Homebrewing Vacuum Tube SSB Radios

Mike Bohn

KG7TR

Duke City, September, 2018

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Radios I've Built

Novice Xmtr & PS, 1961

4 Band SSB Xmtr, 1968-1974

Vintage SSB Special, 2009

20m Cheap 'N Easy II, 2012

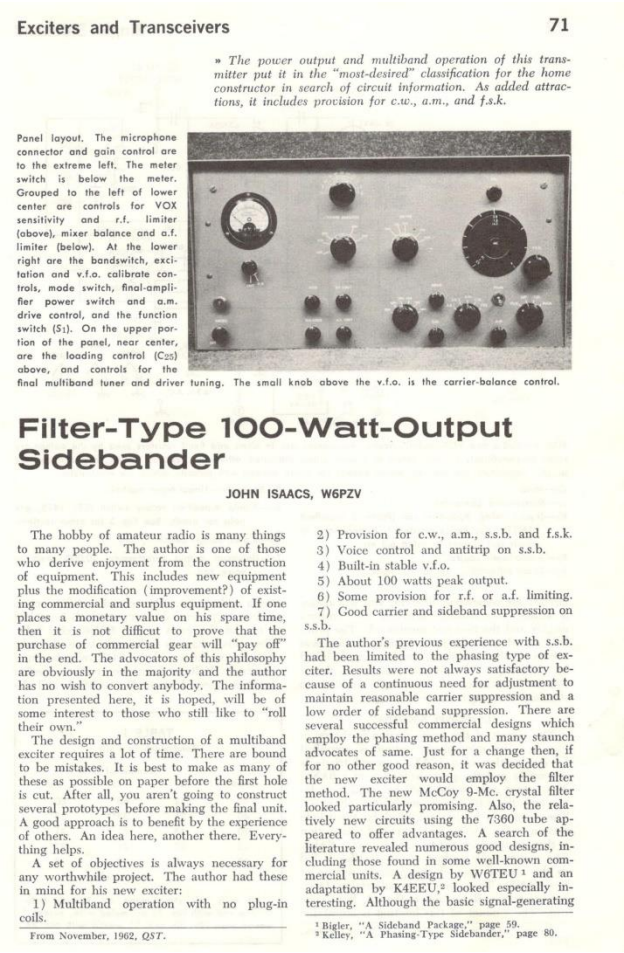
80m Cheap 'N Easy II, 2013

Octalmania Xmtr/Rcvr, 2010
HB-600 Linear, 2012

Octal Tri-Bander Transceiver & 2X813 Linear, 2015-2016

75S-2B Receiver, 2016-2018

My First SSB Transmitter



Exciters and Transceivers 71

» *The power output and multiband operation of this transmitter put it in the "most-desired" classification for the home constructor in search of circuit information. As added attractions, it includes provision for c.w., a.m., and f.s.k.*

Panel layout. The microphone connector and gain control are to the extreme left. The meter switch is below the meter. Grouped to the left of lower center are controls for VOX sensitivity and r.f. limiter (above), mixer balance and a.f. limiter (below). At the lower right are the bandswitch, excitation and v.f.o. calibrate controls, mode switch, final-amplifier power switch and a.m. drive control, and the function switch (S_1). On the upper portion of the panel, near center, are the loading control (C_{25}) above, and controls for the final multiband tuner and driver tuning. The small knob above the v.f.o. is the carrier-balance control.

Filter-Type 100-Watt-Output Sidebander

JOHN ISAACS, W6PZV

The hobby of amateur radio is many things to many people. The author is one of those who derive enjoyment from the construction of equipment. This includes new equipment plus the modification (improvement?) of existing commercial and surplus equipment. If one places a monetary value on his spare time, then it is not difficut to prove that the purchase of commercial gear will "pay off" in the end. The advocators of this philosophy are obviously in the majority and the author has no wish to convert anybody. The information presented here, it is hoped, will be of some interest to those who still like to "roll their own."

The design and construction of a multiband exciter requires a lot of time. There are bound to be mistakes. It is best to make as many of these as possible on paper before the first hole is cut. After all, you aren't going to construct several prototypes before making the final unit. A good approach is to benefit by the experience of others. An idea here, another there. Everything helps.

A set of objectives is always necessary for any worthwhile project. The author had these in mind for his new exciter:

1) Multiband operation with no plug-in coils.
2) Provision for c.w., a.m., s.s.b. and f.s.k.
3) Voice control and antitrip on s.s.b.
4) Built-in stable v.f.o.
5) About 100 watts peak output.
6) Some provision for r.f. or a.f. limiting.
7) Good carrier and sideband suppression on s.s.b.

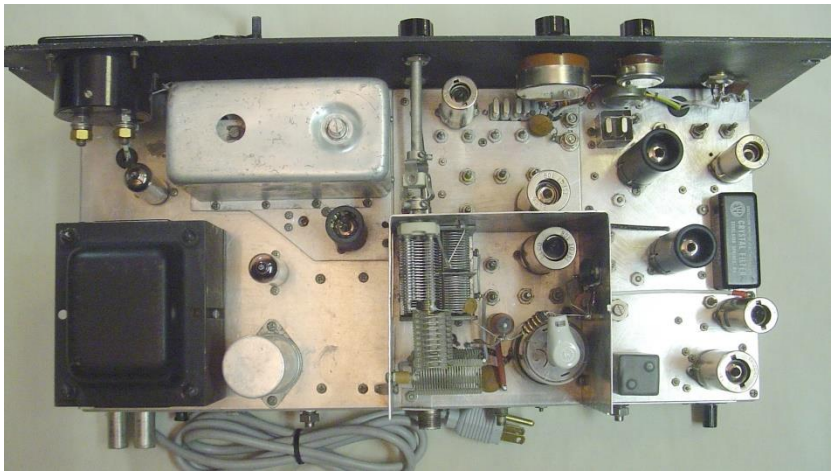
The author's previous experience with s.s.b. had been limited to the phasing type of exciter. Results were not always satisfactory because of a continuous need for adjustment to maintain reasonable carrier suppression and a low order of sideband suppression. There are several successful commercial designs which employ the phasing method and many staunch advocates of same. Just for a change then, if for no other good reason, it was decided that the new exciter would employ the filter method. The new McCoy 9-Mc. crystal filter looked particularly promising. Also, the relatively new circuits using the 7360 tube appeared to offer advantages. A search of the literature revealed numerous good designs, including those found in some well-known commercial units. A design by W6TEU [1] and an adaptation by K4EEU,[2] looked especially interesting. Although the basic signal-generating

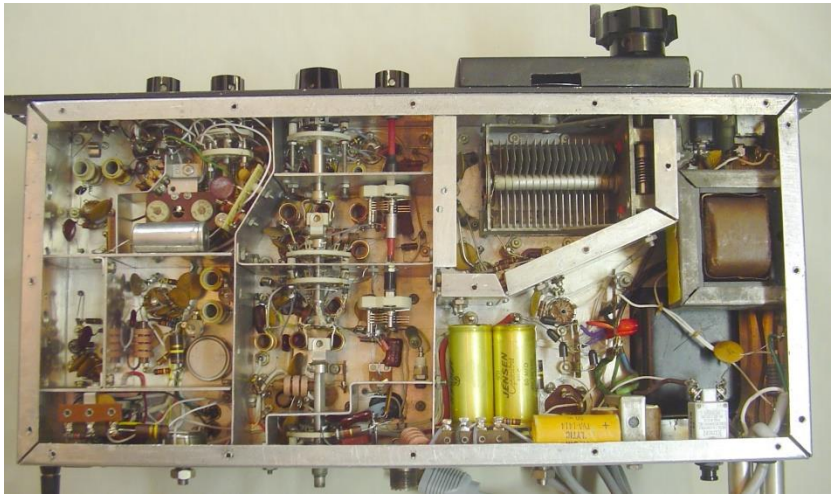
From November, 1962, *QST*.

[1] Bigler, "A Sideband Package," page 59.
[2] Kelley, "A Phasing-Type Sidebander," page 80.

