughts I had discussed with Tim about rising edge speeds in transmission lines:

"Yes, absolutely: it becomes very easy to visualise if you think of the Catt description of a step moving down a line. The input energy is stored in the insulating medium between the line's conductors: the lines themselves merely guide the step to it's destination. The losses the step suffers are due to the current down each line, I^2R, plus the radiated energy of the step as it moves charges down the line. Try it with a twin wire line: one line right next to a MW A.M. receiver ferrite rod antenna, the other looped well away, feeding a 24 watt 12v bulb at the far end. You will hear a click every time you connect a 12 volt battery as the step passes on closing the circuit."

I replied: There you go! Quantum Field Theory with a battery and bulb! This simple experiment illustrates the edge of the DC step function contains many high harmonics. The Laplace / Heaviside transform of a step with infinitely fast edges contains EVERY frequency: if it were possible to create this in a laboratory, you'd see a flash of light as this step passed your viewing station. The problem comes in the time it takes for the electric field to travel in an insulator - in this case, the cable's insulation - but in outer space, in near perfect vacuum, it might be almost possible IF you have a gate that can switch an edge in the Planck Time, that is: 5.391×10^{-44} seconds, give or take a smidgeon, and drive the inductance and capacitance of a perfect vacuum. The Planck Time is the lower bound value for two connected events to occur; in this case the application of the voltage and the field occurring in the transmission line; i.e. a bit sharpish.

The quantum unit of time - the time it takes for light to travel the diameter of an electron - is the Chronon; this it seems, depending on circumstances, is the discrete step that time changes in. As *quantum theory dictates, time is not a smoothly flowing analogue function but moves in miniscule discrete jumps of one Chronon. This is part of Caldirola's work from 1980, more details at https://en.wikipedia.org/wiki/Chronon. A Chronon (again, depending upon circumstance) is approximately 6.27×10^{-24} seconds - for an electron, that is.*

There are attempts to study the quantum nature of time, using Infinite Dimensioned Hilbert Spaces, but that's about as abstruse a proposition as trying to cross London on the Underground in less than an hour! I suggest you look at https://www.britannica.com/technology/chronon for a comprehensive (and printable) discussion, be it a linear progression on an N-Dimensional plane or a convoluted N-Dimensional Manifold. I'll leave it there, as I haven't time, interest or the philosophical training to go into it any further. Suffice to say I'll stick to valves, at least they keep your mug of tea warm whilst you're tuning up!

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A Conundrum, following on from Chronons...

Many years in the future, in a lab somewhere, are a couple of Technicians setting up some Test Gear, to check the rise time of the output of a newly developed Quantum logic gate: it has been designed to have ZERO rise time, using the Quantum property of a charged particle (unknown to us ancient Earthlings in 2020) called a Yubba Ray, which has (like the Neutrino) zero mass, and is capable of being in two places simultaneously, as Feynman's "Sum of Many Paths" theory explains.

The question is: can ANY technology in this Universe ever generate zero rise time? To make it simpler to imagine, the lab is in deep space, there is no gravity, no gas molecules, indeed, a perfect vacuum, and no adjacent electrical or magnetic influences. Imagine the gate output is just a point that changes potential in ZERO time.

If any such gate output has ZERO Rise Time (i.e. a "ZRT" gate), could it ever be connected to another gate to make a logic function? In other words, what is the fan-out of the ZRT gate? What current would the ZRT output have to source / sink to create a true ZRT gate?

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A note about Copyright and similar matters

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Tim's Topics

Here's a lovely regen. receiver by Tim. It's simple, effective, and functional by separating the detector from the Q-Multiplying RF amplifier. Enjoy!
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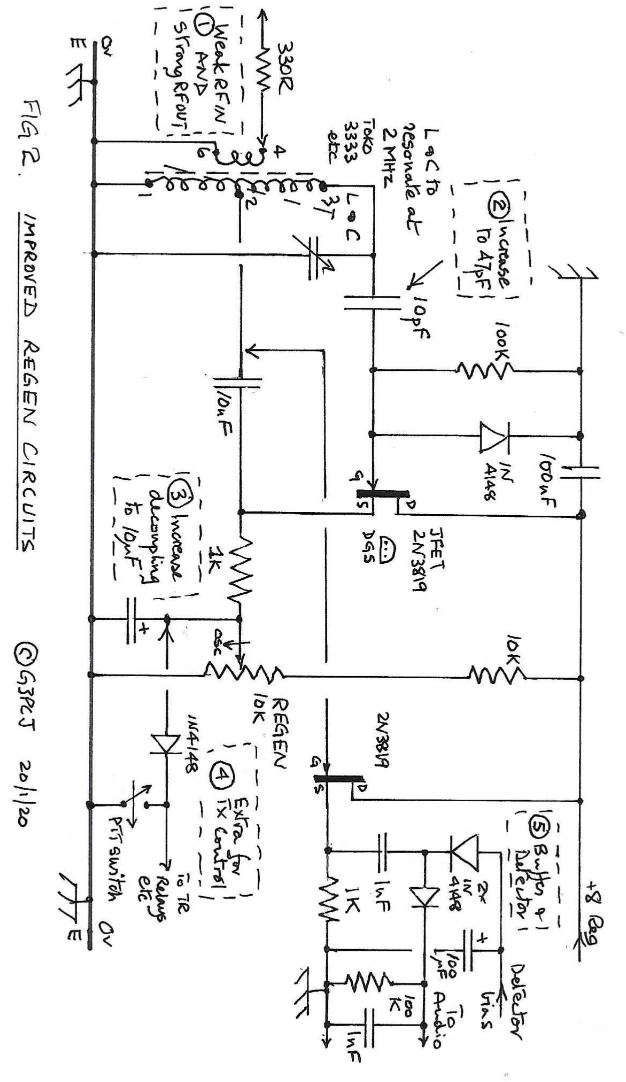

My apologies for the odd image rotation!

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Components and Circuits

40673 - a friend indeed

I had been prompted by a certain gentleman (“from the left coast” as he often says in his podcasts) that jfets would substitute for a 40673 dual gate mosfet; surely the most useful signal handling semiconductor ever made. As most know, RCA, the manufacturers of the original (and ubiquitous) 40673 ditched the production for pastures new some years ago, but so universally useful is the venerable 40673 that you’ll find it specified in designs seen even recently. The question, therefore, is: “how do I build a circuit with all the capabilities of a 40673, with modern easily available components?”. Certainly, dual gate devices are available; some run out at £10.00 or so each with
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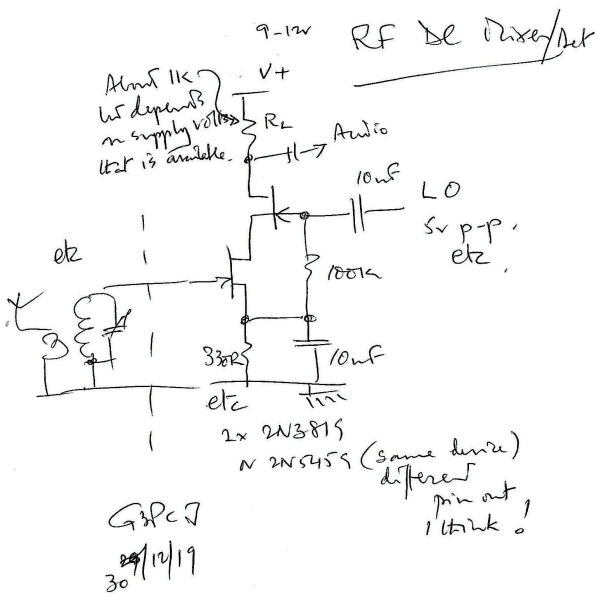
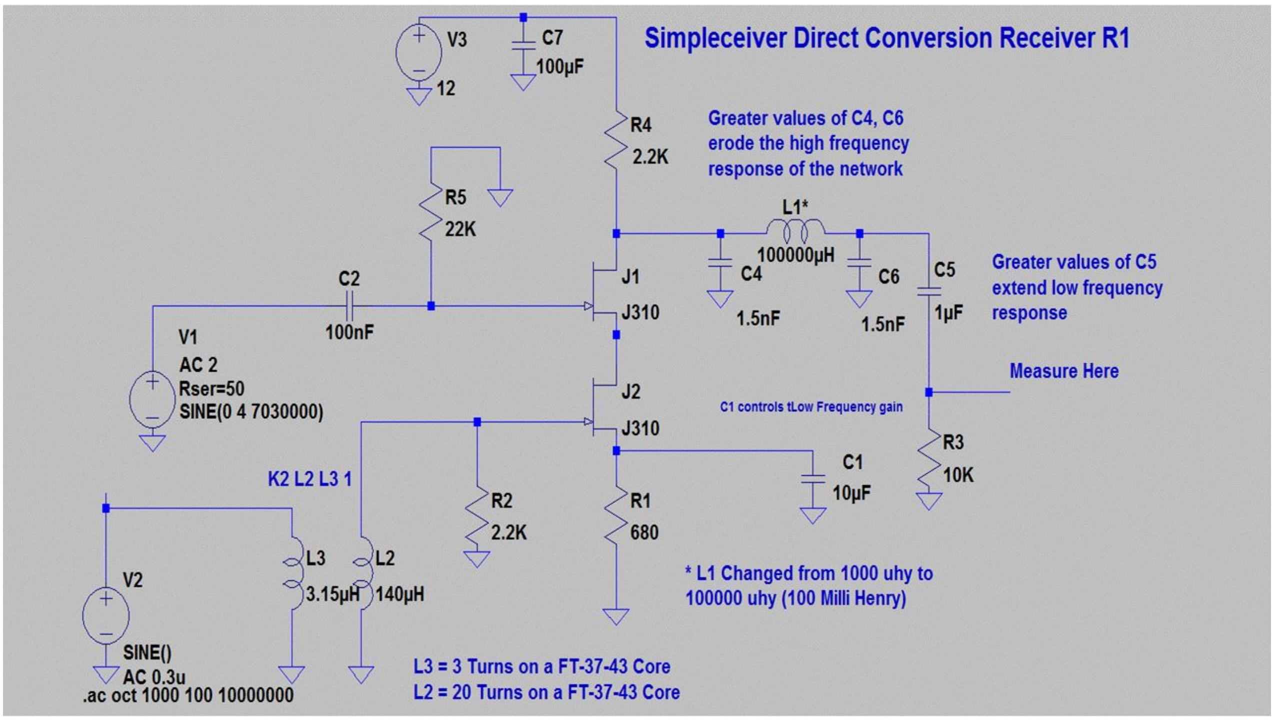
horrendous shipping charges, or others, as per http://www.digitroncorp.com/Products/Product-Line/Dual-Gate-Mosfets are available in TO72 packages (i.e. with legs on for through hole pcb mounting) but... you'll need to be ordering in quantity to secure.

Below is a mixer design Tim has run previously in his designs and had excellent results with; this is his quick sketch:



Pete Juliano (N6QW) reminded me.... below is his design using SPICE simulation which showed considerable promise, which he entitles the "Simpleceiver":



And here's an article from commercial radio manufacturers who have hit on a similar solution:

"*The cascode jfet was used commercially. In part that may have been because it became available maybe a couple of years before dual-gate mosfets, and even then, some makers waited a bit longer again (about another year I think) until protected-gate dual-gate mosfets became available before using them.*
FM tuner RF amplifiers was an early application for the cascode jfet. Scott was one of the first, with a jfet shunt cascode RF stage in its top-end FM front end towards the end of 1965. Heathkit used a jfet shunt cascode RF stage in its AR-15 of late 1966, and I think stayed with jfet-based FM front ends for about a decade, even though it had adopted dual-gate mosfets for AM in 1969.
B&O reworked the front end of its Beomaster 5000 tuner to use a jfet series cascode in place of the original germanium bipolar RF amplifier.
In general though, jfets gave way to dual-gate mosfets for FM front-end applications by the end of the 1960s. Economics may have been a contributing factor, in addition to relative performance. One dual-gate mosfet probably cost a bit less than two jfets.
There were also commercial applications. The GEC RC410R HF receiver (1967) had two tuned RF stages, each using a jfet series cascode with agc bias applied between the source and gate of the lower unit. Apparently the original RF amplifier design was bipolar, but with this the desired noise factor and intermodulation performance could not be achieved at higher frequencies, so a change to jfets was made.
The Marconi Hydrus point-to-point ISB receiver (1968) used series-cascode jfets in the RF amplifier, mixer and IF amplifier positions. In the RF (and I imagine the IF) case, agc bias was applied to the gate of the upper unit. For the mixers, the signal was applied to the lower unit gate and the oscillator input to the lower unit source. Thus both the signal and oscillator were looking into a cascode. Given that the first oscillator input could be as low as 41.5 MHz and the IF output was at 40 MHz, and wideband (± 0.6 MHz), my inference is that it was thought desirable that the oscillator input as well as the signal input be screened from the output in order to minimize regeneration opportunities.
The Eddystone EC964 marine spot-frequency SSB receiver used a triple jfet array for its 2nd mixer, said to be chosen for good signal handling in a position were low noise was not essential. This could be seen as a jfet series cascode with the upper unit replaced by a source-coupled pair. The oscillator went into the lower unit gate, the signal into the left-hand upper unit gate and the output was taken from the right-hand upper unit drain.
Thus were there various ways in which the jfet cascode was used. Whilst the signal input was (mostly) the lower unit gate, agc bias and oscillator injection points varied. With dual-gate mosfets, there seemed to be more uniformity, with signal nearly always on gate 1, for amplifiers, agc bias on gate 2 and for mixers, oscillator on gate 2. An exception to the latter was in VHF TV tuners."

From: https://www.vintage-radio.net/forum/showthread.php?t=154799

Below is an article I saw along similar lines...

Some notes about (jfet) Mixers, by Russell Kincaid

A mixer consists of a non-linear device which handles two signals of different frequency. The output has the original two signals plus the sum and difference frequencies. A filter is required at the output to select the desired frequency, usually the difference frequency. A diode makes a good mixer but the best you can do is -6 dB gain from RF input to IF output. An XOR logic gate can also be used as a mixer within its frequency range.

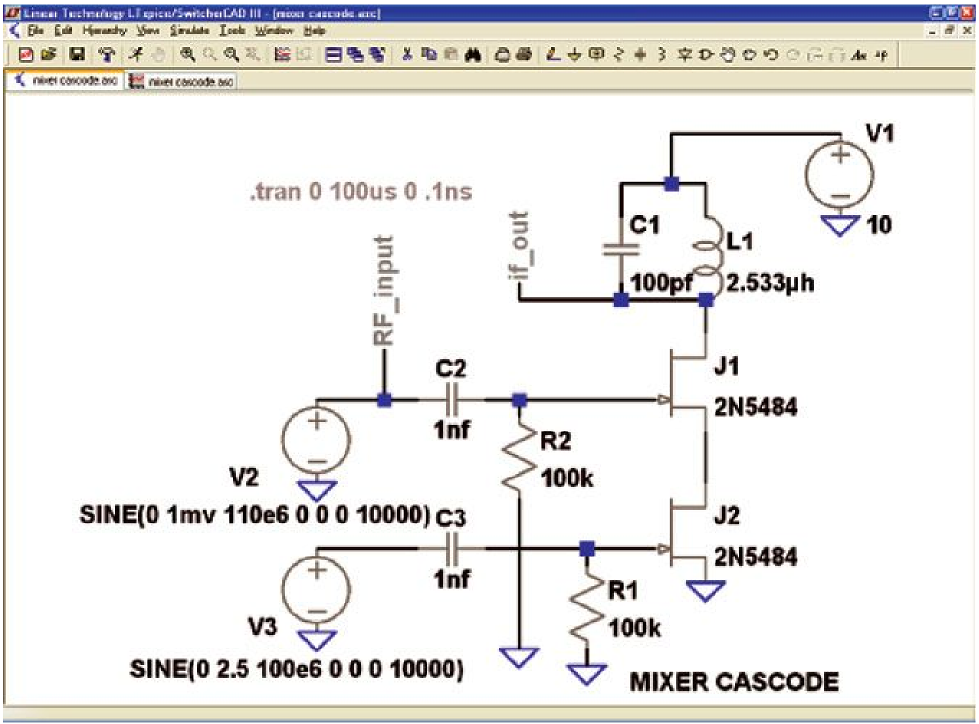


FIGURE 1.

Your request for a two transistor circuit brought a cascode circuit to mind, so I threw together the circuit of **Figure 1** in the LTspice simulator. The RF input to J1 is 2 mV peak-to-peak at 100 MHz; the local oscillator (LO) input to J2 is five volts p/p at 110 MHz. The output circuit is tuned to the difference frequency of 10 MHz. **Figure 2** is the output signal. The 10 MHz is about 70 mV p/p, a gain of over 30 dB. The LO output is significant, more filtering is needed.

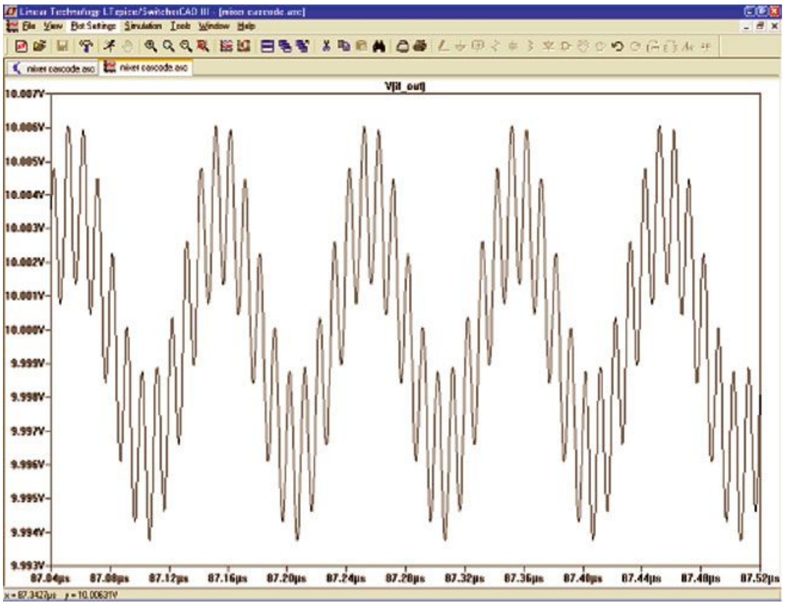


FIGURE 2.

A single transistor can be used as a mixer and oscillator at the same time, but the problem is that a strong RF signal can "pull" the LO off frequency, causing increased interference and reduced gain. This problem increases as the RF and LO signals get closer together.

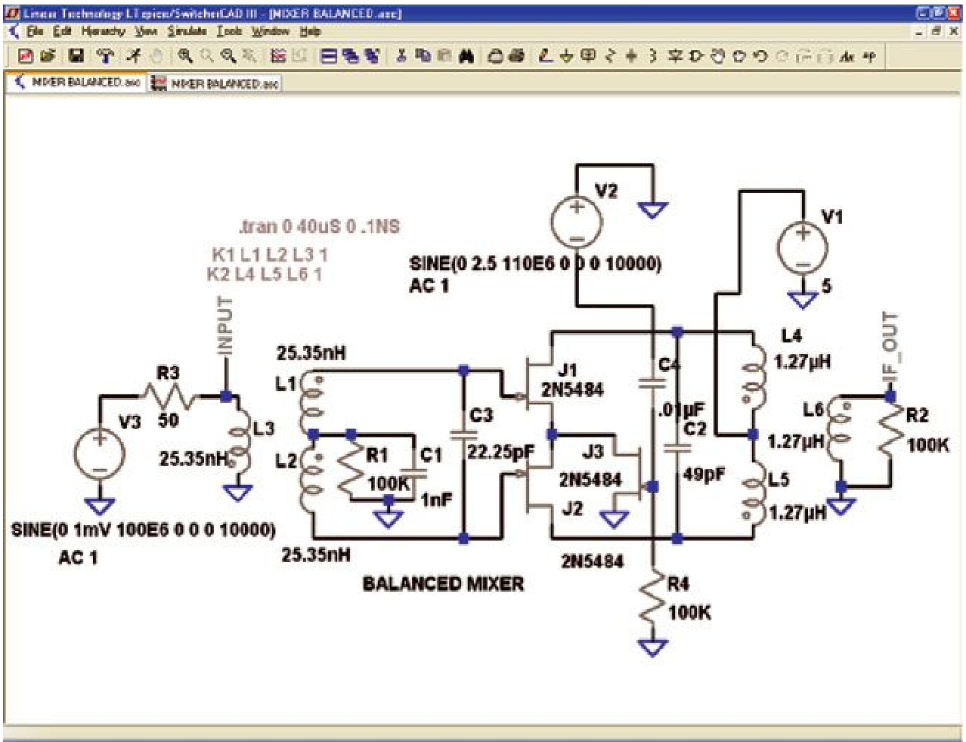


FIGURE 3.

There is a lot of interest nowadays in balanced mixers which will reject the LO signal, making the output filtering easier. A single balanced mixer rejects just the LO, a double balanced mixer rejects both the RF and the LO. **Figure 3** is a single balanced mixer. The input transformer is center-tapped to provide push-pull drive to the output transformer, through the JFETs. The local oscillator drive is common mode and does not couple to the output. The output transformer must be well balanced, such that when the same signal is applied to both sides, the result is cancellation. As you can see in **Figure 4**, there is no LO in the output waveform. The 10 MHz is 70 mV peak, a gain of over 36 dB.

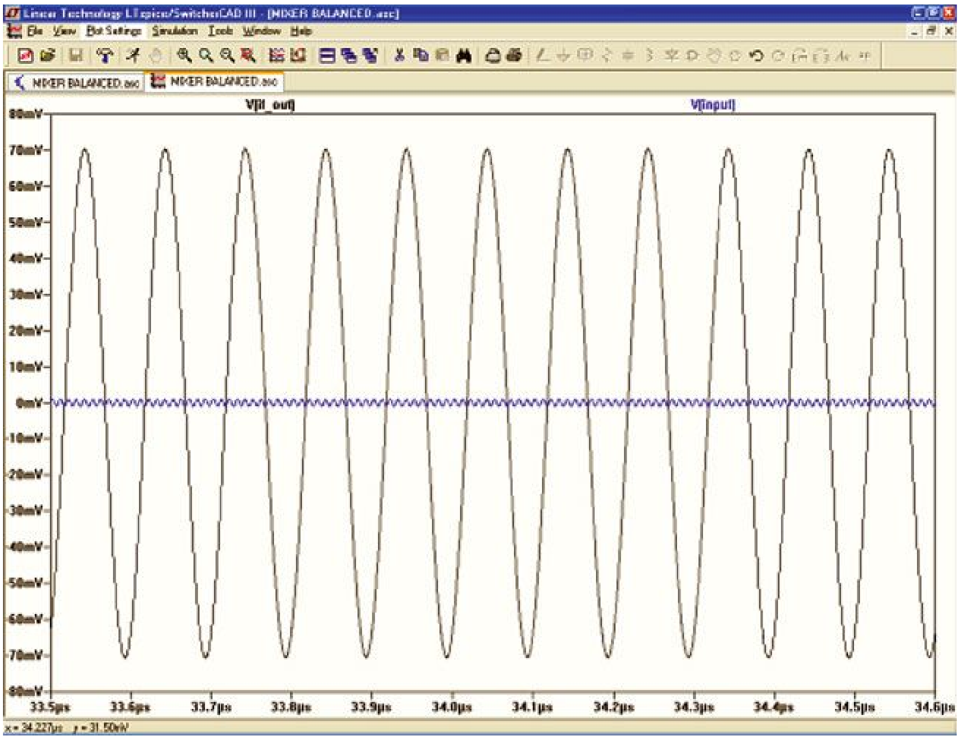


FIGURE 4.

I used the 2N5484 because it was in the library; it is similar to the MPF102, and costs 11 cents.

Pete Juliano and Tim Walford have long been advocates of using modular circuit blocks (as I have too) which can be "built" into both receivers and transmitters using relay switches to steer the signals in the appropriate direction.

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Bidirectional Amplifiers

From: https://www.everythingrf.com/community/what-are-bidirectional-amplifiers

A **Bi-directional amplifier** is a device that supports two-way communications and amplifies the signal in both transmit and receive mode. It consists of a power amplifier (PA) at the transmit end and a low noise amplifier (LNA) at the receive end. In receive mode, this device amplifies a weak input signal and feeds it to the radio. While in transmit mode, it amplifies the signal coming from the radio and transmits it further, extending the range of the signal.

Bi-directional amplifiers are most often used to extend the range of a cellular or radio systems. They are also used for transmitting and receiving radio signals in key applications such as unmanned aerial vehicles (UAV), unmanned ground vehicles, L and S-band radar, military radio,
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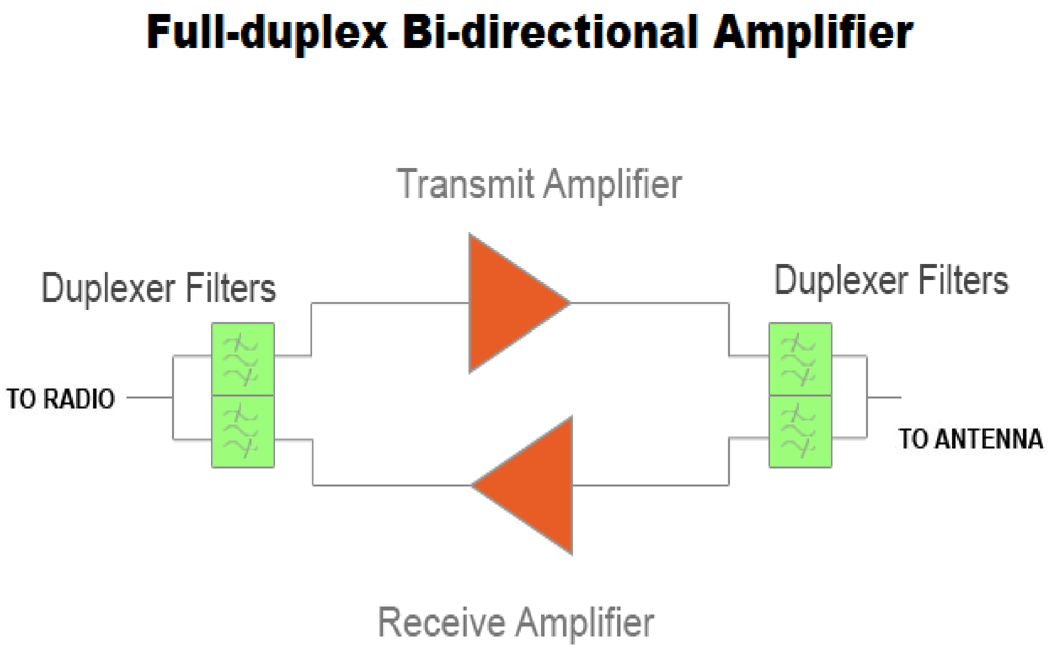
commercial air traffic control, weather and earth observation, satellites and high gain driver power amplifiers.

There are two types of Bi-Directional amplifiers:

Full-duplex Bidirectional Amplifier: A full-duplex bi-directional amplifier can simultaneously perform transmit and receive function. This simultaneous operation is possible by having a separate transmit and receive frequency or by frequency division multiplexing (FDM). This amplifier uses duplex filters to prevent the transmit signal from interfering with the receive channel.

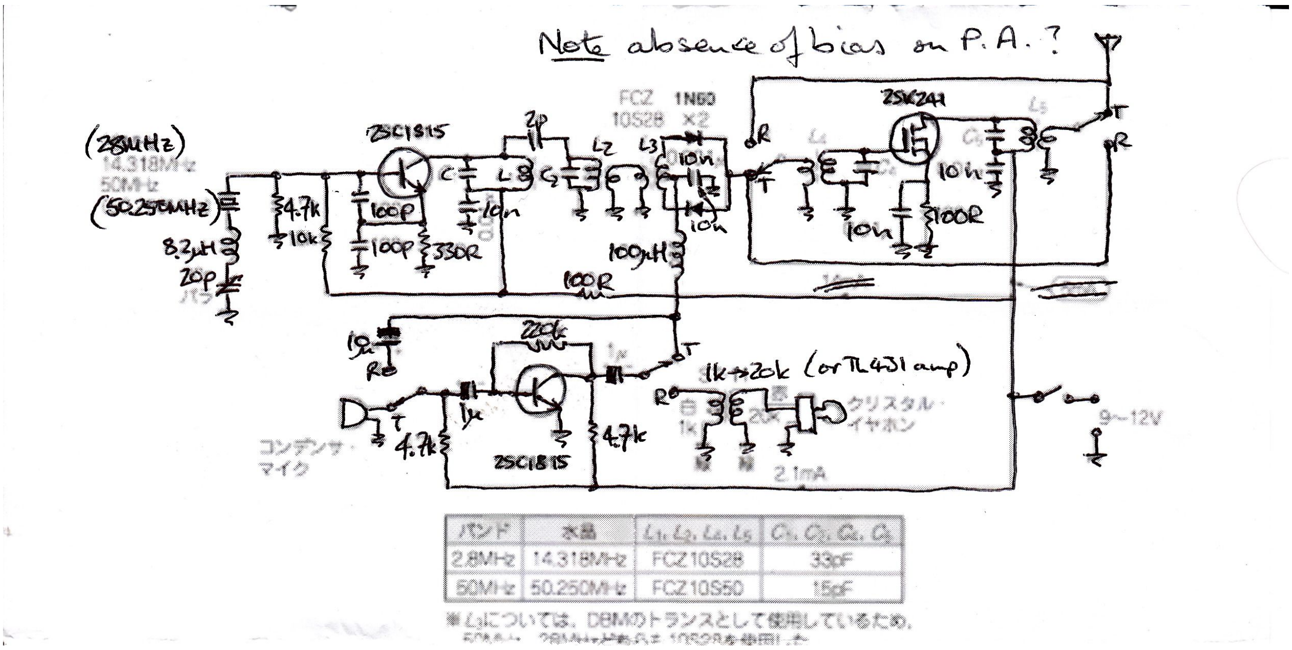


Half-duplex Bidirectional Amplifier: A half-duplex bi-directional amplifier performs either the transmit or receive function at one time. In this amplifier, transmit and the receive function are selected with the help of a switch at the input and output ports, or by the use of intelligent biasing.

Bidirectional Amp. example

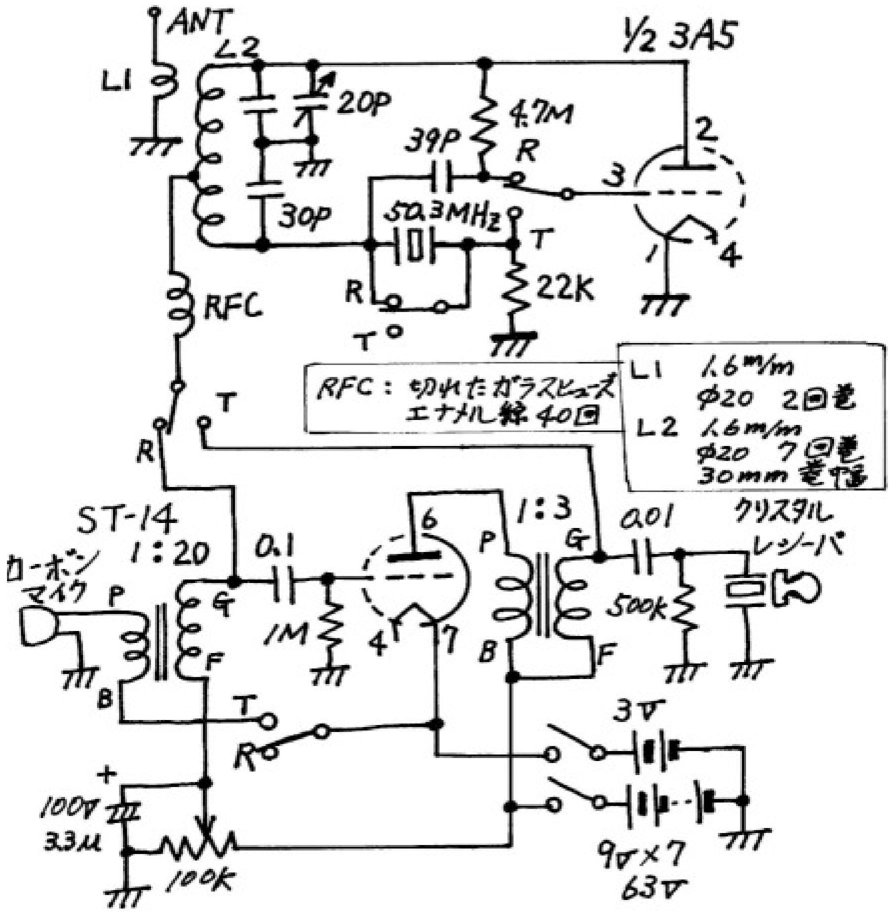
From: JF10ZL

This is a genuinely elegant little transceiver; it is simple, functional and a little beauty to operate. Sure you won't be flushing out rare Dx, but hey, let's appreciate local (and not-so-local) telephony. It's hard to beat!



Note the P.A. device is used as an RF amplifier on receive - truly bidirectional via relay switching. Please forgive my scribbling and notes!

Using a double triode:



Note how the oscillator / PA is switched to become a regen receiver; not truly bidirectional, but a clever use of the stage in two different “directions”.

A Transceiver using bi-directional stages

From those magicians in silicon, Ben Kuo, KK6FUT and Pete Juliano, N6QW comes yet more simple and elegant design:

Let’s Build Something: Part 1

Ben Kuo—KK6FUT kk6fut@verizon.net
Pete Juliano—N6QW radioguy90@hotmail.com

This article is the first of a series designed to introduce newcomers to the wonderful world of home brewing your own equipment. Absolutely no experience is required beyond an ability to read simple schematics and do some basic soldering. If these two skills are new to you, there are many excellent resources on YouTube and similar sites, or in the *ARRL Handbook*.

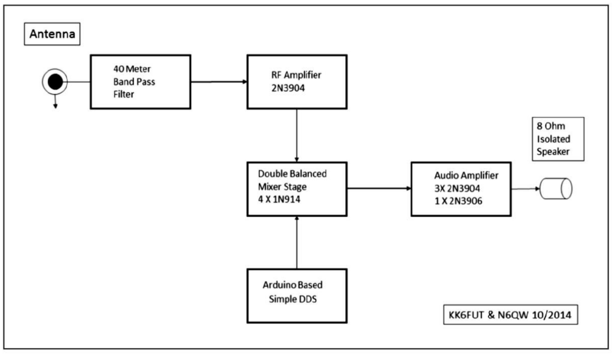


Figure 1—Direct conversion receiver block diagram.

The authors realize that building your first, homebrewed radio project can be very intimidating, especially if you don't have an Elmer in your neighborhood for ongoing guidance. We hope to provide the next best thing in the form of a series of supplemental YouTube videos which show the details of building many of the circuit blocks for this project. A listing of the URL's for the portion of these videos that relate to the first part of this project appears at the end of this article.

We have further simplified the overall project by using a very simple building technique that is as old as ham radio itself—breadboarding. Early radios were often constructed by fastening parts to a board meant for cutting bread. We will do something very similar. In our case, we will be constructing each stage on a small piece of PC board stock obtainable on the popular web auction sites and then mounting each stage on a board for interconnection. We will worry about packaging the total project later. “Al Fresco” construction greatly aids in understanding the circuit elements and most importantly for making changes or repairing modules. Later once everything is perking along you can think about optimized packaging and shrinking down the size. There is nothing wrong with a bread board radio—our ham forefathers operated exactly that way!

The stages will be built using an easy method of Manhattan construction. This involves gluing small pads of PC board stock to a larger blank board for use as junction points. For ease of construction, we will be using MePads and MeSquares available from W1REX at www.QRPme.com. These boards take Manhattan construction way beyond super gluing copper squares to a PCB and enable the homebrewer to focus on building hardware and not removing super glue from their hands! Our goal: make this a fun experience without having to have years of tribal knowledge before soldering the first connection.

Where is this project ultimately going? We will tell you if you promise not to panic. When you finish this deliberately simple set of projects, you will end up with a fully functional QRP SSB transceiver. But don’t worry as we promise to take it slow and easy. In the meantime, you will be building all of the modules that will eventually comprise the transceiver. You will find that, as the project progresses, you will finish intermediate, useful pieces of equipment at the end of each article in the series. The various modules will be reused at each stage, so nothing (or at least not very much) becomes a dead end.

For this Part I article, we describe a very, very simple receiver project, which takes advantage of the wide availability of the Arduino microprocessor and direct digital synthesizer (DDS) modules and couples that with a simple, homebrew double balanced mixer (DBM), a one transistor RF amplifier, a band pass filter made from commercial IF transformers and a few simple transistors as an audio amplifier, which gives you the ability to listen to sideband (voice) [and CW] ham radio transmissions. It goes without saying that both of us were amazed at how good the receiver sounds and we you think you will be too!

Why Sideband?

Traditionally, the first ham radio homebrewing projects have been CW transmitters and receivers. However, with the removal of the code requirement to becoming a ham radio operator in recent years, there has been a dramatic falloff in the use and proficiency in code. That lack of code ability means that there is an entire generation (or two) of ham radio operators for whom code is non relevant. Putting aside the politics and arguments over the loss of code in the ham radio community, this poses a huge problem for attracting prospective homebrewers to the hobby. Many new hams simply want to talk, using radios they built and not resort to pounding brass. This project sidesteps the CW code issue by going directly to SSB.

Unfortunately, coupled with the lack of CW proficiency, there has been a big loss of available kits for new homebuilders—the traditional entree into homebrewing for radio. Kits like the single band SSB White Mountain—a traditional entree into building your own SSB transceiver—are now discontinued, and projects like the BITX and Minima—although excellent designs—are a huge jump for the new builder. This project attempts to help the new builder along the path to building more complex projects or, hopefully, tackling their own radio designs from scratch!

How Direct Conversion Receivers Work

The first part of our project will be a direct conversion receiver. You’ll see later how the parts to this receiver will be used in the final project. In a receiver of this type, an oscillator (in our case, a DDS) operating at the exact frequency of the sideband signal is used as one input to a double balanced mixer. The desired sideband signal is the second input to the mixer and the difference frequency is the desired audio output. In this case, there is no intermediate frequency (IF) and the result is sometimes referred to as a zero IF receiver. Direct conversion involves, as its name implies, a direct conversion of off the air signals to an audio base band. A typical example would be a 40 Meter (7 MHz) SSB signal that is converted to audio directly via a mixing process. For this to happen, we need but a few circuit blocks, shown in Figure 1.

A double balanced mixer produces sum and difference frequencies of the signal coming from the antenna, and the local oscillator. For example, an incoming signal at 7.2 MHz would be mixed with either a 7.199 MHz local oscillator or a 7.201 MHz local oscillator—depending on what sideband (upper or lower) we want. In the first case, two frequencies would be produced: the sum which is 14.339 MHz and the difference is 1 kHz, which is the one we want. In the second case the sum is 14.401 MHz and the difference is 1 kHz, again this is the one. All mixers are capable of producing these sum and difference products. The term "double balanced" implies that the original signal and local oscillator frequencies are deliberately nulled out as part of the mixing process and do not appear at the output.

To clean things up a bit we do a bit of audio filtering following the DBM and top that off with an audio amplifier block.

As shown in Figure 1, there are five major blocks to this project: the local oscillator (Arduino with DDS); our homebrew double band mixer (DBM); the audio amplifier circuit, the input band pass filter and finally an RF amplifier block. All of these blocks will be used in the final SSB transceiver circuit.

We have found that building "backwards," that is building projects from the output to the input, is a key to success in these projects. We will use that method here. This allows you to carefully debug the circuits, ensuring each block or stage is fully working before moving on to the next part. Most kits and construction instructions today tend to emphasize a "stuff and smoke" approach—stuff all the components, plug it in, and see if it smokes.

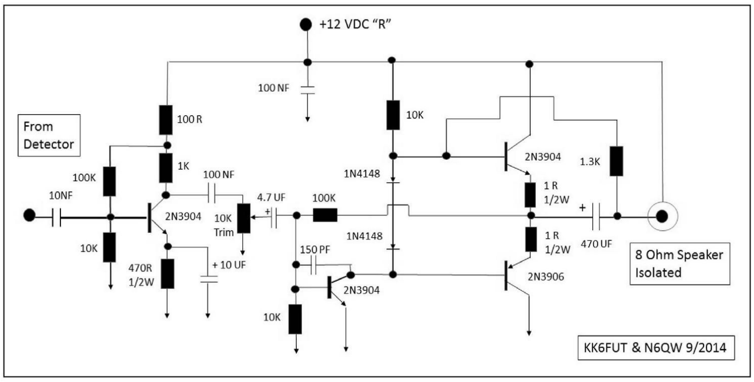


Figure 2—Audio amplifier schematic.

However, that approach means lots of smoked parts, and no understanding on what does or does not work in your circuit! We will start with the audio amplifier and work our way forward.

Before we begin, let's talk a bit about construction. After you have built each stage, you will be attaching the stage to a large board (2 ft. × 2 ft.) using a few wood screws. Then, you will need to supply power for operation. A suggestion is to bring the power into terminal strips (available at Radio Shack) and then power can be distributed to the various modules where power is required. You might also want to cut all of the blank PC boards used for the various stages at once. The sidebar to this article shows a plan for efficiently cutting these boards. If you are not familiar with how to cut the boards, there are quite a few methods exhibited on YouTube videos. However, most of these methods release fiberglass dust into the air. For this reason, you should always wear a mask and safety glasses during this activity.

First Major Piece: The Audio Amplifier

It would have been a simple matter to pop in a packaged amplifier such as an LM-386 or TDA7052 for this project. But, we think you will learn more by working with discrete components. Figure 2 is the schematic. The audio amplifier consists of a 2N3904 pre-amplifier, a second 2N3904 as a pre-driver and a complementary pair 2N3906/2N3904 for the output. Word of warning here—The audio output jack is "hot," so if you later install the amplifier in a metal box you will need to insulate any output connections from that box as you cannot directly ground the output connector to the chassis.

YouTube Hint: If you want to see how the amplifier is laid out, just watch the corresponding YouTube video. You will be able to see how the pads are placed on the blank PC board and how the various components connect.

Testing of the amplifier once completed follows the rigorous N6QW amplifier testing process. Step 1: After checking for shorts, solder bridges, wrong connections, wrong part values or the wrong polarity of the power being supplied AND finally using an isolated phone jack with 8 ohm speaker attached, apply power. If it doesn't smoke or your power supply trips proceed to Step #2 where you take a metal objects such as a tip of a screw driver and touch the input—if you hear a large hum in the speaker—the test is complete. If no hum, go back through step 1. How much more rigorous can you get?

Tribal Knowledge tip! A simple way to avoid hooking the wrong polarity to the circuit is to place a diode in series with the + lead to the board under test. The cathode connects to the circuit and the anode to the source supply. If you get the source leads reversed current will not flow. The arrow part (banded end) of the diode points the way!

Mixing It Up: The DBM

The Double Balanced Mixer (DBM) can be thought of simply as a frequency converter. In Part I we are converting signals in the 40 Meter ham band to an audio output. In applications such as a mixer stage which we will do in the final SSB

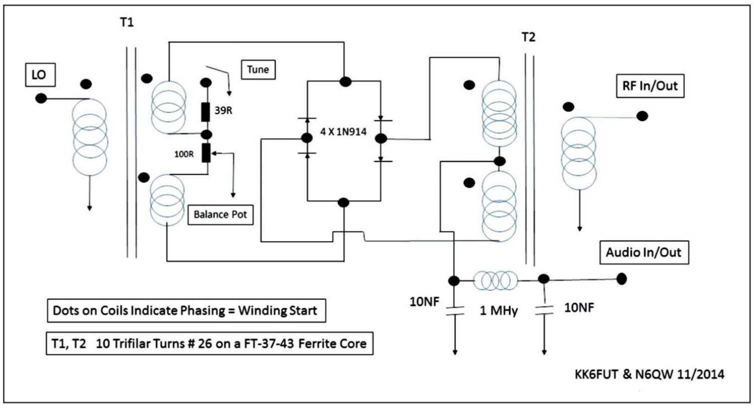


Figure 3—Double balanced mixer schematic.

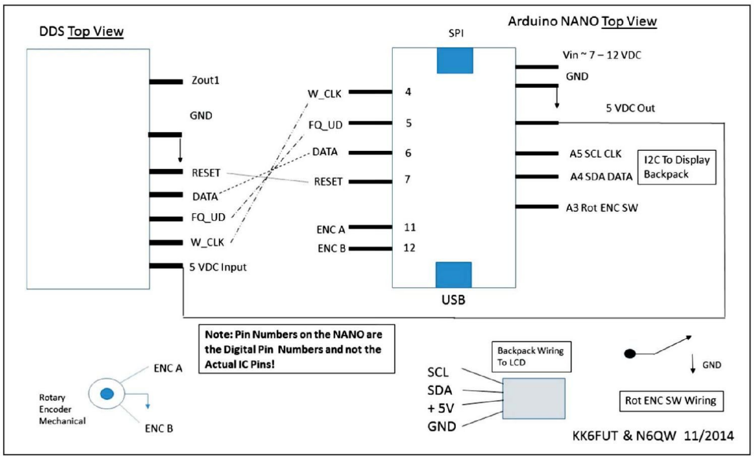


Figure 4—Arduino DDS schematic.

transceiver build, the DBM is employed as both a receiver and transmit mixer stage so that on the air signals are converted not to an audio based band but to an intermediate frequency (IF). Example: 40 Meter signals at 7.2 MHz are mixed in the DBM with an LO (VFO supplied by the DDS) of 12.1152 MHz and the difference frequency (which is what we want) is 4.9152 MHz. Our homebrew crystal filter will operate at this frequency where the signal will pass on to a second Double Balanced Mixer stage. Here, this DBM becomes a Product Detector on Receive and a Balanced Modulator on Transmit. The signal coming in at 4.9152 MHz is mixed with a BFO signal slightly above (or below depending on the sideband in use) 4.9152 MHz and the difference is audio. In the transmit mode, the first mixer stage now outputs the signals back to the 40 Meter band. We'll describe this more in the rest of the series.

This is where the mental light bulbs should light brightly. Our Part I direct conversion receiver is nothing more than a product detector connected to an antenna and in lieu of a fixed BFO frequency we are making it tunable. So what is being built in Part I is the back end of the SSB transceiver. Notice we said light bulbs as the second bulb is that the DBMs are bidirectional! If we hook up a microphone amplifier instead of the audio amplifier, that same product detector circuit becomes a balanced modulator. So what was the input to the product detector is now the output of the balanced modulator. This means that Part I will give us much of the circuitry needed for the low level transmit part of the SSB transceiver. The Double Balanced Mixer Schematic is shown in Figure 3.

YouTube Note: There are a series of three YouTube videos on the DBM that take you from the basics of the DBM through the final construction and these appear on the N6QW YouTube channel.

Tribal Knowledge Tip: The Importance of Heat Sinking any Diodes before soldering!

One of the keys to constructing a double balanced mixer (DBM) is proper construction technique. One of those techniques is making sure that sensitive components—in this case, your diodes—are properly heat sunk during the soldering process. The authors are a fan of using a hemostat, affixed between the point of soldering and the device itself, to make sure you do not overheat the diode. Soldering tips can reach an excess of 800 degrees, enough to render a diode (and other components) useless. Those hemostats are removed after the solder has cooled. We are now careful to mention this removal process for in an earlier article we failed to mention the removal of the hemostats. An email from a builder inquired how to fit that project into an enclosure with the hemostats dangling all over the circuit.

Modern Oscillator: The DDS

When we first started working on this project, we looked at a number of different options for an oscillator, including a VFO, varactor tuned oscillator, and a DDS. After building several versions of this oscillator, we decided that the easiest option—surprisingly—was to go directly to a DDS, due to the ease of soldering modules together, and the ability to directly use this DDS for our full fledged transceiver in the future.

There are three major parts to the DDS: the Arduino microprocessor to control the DDS, the DDS itself, and an LCD display and rotary encoder to allow us to change the frequency. Fortunately for us, there are only four lines we need to connect between the Arduino and the DDS, and only four lines between the Arduino and our LCD display. This actually makes using a DDS one of the simplest parts of this project.

The schematic for this oscillator is shown in Figure 4, which includes the hookup for the Arduino Nano and the AD9850 DDS Board. The Nano and the

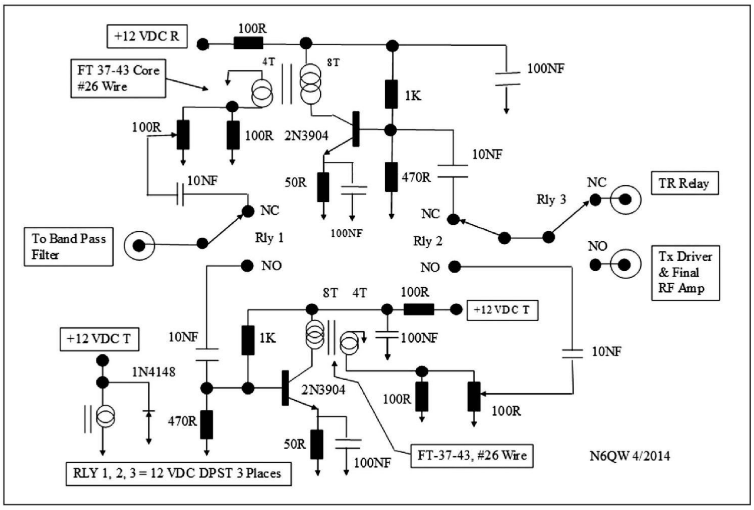


Figure 5—Bilateral Rx/Tx RF amplifier schematic.

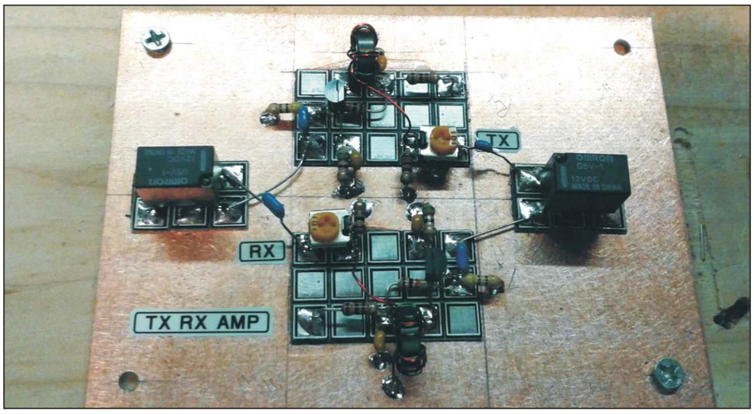


Figure 6—The completed Rx/Tx RF amplifier.

AD9850 can be found on the major auction sites for very little cost. The Nano was chosen because of its small size. That said, the Uno R3 or even the Pro-mini can be used. The Uno is much larger physically and the Pro-Mini lacks the serial interface hardware. Moreover, no matter which Arduino device is used, just wire to the Digital and Analog pins for those respective boards. The other observance is that when loading the sketch you must select the device you are using and the appropriate COM Port. Most of the Arduinos like to see an input power to the Board in the range of 7 to 12 VDC. The easiest answer is a 9 VDC 1 amp regulator that is hung off of the main power supply rail (12 - 13.8 VDC).

We have NOT shown a booster amplifier on that schematic, which is optional for the receiver project, but may be required for full driving of the mixer stage when the transmit functions are added. The booster is a utility type amplifier stage employing a 2N3904 that is used in other parts of the radio—remember reusable blocks? Just build another RF amp as described later and insert it between the DDS and the mixer stage.