- This radio started out as a four band phasing rig with the B&W PS network
- Converted to a filter rig when I could afford a filter, based on radio at left
- 12 tubes total. 7360s used for 9 MHz balanced modulator/carrier oscillator and mixer
- The 9 MHz filter was from ESEL. Ever heard of them?

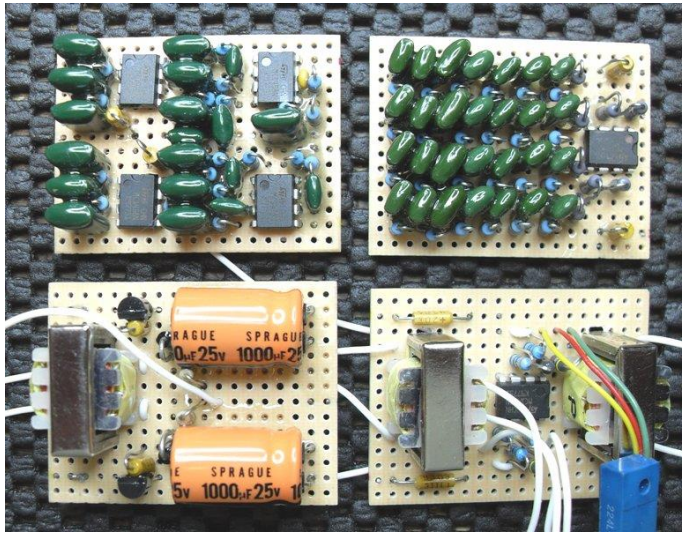
In Over My Head!





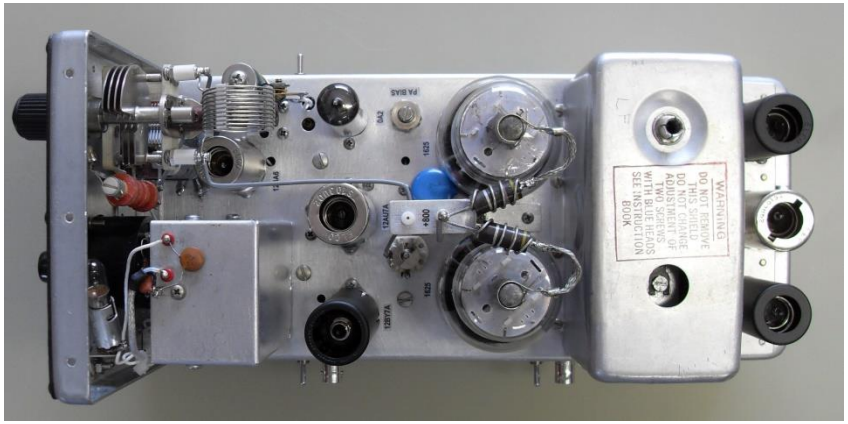
- When I built it I was in my early 20s – it never occurred to me I might not be able to make it work!
- My test equipment consisted of a 75S-1 and Heathkit VTVM with RF probe!
- Chassis not deep enough for a band switched radio – a major lesson learned.
- I found the 7360 circuits to be very troublesome.
- It actually does work, but still has some issues like low output on 15m.
- It’s too cramped to make any significant changes now – besides, why change a piece of history?

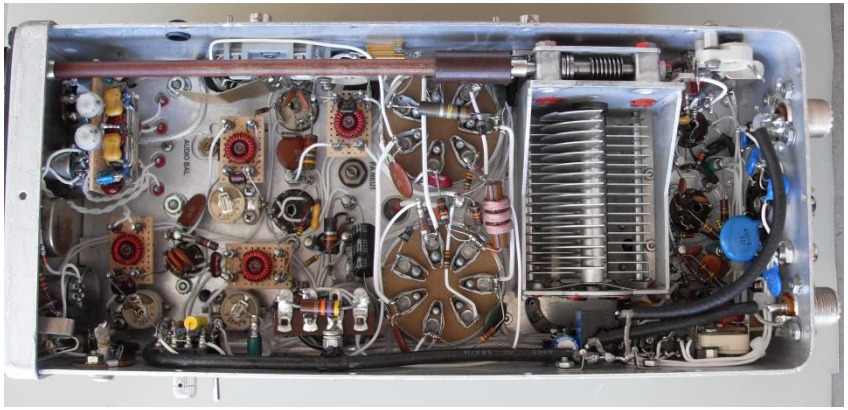
The 20m Vintage SSB Special

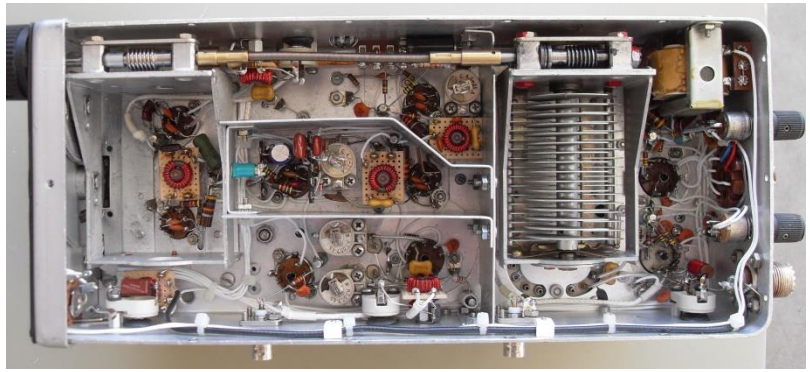


- My first homebrew SSB radio after a 40 year hiatus
- Transmitter is a phasing rig inspired by W2EWL's Cheap and Easy. Receiver uses McCoy xtal filter. They are connected together for transceive.
- Heart of the transmitter is a solid-state audio filter and sixth-order phase shift network shown on right