We've also included pre-built software (Simple DDS), which allows the use of the DDS on a single band, and handles input from the rotary encoder to change the frequency. You do not need to know how to write software on the Arduino to use this—we've already included everything you need, and all you need to do is load the software onto your Arduino using the Arduino IDE.

The software needed is on the N6QW Website under the Arduino Link. Use this link to find the software, http://www.jessystems.com/arduino_build.html. This link has the software in the section marked Sketches.

The RF Amplifier: So Much from a 2N3904

The signal levels coming from your antenna are pretty small, and running those through a DBM is not all without some penalties. For all of the good stuff about a DBM, such as rejection of the incoming and LO signal at the output and lower noise than active mixers, the offsetting penalty is that they are a gain loss device suffering up to 5 or 6 dB loss. (DBMs are what is known as passive mixers meaning they do not provide any gain.) That means that off-the-air signal levels are further reduced in the mixing process. There are many ways to handle this, including tacking on a post mixer amplifier, using a high gain audio stage and adding an RF preamplifier to boost the signals ahead of the DBM. We did two of the three by adding an RF pre-amplifier stage and a high gain audio stage.

This pre-amp is un-tuned and thus broad banded, so everything coming into the antenna is amplified. Because of that, we need to include a band pass filter, which limits those signals to only the ones within our desired, 40m ham band. The Rx pre-amp stage provides better than 10 dB of gain which helps make up for the gain loss in the DBM. The parts cost is low in comparison to the gain available. (Certain circuit configurations of a 2N3904 can result in 15 dB of gain—so quite a lot of uumphf for a transistor that when bought in bulk can be had for 3 or 4 cents.)

This circuit block will be used in the final SSB transceiver serving the same purpose. In addition, the very same circuit will be duplicated and will serve as the Tx pre-driver circuit in the SSB radio. So, building two at the same time is probably a good idea, even though only one amplifier is used in the direct conversion receiver. Figure 5 shows the schematic for a two amplifier configuration with relay switching. The completed amplifier is shown in

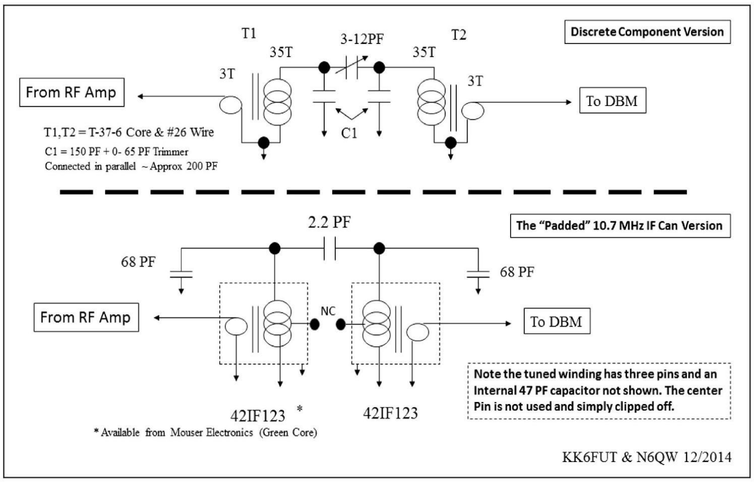


Figure 7—Bandpass filter schematic, with two options for building.

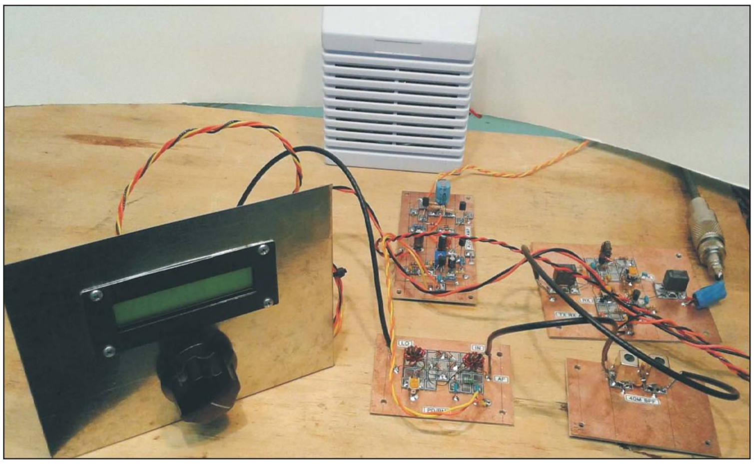


Figure 8—The finished direct conversion receiver.

Figure 6. Once again, when the circuit is completed follow Step 1 in N6QW's rigorous test process before applying any power!

The Band Pass Filter: Nothing to do with Rock Music

As mentioned earlier, the RF preamplifier being broad band will amplify anything coming through the antenna. As we tested this, we found you can faintly hear WWV and nearby shortwave stations coming through the speaker, which is a testimony to as "broad as a barn". The addition of a band pass filter helps keep most of the crud from being heard. The filter is a critical part that will be used in the SSB transceiver so that is another block that will be re-used.

There are two ways to build the band pass filter, both of which are shown in Figure 7: one involves a hand calculation using discrete components (harder but worth learning about) and the other uses packaged IF transformers (Mouser P/N 42IF123) along with three fixed capacitors. Since our goal in this article is to get you up and running, we suggest you build the IF transformer version as we will describe here. In a later part of this series of articles, we will suggest and describe a hand calculated band pass filter.

Building the filters requires adding some capacitance to the packaged IF transformers to lower the tuning range from 10.7 MHz to the 40M band. The 68 pF capacitors in parallel with the transformers accomplish this function. The external 68 pF adds directly to the 47 pF capacitor inside the transformer and resonates with the 4.7 µH coil at approximately 7 MHz. The tunability of the inductance accomplishes a resonance inside the 40M band. The third capacitor (2.2 pF) establishes the degree of coupling between the two transformers. Simply connect the parts as shown in Figure 7 and proceed to the tuning process described below.

Alignment of the homebrew filter following the Step #1 process involves N6QW's "Tune For Maximum Smoke" (TFMS) procedure. The circuit can be peaked for the loudest signal once installed in the radio. Or if a scope is available, feed the DDS signal operating at 7.2 MHz into the filter input and terminate the filter output with a 50 ohm non-inductive resistor. Next place the scope probes across the 50 Ohm resistor and observe the scope pattern. Adjust the pattern for a peak and note the value. Then tune at 7.1 MHz, and at every 25 kHz points, up to 7.3 MHz take similar readings. One can then plot a curve of the voltage reading versus frequency and thus characterize the filter. A flat response is what is desired and a bit of tweaking of the transformer tuning slugs will help improve that response. You will learn a lot about band pass filters using this method.

YouTube Hint: One of the "YouTube videos" that is referenced at the end of the article gives painful detail on how to do this.

Incidentally, these transformers can also be used as filters on other bands. For instance, N6QW has used these modified IF transformers in his multiband KWM-4 transceiver project. However, the transformers are not suitable for coverage across the entire 75M/80M band. In that instance, a filter using the hand calculation method is more suitable. For 30M and below, the procedure is very similar to what is described above. Just add a different capacitor to resonate with each transformer coil. Once you go past 30M up in frequency, one must "carefully" remove the 47 pF cap on the bottom side and use smaller values of capacitors across the tuned winding

Conclusion and Next Steps

Figure 8 shows what your receiver should look like at this point. It should be working successfully and you should be hearing signals.

We'll continue this series with our next article, which will allow you to proceed with the transformation of this simple direct conversion receiver into a SSB transceiver. Figure 9 shows how the modules built in Part I will be used in the SSB transceiver.

See the table below for YouTube video URLs and content descriptions. Hopefully, they will help you build this project successfully!

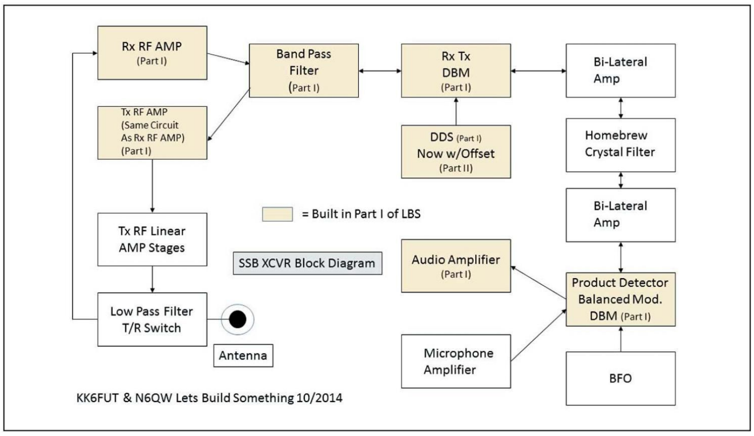


Figure 9—SSB transceiver block diagram.

YouTube URLs & Description

https://www.youtube.com/watch?v=GFZL8avwD3Y&list=UU4_ft4-oTdCMlWlL4XXHScg — Let's Build Something Demo of the Prototype

https://www.youtube.com/watch?v=kzcvNzpMv3U&list=UU4_ft4-oTdCMlWlL4XXHScg — Homebrew Double Balanced Mixer Part I of 3

https://www.youtube.com/watch?v=86n5gjlgmmI&list=UU4_ft4-oTdCMlWlL4XXHScg — Homebrew Double Balanced Mixer Part II of 3

https://www.youtube.com/watch?v=lShnfyXzCcs&list=UU4_ft4-oTdCMlWlL4XXHScg — Homebrew Double Balanced Mixer Part III of 3

https://www.youtube.com/watch?v=BjqvvzI1YLg&list=UU4_ft4-oTdCMlWlL4XXHScg — Building the 40M Band Pass Filter

https://www.youtube.com/watch?v=8p39-5Qcf3U&list=UU4_ft4-oTdCMlWlL4XXHScg — LBS Audio Amplifier Stage

https://www.youtube.com/watch?v=woFpYpSqzKA&list=UU4_ft4-oTdCMlWlL4XXHScg — Final Configuration

https://www.youtube.com/watch?v=b7BGB2oZNEo&list=UU4_ft4-oTdCMlWlL4XXHScg — Installing the Arduino/DDS in the Let's Build Something Direct Conversion Receiver

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Pullen Mixers

(since we're talking 40673's and such in this Hot Iron)

Just to throw a spanner in the works... the Pullen, or Cathode Coupled double triode mixer (see "A Like-New Mixer Circuit" by Staff 73 magazine, October 1961) can put up a hard-to-beat performance even nowadays (so long as you're not demanding ultimate low noise performance, which, on the current HF bands, isn't an issue what with all the man-made noise). For big signal handling you'll struggle to beat valves unless you're planning on a packaged diode double balanced mixer or a Horobin ("H-Mode") mixer - both of which demand premiums with either hefty local oscillator drive or complexity in the drive circuits to guarantee perfect switch phasing. For the H-Mode mixer, this factor can limit them to low HF bands unless you're willing to do some serious engineering. Digital drive to the H-Mode mixer can be used, yes, by all means; but I'll bet a penny to a pound you'll meet the wonderful world of "clock skew" on bands above 20m if you don't perfectly balance the clock parasitic time delays - nigh on impossible, as many a digital designer found to their cost! And... you'll have to keep the balance in control over a wide frequency range, too, somewhere along the line. Rather you than me! As ever, you pays your money and takes your choice!

The original article from 73 magazine is reproduced below. The description and biasing is important; it's how the mixer works. It would be a very interesting experiment to use 2N3819 jfet's in this circuit (with power rails and bias adapted of course).
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A Like-New

Mixer Circuit

By Staff

73 Magazine
October, 1961.

Would you like to improve the sensitivity and the stability of your receiver?

If you would, and don't mind delving underneath the chassis a bit, one of the quickest routes is to modify front-end circuitry. The technical article, "Up Front," in our March issue contained a rather complete collection of improved front-end circuits.

However, here's one which escaped attention when the article was prepared-and which has escaped almost everyone's attention since it was first developed. That's why we're calling it a "like-new" circuit; it's been around for a spell but it might as well be new since almost no one knows of its existence.

Before going into this circuit, it might be well to review the characteristics of a good mixer. The ideal mixer in a superhet receiver should:

(1) produce no spurious frequencies,
(2) provide ample gain for the signal,
(3) contribute no noise to the signal,
(4) provide complete isolation between oscillator and signal to prevent undesired radiation,
(5) present as light a load as possible to the oscillator to preserve frequency stability.

These characteristics, at least to a degree, are mutually incompatible with most conventional circuits. For instance, isolation of the oscillator from the signal circuit usually requires screening grids in the mixer tube, which in turn raise the mixer noise level and violate objective 3.

As pointed out in our aforementioned technical article, the best compromise to date has been the 6AC7 used as a pentode mixer, following the circuit described in Langford-Smith[1]. This circuit provided low noise, adequate gain, little in the way of spurious output, and adequate isolation for most purposes.

However, the particular version of the twin-triode cathode-coupled mixer which we're describing here outdoes the 6AC7 on all counts except gain, and runs it a close race there. On top of this, it can be installed in any set which uses an octal-base, a 9-pin, or a 7-pin mixer tube without changing the socket, since suitable twin triodes are available in all three basings.

The circuit is not original; it was found in K. A. Pullen's book "Conductance Design of Active Circuits," a volume[2] which incidentally should be in the library of every serious ham designer (plug unsolicited; Radio Bookshop please copy), and was field-tested in a vintage BC-779 in comparison with both a 6L7 and a 6AC7.

Results were judged on a purely subjective basis, due to lack of test instruments suitable for adequate and accurate measurements. numerical values mentioned here are calculated figures, but the field tests confirm them as closely as possible.

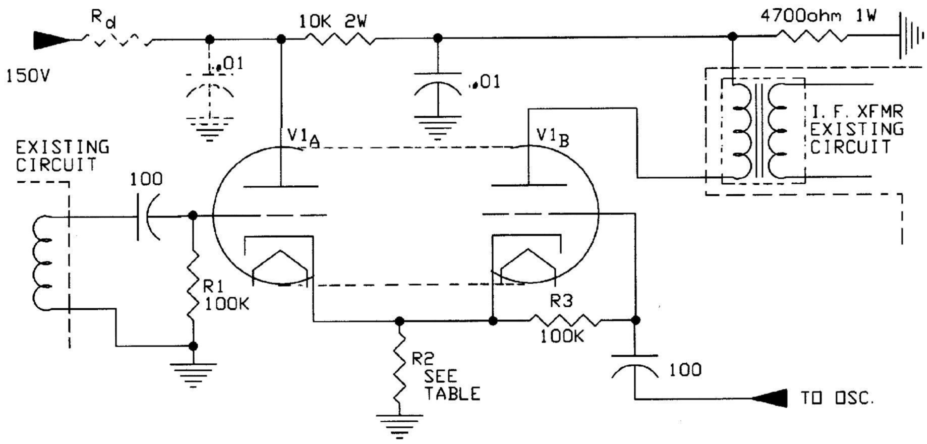


Fig. 1.

The full circuit is shown in the schematic, Fig. 1. Table I lists parts values and operating conditions which vary with different tube types or design objectives.

At first glance, you may be led to believe that this is approximately the same circuit as that recommended by Geisler[3] or Lee[4], or may be a version of the Crosby triple-triode product detector[5]. While the general configuration is similar, the circuit operation and its advantages are radically different.

The key point is the low value of plate voltage supplied to V1B. Pullen recommends only that V1B's plate supply be "considerably" lower than that for V1A. The best operation was found with 50- and 150-volt supplies, respectively, and component values shown are for use with these voltages.

By operating the two nominally-identical triode sections with a common cathode resistor but at two different plate-supply voltages, a relatively small change in current in one tube will cause a large change in the gain of the other. This is accomplished without sacrificing average gain in either tube.

In addition, the cathode-follower action of each stage completely isolates the oscillator from the signal circuit. Since the signal sees only a pair of triodes, noise is not increased.

This circuit is a true linear mixer rather than a detector; its output contains only the two original frequencies and the "product" of the original signals (numerically equal to the sum and difference frequencies but without their usual noise content). The chain of spurious frequencies usually found in detection-type mixer circuits is absent.

Those who have tried triode mixers before, even of the cathode-coupled variety, may wonder about gain. Calculations showed that the version first tested should have shown a conversion gain of about 20, as compared to the calculated pentagrid mixer gain of about 5 under the same conditions.

The test signal was a broadcast station with consistent strength. S-meter reading with the pentagrid mixer was recorded and the twin-triode circuit then substituted and mixer alignment readjusted. The S-meter showed just under 2 units improvement.

Considering the free-wheeling calibration of most S-meters, and this one was no exception, this is a remarkable correlation of theory and experiment. Frankly, we disbelieved it and substituted another tube which had a calculated gain of 13. After realignment, the S-meter dropped one unit.

Regardless of such gain figures, which are dependent on many variables not all of which are under control, this version of the twin-triode mixer shows more signal gain than many pentagrid mixers. Its noise figure is so low that mixer noise simply disappears, even with three *IF* stages following. The result is almost complete silence between stations, leading one to believe at first that the circuit is a dud. Then, though, a fading long-hop signal will come through, moving almost instantly out of the no-signal region into clear audibility, and the design is vindicated.

Every type of twin-triode tube tested to date works in this circuit, but some give better results than others. As noted in Table I, oscillator injection voltage requirements vary drastically from tube to tube. In a like manner, sensitivity varies.

Among octal-base tubes, the 6SN7 gives greatest gain but requires higher voltages to get there. The 6SL7 develops its gain (just half an S-unit less) with much weaker signals and much less oscillator injection. Therefore, the 6SL7 is recommended.

Table I.
Voltage Requirements for Various Tubes and Values of R2 With Typical Conversion Gain

Tube	6SN7 (also 12AX7)			6SL7 (also 12AU7)			12AT7			6J6	
Value of R2	100	500	1000	100	500	1000	100	500	1000	100	1000
Input--Voltage (Signal)	2.1	10.5	21	0.32	1.6	3.2	1.4	7.0	14.0	2.1	21
Input--Voltage (Osc.)	2.5	11.5	22.4	0.42	1.9	3.6	1.6	7.0	13.1	2.3	22
Conversion-Gain if IF Xfmr impedance Is 50K ohms (For Comparison)	18.5	18.3	18.0	13.9	13.7	13.6	100	150	160	80	130

Dozens of twin triodes are available on 9-pin bases; among the most popular are the 12AX7, the 12AU7, and the 12AT7.

The 12AX7 is directly comparable with the 6SL7, and the 'AU7 with the 'SN7. However, the 12AT7 is the hottest tube available for this circuit, with a gain of more than 100 and comparatively low injection- and signal-voltage requirements, so it's the only recommended type. If you're willing to change sockets, the 12AT7 is the best for any set regardless of original tube type.

In the 7-pin basing, there's only one choice – the 6J6. Aside from the fact that the 6J6 is the only 7-pin twin triode easily available, it is surpassed only by the 12AT7. Gain is in the neighborhood of 100 (see Table I).

The entire circuit is simplicity itself to install. Remove all old connections from the mixer-tube socket, being careful not to cut short either the grid lead from the tuning coil or the plate lead from the *IF* can. Then rewire according to the schematic.

If you don't have +150 vdc available in your receiver (many don't), install resistor Rd and its bypass capacitor (shown on the schematic in dotted lines). Value of Rd must be determined by trial and error. Start with 50K ohms, and work down until you find the resistor which gives 150 volts at point A after everything has warmed up.

With the new mixer installed, you'll have to realign the mixer tuned circuits. The cathode-follower inputs reduce input capacity so drastically as to completely detune the stage, so don't be surprised if nothing comes through at first.

The input capacity change has least effect at the low end of any band, so it's best to reverse normal alignment procedure and start by adjusting the *trimmer capacitors* in the tuning assembly at the *low end*. Simply adjust for maximum signal strength (or higher S-meter reading).

Next, tune to the high end of the band and rock the trimmer slightly to see if the adjustment is optimum. If not, adjust the trimmer again for the best high-end signal strength.

If the high end required adjustment, return to the low end but this time adjust the coil slug for maximum signal. Then return to the high end and readjust the trimmer. You may have to repeat this slug-at-low-end-and-trimmer-at-high-end procedure several times to restore tracking, since the change in input capacity usually amounts to about 10 mmfd, which upsets original tracking adjustments.

F_{sig}

an output of

$$K_{total} = K_1 \times K_{2av} \times F_{osc} \times F_{sig}$$

, and since AC signals are *vector* rather than *scalar* quantities, the indicated multiplication must be carried out by vector rather than by straight arithmetic methods. The result is that the output consists of the original two frequencies, the numerical sum of the original frequencies, the numerical differences, *and nothing more.*

Getting away from the exotic mathematics, the big difference between this process and detection-type mixing using non-linear devices such as diodes or overdriven tubes is that only four output frequencies are present. Harmonics and spurious outputs are not.

In addition, the cathode follower is far more tolerant of overload than is any other basic amplifier circuit, and as a result no clipping or distortion occurs in the mixer.

A common problem with many conventional mixers is cross-modulation, in which two carriers become "intertwined" and an unwanted signal rides in on the one you want.

Even under extreme conditions, such as local injection of a signal strong enough to almost block the *IF* strip, cross-modulation could not be induced in this mixer. Apparently this is another by-product of its unusual method of operation.

Although no tests have yet been made, Pullen's analysis of the circuit indicates that it should provide a good high-output product detector for converting SSB and CW to audible signals; simple substitution of an RC coupling network (or an audio transformer) for the *IF* transformer is the only circuit change, though you might want to increase the value of resistor R2.

In summary, this overlooked mixer circuit appears to offer extreme advantages over more conventional circuits in all of the five characteristics of the ideal mixer, with fewer parts than usually required. It works as well in the set as it does "on paper" in the design stage, and can easily be adapted to any receiver. Try it, and let us know how it works for you.

References:

1. Langford-Smith, F., “Radiotron Designer's Handbook”, Fourth Edition, Radio Corporation of America, Harrison, N. J., 1968, pages 988 and 967.
2. Pullen, K. A., “Conductance Design of Active Circuits”, John F. Rider Publisher, Inc., New York, 1969.
3. Geisler, Leonard, "Souping The Super-Pro," CQ Magazine, December, 1957, page 80.
4. Lee, Cmdr. Paul, "Save Your Super-Pro For SSB," CQ Magazine, September, 1958, page 52.
5. 73 Staff, "Beat Generation," 73 Magazine, February, 1961, page 28.

Uncited by number. 73 Staff, "Up Front," 73 Magazine, March, 1961, page 32.

(Editor’s Note: In the original circuit, as published by Keats Pullen, a triode HFO’s output is coupled through another cathode-follower to the input grid of the mixer, V1B. This substantially alleviates, if not totally eliminates, the pulling on the oscillator that was noticed in the follow-up 73 Magazine article of August 1966 entitled “Another Look at the *Like New* Circuit”)

Receiver Topics

A simple "TV" tube receiver

From: http://www.electronixandmore.com/index.php with many thanks to Jon.

This wonderful design shows that, with good imagination (and a copy of Grayson Evan's Book, "Hollow State Design"), you can make a thoroughly useful receiver using "unpopular" TV type valves readily (and cheaply) available in our favourite online auction pages; and the valve "equivalents" referred to in the Data section of Hot Iron will help you root out other possibilities.

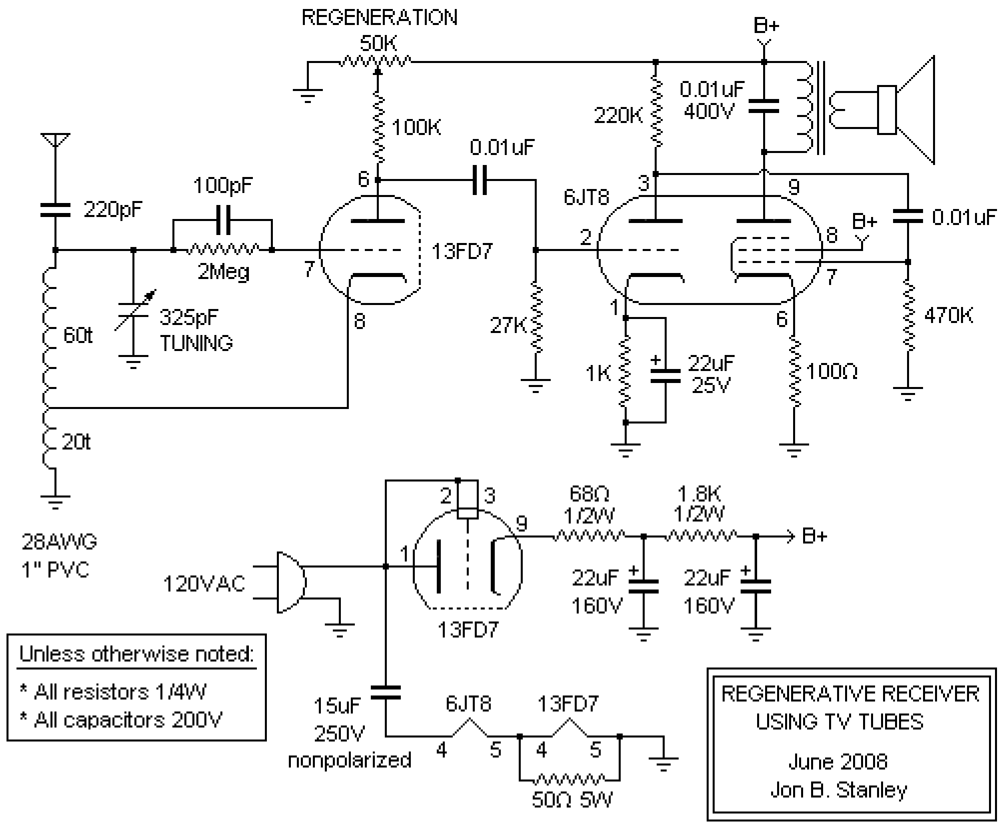
TV Tube Regenerative Receiver

Return to Home
Return to Projects

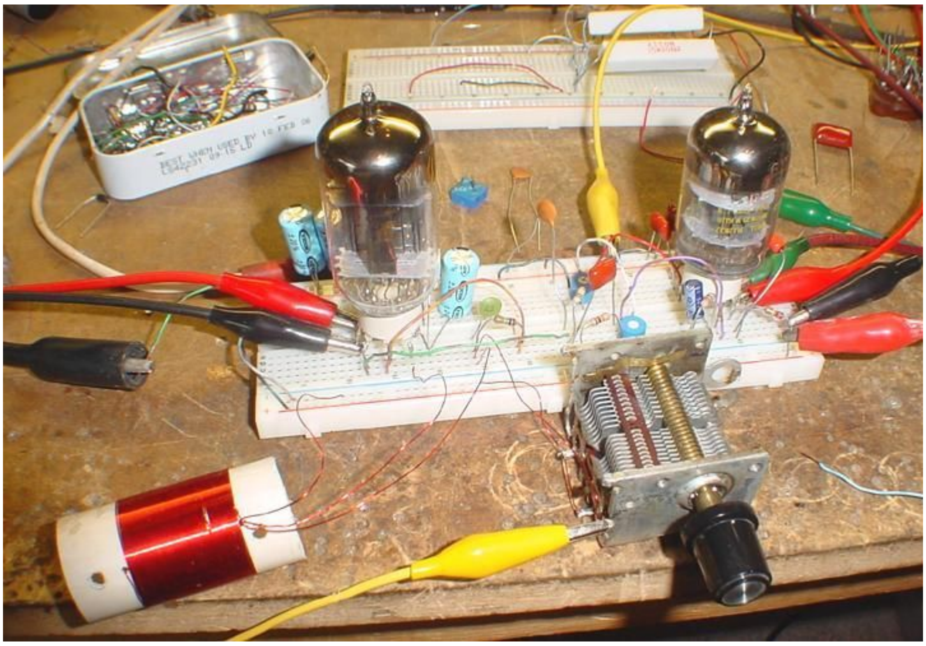
Over the years I have amassed many TV tubes and many of these tubes are interesting because they contain many tube sections in one package. I have built an audio amplifier using a 6LU8 here. Out of the tube pile, I picked a 6JT8 and pulled up the data sheet on the tube. The 6JT8 contains a high mu triode and sharp cut off pentode, which are often used as a sync separator and video amplifier respectively in a colour television. On the other hand, the tube is perfect for creating an audio amplifier. The high mu triode is used in the preamplifier and the pentode as the output for driving the speaker. A circuit based on the audio stages of an AA5 radio was wired for the 6JT8 tube. A loud hum resulted when I touched the input of the amplifier so the next thing was to make this amplifier a bit more useful.

In a dusty corner of my closet was a crystal radio someone built from around the fifties. The crystal radio came with a bunch of other stuff in a box I had bought from an auction. It needed high impediance earphones and I don't carry anything of this sort but a high gain amplifier is a nice subsitute. After dusting off the crystal radio that sat in its niche for several years, I hooked up the earphone terminals to the input of the 6JT8 amplifier and connected a measly 6 foot antenna to the radio. To my amazement, the crystal radio actually picked up at least three stations. I thought to myself, if that simple radio consisting of a mere coil, a variable capacitor, and a single 1N34 diode can pick up stations then I should be able to build a radio that is far simpler than the superheterodyne I built years ago. Before the superhet, I had built various crystal and regenerative receivers that never seemed to work, but in hindsight I realize that these radios may have *almost* worked but I lacked the experience and knowledge back then to get them running. It's quite a shame that none of these radios I built in the past exist anymore because I stripped the parts to use in other projects.

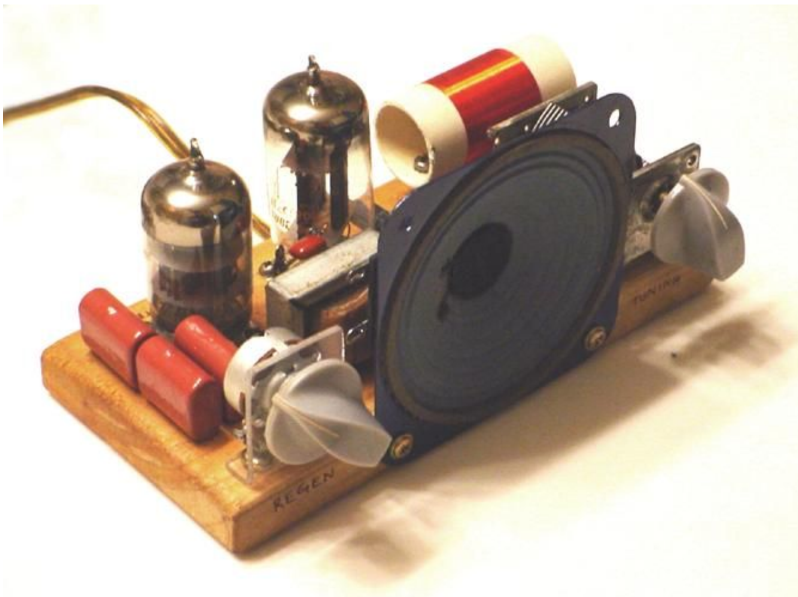
So, some eight years later I took a stab at building another regen receiver. After searching around online, I found a 12AT7 based regen that seemed simple enough to build. To my amazement, the radio worked on the first try so the next step was to find another TV tube that contains a rectifier and high gain triode in one package. During experiments when the 6JT8 was being used as the audio amplifier, the 170VDC B+ was provided by a semiconductor diode from 120V mains during the experiments. I was determined to replace the diode with a hollow-state equivalent to make a true all-tube regenerative receiver. After digging through various TV tubes and pulling up data sheets, I found a 33GY7 that contains a diode and pentode, which could be used as the rectifier and audio output respectively and the 12AT7 for the regen and preamplifier. It turned out that the pentode in the 33GY7 consumed a lot of power, which may be due to an internal short. I confess that I never tested the tube, but the 33GY7 clearly a poor choice for my goals. The next tube was even more promising, a 13FD7 that contains a low mu triode and a high mu triode intended for the vertical circuits in a TV. The 6JT8 could be brought back in the design as the audio amplifier, and the 13FD7 for the rectifier and regen. The low mu triode was capable of supplying sufficient current for the B+ so it was wired as a diode. The high mu triode section of the 13FD7 was used for the regenerative receiver. The circuit was rewired on the breadboard to adapt the 13FD7. The radio worked very well and was able to pick up at least five stations with a very short antenna. The next step was to move and permanently enclose all the components from the breadboard to a wooden board and voila, the TV tube regen radio was born. Below is the schematic of the final design.

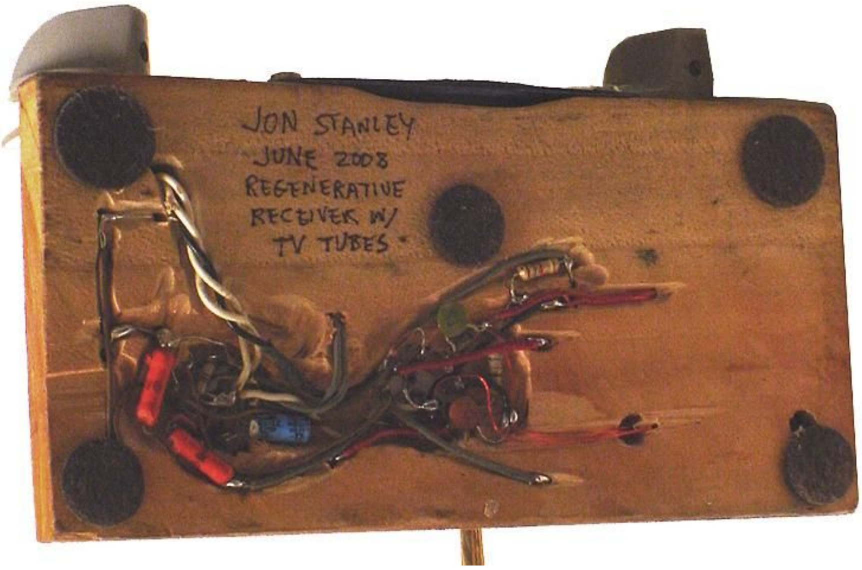


Note that the radio is transformer-less (*I **ALWAYS** ADVISE AN ISOLATING TRANSFORMER! G6NGR*) and the tube filaments derive their power from 120V mains while in series with a 15uF 250V non polarized capacitor. (*see the article later in this issue on mains connected capacitors! G6NGR*) The 15uF capacitor drops about 105 volts at 0.725A at a 60Hz line frequency. Most of the smaller parts such as the 1/4W resistors were stuffed under/inside the wood board. The radio picks up several stations with a short antenna.



The radio was first built on a generic breadboard for experimenting. I soldered longer leads to the tube sockets so they could plug into the breadboard easily. The filament power for the two tubes were supplied by two separate low voltage bench supplies.




JON STANLEY
JUNE 2008
REGENERATIVE
RECEIVER W/
TV TUBES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Audio Topics

Using a power transformer for valve audio amps

Valve audio output transformers are rare as dobby horse droppings nowadays, or nosebleed expensive - so try a mains transformer as a switch hitter until the genuine substitute is available. 230v to 6v are a good bet; a 2 or 5VA size will be adequate for a few watts of audio, but don't expect hifi!

Primary Volts rating	Sec'y Volts rating	Speaker Ohms	Anode Resistance
415	24	8	2.40k
380	24	8	2.05k
230	24	8	735R
230	15	8	1.88k
230	12	8	2.94k
230	6	4	5.87k
115	24	8	184R
115	15	8	470R
115	12	8	734R
115	6	4	1.47k

How to work out any impedance value:

(1) Calculate the Primary volts divided by secondary volts to get the turns ratio, "TR"

(2) Square the value you calculated for "TR"
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(3) Multiply this number by the loudspeaker resistance (commonly 8 ohms) to get the equivalent anode resistance.

For instance, consider a 115v to 5v rms transformer.

TR = 115/5 = 23. Square this number: TR^2 = 529. Multiply by the loudspeaker resistance you want to use, say 16 ohms: Anode resistance = 16 x 529 = 8.464k-ohms.

Wire the loudspeaker to the low voltage secondary; the high voltage primary is the anode load. HiFi it's not, but it will get you going until a proper replacement arrives. The iron in power transformers is designed for 50 / 60 Hz duty; you'll notice a degradation in the treble frequencies. Counteract this by using capacitors for treble boost (look up "tone control circuits", for example) on the primary side to lift the HF response; a bit of "cut and try" with whatever capacitors you have to hand will usually find a workable value. If you're a CW / Morse operator, you can peak up your preferred audio note (usually ~800Hz or so) with a resonance peak using parallel capacitors on the anode side, which will give you useful filtering and tighter receiver bandwidth gratis.

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Oscillator Topics

"Over and Under" frequency control

Many moons ago I had a job which required me to generate "over and under" frequency signals by comparing an incoming pulse stream with a precision reference square wave. With a handfull of NAND's, NOR's, and an inverter or two, I created the required signals. The problem was though, as the incoming pulse train closed in on the reference signals, the gates delivered narrower and narrower pulses: the gate speeds became an issue when I pushed the incoming frequencies up to 10MHz and beyond. I used low pass R/C filters to generate DC error signals from the "over and under" gates, very much as a PLL loop is stabilised by a LPF on the phase comparator output.

With modern 74HC gates, however, the speeds are well up to 50MHz; and using these simple digital comparison techniques would easily cope (in theory...!) with the HF bands. It would be possible to make oscillators that, given accurate timing references, could stay rock solid infrequency (in theory...!). The obvious flaws to this scheme are the phase noise characteristics, which weren't an issue in my low HF application, and the response to sudden shifts - anything with a LPF in the system can't react instantly! This also precludes any frequency agile requirements; not that amateurs are likely to be allowed "frequency hopping" and similar techniques!

The Huff-n-Puff system is a close cousin of these techniques: and again with modern 74HC gates, a simple oscillator can be stabilised to very effective limits. There are several existing logic gate Huff-n-Puffs which give superb results when implemented with 74HC gates; a web search will bring many ideas.

Timing reference pulses are the key in these techniques, or indeed any other "counting" or "comparison" circuits. A glance at:
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https://processors.wiki.ti.com/images/f/f1/TI_GPS_PPS_Timing_AppNote.pdf will give background for generating the timing pulses to high accuracy.

Transmitter Topics

An "Oddball" Tube A.M. Tx

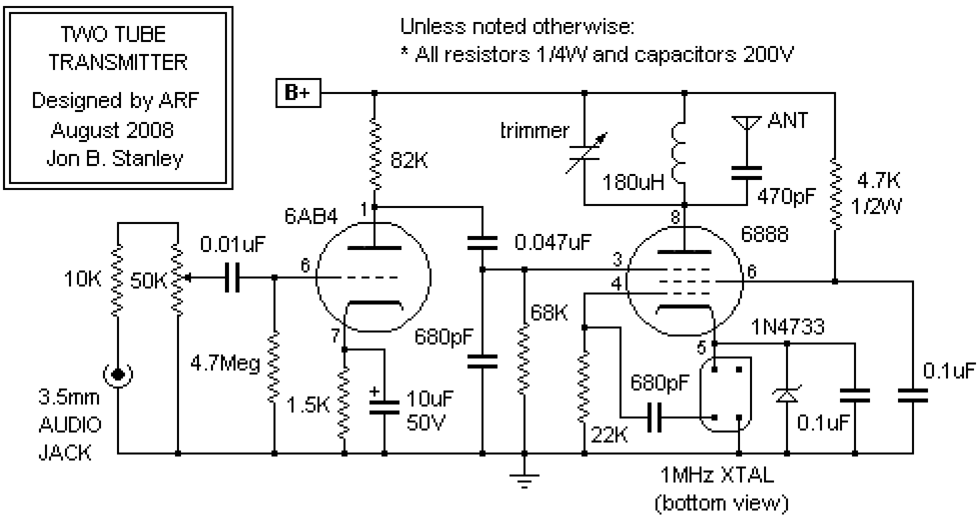
Following on from the receiver earlier in this edition, here's a lovely transmitter to go with it: it also uses an "Oddball" pentode very successfully and elegantly with suppressor grid modulation. Obviously a switch or two and a keying relay will produce a very nice QRP CW transmitter. "Where do I get such an oddball valve / tube?" you ask... look at:

https://www.ebay.co.uk/sch/i.html?_from=R40&_trksid=m570.l1313&_nkw=6888+pentode+tube&_sacat=0

Or check the valve / tube alternative references in the Data section of Hot Iron. For pentodes with an internal Suppressor grid to cathode connection, consider Screen grid modulation or Cathode modulation; each with added touch of Control grid modulation for better audio. You can use demodulated RF output as a feedback signal to "linearise" the audio response for these "unconventional" modulation methods.

Whilst this schematic is set up for 1MHz MW transmission, aspiring amateurs will very readily substitute a crystal oscillator more suitable - please note: a low pass filter is required for the antenna connection!

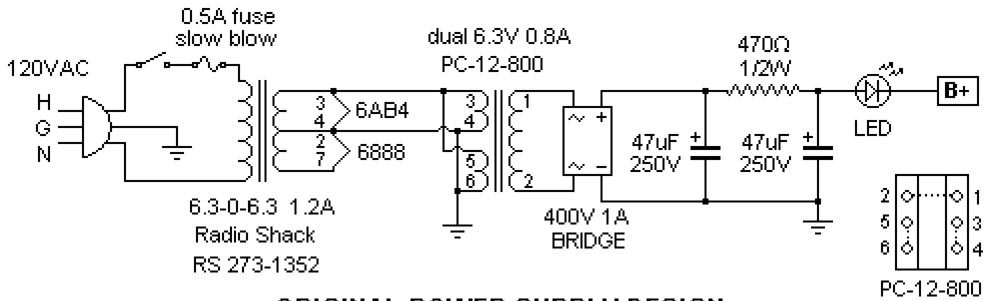
Some fellow ARF (Antique Radio Forum) members offered to send me some parts to get started on a quite successful 6888-based AM transmitter. The 6888 is an oddball octal tube that goes by the description of "dual control pentode" because its first grid and suppressor grid both are used as a control grid. In the kit design, a 6AB4 or 6C4 is used as an audio preamp and the 6888 as the transmitting tube. Below is a schematic of the transmitter as designed by members on ARF.



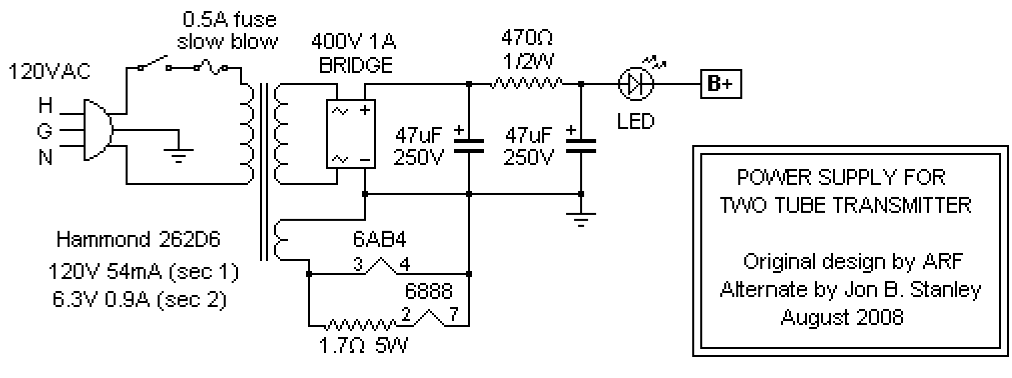
The circuit is fairly straight forward for a transmitter but there are some noteworthy features. The 1MHz crystal oscillator requires 5 volts and produces a nice square wave output at 1MHz. These oscillators are normally used in TTL or computer circuits because it is a self-contained oscillator rather than a mere crystal. The cathode current by the 6888 is sufficient to provide power to the crystal oscillator and a 1N4733 (5V 1W zener) is used to regulate the voltage. The oscillator output controls the first grid of the 6888 to create a clean 1MHz carrier on the plate. The inductor and trimmer capacitor above the plate of the 6888 serves as a tuned LC tank. The trimmer capacitor will adjust the output strength and thereby the range of the transmitter. The range is largest when the LC circuit resonates at 1MHz.

For use with stereo audio, another 10K is used from the second connector to the 50K pot to basically combine both channels into a mono channel before being transmitted. The 6AB4 serves as a very high gain preamplifier. The carrier is modulated by feeding the audio signal from the 6AB4 into the other "control" grid of the 6888.

The power supply is solid-state and uses a bridge rectifier to provide a very smooth B+ for clean audio quality in the transmitted signal. The original design used two back-to-back low voltage transformers to provide filament power and isolated mains voltage. The isolation allows this transmitter to be safe to use with just about any audio equipment without the hazard of shorts or shock. Although I was sent the odd PC-12-800 transformer, I did not feel like sending in a mail order for the Radio Shack transformer so I used a Hammond 262D6 transformer that I had left over from an experiment. Below are schematics of the original and alternate designs.



ORIGINAL POWER SUPPLY DESIGN



ALTERNATE POWER SUPPLY DESIGN

The PC-12-800 is a dual secondary transformer that is capable of producing 12V 0.8A with the secondaries in series, or 6V 1.6A in parallel. The Radio Shack transformer is 12VCT 1.2A and half gives sufficient power for the 6V 0.8A filament power requirements of the 6888 tube. The other half provides power to the 6AB4 and the two 6V windings of the PC-12-800 transformer to produce isolated 120V on the other side.

Another interesting thing to note is the use of an ordinary indicator LED in series from the B+ to the transmitter load. When the transmitter is first turned on, the LED remains off and slowly illuminates to full brightness when the tubes warm up completely. The LED is a good indicator of the load current and most LEDs are limited to 20mA of current so I figured the 120V 54mA winding of the Hammond transformer should have no problem. During construction I experienced some unforeseen short or miswiring in the circuit that caused the transformer to heat up quickly and give off the smell of fresh polyurethane. Not good. The bridge rectifier ended up ruined and caused a 500mA !!! load on the 120V 54mA secondary of the transformer. Now with the issues cleared up, the B+ runs at around 180V at 20 to 25mA as expected. Before determining the cause of the short on the 120V secondary, I assumed the overheating was due to the 50mA excess load on the 6V winding. The 6888 and 6AB4 filaments combined draw 0.95A at 6V while the transformer is only rated for 0.9A. However, inserting a 1.7 ohm 5W resistor reduces the 6888 filament current to a reasonable 0.75A to bring the overall current load to a tolerable 0.9A for the transformer, albeit a slight reduction in transmission strength due to a cooler 6888 tube.

The 50K pot in the circuit controls the amplification of the input audio signal and in effect controls the modulation strength of the output. For strong audio signals, too much amplification would result in over modulation and distortion. In short, the pot is used to adjust the output to achieve 100% modulation for best audio quality.

The transmitter components, including the Hammond transformer, were quite literally crammed in a roughly 2x5x2 inch Radio Shack project enclosure box. When in operation, the transmitter was able to reach many radios in the entire house with a short 3 foot telescoping antenna. With a portable CD player as the audio source, the audio quality of the transmitted signal through many AM radio receivers were very good.

Single Sideband FM...

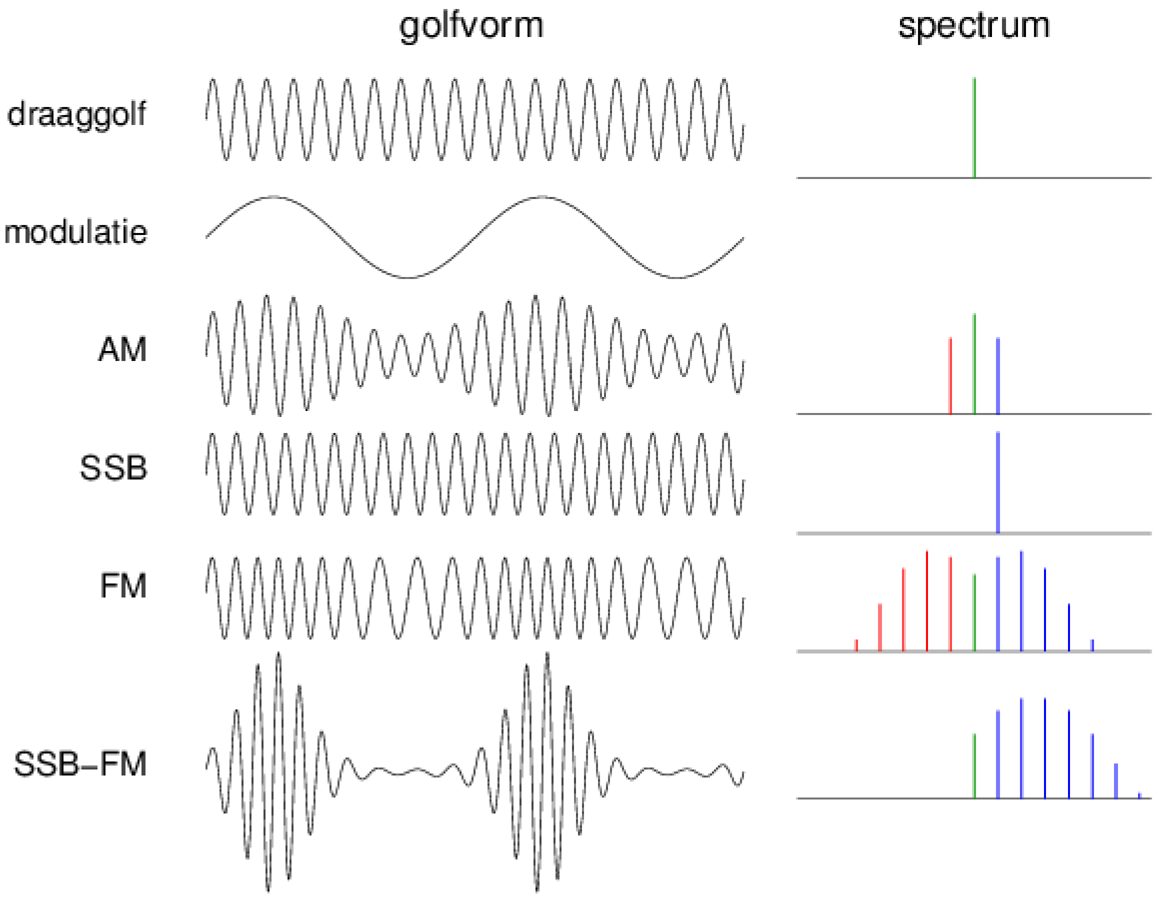
Pieter-Tjerk de Boer, PA3FWM pa3fwm@amsat.org
(This is an adapted version of an article that I wrote for the Dutch amateur radio magazine *Electron*, July 2012.)

This instalment is about SDRs, about inductors, capacitors and antennas, and starts with a strange modulation type.

Single-sideband FM

When studying for an amateur radio license, one learns about several modulation types, in particular amplitude modulation (AM), frequency modulation (FM) and single-sideband modulation (SSB). SSB saves bandwidth in comparison to AM by omitting one of the two sidebands, because they contain identical information anyway. With FM, there are also sidebands on either side of the carrier. Does that mean one could make a single-sideband version of FM?

Indeed, in the 1960s research has been done into "SSB FM". That was not done by taking a normal FM signal and filtering one sideband, but by *simultaneously* modulating the carrier's amplitude and frequency. This method was invented in (1) based on a mathematical analogy with "normal" SSB.