The Vintage SSB Special



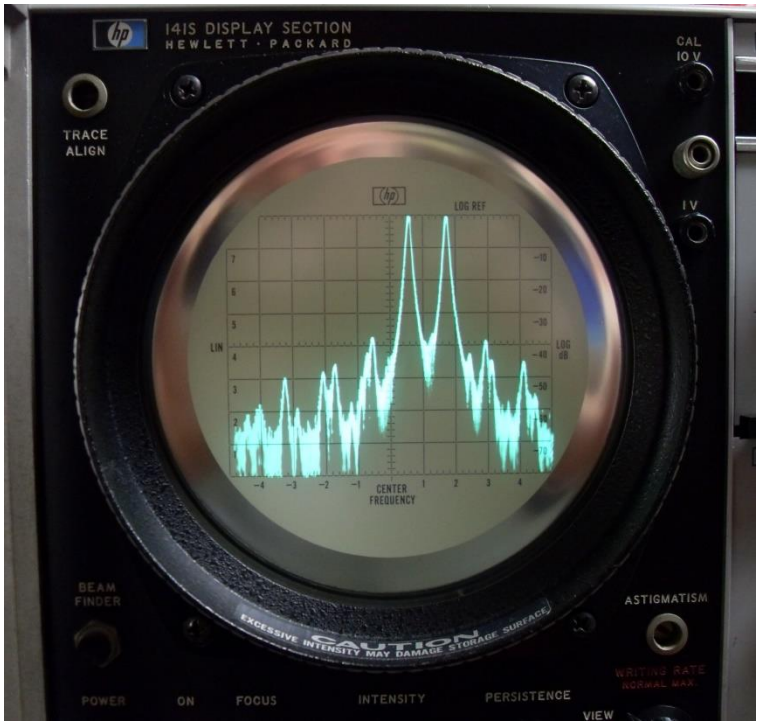


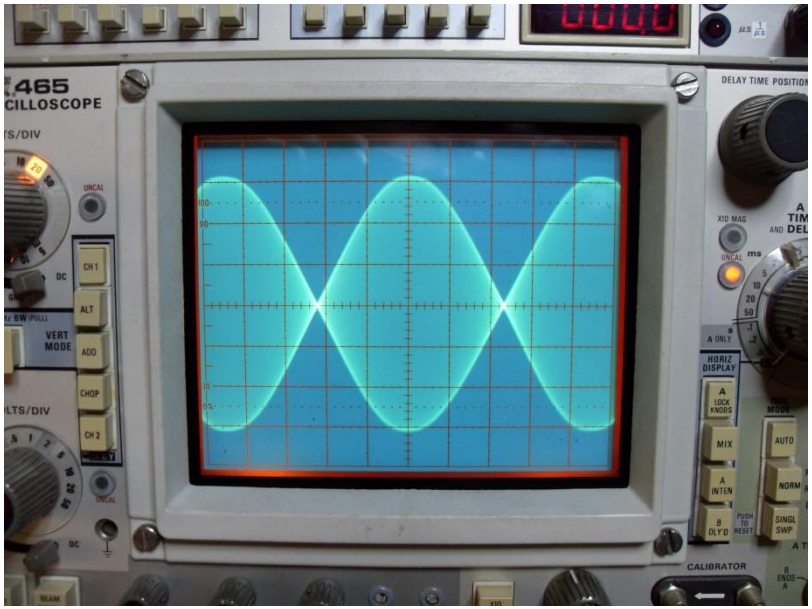


Transmitter Top & Bottom

Receiver Top & Bottom

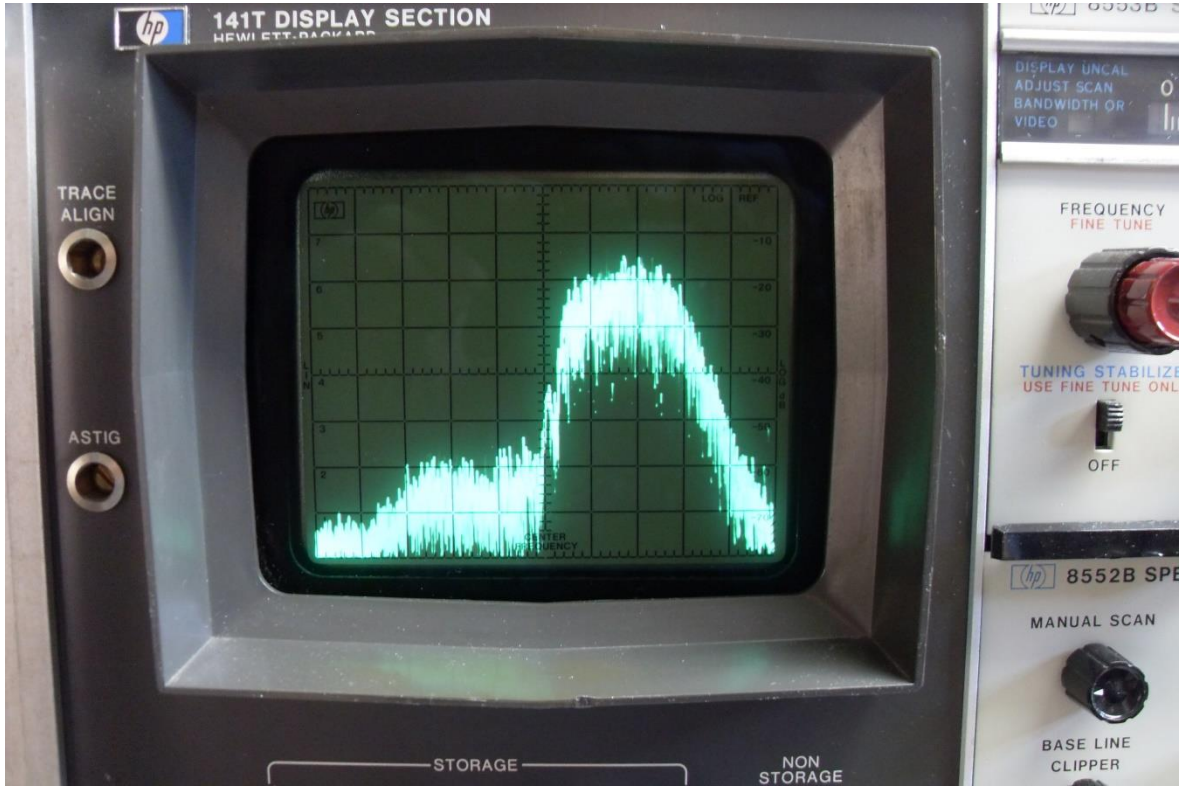
The Vintage SSB Special





Two-tone RF output at 40 watts PEP. This radio produces very clean SSB.

The Vintage SSB Special

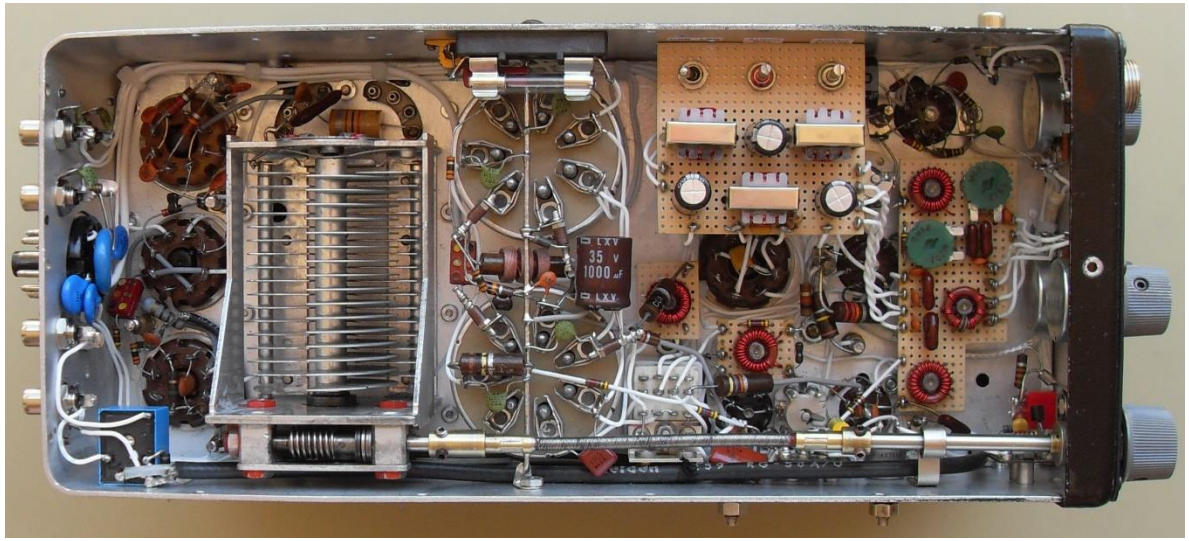


“White noise” audio input experiment verifies 2.5 KHz bandwidth of 8 pole solid state Butterworth filters

20 Meter Cheap ‘N Easy II

- KG7TR’s 21st century rendition of the W2EWL classic
- As in the original, uses the B&W 3502Q4 phase shift network and WWII 1625 PAs
- Performance and user enhancements:
  - ✓ Stable Colpitts VFO
  - ✓ Separate dual triode mixer stage
  - ✓ ALC
  - ✓ Metering
  - ✓ PTT
  - ✓ Built-in antenna and T/R relays
  - ✓ Spot function
- Now owned by K5LYN

20 Meter Cheap ‘N Easy II



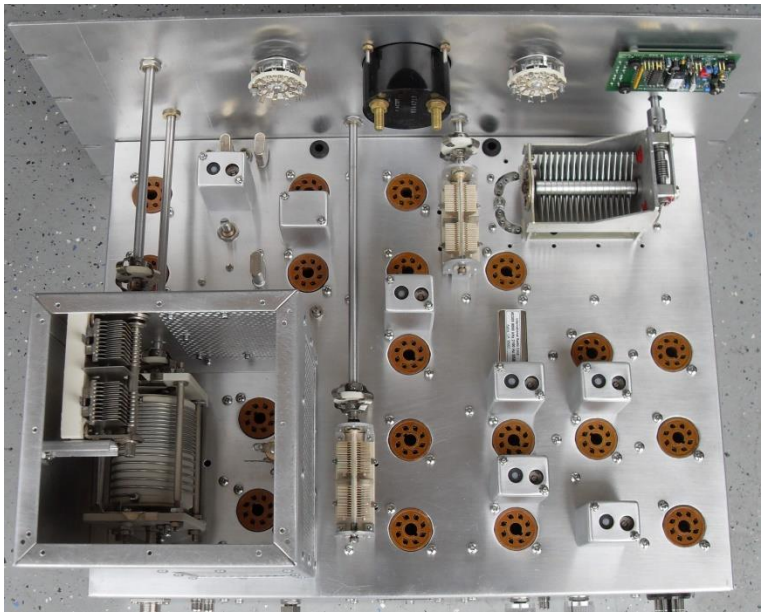
Inexpensive transistor audio transformers from Mouser are used in place of the unobtanium surplus units in the original W2EWL design.