Let's compare the different forms of modulation. The top part of the figure shows an unmodulated carrier, both in the time domain (the sine wave) and in the frequency domain (the spectrum diagram at the right). Just below this, the modulating signal is shown, in this case a slower sinewave. Below this, AM and SSB are shown; the sidebands have only a single peak here because the modulation is a pure sinewave.

Next is FM: we see that the amplitude is now constant, but the frequency varies: in the peaks of the modulation, the frequency is highest, in the valleys it is lowest. The spectrum is more complicated: even with a pure sinewave as modulation, there are multiple components in each sideband.

At the bottom, single sideband FM is sketched. If one looks carefully, one sees that the frequency varies here exactly like with normal FM. Much more noticeable however is that the amplitude is also varying: in the modulation peaks the amplitude is high, but the signal disappears almost completely in the modulation valleys. This amplitude modulation is not linear, but is performed via an exponential function; that explains why the envelope is no longer a nice sinewave. In the spectrum we see that the lower sideband is completely gone, but the upper sideband extends even a bit further than with normal FM.

Can we intuitively understand what happens with SSB-FM? The effect of the amplitude modulation is clear: in the valleys of the modulation, the amplitude is reduced quickly; this is when the frequency would be below that of the carrier itself, i.e. in the range of the to-be-suppressed sideband. In the peaks of the modulation, the frequency is on the "good" side of the carrier, and the amplitude is increased. Intuitively, this already suggests that the upper sideband will be made stronger and the lower sideband weaker. By modulating frequency and amplitude simultaneously, *both* modulations contribute to both sidebands. Both of these contributions add, and then it can happen that the AM contribution precisely cancels the FM contribution. If one does this precisely right (mathematically proved), *all* lower sideband contributions cancel, leaving only the upper sideband, which however has become a bit stronger and wider.

Is this SSB-FM good for anything in practice? Well, not really (otherwise, it would surely have found more use). SSB-FM needs less bandwidth than normal FM, but still more than "real" SSB (i.e., derived from AM). An advantage of SSB-FM is that it can be demodulated by a normal FM demodulator. However, a disadvantage is that during the valleys of the modulation the transmit power is almost zero, especially at large modulation index (deviation). Practically, this means that the valleys of the modulation will have a rather bad signal to noise ratio.

In the 1970s, several Dutch amateurs (in particular PA0EPS) invented something related but different, namely "SSB-compatible FM", also called "phase-locked loop SSB" (2). This was made by sending a normal SSB signal through a PLL. The PLL then creates a signal with constant amplitude, whose frequency depends on the SSB signal. Thus, the signal only varies in frequency (so we can justly call it FM), but in a way which can still be listened to using an SSB receiver (hence "SSB-compatible"). The main purpose was to reduce interference to consumer electronics.

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A solid state 4CX250B? Nearly!

This is from John Kirk, VK4TJ, and describes my thoughts to a "tee"...

"I'm really a QRP'er. Honest! It's a lonely life, here at the edge of the planet, made that much more lonely by the insidious proliferation of switch mode power supplies, which seriously impair most of my QSO partners ability to dig deep for the weak ones. I had a rant about this in a recent "K9YA Telegraph" article. While it made me feel better, it didn't actually result in any more QSO's. If I cannot change your predilection for surrounding yourself with RF-noisy electronic gewgaws, I must give up the hobby or go QRO to tip the scales back in my favor. So QRO I go. Reluctantly. With much trepidation, for I have not worked with hollow-state devices or high voltages for some years. Subconsciously, I think I must have wanted this project to fail, because I imposed upon myself the ludicrously low budget of $25 – just 1 percent of the price of a new amplifier. The fact that you are reading this hints that, beyond all expectations, the project did in fact deliver the (white) goods.

Bill of Materials

Tube: No contest – cash in some of your cold war dividend and purchase a few GI-6B's from Vladi, UT5JDS. At just $7, these are the hands down clear winner in the watts per dollar sweepstakes. With 350-watt anode dissipation, you can expect 500 to 600 watts output from one tube. As you will read later, this dovetails nicely with the limitations imposed by our scrounged transformer. It's a bit frightening to contemplate the use of a self-described "microwave oscillator" tube in an HF amplifier, but in practice, they work out just fine. Being a triode, we neatly sidestep the beginner jitters around screen supplies and sequencing of power turn-on. Better still, the GI-6B really doesn't
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need a socket. Priced 4CX250 sockets lately? You'll understand why your new best comrade is in fact, a Red Army defector.

Plate Blocking Capacitor: While you are in negotiations with Vladi, price in a few 5 kV capacitors. At $3 ea or so, they won't break the bank either, and can be rather hard to find in the capitalist economy.

Socket: Wait a minute - I just finished telling you that the GI-6B doesn't need a socket! Pay attention, will ya! Seriously, it is convenient to be able to replace the tube without ripping the amp completely apart. I am deeply indebted to Frits, PA0FRI

http://www.xs4all.nl/~pa0fri/Lineairs/GLA1000/gla1000eng.htm

for pointing out the ordinary tool clips make good contact rings for the GI-7B/GI-6B.
Frits only used tool clips for **temporary** sockets, but in practice, I've found that they are a perfectly acceptable permanent solution.

Plate Transformer: Raid the kitchen garbage for a defunct microwave oven, preferably a 1 kW, or even 1.1 kW nuker. Dead it may be, but I've only ever seen one with a defunct transformer – generally, it is the magnetron that fails. Repair is not generally cost-effective, given that microwave ovens are currently on sale at my local "Junky John's" for $49 AUD. You are going to read all sorts of rubbish about microwave trannies – that they lack insulation at the earthy end, that it is somehow "too special" for our purposes, perhaps even that it eats it's own young, but your own investigations will reveal that they have just as many wraps of paper and varnish at the earthy end as they do at the hot end. Snip the grounded end at the rivet, build a front porch for the liberated connection out of etched PC board or some other suitably insulating material, and you are away. Don't forget to bung out the magnetic shunts – laminated rectangles of steel located betwixt the primary and secondary windings. It **is** true that the magnetizing current is rather high in a nuker tranny. If you suffer from cold feet in winter, it is recommended that you build the power supply in a floor-mounted separate enclosure so that you can warm your toes on it. Otherwise, find two roughly equivalent transformers, and wire them up series primary/series secondary. This dramatically reduces the standby current, and probably pulls the combo well back from the hairy edge of saturation as well. Sadly, microwaves are obviously spec'd out in "marketing watts", a unit of measure not bound by the physical constraints of our universe, so there is not much point in hosing up a second GI-6B in parallel to go for the full gallon. That's also why we're such fussy garbage-pickers, sending our meal back repeatedly to the kitchen if it isn't at least a 1 kW nuker.

You'll probably find that the secondary voltage is a tad high for our purposes – around 2200 VAC if yours are like mine. There is plenty of anecdotal evidence that the GI-6B will cheerfully withstand this, even full-wave rectified, but if you are lucky, you may find that turns can be removed from the secondary. No? Then consider **adding** turns to the primary (usually easier). Anything you are able to do on the primary side will, as an added bonus, also reduce the rather high magnetizing current.

Rectifiers: You guessed it – dead microwaves again. You'll need about four carcasses, so put the word out amongst your friends. Don't have any friends? Join your local "Freecycle" group (q.v.). You will be amazed how fast the dead can move (towards your junk box), and in what numbers!

Filter caps: There are two ways to go here – you can liberate lovely 1 uF oil-filled caps from microwave ovens that will probably provide you with years of trouble-free service, but you will need to find about 20 of them to parallel up. As an added bonus, each comes with an integral bleeder resistor - but – even 20 in parallel probably isn't enough bleeder for our purposes. Alternatively, if there are any PC CRT's left on the planet that haven't already been bulldozed, they generally contain at least one 220 uF, 450 volt electrolytic. Series up about 8 of these, and you've got a really nice filter bank. Of course, you then have to come up with equalizing resistors. Your call.

Blower: Yep, microwave again. Like most external anode tubes, the GI6B's **gulp** the air. In large doses. Conventional wisdom states that only an (expensive) squirrel cage blower can do the deed – that blade fans simply cannot handle obstruction. Sadly, conventional wisdom is nearly right. A cardboard mock-up, including a chimney around the fan blades and the anode cooler yielded – nothing! It was only when I mounted the tube axially, and cut a "wind tunnel" the same diameter as my blower blades into my enclosure, that I began to see any air movement across the anode cooler. Obviously, we must screen this opening with hardware cloth to keep prying fingers from finding our 2 kV supply, but mine was going into a 19 inch rack, so I'm pretty safe on that score. I also mounted the microwave blade fan as close as humanly possible to the cathode of the tube. The proof of the puddin' is obviously in the eatin': I see less than 2 degrees C temperature rise on the anode cooler after a 15 second "brick on the key" episode. I'm calling that a win! And, no, I'm not going to tell you how I made those temperature measurements – I'll reserve that for an episode of "Mythbusters". Or maybe a remake of "Dumb & Dumber".

Filament Choke: For a change of pace, we'll raid a dead CRT or television for this one. PY2WM put me on to the potential source of balun material in his brilliant treatise:
http://py2wm.qsl.br/balun/Balun_with_free_ferrite.pdf
It would appear that the flyback core, with its almost supernatural permeability, would serve us best. I glued the two halves of my victim end to end in order to keep the "gozinta" end well separated from the "gozouta". The swastika-like end result no doubt raises a few eyebrows, but performs well.

Filament transformer: I think mine came from a defunct AM/FM stereo receiver – I don't really know. The GI-6B wants a rather modest 12.8 volts or so at 2 amps, which shouldn't be too hard to come by. Don't ignore OEM or even PC power supplies. We're not slighting the sexual orientation of the filaments – they really are AC-DC! If you are really stuck, you could bung the secondary turns out of one of the baby 600-watt microwave transformers you accumulated along the journey, and replace them with a 12.8-volt low voltage secondary. There would be ample room for another "control electronics" winding for relays and suchlike.

Bias Board: My circuit was a blatant theft from: http://www.nd2x.net/oz1dpr/schalt.jpg
because the parts required were all in my junk box. No parts made of unobtainium here! I suspect my pass transistor was once a TV or CRT horizontal oscillator device, but I'm not really sure. Feel free to make substitutions – the circuit is quite tolerant of that.

Meters: Mine were QA rejects from my former employer. Since you are unlikely to be so lucky, I might suggest plant pot moisture meters. If it amuses you, you may leave the original calibration of "moist" to "wet" in place, or freehand some new scales. For a distinctly high-tech look, I am told that Asian Ebay sellers periodically put their DVM's on special for the princely sum of $1.99 each. You are unlikely to better this price, analog or digital! Of course, now you **really** need a "control electronics" DC supply – no way I'm reaching in there to change those 9 volt batteries!

Plate RF Choke: You guessed it – microwave again. I unravelled a blower motor winding for wire, and spooled it onto a ½-inch or so diameter dowel. I may have got a bit carried away, as my choke came in at over 400 microhenries, vastly more than we need, but no nasty resonances were noted, at least like where I like to operate, so I'm calling it a win.

Cheese Slicer "Tune" Capacitor: Sorry, you are on your own here. I prised mine from the fingers of an old geezer too long in the tooth to homebrew any longer, but if you are too proud to beg, you can always have a go at building your own:
http://www.eham.net/articles/5217

Plate Inductor: I happened to have a chunk of B & W Minidux in the junk box, so used that, but it's nothing you couldn't replicate with a bit of 2-inch PVC pipe and a bit of household wire. My amp is an untuned input, so a band change, while not trivial, is as simple as changing a tap – but not to be undertaken while half asleep! A roller inductor might be a better option, but would almost certainly blow out my modest project budget. A band switch capable of this kind of power is clearly out of the question! Interesting economics, eh? When playing with 7-dollar finals, it's actually less expensive to build 9 monoband amplifiers than to purchase a band switch!

Multi-gang "Output" Capacitor: I suspect that the aforementioned defunct stereo tuner might have donated this – I don't really know. It is about a 6-section variable capacitor, and, with all sections paralleled, yields about 1000 pF at maximum – not quite enough for 160 meters, but certainly more than adequate for 80 through 10 meters. As Bill Orr, W6SAI, amplifier guru extraordinaire, was quick to point out in the "West Coast Handbook" ("Radio Handbook", most editions), we're back to 50 ohms at this point in the circuit, so the plate spacing requirements are not onerous.

Relays: Ordinary control relays are quite adequate at HF – study any 70's vintage boat anchor, and you'll see what I mean. I'd like to say that I scavenged these from a dead microwave as well, but in reality, the beefy relays in a nuker always seem to be SPST. We want SPDT. I have no idea where mine came from, but suffice to say, they're a common item in the scroungers marketplace.

Chassis/Sheet Metal: You guessed it – microwave again. The presence of both an outer and an inner skin (cooking cavity) presents both some challenges and some opportunities. We can let components "dance on the ceiling" if we choose, knowing that their mounting bolts will not show, but some of the soldering is reminiscent of keyhole surgery, so special care must be taken to avoid cold solder joins. The sheet metal between the power supply compartment and the cooking cavity makes a very nice plate/grid shield, which we sadly violate, of course, when whittling our wind tunnel through the lot, but no signs of instability were noted. Although steel, the microwave oven carcass is of light enough gauge that there is no danger of burning out drill bits - an absolute pleasure to work with

Besides, how many other enclosures colour coordinate with your kitchen décor, and come with bragging rights: "Amp here is a Samsung, OM – strictly an appliance operator here".

Test Equipment & Fault Finding

Bird 43

Those of us who have done battle with power RF know Bird 43 instruments: simple, rugged, reliable and a true engineer's friend. Amateurs too can access a wealth of useful graphs, nomograms and data from the Bird user guide and notes, particularly the Loss vs. SWR charts and the like, for those who believe (incorrectly) that only a 1:1 SWR is acceptable. Take a look at:

https://birdrf.com/~/media/Bird/Files/PDF/Manuals/920-43.ashx

The information is applicable and useful to all amateurs.

Joe and his Multimeter...

Joe was a Technician who appeared one morning in the Autoprobe Test hall, where silicon wafers full of transistors were being probe tested for functionality - a basic 5 parameter go / no-go test. Duds were given a spot of ink, so the opto-electronics in the die bonders could ignore marked dies and move onto the next good device when the wafers went for die bonding onto the lead frames.

Joe had arrived without a toolkit - so a trip to stores got him a kit, plus a multimeter from the cupboard. Joe was not happy! Joe wanted a digital multimeter (not our favourite AVO MultiMinor analogue job) with a transistor test function, capacitance measurement, temperature sensing, just about every test function you could think of. So I got him a digital multimeter, garish yellow, from the local hobbyist electronics shop, and Joe was over the moon. For about a day! Problem was, he couldn't decide WHICH transistor to test, of the hundreds in the machine. Joe had the means to find almost any electrical value in the circuit; but it didn't help him diagnose faults. He could measure a mass of information; and soon realised that information is useless unless you know what to do with it!

The moral of this tale (apart from don't employ Joe in a fault finding job...): measuring every possible voltage, current and resistance IS NO USE WHATSOEVER. Fault diagnosing needs clear logical thinking, a multimeter - analogue or digital - that will show volts, amps and ohms, and a notebook and pencil to record what you've measured and where.

Applying this to amateur radio, you can have Mini network analysers, multi-function RF test gear, signal generators, RF voltmeters, Smith charts and a myriad other esoteric bits of kit; but believe me measuring or knowing every variable WON'T FIND FAULTS OR SOLVE PROBLEMS.

The rules of basic fault finding will find 99% of most problems. They are:

- Always check the power supplies!
- If point "A" is wired to point "B", don't assume it's electrically connected until you've tested continuity "A" to "B" then "B" to "A" and got the same (low ohms) reading both ways.
- Transistors have junctions; test them for continuity (on ohms or "diode" test) base-emitter, base-collector for conduction one way but not the other; and collector-emitter is open circuit.
- MOSFETs have no junctions; but continuity testing (watch polarity!) with the gate connected to source = open circuit; gate open and touched with a finger = short circuit drain to source (the AC mains pick-up on your finger turns the MOSFET on).

- Any transistor, IC or electrolytic capacitor that's boiling hot is suffering: be kind to your components, they do not like it up 'em! Either they are dud, or, more likely, something's low resistance in their vicinity, or they are in (unwanted) oscillation.
- Any electronic circuit has inputs and outputs: if you have output(s) with no input(s) then you've got either Divine Intervention (rare) or a circuit that's unstable or got shorts somewhere.
- It's almost impossible to see wiring mistakes on a strip board construction you've built yourself. Check every connection (and track break); pencil over the schematic diagram to show which connection you've just checked. Look too for tiny solder bridges between tracks, use a craft knife to cleat the gaps between the tracks.
- If you have the correct input(s) and no output(s) then that stage is dud, check from the input(s) forward toward the output(s), and look especially for open circuits.
- If that doesn't yield a result, check backwards from output|(s) back to input(s).
- To find dud coupling capacitors: try a capacitor on wire leads temporarily jumped in parallel with the suspect o/c coupling capacitor. If the stage comes to life with the shunt capacitor connected, you've an o/c coupler.
- Always replace resistors with identical parts; wirewounds are inductive, and if used in the emitter (or source) of an RF device, will most likely create a potent VHF oscillator.
- If adding an extra capacitor in an attempt to stop oscillation makes matters worse, odds on the stage is "squegging". Reduce the original capacitor a bit, and try again.
- If the antenna isn't resonant - or near resonance - then you'll need to add either inductance or capacitance **at the antenna** to get resonance.
- Don't waste time and effort trying to measure an antenna's reactance; out with your grid dip oscillator, and note the resonant frequency. If it's below your desired frequency, put some capacitance in series with the feed. If the resonant frequency is too high, add series inductance in the feed. It doesn't matter a Tinker's damn what the value of capacitance or inductance is, just try adding the capacitance or inductance until you have SWR of 1.5 or less. To work across a wide band of frequencies, you'll need to make the capacitance and / or inductance variable in some way.
- NEVER try to add reactance at the transmitter end of a co-ax feeder. Put it right at the antenna feedpoint.
- If the antenna impedance doesn't equal the co-ax transmission line characteristic impedance, you'll never get a good match; you need a transformer to get the impedances equal. This can be a tapped coil, "balun" or conventional primary / secondary transformer. The tapped coil is most useful for adjusting but make the taps secure and tight.
- Check the SWR is low enough across the range of frequencies you want to work.

- If the SWR is constantly low at ANY frequency, you've not got a perfect antenna; you've got a "dummy load"! Be aware that gross earth losses under a Marconi antenna can give the illusion of wideband low SWR, but yield very poor radiation as your RF is warming worms.

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Noise Source for Impedance Bridges etc.

In spite of the above "KISS" methods, a Noise Bridge is useful. Zeners will generate noise, but far better is detailed below.

(With grateful thanks to Gary Breed, K9AY and Terry Mowles, VK5TM)

A Logic Chip Comb Generator

A comb generator makes thousands of energy spikes across a very wide spectrum, making an ideal alternative to zener noise sources, with a better output over many decades. Examining the circuit (below) you'll see it relies on the propagation delay of NAND gates. I would suspect using Schottky LS TTL NANDs you'd get more in the higher frequencies; LS TTL gates are quick little beggars, but using CMOS in no way detracts from this ingenious circuit.

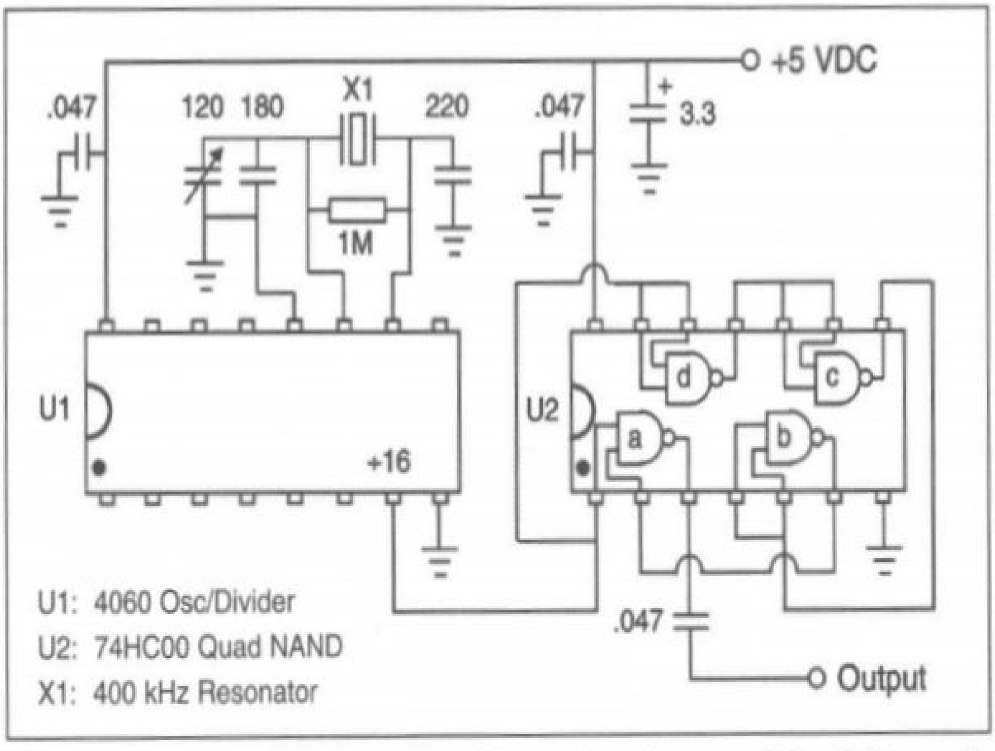

Figure 2—Circuit diagram of the simple two-chip HF comb generator.

On power up my oscilloscope showed it was all working...
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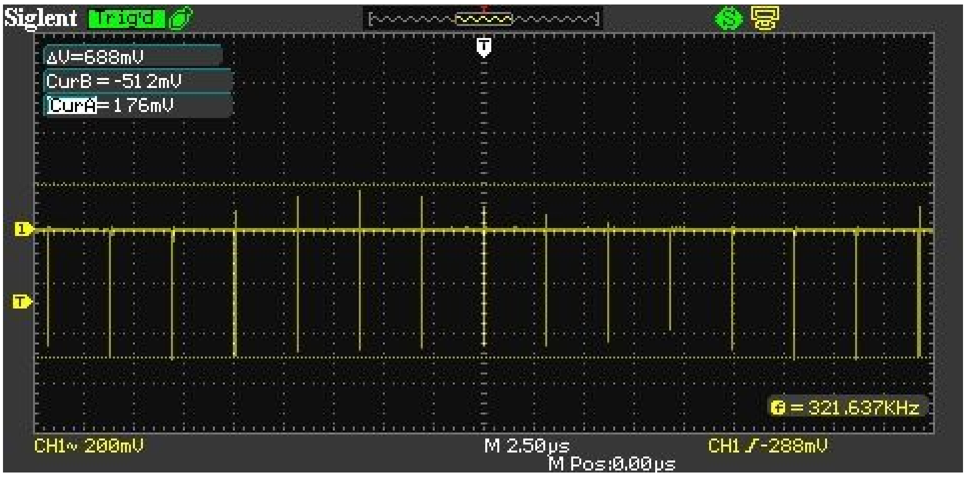
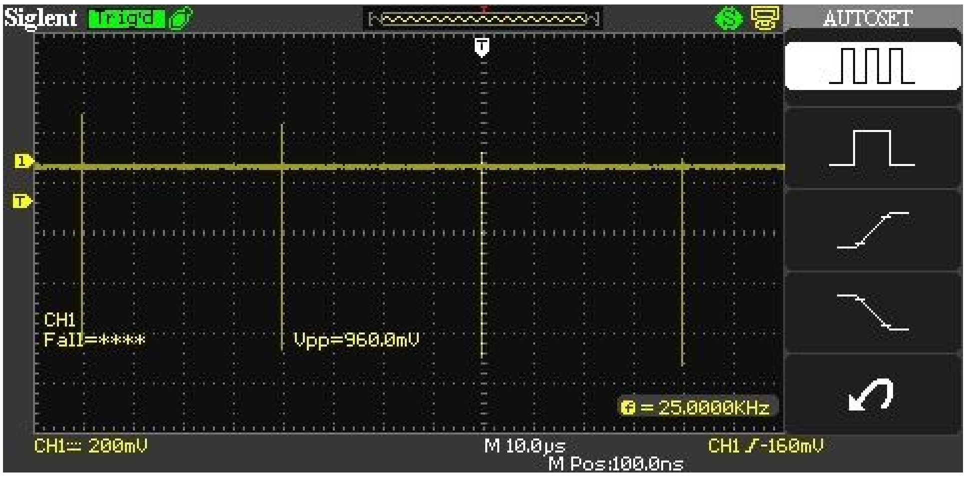


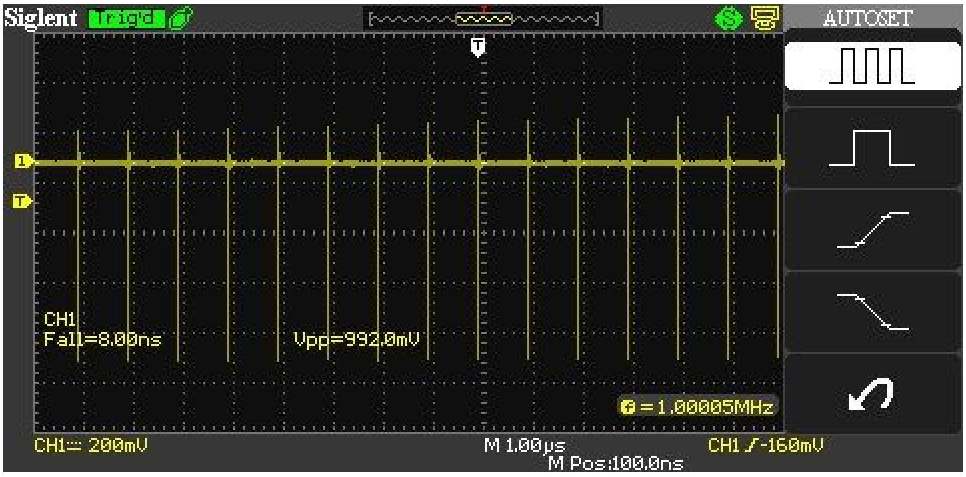
... except that it wasn't properly. The output was 321 kHz - not the 25 kHz it was supposed to be. Changing the ceramic resonator didn't help so I started googling for further knowledge - and found this document. Specifically, the clue was on page 14. Apparently ceramic resonators are known for going off at harmonic frequencies. The author suggested that capacitance around the ceramic resonator should be increased. So I added 100pF to the capacitor connected to pin 10 of the 4060 oscillator chip.

That was enough to make it oscillate correctly on power up, but when switched to the 1 MHz crystal position (that I had added) and then back, the resonator misbehaved again. Another 100pF fixed it.

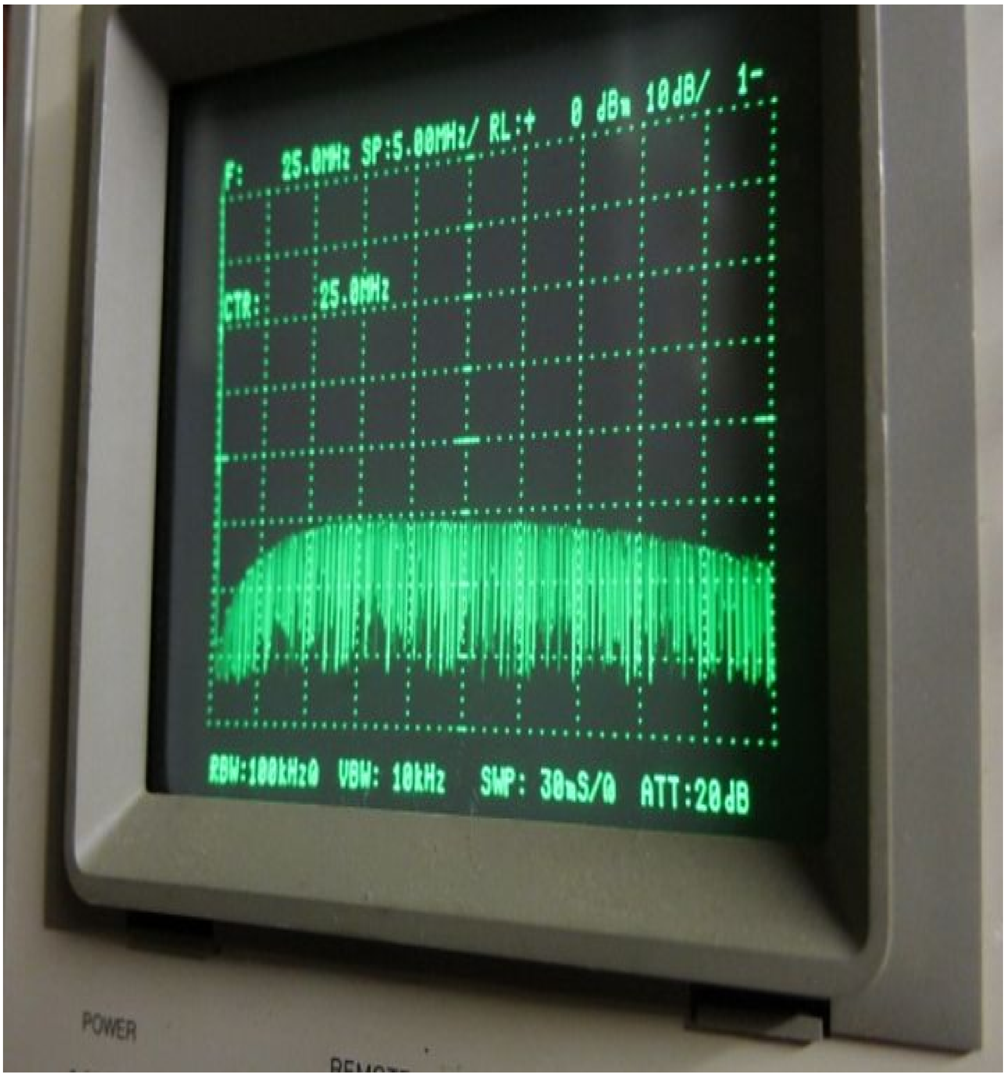


So it would seem that Gary's resonator and mine weren't quite the same and I had to modify his circuit. The resonator that you buy might need similar adjustments - or maybe none.

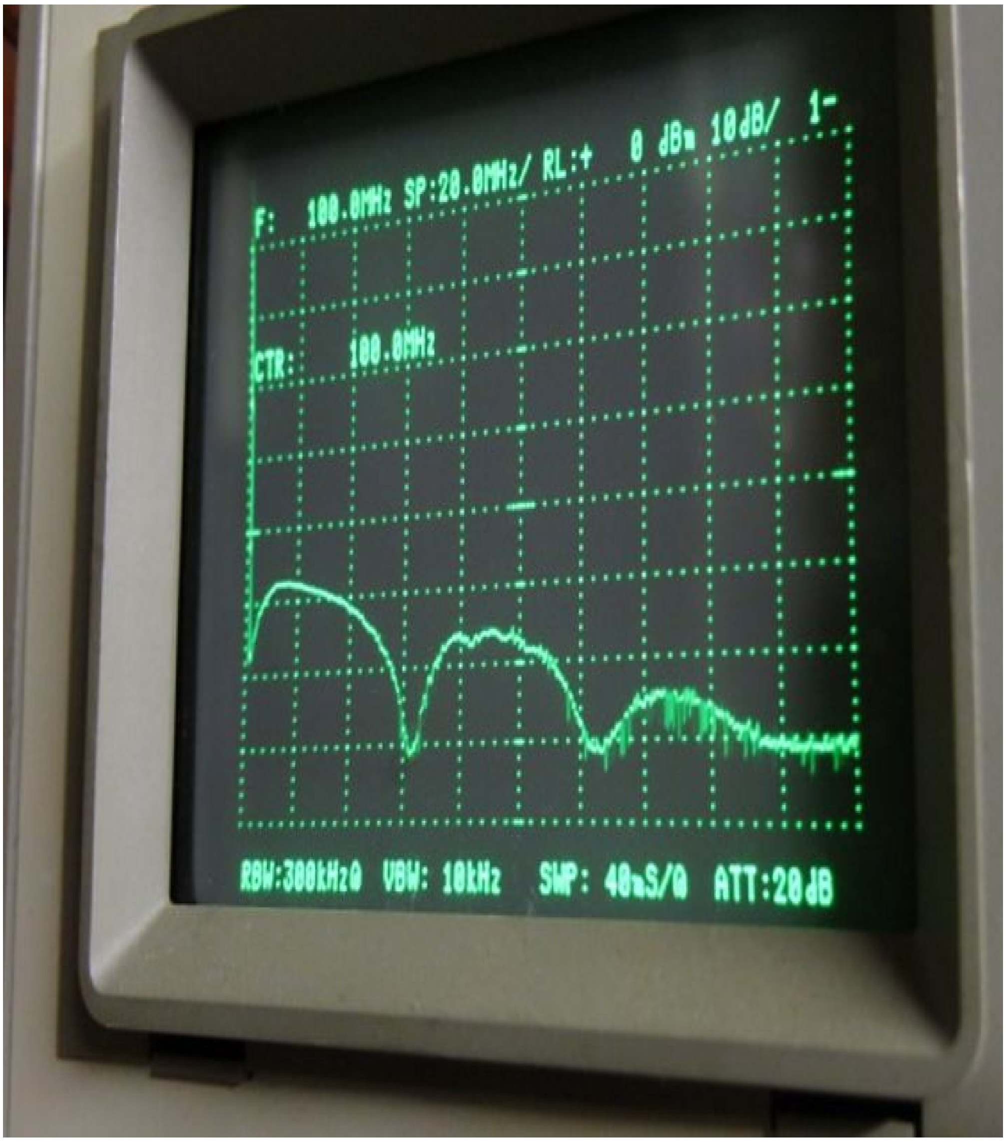
The 16 MHz crystal (for 1 MHz output) isn't bang on but close enough...



K9AY says that the comb generator "creates S9+ signals every 25 kHz from low frequencies to well beyond 30 MHz". He is being too modest because his design is much better than that and goes "very far beyond 30 MHz".
The spectrum analyser screenshot below is centred on 25 MHz with 5 MHz horizontal divisions. So you can see that there is a useful output way beyond the HF bands.

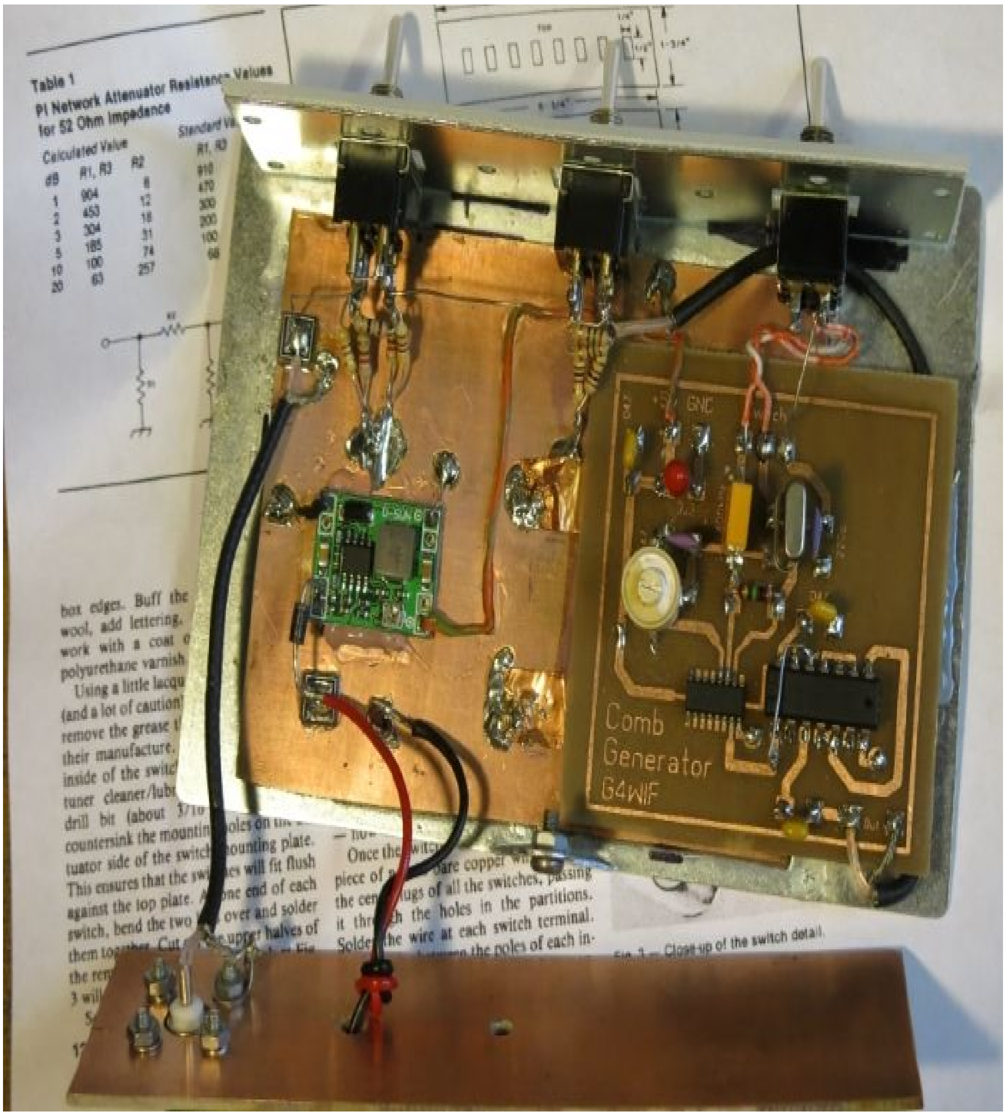


This other shot shows output to 180MHz with low points at 80MHz and 125MHz. This was a max signal trace to show more clearly the signal levels.



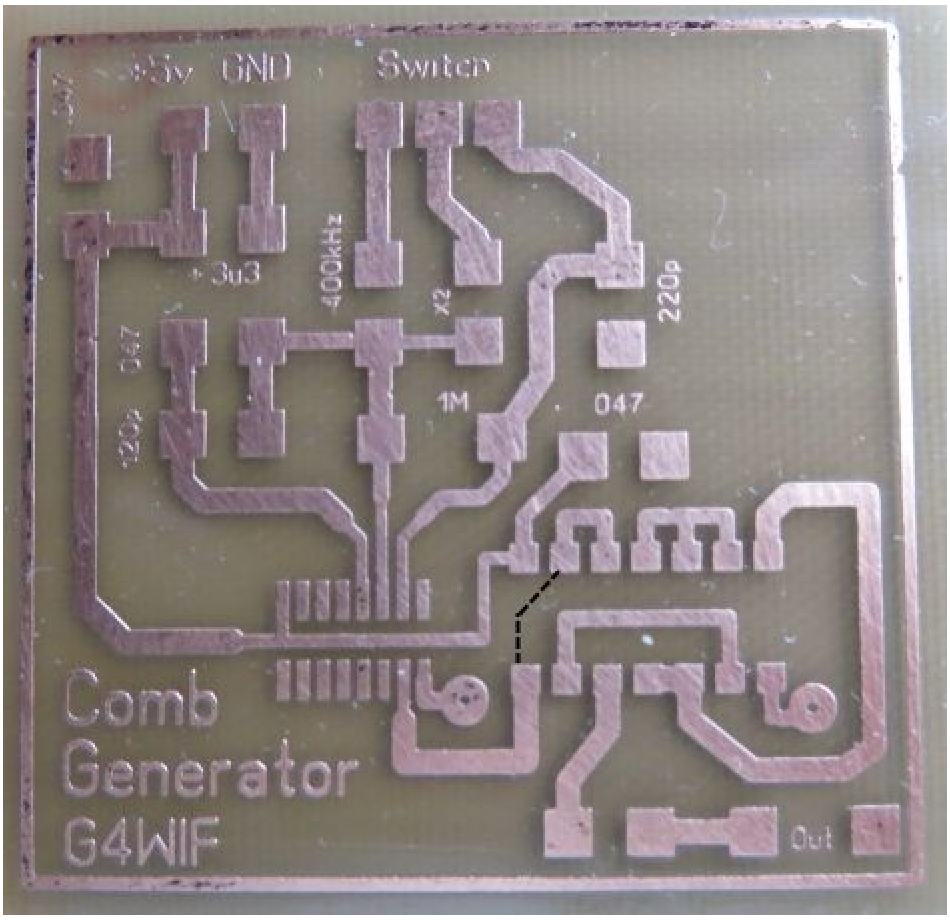
To vary the output I have added some switched attenuators to the K9AY design - which has as its signal source a 400 kHz ceramic resonator to provide 25 kHz signals (once divided down by the simple circuit).

I also added a 16 Mhz crystal to give me the alternative of 1 MHz signals via a switch. The attenuators provide 3dB and 10dB reduction in signal and the resistor values came from an article in September 1982 issue of QST. If you don't have the precise resistors in your junk box for the attenuator then this parallel resistor calculator will get you close.



The small (left hand side) printed circuit board which the red and black power leads attach to is a very inexpensive switched mode "buck converter". This takes the 12 volt input and provides the 5 volt supply to the generator. There is an idiot diode in the supply in the event of one of those senior moments when the leads get reversed.

This is the double sided printed circuit board etched using the toner transfer method.
Due to the way I designed the board, it must be double sided with connections to the reverse side ground plane. I've indicated in the Sprint Layout file where those connections are made.



You can see a black dotted line where I missed a track!

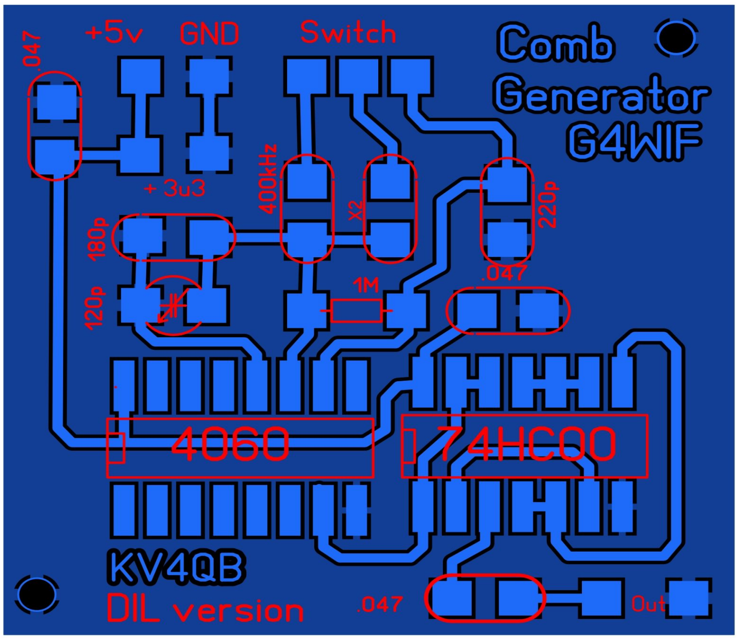
The more observant might notice that the 4060 chip is surface mount while the 74HC00 is D.I.L.

There is no special reason why I chose those package formats - other than when I ordered the chips, these were what was available at the right price and delivery time. The muppet building method is essentially surface mount and few of us older home constructors couldn't benefit from a decent bench magnifier anyway!

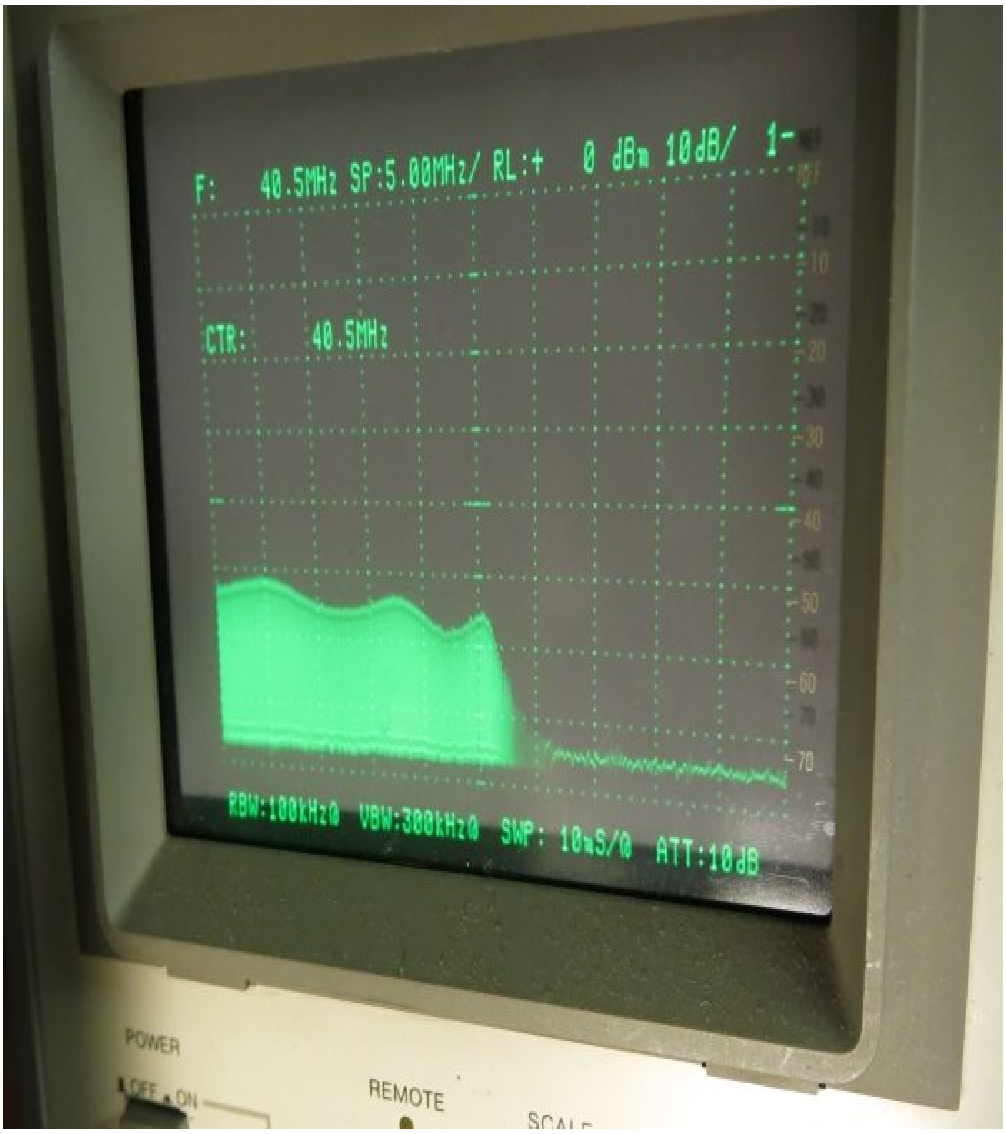
You will also note that as my home brew process doesn't do silk screen printing of component designation, I etch that in the top copper layer (as you can see above Sprint files).

You also might like to download a set of and reworked Gerber files by Terry, VK5TM.

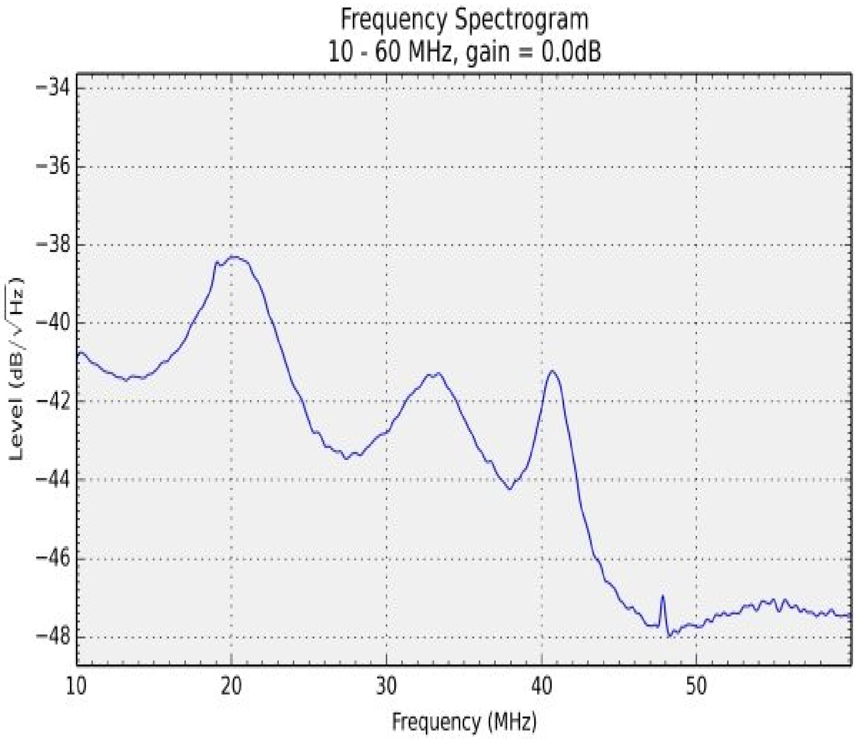
Another choice is the layout from DuWayne KV4QB. In his version he used 4060s that are 16 pin DIL type not SOIC. Muppet construction also modified to use a copper ground plane on the top and eliminate the need for any drilling.



I tried to test it using my zener noise generator which falls off in output as frequency increases. It was suggested to me that a comb generator would have a more consistent output - and that has proven to be so. With the output switched to the 25 kHz position, noise was injected into the filter and the output of the filter observed first on my spectrum analyser. Here is the result:



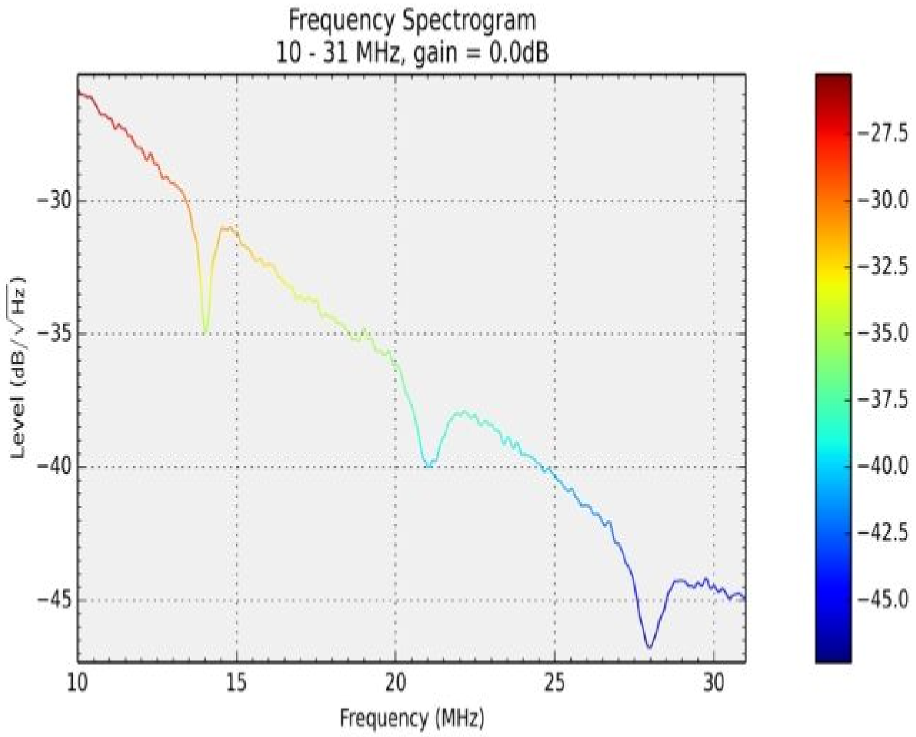
Clearly there is ripple and the cut-off comes a little higher than I would like - but the low pass filter can definitely be seen to be working and I can now make final adjustments to the filter.