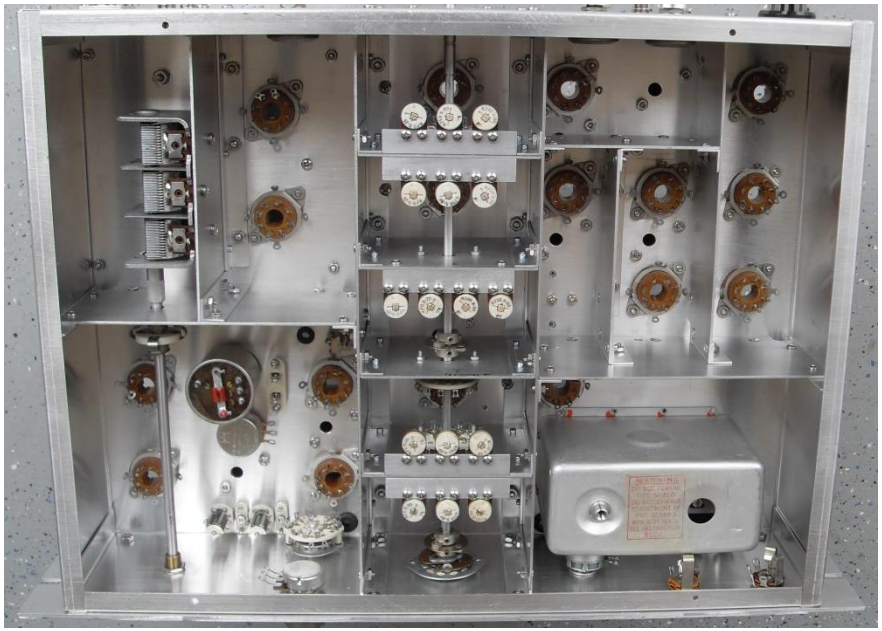
Octal Tri-Bander Transceiver

Matching Power Supply/Speaker Unit

- Most complex project to date – 19 octal tubes
- Basically the Octalmania radios combined into a transceiver
- New buffer/premixer circuit added for 40m
- Covers 80, 40 and 20 meters with a single bandswitch

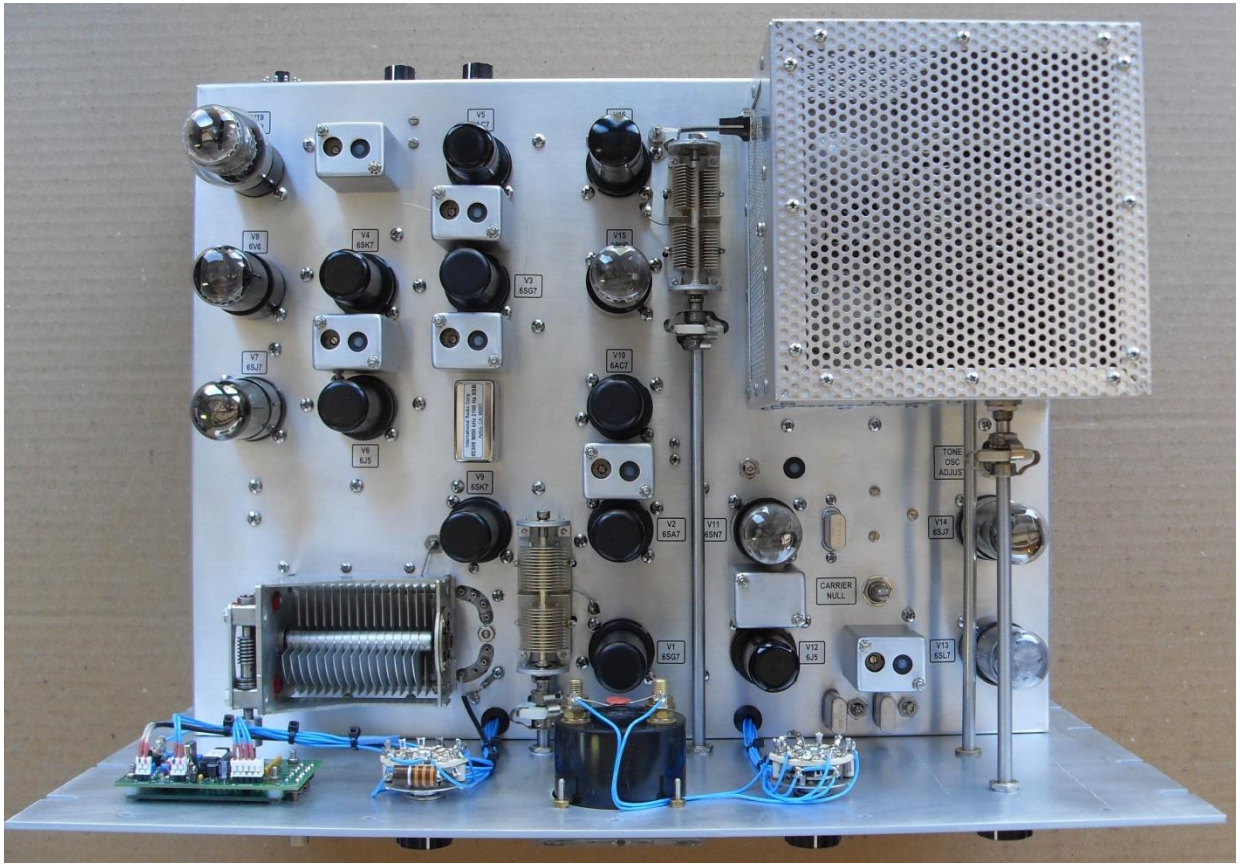
Octal Tri-Bander Transceiver





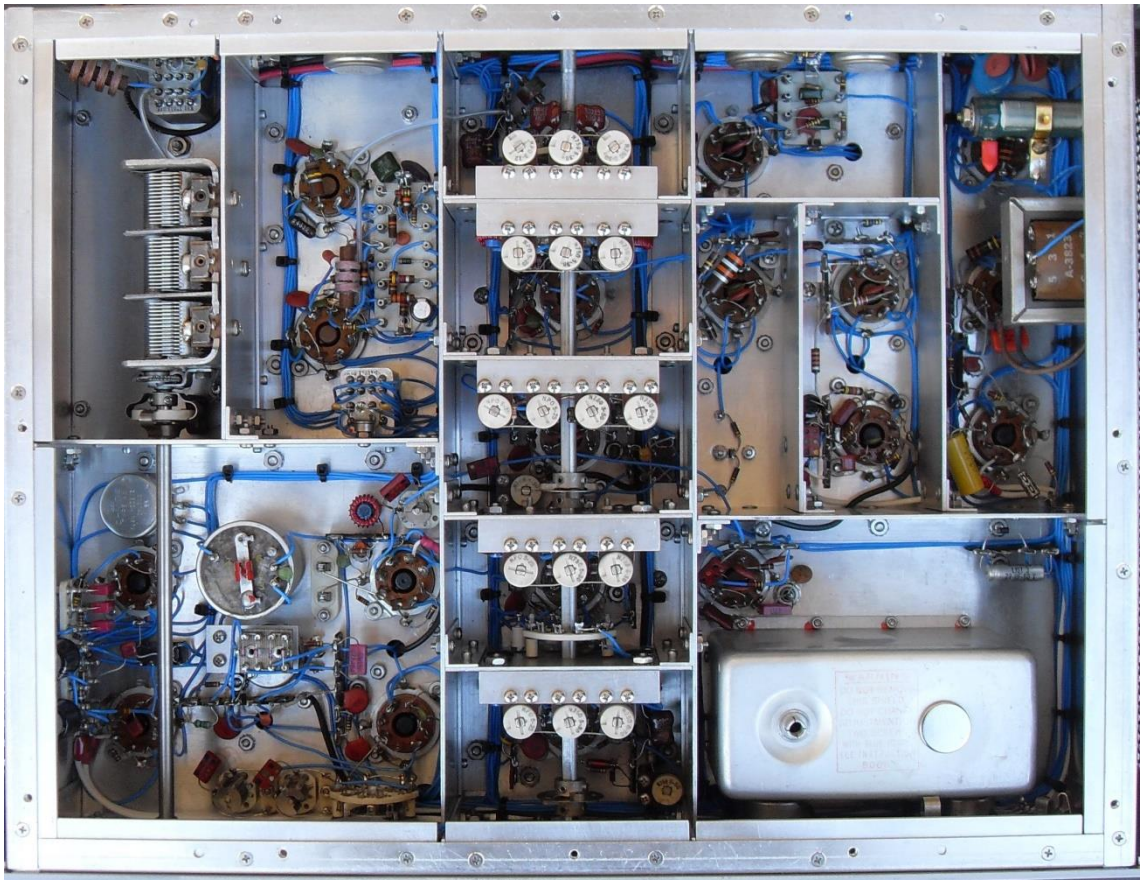
Sheet metal work done, ready to start wiring. A lot of thought went into laying everything out. Transmitter circuits are on the left and receiver circuits are on the right. Bandswitched circuits are smack in the middle.