My spectrum analyser is set to 10dB per vertical division while the dongle vertical scale is more “stretched”. So it looks more “hilly” - but essentially, it is telling the same story.

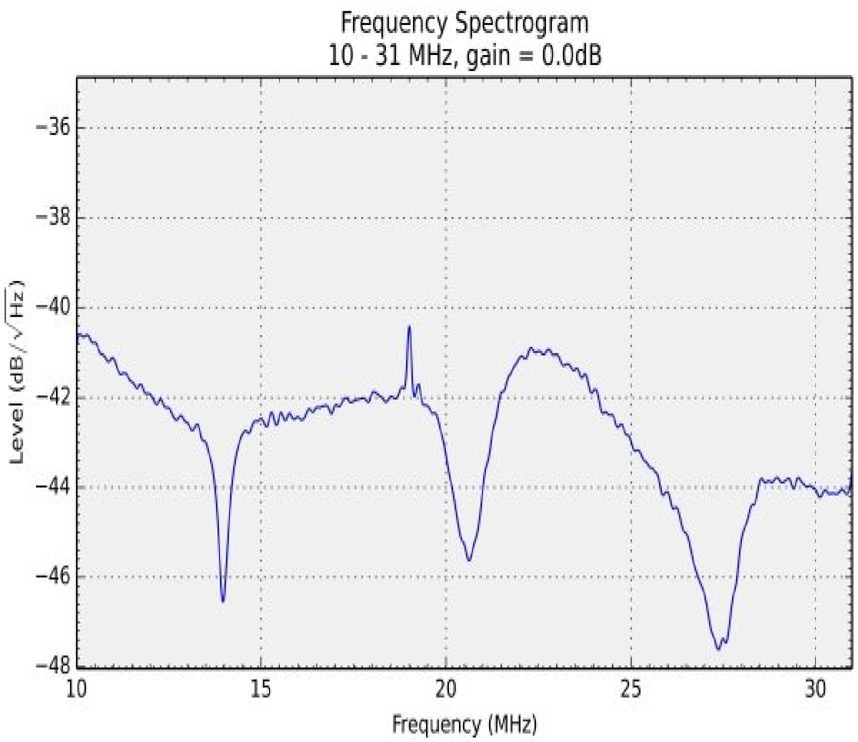
It it clear to see that this inexpensive set up is telling me much the same thing regarding the filter response - and for considerably less cost than a spectrum analyser. Certainly it isn't the precision instrument the real spectrum analyser is, but it doesn't do a half bad job.

A while ago I built a Return Loss Bridge and just for hoots I tried shining wide band noise from a zener noise generator into it and observing the result of a test of my tri-band trapped vertical antenna with a TV dongle spectrum analyser. This is the result:



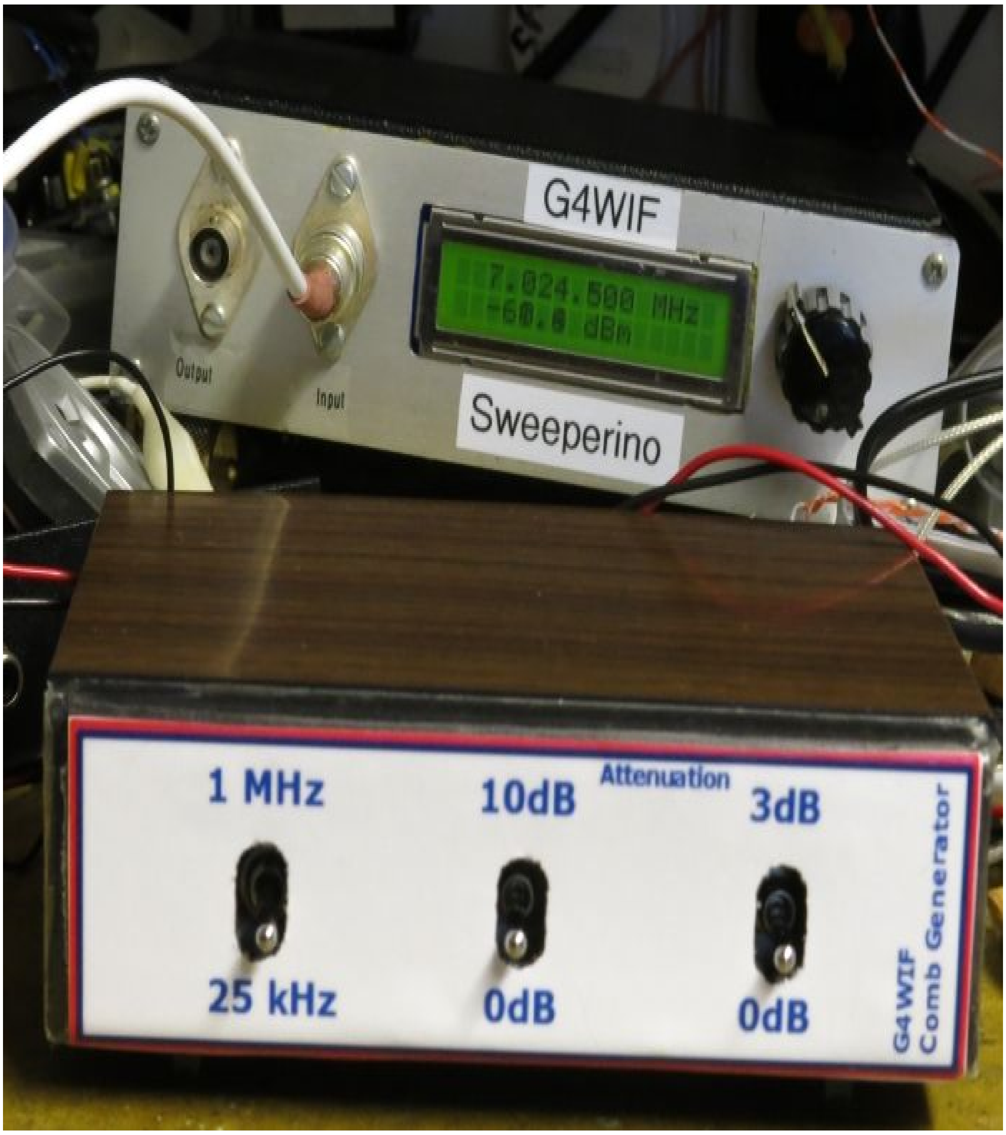
Well it worked after a fashion but of course, that fall off in signal level is due to the zener noise dropping off as frequency increases.

So I tried the experiment again, this time using the comb generator set to 25 kHz pulses:



This is a more useful result and while I wouldn't claim this is a measuring device, it does fall into the category of an "indicating device" - and one that provides some indication of return loss relative for each of the three bands. I'm waiting for warmer weather to work out why my antenna has shifted "LF" a bit. My antenna analyser is telling me a similar story.

Here is a picture of the finished project on the bench with the Sweeperino.



Antenna Topics

Auto RF changeover switches

Readers will recall I addressed this issue in a previous Hot Iron; here is slightly different approach that achieves the same end. The time delays are adjustable in both cases, so it's up to you!

TX/RX Sequencer

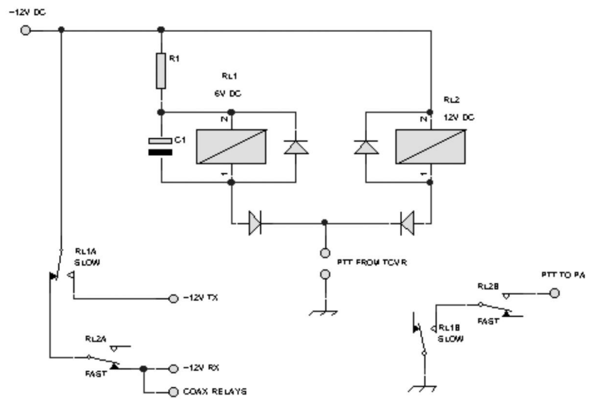
A simple, reliable sequencer

From The VHF/UHF DX Book, page 11-30

This sequencer is suitable for a lineup of HF transceiver - VHF/UHF transverter - PA, but it can be adapted for other systems too.

It allows key-controlled changeover or direct PTT without damage to the preamp, the coax relays contacts or the PA. I've used this sequencer for about 18 years with never a single failure.

The sequencer uses two DPDT relays. RL2 is a 12V DC relay and operates at normal "fast" speed. RL1 is the "slow" relay - a 6V DC relay with a dropping resistor R1 approximately equal to the coil resistance of RL1. Electrolytic capacitor C1 slows both the make and the break of RL1 by a few hundred milliseconds. Choose C1 so that the two relays produce an audible double "ker-lick" when the PTT line is grounded and ungrounded (about 470uF).



The way you interlink the "fast" and "slow" contacts on the two relays depends on your switching requirements. The sequence must be:

RX to TX
1. Mute receiver
2. Change over coax relays **quickly**
3. **Wait** for relay contacts to stop bouncing
4. Enable the PA
5. Apply RF drive

TX to RX
1. Remove RF drive **quickly**
2. Disable PA
3. **Wait** to be sure RF has gone
4. Change over coax relays
5. Enable receiver.

The diagram shows a system where the coax relays are **energized on RECEIVE**. This has the advantage that the preamp is disconnected and protected whenever the whole system is powered down, and if a masthead coax relay fails you can still use the antenna.

Interlinking the relays contacts as shown above will give the right sequence of changeover. The receiver and TX driver are enabled through the 12V RX and 12V TX lines.

You key the transceiver in the normal way, and the sequencer gets its PTT signal from the accessory socket on the rear of the transceiver. The PA gets a delayed PTT signal through RL1B and RL2B, and also the 12V TX line is delayed, so no RF can reach the coax relay until it has had plenty of time to change over.

When you release the main PTT, the transceiver cuts off the RF drive and releases the PTT to the sequencer. RL2B quickly disables the PA. The 12V TX line is still on, but that doesn't matter because there is no RF drive from the transceiver. After a short delay, the coax relays change over, the 12V TX line goes off, the 12V RX line comes on, and the receiver is working again.

Chinese Flag Pole Kits

From VK4TJ...

I purchased a 7.1 mtr "Aussie Flag" version, the tallest I could find. On arrival, it appeared to be quite well constructed, consisting of 5 tapered aluminium sections of approximately 1.8 mtrs each. The sections "lock" in rather the same fashion as a painters (or pool) pole. Although I did not test it, I rather suspect you have no choice over how much of it you deploy - the "twist and lock" internal connectors probably only function with every section fully extended. The first mild surprise was that there is no continuity between sections – obviously, the unseen internal "twist and lock" mechanism is plastic and insulating. Luckily, I had quite a few worm gear clamps of the appropriate size, so I made up short jumper wires and clamped them around each of the pipe transitions. One could do the same thing with a drill and self-tapping screws, but I wanted, initially at least, to ensure the I did not damage the unseen "twist and lock" mechanisms.

As found, the 7.1 mtr flagpole is resonant around 10 MHz, with VERY reasonable SWR across the 30 mtr amateur allocation. This is worked against my 10 x 12 mtr steel shed as a radial farm – really 10 x 14 mtrs, as there is a lean-to off the back which is almost certainly electrically bonded to the shed, and the antenna feedpoint at 4.5 mtrs above ground. So, if all you wanted was a good 30 mtr vertical, you could stop reading right now!

The only comparison antenna left standing at my shack after recent wind storms is a 55 mtr steel cable chucked over a tree to roughly the 20 mtr mark, with strong horizontal and vertical components. It is worked against the same 10 x 12 mtr metal shed radial farm as a sort of "semi-vertical". Initial impressions were that the flagpole is slightly better on 30 mtrs, but the 55 mtr random semi-vertical is noticeably better on 40 & 80 mtrs. The flagpole should be a pretty good player on 20 mtrs as well, as 7.1 mtrs must be getting pretty close to 5/8ths wavelength, though the feed impedance would be nothing like 50 ohms on 20.

Since the flagpole is conspicuously short of resonance on 40 mtrs and below, I then replaced my 4 non-conductive guys with conductive guys in electrical contact with the apex of the flagpole, of a "silly" length, nearly back to roof level, with just enough "paracord" to ensure that the shed roof was not part of the antenna. Once done, I could not find resonance ANYWHERE! Well, not quite true – the system was 1:1 at 19.5 & 20.7 MHz, but I'd expected something substantially lower than the starting point of 10 MHz. Not to worry – this antenna was envisioned as a sort of "all-rounder" for days when my fleet of tree-supported dipoles was grounded due to wind damage, so I knew my homebrew T-match tuner was always going to be part of the equation.

Impressions AFTER the addition of the conductive guys: Performance on 40 mtr is now roughly equal to that of my 55 mtr semi-vertical random wire. Performance on 80 mtrs is substantially worse. Nobody should be surprised at this – 7.1 mtrs is a pretty tiny fraction of a wavelength on 80! Performance is not so bad as to make the flagpole impractical, however.

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From Frank Barnes, W4NPN

I'm looking at the dipole drawings in Hot Iron 103. These show loading coils in each leg. Eliminating the loading coils and letting the extra length that will then be required drop down from each end of the antenna will make it easy to prune it to resonance and will probably not be quite so lossy as the loading coils. Not too much RF makes it out to the ends anyway. Complemented by...
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Inverted VEE Dipoles

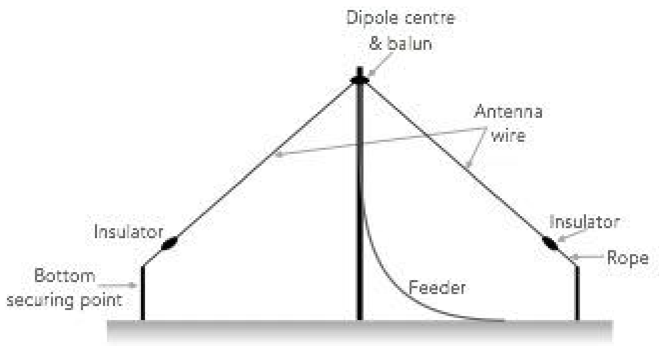
I waa emailed about “inverted VEE dipoles and the simplest way to build one. Below is the “standard” text on the matter; and following the VEE article is a beauty of a folded dipole that reducers the length to half that normally expected in any dipole.

From: www.electronics-notes.com

The inverted V dipole can form an effective antenna system for use on the HF amateur radio bands, or for other applications in many circumstances.
The advantage of the inverted V is that it only requires one high support whilst still achieving a high level of performance - the difference between an inverted V with its centre at the same height as a horizontal dipole is very marginal, and in most instances the difference in performance may not be detectable.

Normally the inverted V dipole is used for HF operation as the advantages of the single support are apparent on these frequencies.

What is an inverted V dipole?
As the name implies an inverted V dipole is a form of dipole that is in the form of a V which has been inverted. Instead of having two main supports - one for either end, both of which need to be as high as possible, the inverted V uses its main high support in the middle, having with ends having lower supports or anchorage points.



The inverted V dipole antenna has a number of advantages. One is that the maximum radiation from any antenna is from the points of high RF current, and a half-wave dipole has this maximum at its centre and for a few feet on either side of the feeder connections. Therefore it is best to make the centre of the dipole as high as possible.

If it is only possible to have one high support, an inverted-V arrangement is obviously ideal. In this way it is possible to use one fairly high mast in the centre of a garden or plot in locations where the erection of a pair of similar supports with their attendant guy wires would be difficult. A roof-mounted or chimney-mounted mast may also serve as the centre support for a ‘V’, and the two ends of the dipole can then drop down on either side of a house or bungalow roof. Such chimney mounting will allow the feeder to be dropped to the shack quite easily if it is located in the house.

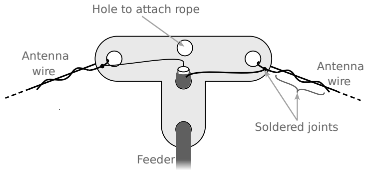
Inverted V dipole performance
Although an inverted-V has its greatest degree of radiation at right angles to the axis of the antenna, its radiation pattern is more omnidirectional than that of a horizontal dipole as a result of the fact that the legs are angled downwards.

The inverted-V has an excellent reputation for long distance communication on the lower-frequency amateur bands where the installation of large verticals or high horizontal dipoles is not practicable.

As an example, the inverted V dipole performance very well at low frequencies and will give good results on the 3.5MHz ham radio band when the mast is only about 14 metres or 45 feet high. This makes it a very attractive proposition for many amateur radio stations. Similarly it inverted V dipole antennas for other bands also perform well.

Building an inverted V dipole for amateur radio
Building an inverted V dipole is very much like that of a standard dipole. There are several elements to the installation and erection of the inverted V dipole.

- ***Mast:*** One major requirement for the inverted V dipole installation is the mast. This should be robust and firmly mounted into the ground. If it is metal construction it is suggested that a good earth connection is provided. Also a pulley should be installed at the top to enable easy hoisting of the inverted V dipole antenna
- ***End anchor points:*** When building an inverted V dipole and erecting it, the anchor points for the two ends should be considered. These must be located so that they do not pose a hazard to anyone in the area. They should also be located so that the antenna wire ends are out of reach. In addition to this the inverted V dipole anchor points should enable the wires to subtend an angle greater than 90° at the top centre point.
- ***Antenna wire:*** The antenna wire should be of suitable quality for use externally. Ideally hard-drawn copper wire so it does not stretch, it can be single or multi-stranded.
- ***Dipole centre:*** Like any dipole there needs to be a centre piece. The centre of the dipole requires the coaxial or open-wire feeder to be connected to it and whilst it may be tempting to simply connect the feeder and let it take the strain, this is not particularly satisfactory when there is a long drop for the feeder – a dipole centre should be used. This will take the strain caused by the tension on the wire, thereby avoiding damage to the feeder over a period of time.

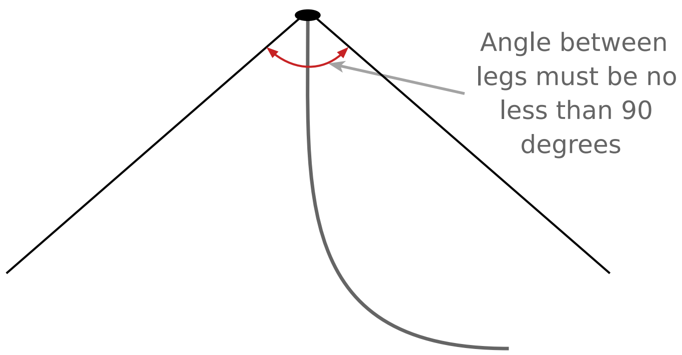


Strictly speaking a balun should be used but it is often omitted especially for receiving applications. The dipole centre (and don't forget the hose TEE piece dipole centre trick shown in Hot Iron #106!) will also provide a means of attaching a rope to enable the pulley system to hoist the antenna centre. A good quality centre should be used wherever possible (*readers of Hot Iron #106 might recall I suggested a plastic hose TEE piece filled with* *silicone bath sealer makes a doozy dipole centre piece; the suspension point is made by a simple loop knot around the "arms" of the TEE, double sided to keep the TEE orientated properly*).

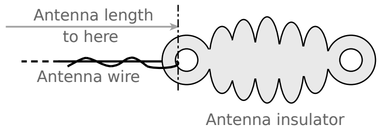
Inverted V dipole installation considerations

When considering erecting an inverted V dipole there are a number of considerations that should be kept in mind when its is being planned

- ***Angle between dipole legs:*** The angle between the sloping wires must be at least 90° and preferably 120° or more. This angle dictates the centre support height as well as the length of ground needed to accommodate the antenna.



- For example, when designed for the 3.5MHz band an inverted-V will need a centre support at least 14m (45ft) high and a garden length of around 34m (110ft). By contrast, a horizontal dipole needs at least 40m of garden and that neglects to take into account guys to the rear of the end support masts. Again, the inverted-V is ideal for portable operation because one for operation on 20m (14MHz) only needs a lightweight 5m (15ft) pole to hold up its centre.
- ***Dimensions need adjusting:*** The sloping of the dipole wires causes a reduction of the resonant frequency for a given dipole length, so about 5% must be subtracted from standard dipole dimensions. However as with an ordinary dipole it is always best to start with the inverted V a bit too log and trim it to operate with its best performance in the areas of the band most used. Also remember that the same amount must be trimmed from each end so that the dipole remains centre fed and there is not an imbalance.
- ***Length measurement:*** Remember when cutting he antenna wire, that the electrical length is measured from the centre of the antenna dipole centre piece to the furthest extremity of the wire.



- Any wire used to fold back around the insulator does not contribute to the electrical length, but needs to be considered when cutting the physical wire length. An allowance also needs to be made for the dipole centre piece as well.
- ***Radiation resistance:*** A further consequence arising from sloping the dipole wires is a change in its radiation resistance. The centre feed impedance of the inverted V dipole falls from the nominal 75 ohms of a horizontal dipole to just 50 ohms. This of course is ideal for matching the antenna to standard 50 ohm impedance coaxial cable.
- ***Bandwidth:*** An inverted-V dipole antenna has a higher Q than a simple dipole so it tends to have a narrower bandwidth.
- ***Keep inverted V dipole ends out of reach:*** It is not recommended that the ends of an inverted-V are allowed closer to the ground than about 3 metres or about 10 feet, even on the higher-frequency bands, because there can be a possible danger to people and especially children or animals touching the wire ends which will be at a high RF potential when energised. The effects, although not likely to prove lethal, nevertheless could result in a nasty shock or RF burn, and it seems unlikely that an insurance company would look kindly at any claims resulting from such an accident.

Coaxial feed is recommended with an inverted-V, and the low-loss heavier varieties of cable can be used to advantage, for there are no sag problems when the feeder is fastened up at the top and also down the length of the mast. The feeder will impose no strain upon the antenna or the soldered connections at its feed point. As with an ordinary horizontal dipole, a balun may be used, although they may operate satisfactorily without one.

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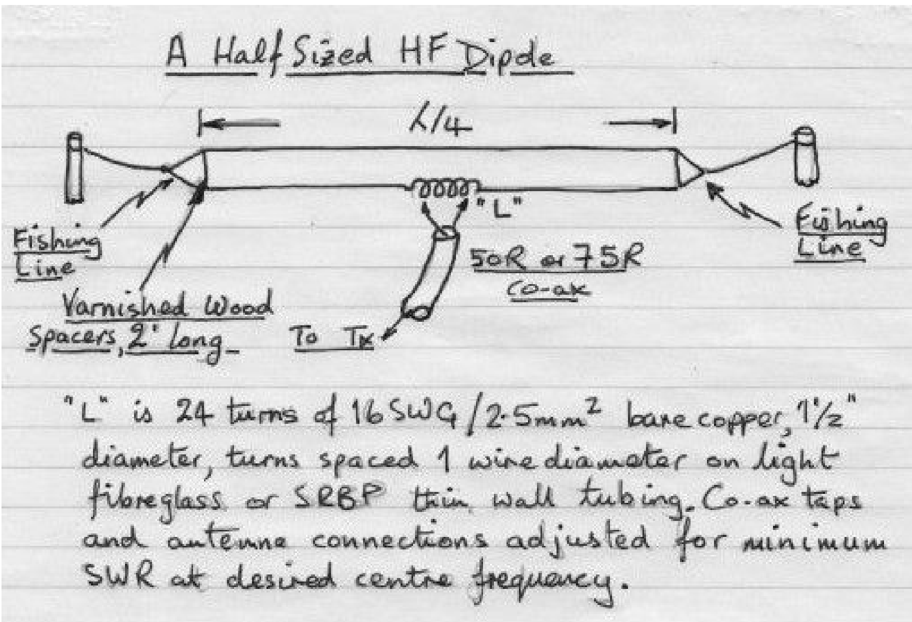
Folded dipole only ¼λ long in total

Also prompted by Frank Barnes, W4NPN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This half sized dipole gives excellent results, and makes matching easy (for cheap 75 ohm TV co-ax too!) with only one coil; but don't expect a wide bandwidth. The more you shorten an antenna, the "tighter" the resonance becomes; but for us A.M. nuts, with only one frequency slot in each band, the job's a good 'un! Keep the wires well separated, as high RF potentials exist along the wires.

Power Supply Topics

Class "X" and "Y" capacitors

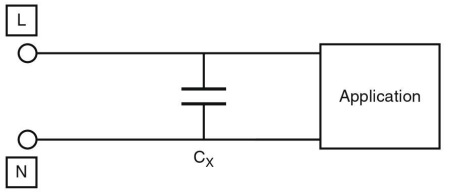
For capacitors connected onto / into a mains supply - a common requirement in this day and age considering mains noise from all the SMPS around the house - you MUST know exactly what capacitor to use. Below is an Application Note from a well known and respected manufacturer:

AC Film Capacitors in Connection with the Mains

Because of the high energy availability and the severe environment of surge voltages and pulses, applications of capacitors in connection with the mains must be chosen carefully. Two kinds of connections and thus two kinds of applications can be distinguished. One is where the capacitor is directly connected in parallel with the mains without any other impedance or circuit protection, and another where the capacitor is connected to the mains in series with another circuitry.

CAPACITORS DIRECTLY CONNECTED IN PARALLEL WITH THE MAINS WITHOUT ANY OTHER IMPEDANCE OR CIRCUIT PROTECTION (ACROSS THE LINE OR X CLASS CAPACITORS)

To help reducing emission and increasing the immunity of radio interference, electromagnetic interference suppression film capacitors (EMI capacitors) are playing a major role in all kind of applications. These capacitors are put directly parallel over the mains at the input of the appliances.



Several functions are combined in these small components: Excellent high frequency properties for short circuiting radio interference, being continuously stressed by the AC mains voltage and not at least having the ability to sustain transient voltages, caused by for example lightning strikes, switching, superimposed on this line.

For EMI capacitors it is a very difficult job to keep fulfilling the stringent requirements for safety and at the same time to miniaturize for offering customers benefits in terms of costs, functionality and mounting possibilities.

Five main characteristics can be seen for EMI-capacitors:

- Excellent capacitive filter: Low inductance and equivalent series resistance are preferred
- Withstanding pulse loads: Uncontrolled mains switching must be sustained
- Continuous biased by the mains voltage: A powerful energy supply is always available
- Withstanding surge voltages: High energy surge voltages could destroy the capacitors
- Safe end of life behavior

It has been noted by several national authorities that safety is top priority for these components. Therefore international safety standards have been developed like IEC 60384-14 (world standard) and UL 60384-14 (US standard). National authorities prescribe that EMI capacitors to be connected directly in parallel with the mains must be proved to fulfill these standards. Approved products receive safety certificates and are allowed to have following safety marks:

COUNTRY	SAFETY STANDARD	APPROVAL MARK
U.S.A.	UL 60384-14	
Canada	CSA E384-14	
U.S.A. and Canada	Combination Mark (UL 60384-14 + CSA E384-14)	c US
China	CQC	CQC
Europe	EN 60384-14 and IEC 60384-14	16

AC Film Capacitors in Connection with the Mains

Based on many years of experience Vishay has brought several EMI product series fulfilling these strong safety standards for across the line applications.

Depending on the customer's application needs following product series are recommended:

CLASS	X2	X1
VOLTAGE	≤ 310 V_{AC}	≤ 480 V_{AC}
Standard across the line applications, stability grade as per IEC 60384-14 (1)	MKP336-2 MKP338-2 MKP338-4 MKP339 F339MX2 F1778	MKP338-1 F339X1 330VAC
For continuous (2) across the line operation, higher stability grade than per IEC 60384-14 (1)	F1772	F339X1 480VAC

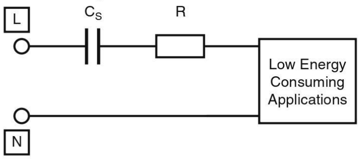
Notes

(1) IEC 60384-14 endurance test conditions require ± 10 % capacitance change after 1000 h testing

(2) Continuous in the meaning of uninterrupted connected to the mains, 24 h/day during several years

CAPACITORS CONNECTED TO THE MAINS IN SERIES WITH ANOTHER CIRCUITRY (SERIES IMPEDANCE APPLICATION)

In many appliances a low voltage supply is needed for simple low energy consuming functions like sensing, phase detection,… To reduce the voltage, reactive impedances are used like film capacitors.



In this case the capacitors are connected in series with the application to the mains and now the functions to be fulfilled are:

- Stable voltage dropper: A stable capacitance must be guaranteed over the total lifetime of the application
- An adjusted tolerance: To guarantee a well defined current supply
- Continuous biased by almost the mains voltage: Internal ionization must be avoided

But what about withstanding surge voltages? And what about safety?

As these caps are connected through another circuitry, the equivalent impedance of this circuit can protect the capacitor. A film capacitor could be destroyed when a high energy pulse is applied and the self healing properties are failing (self healing is the ability to recover after a breakdown). As general rule for standard capacitors, not approved according international standards for EMI capacitors, this can happen if surges occur higher than the guaranteed proof voltage. This is in general 1.6 times the rated DC voltage or 4.3 times the rated AC voltage. As it is generally accepted that surge voltage (1.2 µs rise time/50 µs duration) can occur at the entrance of appliances being 2.5 kV for installation category II and 4 kV for installation category III (IEC 60664-1), it must be verified by the customer that the impedance in series with the capacitor limits the over-voltage to these values. In general this will be the case because it can easily be calculated that equivalent impedances will be in the range of 220 Ω to a few kΩ depending on the low voltage application and by this the surge will be topped off to a few hundred volts maximum.

In all other conditions still an approved safety component must be used, but here the extra functions as stable capacitance and adjusted tolerance must be fulfilled as well. This can only be guaranteed by a different capacitor construction wherein two capacitor sections are internally connected in series.

Also for these series impedance applications Vishay can offer a wide range of products fulfilling customer's needs and requirements:

CLASS	WITHOUT SAFETY APPROVALS (1)	WITH SAFETY APPROVALS	
VOLTAGE	≤ 275 V_{AC}	≤ 310 V_{AC}	≤ 480 V_{AC}
Standard and continuous (2) in series with the mains operation	(3)	F1772	F339X1 480VAC

Notes

(1) The applicant must guarantee that the maximum continuous mains voltage is lower than the rated AC voltage and that maximum temporary over-voltages (< 2 s) are lower than 1.6 rated DC voltage or 4.3 times AC rated voltage. Instructions can be found in the application notes and limiting conditions in the detail specifications.

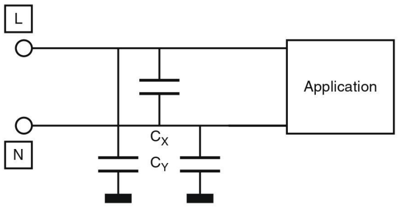
(2) Continuous in the meaning of uninterrupted connected to the mains, 24 h/day during several years

(3) For the right choice of the component, contact rfi@vishay.com

AC Film Capacitors in Connection with the Mains

CAPACITORS DIRECTLY CONNECTED IN PARALLEL BETWEEN THE MAINS AND GROUND (LINE BYPASS OR Y CLASS CAPACITORS)

To help reducing common mode electromagnetic interference, capacitors are connected between mains and ground. For these applications only approved safety components are allowed. Different safety classes and standards are defined in the same IEC 60384-14 and UL 60384-14 standards.



Vishay has following products in its film capacitor portfolio, adapted for the specific customers need:

CLASS	Y2
VOLTAGE	≤ 305 V_{AC}
Standard line bypass applications	F1710 MKP338-6
Line bypass application for continuous operation [(1)]	MKP338-6

Note
[(1)] Continuous in the meaning of uninterrupted connected to the mains, 24 h/day during several years

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Valve Voltages Safety Note

From: http://philsvalveradiosite.co.uk/philsvalveradiosite/safety_issues_1.htm
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I recommend that you must read through this page very carefully before you even think of starting this exciting pastime hobby as there is a very dangerous side to it, regarding the use of high voltages and mains electricity. Mains electricity in the UK comes into the home at 240 volts AC, 60 cycles per second and there is a serious risk of electrocution and possible fires. Valve equipment, particularly high power audio amplifiers use double the voltage ranging from 500 to 1000 volts of DC current stepped up with a mains transformer. Direct contact can cause severe burns and your hands can also become locked and unable to let go until the power is turned off. The HT smoothing electrolytic capacitors can hold a lethal charge, many hours in some cases after equipment is turned off, so I recommend you discharge this voltage by using a bleed resistor of about 470K 1 Watt (*use 1/C (in µF) Meg-ohms to give a 1 second time constant is an industrial electronics axiom*) and a analogue multimeter to check that this voltage is fully discharged.

Please note that when testing and setting up your valve equipment there are times when the power needs to be turned on. It is essential that you keep one hand in the pocket when using high voltage test leads, with the negative lead earthed to the chassis when doing HT voltage measurements by using a crocodile clip and be very careful not to accidentally bridge components by short circuiting with test leads, leading to possible damage. Be also aware that you should keep young children and pets out of the same room you are working in, as they may not fully understand the dangers and keep unattended work areas out of children's reach by locking the place up when you have finished. Provided these rules are always followed, Constructing valve radios and amplifiers can give you many hours of fun and pleasure. Please take time to read the following rules and guidelines listed below.

Safety in the work area

1. Avoid temporary electrical hook-ups such as multiple double adaptors and trailing extension leads, as these over a short period of time, tend to become permanent.

2. Try make use of a suitable spare room for this sort of work. The use of a outside shed or garage is suitable, provided it is kept heated and no damp or wet weather can get in, during the Winter Season. If this is not possible then the kitchen is the only solution, provided you have followed the previous warnings.

3. It is also important to have adequate power and lighting facilities regarding your work area. Make sure all sockets are the switched 13 amp modern square pin type. Also have a master switch that is in easy reach, particularly when first testing equipment, so that you can immediately turn off the power, in the case of danger arising.

4. It is important that the electrical wiring is sound and up to standard. If your home was built before 1962, it is still possible that your house was wired using rubber sheaved cable. If so, it is worth getting advice from a competent electrician and having your home rewired, as it may not become immediately apparent, the installation can work well for many years but the hidden danger of a fire or electric shock is waiting there. The use of a socket tester, available from most DIY electrical stores can reveal if your sockets are wired correctly.

It is also very dangerous to not have any electrical safety earth. Under fault conditions it is possible for a metal case electrical appliance to become live without immediate warning. This is usually caused by a damaged flex or faulty mains transformer leading to a earth leakage.

Why fuses are very important

1. A fuse is designed as the weakest link in any electrical circuit for a number of reasons. It is a thin piece of wire enclosed in a ceramic tube or plug in type holder used in distribution boxes.

2. Without it, your electrical appliances would work OK, but should a fault, such a damaged cable or high current fault arise, there could be a high risk of a fire or electrical explosion.

3. The main function of a fuse, is when danger occurs the thin piece of wire melts, sometimes with a mighty bang, when a heavy short circuit occurs.

4. There is another two types of fuse that have been around for about the last 20 years or so.

5. Circuit breakers. A circuit breaker is a magnetic switch, now common in many household consumer units, it is designed to trip off and can be reset, should a fault or current overload occur and is more safer and reliable.

6. Residual Earth Leakage Current Breaker. Not strictly and not to substituted as a fuse, it used in many circumstances where water is involved such as electric showers and outdoor appliances. Should a outdoor appliance become faulty or the casing becomes live, it is designed to trip off, when there is a slight current leakage to earth of only 30 milliamps preventing a fatal electric shock.

7. Fuse rating. It is very important to use the correct size fuse for its protective purposes. For example mains plug fuses have about 3 different ratings. 3 Amps is uses on appliances up to 720 watts, such as hi fi equipment, table lamps and coffee makers. 5 Amps is used on appliances up to 1200 watts such as Vacuum Cleaners, small electric fires, computers and colour TVs. 13 Amps is used on appliances up to 3120 watts such as electric kettles, washing machines and heaters. Please note that this only protects the flex and the correct fuse in the appliance is probably lower, which should be the case, when valve equipment is concerned because it uses lower currents.

8. Mains and HT Fuses are usually employed in all high quality valve radios and Television Receivers. The purpose of the mains fuse is to protect the mains transformer from damage when a serious overload occurs, That can happen due to a faulty rectifier valve or smoothing capacitor. This is usually wired in the live side of the mains preferably before the mains switch of the equipment. However, This does not always give full reliable protection on the secondary side of things, as it is known that a output valve can fail, leading to burn out of the output transformer which can also lead a expensive repair on your hands. A HT fuse is usually wired in between the positive side of the second filter capacitor and the HT Rail on the equipment concerned to give complete protection.

Safety concerning Electrolytic Capacitors and the danger related with old Radio sets

As I mentioned earlier about safety regarding high voltages involved with valve equipment, electrolytic Capacitors pose the most danger. The reason being is that they behave like high voltage batteries which can store a very lethal charge over a considerable period, from months to even years when left idle. Also they can explode with a loud frightening bang, depositing there innards all over the place, particularly if connected in the Wong polarity or if the voltage rating is exceeded. Electrolytic Capacitors also deteriorate with age when not used for a long time resulting with the same similar circumstances. Although modern electrolytic capacitors are now very reliable, this is not the case with a radio that has been asleep in the loft for the last 30 years and regardless of the old guy telling you it worked brilliant when last used, the chances is are that if you restored power to it again, The capacitors could explode causing more damage to the set and there could also be a risk of fire, if the set is left unattended. Why does this happen? Electrolytic capacitors are made of aluminium foil, rolled in the insulation form of an electrolytic pastcompoundthat forms the dielectric capacitance and when not used for a long time the dielectric becomes fragmented, Causing breakdown of the dielectric insulation which leads to leakage and short circuits. It is possible to reform these components by steadily applying a low current, Which can except in some cases heal the capacitor back to its useful life.

Safety Precautions Regarding Live Chassis AC/DC Equipment

As recently up to the mid 1950s, many towns where not supplied with electricity by the National Grid and the mains was sometimes DC. Connecting a AC Mains set incorporated with a mains transformer to a direct current supply due to the incompatibility would cause serious damage, rendering the set useless and possible risk of a fire. To overcome this problem a series valve heater chain consisting of the heaters wired up like Christmas Tree bulbs was incorporated, often followed by a series high wattage resistor to make up the required voltage. The High tension side of things mostly consisted of a half wave valve rectifier and simple capacitor input filter, followed by a surge resistor to limit the current. As a result due to no mains transformer, one side of the mains is connected to the chassis and there is a serious risk of electric shock if the polarity of the mains is unknown. To correct this problem it is best to make sure that the mains lead is fitted to a none reversible plug with the black lead connected to the natural terminal. It is also safer to confirm this by touching the chassis with a neon mains test screwdriver. The aerial and gram pickup sockets used high voltage isolating capacitors and it is not unknown for these to breakdown, leaving an additional shock hazard on the horizon. Always make sure these capacitors are replaced with the proper 1000 Volt Class, designed for this purpose (*class X & class Y types*). Also beware of exposed metal knob shafts that can also be very dangerous by making sure the grub screws are tight and cant be touched by using special filler designed for the protective purpose. You will find in many old radio magazines some very tempting radio circuits that use this method as a way to cut cost, but my advice is to play it safe and build a design using a mains transformer.

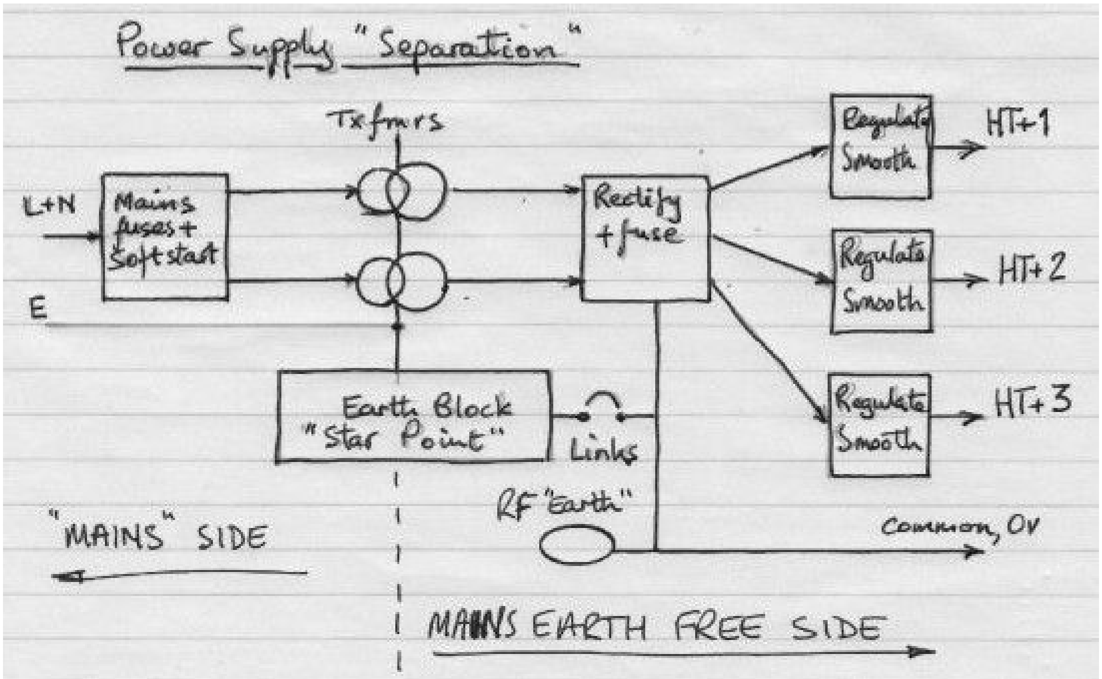
Heat and Component Reliability

Compared to transistor circuits, valves generate more heat because of the hungry current consumption regarding the valve heaters and high voltage HT Line. It is this problem that results in component failure, in these circuits over the years of there working life. As a rule of thumb I always replace the lower power resistors with no less the 1/2 a watt, for improved reliability and as another example I always substitute a 450 Volt electrolytic capacitor for the 350 Volt type, particularly in power supply circuits, as that way you gain improved reliability rather then working close to the limit. There is a excellent website run by Paul Stenning and can be found by clicking on the following link UK Vintage Radio Repair and Restoration . It has some useful projects such as a capacitor reformer and a series lamp current limiter. Useful when testing your newly constructed radio for the first time.

Power Supply Voltage "Separation"

If you look at any high power DC supplies if RF generators, you'll find the designers always separate the different voltage regimes: this means the mains side is separate from the HV AC transformer outputs; which are again separated fromn the regulators and fusing for the various DC outputs. The key is to separate the different voltages and types, as in the diagram below.

You'll notice the earth block / star point. This is a common feature; the RF earth, the rectifier "common" and the mains earth might have to be separated for safety or operational requirements. This is very good amateur policy: it's not a good thing having RF currents flowing in the domestic AC mains wiring, even if it's fun to see the cat getting an RF spark on its nose from a plug socket screw!

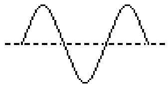
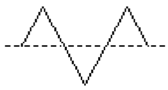
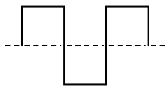


Data and Information

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

Basic AC Relationships

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

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

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

The Unobtanium & Obsoletite files...

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

Useful cross-reference web pages:

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

https://archive.org/details/TowersInternationalTransistorSelector

For Solid State fans...

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

2N5179	BFY90	½ watt VHF NPN
2N3866	BFY90	½ watt VHF NPN
2N4427	BFR91	1 watt VHF / UHF NPN

ZTX300	BCY70	0.3 watt HF NPN
OA91	1N60/61	Ge signal diode, 50v, 50 mA

Alternatives to ZN414 = MK484, YS414, TA7642, UTC7642, LMF501T, LA1050.

For Valve / Tube fans...

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

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

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

(THE 'Magnum Opus' of bottle lists)

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

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

Some not very obvious alternatives:

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

ECL82 = LCL82 (10.7v heaters) = 11BM8 (10.7v heaters) or PCL82(16v) / UCL82(50v) / XCL 82(8.2v). There are dozens of equivalent or similar electrode structures but with different heaters. For instance: PCL82 = 16A8 = 30PL12 = 16TP12 = 16TP6 = 16Ф3П Different heater volts = 8B8 (8.3v ac)

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

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

HF & VHF Output Types:

Search as I might, I can't find a cheap alternative to a 4CX250B (or the bases)! My apologies... I'm still searching!

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

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

Audio valves; useful for low band RF:

From an article by Robert H. Levi

"My Favorite Tubes"
by Robert H. Levi

Small Signal Tubes:

12AX7

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

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

12AU7

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

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

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

12AT7

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

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

6DJ8

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

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

Rectifier Tube:

5AR4

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

Other Dual Triode Tubes:

6SN7

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

The available brands of these tubes are highly variable musically and microphonically. The vintage GE and RCA are very fine if hand selected. The Electro Harmonix is very good, too.

6SL7

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

Same comment as 6SN7 type.

Output Tubes:

EL84

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

EL34

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

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

6550

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

6L6

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

Same comment as EL34 type.

KT88

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

Wire Information...

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

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

Note: 3Φ supplies external to machinery or distribution systems may use some of these colours; **check, check and check again** what the wiring is!
NEVER, NEVER, assume a blue wire is a neutral; you may have an old 3Φ installation which ran colours as follows:

Red	Phase 1
Yellow	Phase 2
Blue	Phase 3
Black	Neutral

Valve Electrode wiring:

Gray	heaters or filaments
Red	DC power supply positives (numbered sleeves indicating voltage)
Black	returns, commons, NOT grounded
Orange	screen grids
Yellow	cathodes
Pink	control grids
White	anodes
Violet	AC / DC control signals (AGC, etc.)

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

Valve Electrodes:

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

DC Supplies:

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

Miscellaneous Wiring (control signals & the like):
White or mauve

AC Supplies (modern UK &European):

Active or Phase	Brown
Neutral	Blue

Earth	Green/Yellow stripe

AWG Table

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

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

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

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

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

Wire Gauge Resistance per foot

4	.000292
6	.000465
8	.000739
10	.00118
12	.00187
14	.00297
16	.00473

18	.00751
20	.0119
22	.0190
24	.0302
26	.0480
28	.0764

Current ratings

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

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

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

Resistivities at room temp:

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

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

Thermal conductivity at room temperature

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

bismuth	0.084
iodine	43.5E-4

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

Copper wire resistance table

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

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

Wire current handling capacity values

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

Mains wiring current ratings

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

Cross-section	Overload current

CSA / area	rating
0.5mm²	3A
0.75mm²	6A
1mm²	10A
1.25mm²	13A
1.5mm²	16A

Typical current ratings for mains wiring

Inside wall

mm^2	Amps
1.5	10
2.5	16

Equipment wires

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

Wire sizes used in USA inside wall

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

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

PCB track widths

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

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

Equipment wires in Europe

3 core equipment mains cable

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

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

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

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

U.S.A. Common Cable colour Codes

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

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

•**Neutral wires:** white or grey

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

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

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

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

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

•**Neutral wires:** blue

•**Single phase live wires:** brown

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

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

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

•**Neutral wires:** white

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

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

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

A.M. Frequency slots in Amateur HF Bands

All Frequencies in MHz

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

1.850 (W. Europe)

1.933, 1.963 (UK)

1.825 (Australia - daytime)

1.850 (Australia - evening)

80 Metres: 3.530, 3650 (South America)

3615, 3625 (in the UK)

3705 (W. Europe)

3.670 & 3.690 (popular AM frequencies, Australia)

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

60 Metres : 5.317

40 Metres: 7.070 (Southern Europe)

7.120, 7.300 (South America)

7.175, 7.290, 7.295 (USA)

7.143, 7.159 (UK)

7.125 (Primary AM Calling, Australia)

7.146 (Secondary and WIA Sunday morning Broadcast, Australia)

20 Metres: 14.286

17 Metres: 18.150

15 Metres: 21.285, 21.425

10 Metres: 29.000-29.200

6 Metres: 50.4 (generally), 50.250 Northern CO

2 Metres: 144.4 (Northwest)

144.425 (Massachusetts)

144.28 (NYC-Long Island)

144.45 (California)

144.265 (Los Angeles, CA)

Other AM Activity Frequencies

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

FM Frequencies

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

VMARS RECOMMENDED FREQUENCIES

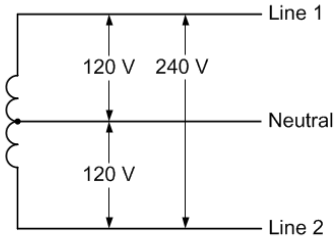
3615 Khz	Saturday AM net 08:30 – 10:30
3615 Khz	Wednesday USB net for military equipment 20:00 – 21:00
3615 Khz	Friday LSB net 19:30 – 20:30
3615 Khz	Regular informal net from around 07:30 - 08:30
3577 Khz	Regular Sunday CW net 09:00
5317 Khz	Regular AM QSO's, usually late afternoon
7073 Khz	Wednesday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

Electrical Supplies - Courtesy LEGRAND equipment

Common Electrical Services & Loads

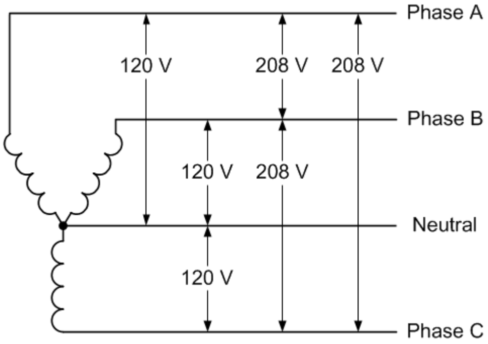
In the following drawings, the coil symbols represent the secondary winding of a utility service transformer or other step down transformer. Electrical code regulations in most jurisdictions require that the neutral conductor be bonded (connected) to the earth safety ground at the electrical service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

Single Phase Three Wire



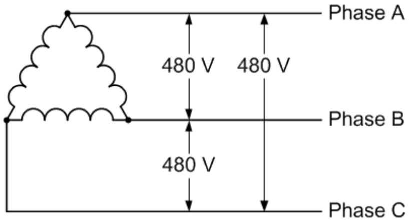
Also known as an Edison system, split-phase or centre-tapped neutral. This is the most common residential service in North America. Line 1 to neutral and Line 2 to neutral are used to power 120 volt lighting and plug loads. Line 1 to Line 2 is used to power 240 volt single phase loads such as a water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

Three Phase Four Wire Wye



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

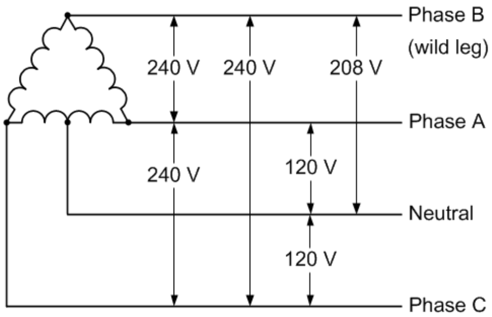
Three Phase Three Wire Delta



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

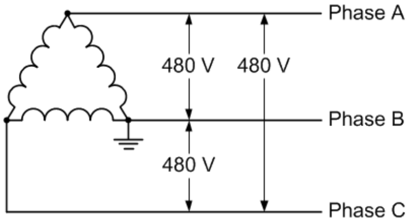
Uncommon Electrical Services

Three Phase Four Wire Delta



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

Three Phase Two Wire Corner-Grounded Delta



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

International Electrical Distribution Systems

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

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