Octal Tri-Bander Transceiver



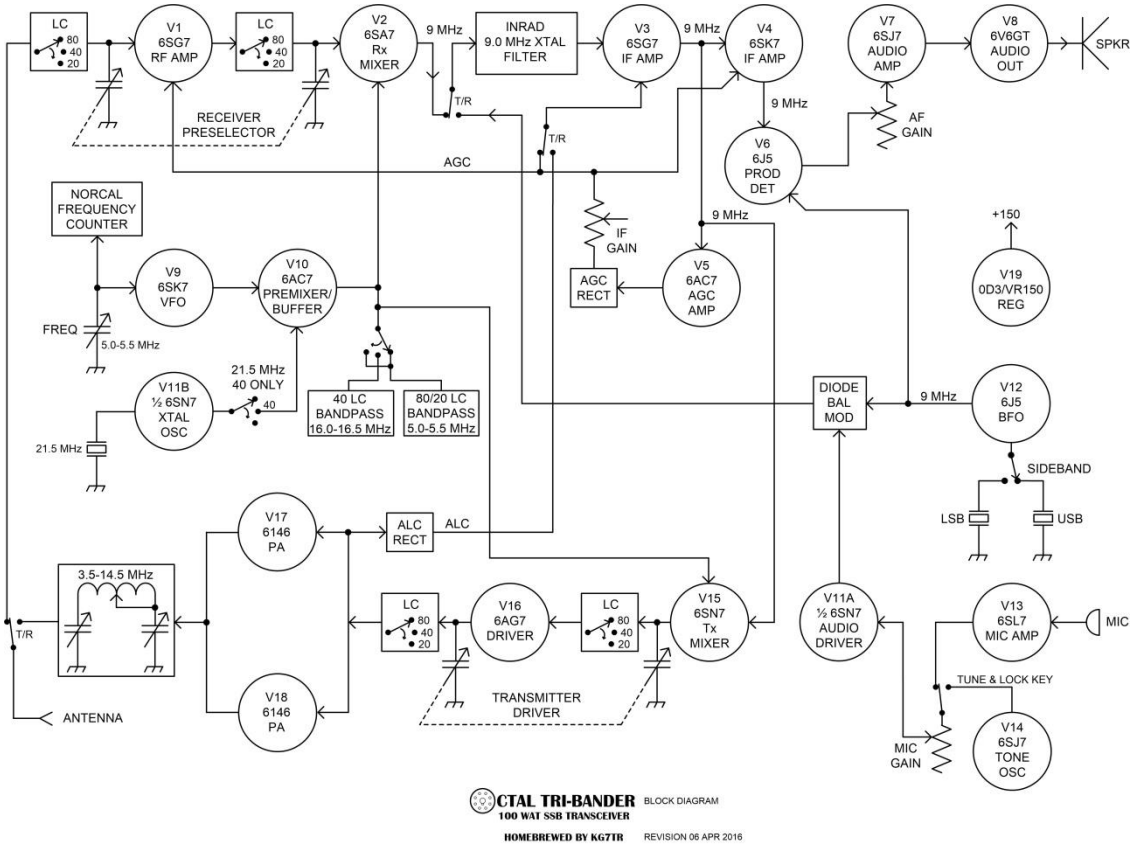
Top view of completed radio. Receiver preselector and transmitter driver use separate tuned circuits, unlike most tube type transceivers.

Octal Tri-Bander Transceiver



Bottom view. 4” high chassis allows ARC-5 VFO components to be mounted upside down for a more useable location of the main frequency knob.

Octal Tri-Bander Transceiver

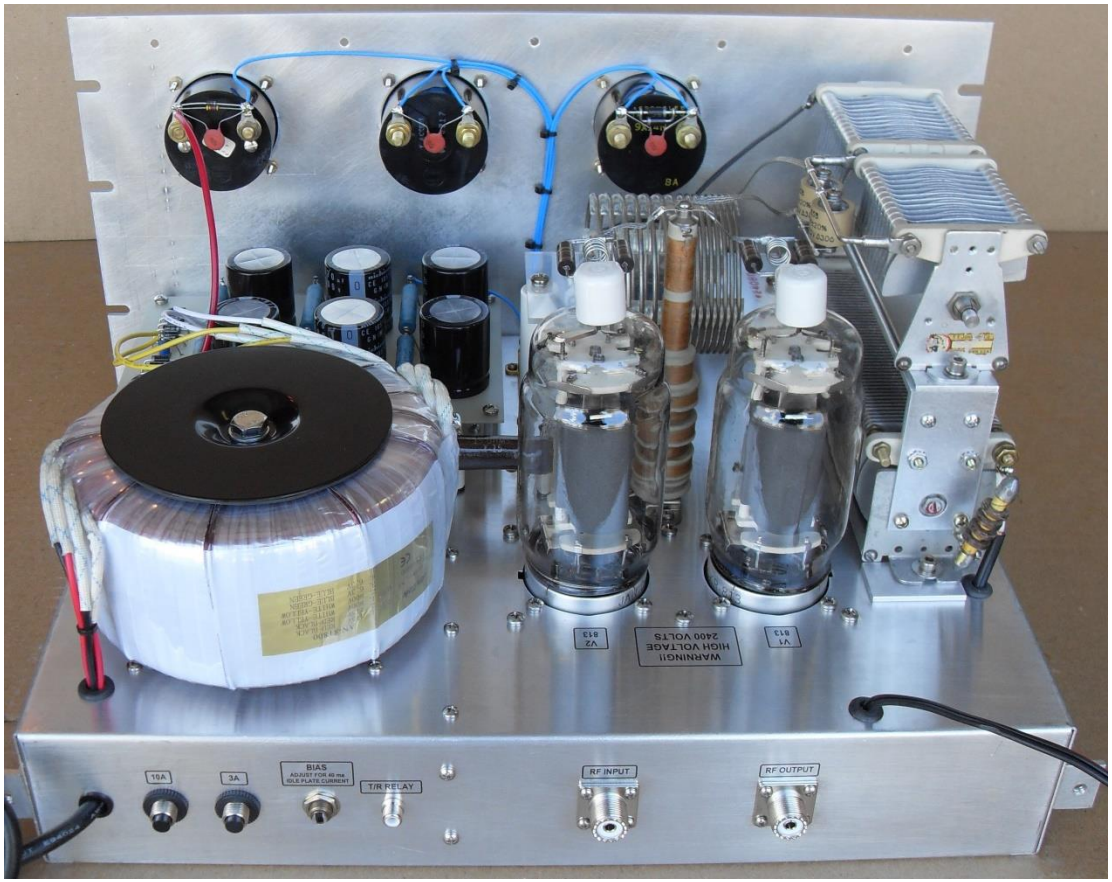


Block Diagram. I actually wired and tested the whole radio from a penciled version of this, and kept rough schematic notes where necessary. When the radio was finished and working right I drew up the final, detailed schematics.

2X-813 Linear

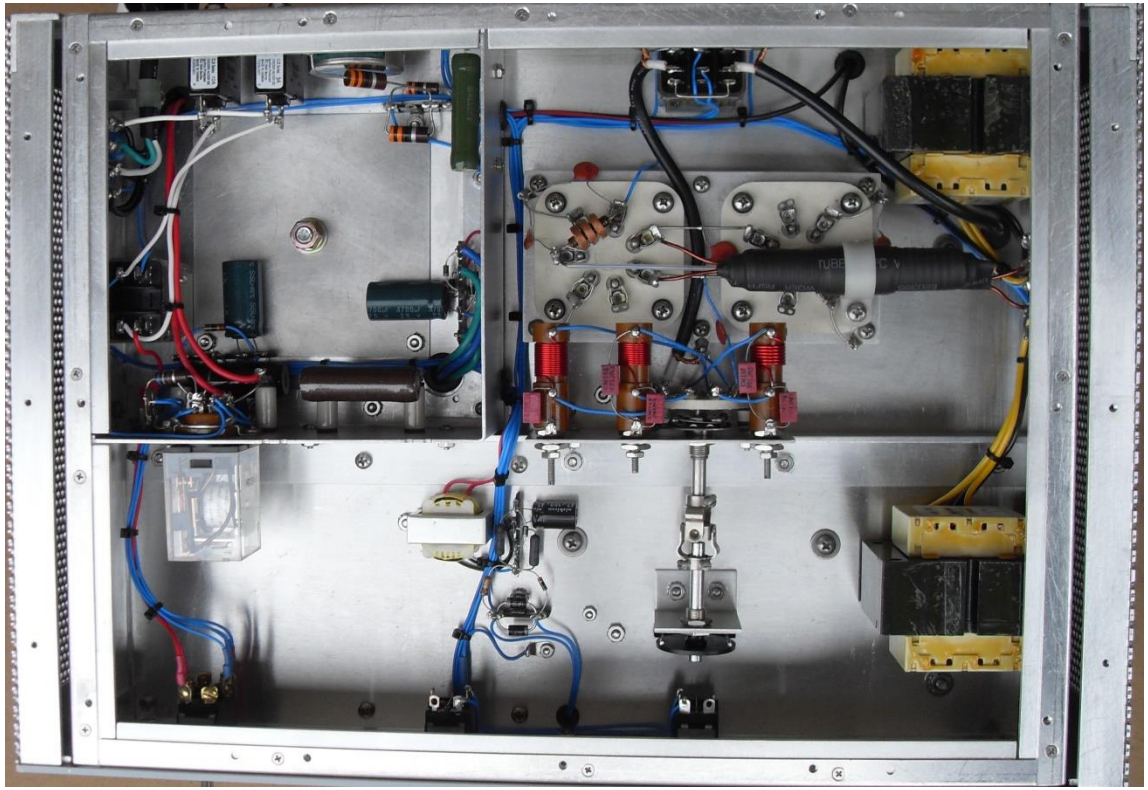
This linear was built to go with the Octal Tri-Bander. I always liked the look and feel of an 813. This amplifier uses a pair of them in grounded grid. A lot of the design is similar to my HB-600 linear. NOS Triplett meters monitor grid mA, plate mA, and plate VDC.

2X-813 Linear



An Antek 800VA toroid feeds a voltage doubler that provides about 2,250 VDC no load. The PA coil is an Illumitronic pi dux 2408D4 pruned for 80, 40 and 20 meters. Bandswitch is a Radio Switch unit. Braided wire for RF wiring allows flexing as chassis is handled.

2X-813 Linear

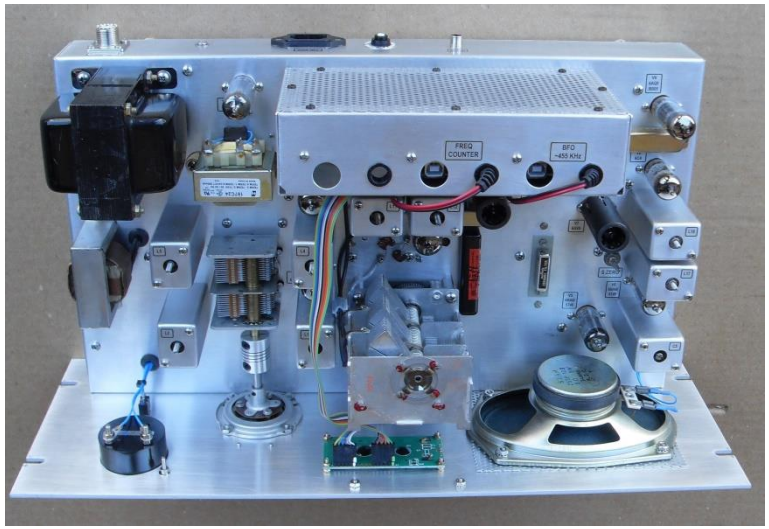


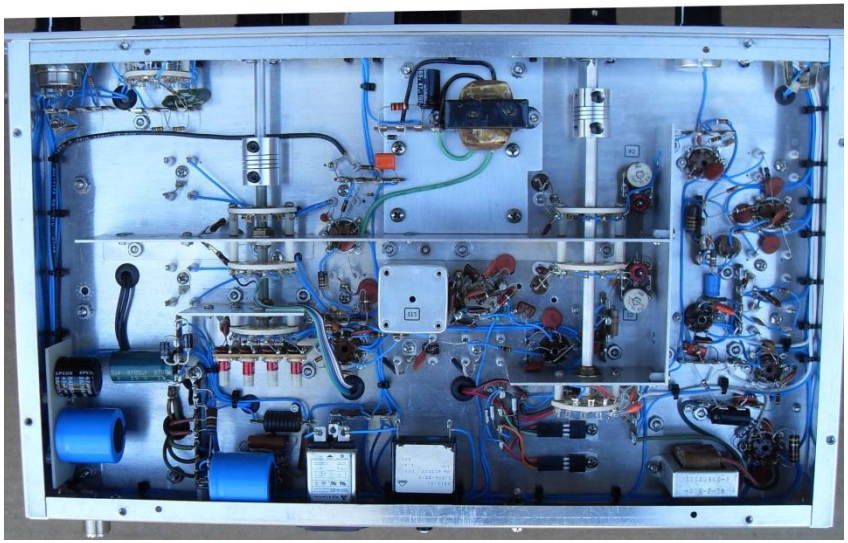
Bandswitched, tuned input circuits are used. Two 5 volt, 10 amp control transformers are connected in series to provide filament voltage for the 813s. The filament choke is from an Amidon kit. The chassis is braced with angle stock and a right angle shield to provide a robust foundation for the toroid power transformer.

75S-2B Receiver

This receiver was built because I got a NOS Collins SSB filter at a hamfest, and just had to do something with it. The radio receives SSB and AM on the classic five bands 80 thru 10 meters. The front half is like a Drake 2B receiver, while the back end clones a Collins 75S-3 receiver, hence the moniker “75S-2B”.

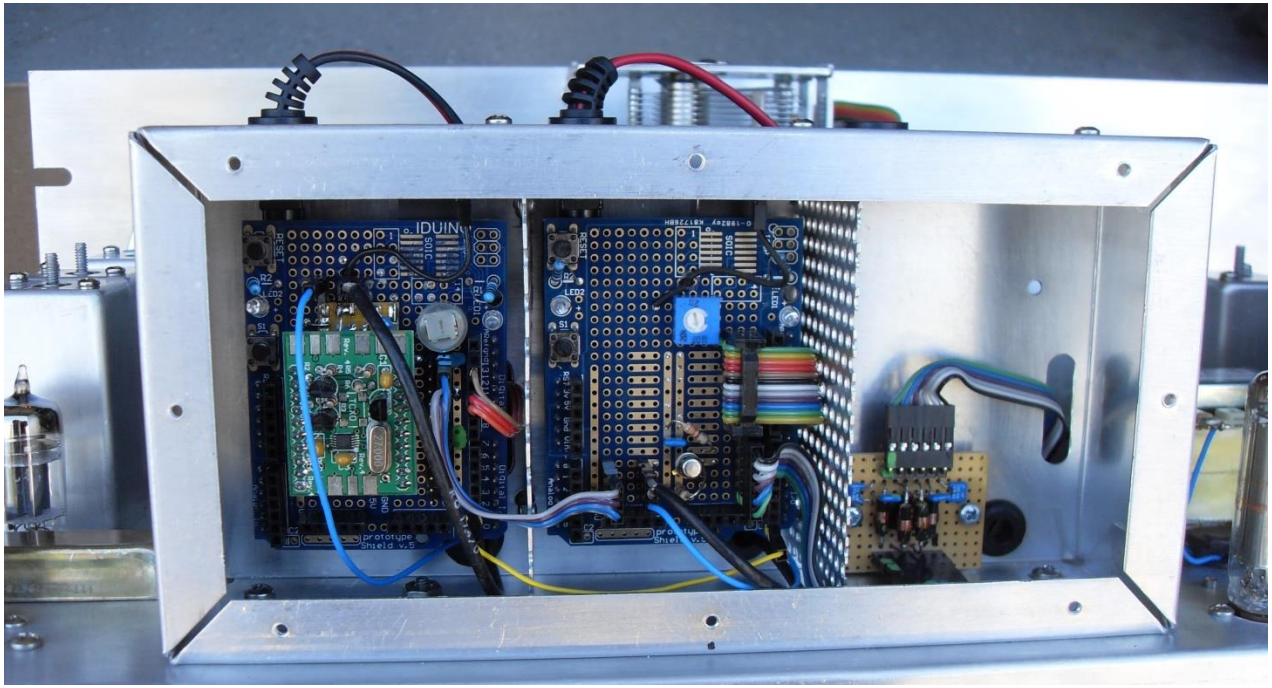
75S-2B Receiver





The 80 thru 10 meters preselector is seen on the left, and uses a 2 section variable cap from RF Parts with National vernier drive. The 3 section variable cap in the center is from a scrapped ARC-5 receiver, and tunes the first IF of 3.5 to 4.0 MHz. Bottom view at lower left shows heterodyne xtal oscillator, which injects 11.0, 18.0, 25.0 and 32.0 MHz into 1st mixer for 40, 20, 15 and 10 meters respectively. It uses off the shelf microprocessor crystals that were less than one dollar each.

75S-2B Receiver

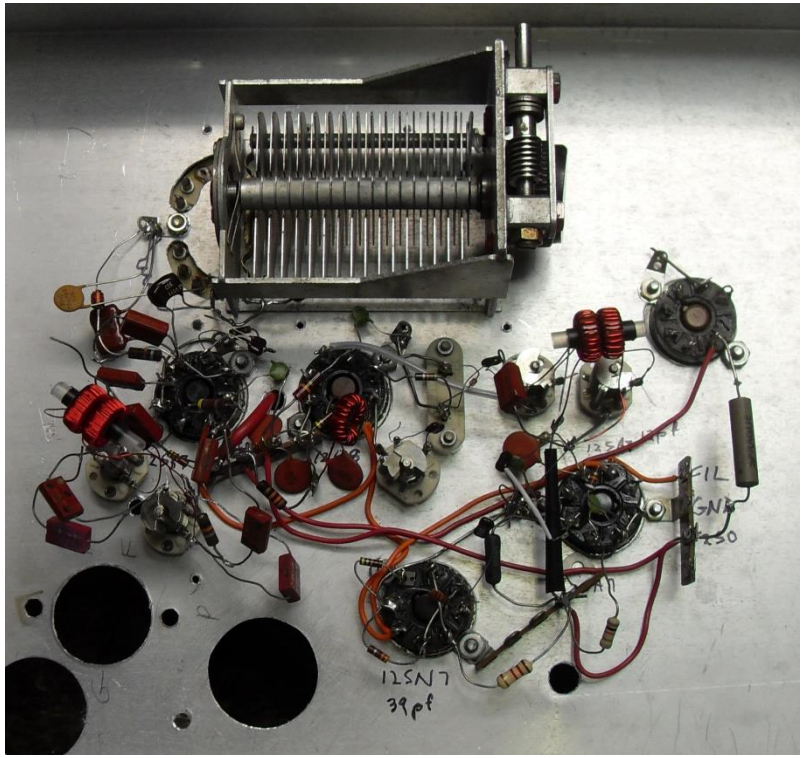


Inside the solid state subchassis. At left, Arduino controlled Si5351 synthesizer is used for the BFO, with homebrew amplifier added to drive product detector. In center is Aduino freq counter and LCD display driver. Many spurious noise problems were encountered with Arduino controlled AD9850 and Si5351 modules, and caused major changes midstream in the build.

Starting New Projects

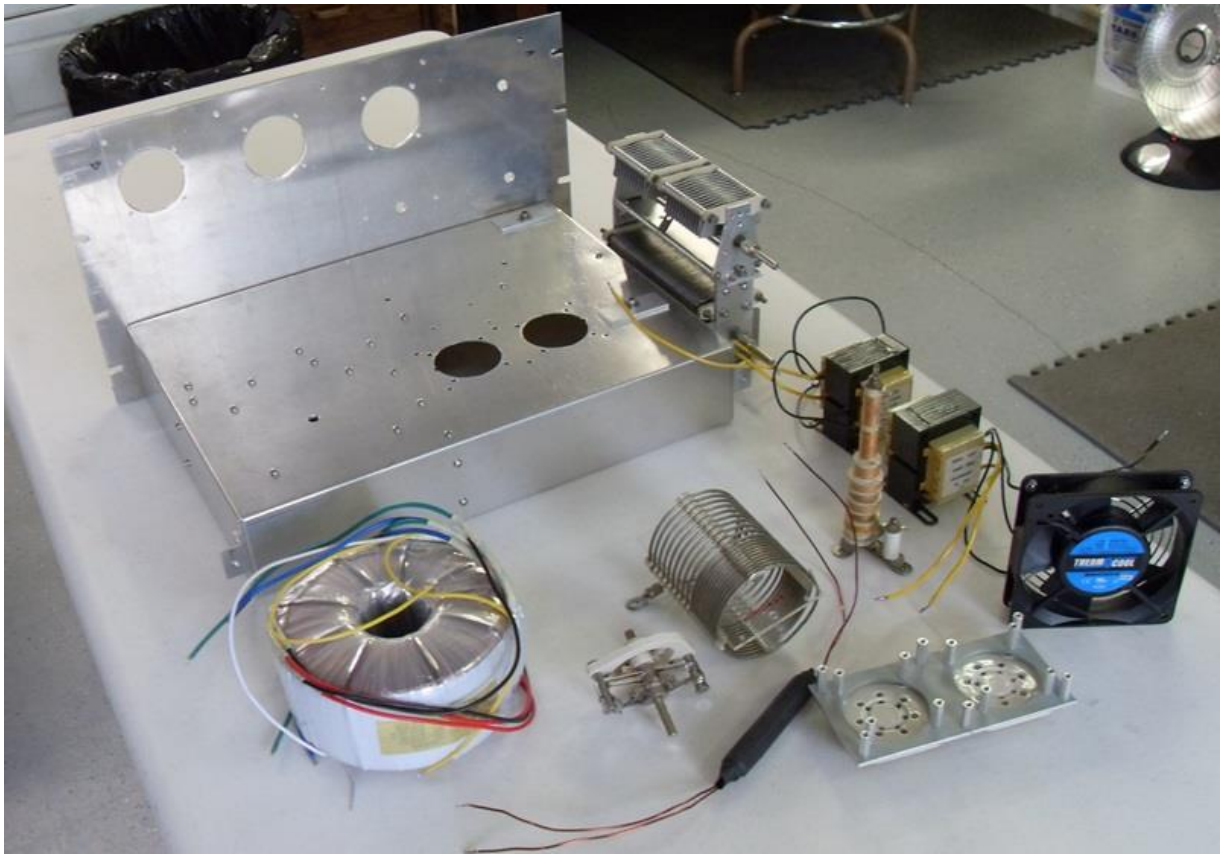
- For me, a new project has typically started with the acquisition of one or more key components, such as:
  - ✓ Crystal or mechanical filter
  - ✓ Rotary inductor
  - ✓ Power Transformer
  - ✓ Audio phase shift network
  - ✓ Transmitting variables
  - ✓ ???
- Then I develop a rough vision of what the final product might look like.
- Existing inventory of “junque” is surveyed to see what might be used.
- Want lists are made for hamfests, eBay, or new purchase.

Breadboarding Circuits



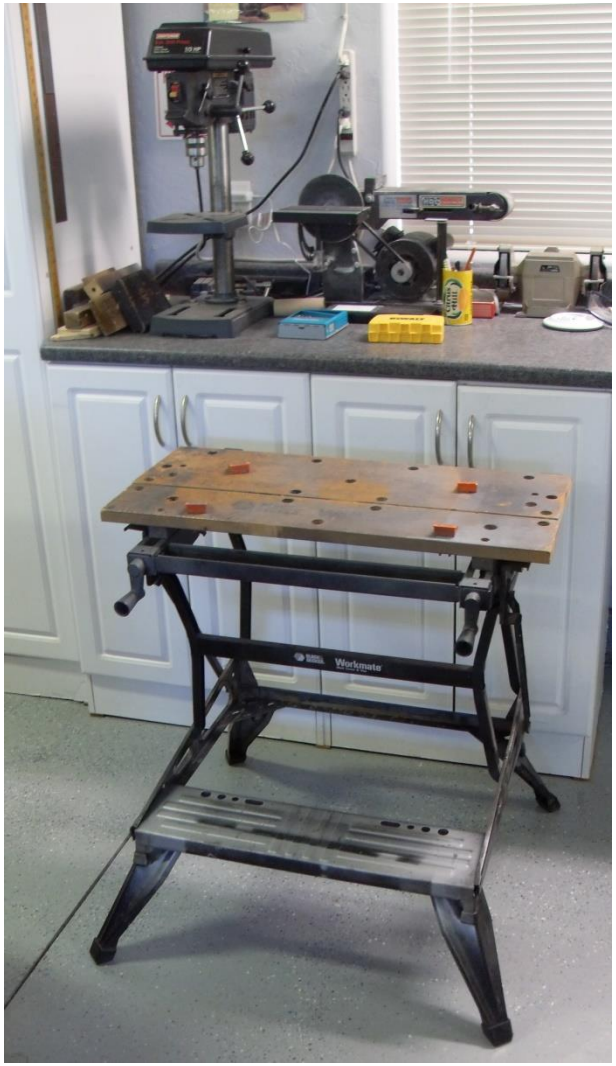
When I have to use a circuit I've never tried before and there is risk of a lot of tweaking, I breadboard it first on an old junk chassis. This is the breadboard used to develop the new 40m buffer/premixer circuit used in the Octal Tri-Bander.

Laying Out the Radio



Layout is mostly about making sure RF paths are short, the front panel is functional and pleasing in appearance, there are no interferences, and parts can be removed and replaced if necessary. This is the 2X813 linear under construction.

Doing the Metalwork

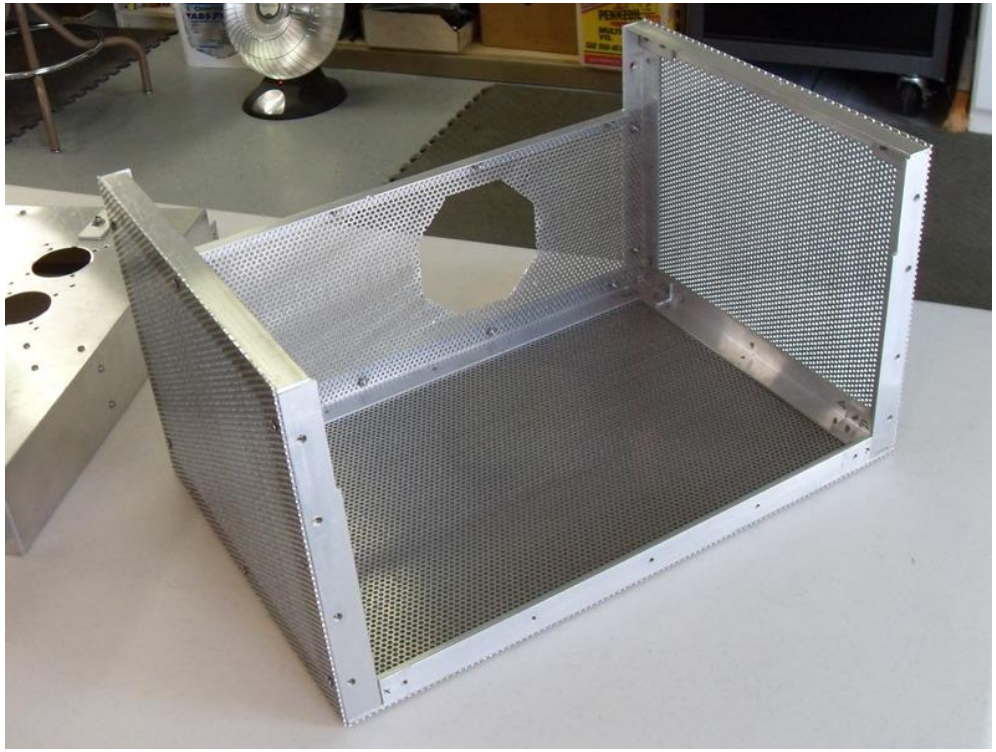


- All of the metalwork in my homebrew radios was done using the tools seen on this page and the next.
- Noticeably missing is a press brake or shear.
- I have never taken so much as a high school shop class.
- All methods and techniques used were learned by trial and error, and are not necessarily the best or fastest way to do things.
- To make shields and cabinets, I use angle and sheet stock, pop rivets, and machine screws in tapped holes.
- Metal was cut slightly oversize using a saber saw, and cleaned up and squared with lots and lots of filing!

Doing the Metalwork

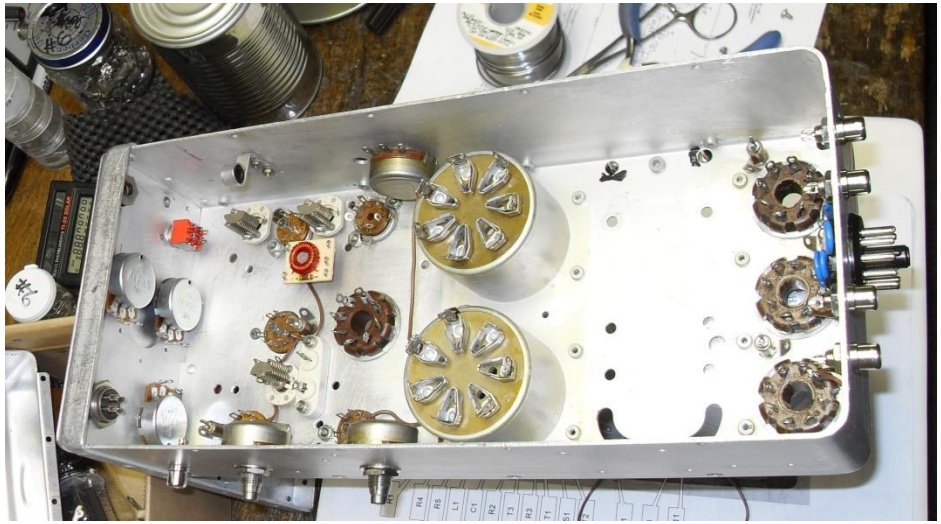
These are all pretty common tools, and most are not expensive. I did collect an assortment of chassis punches, which proved invaluable for making holes for tube sockets and meters. Of course you can drill and file out those big holes, but it will take a few extra days and they might be almost round when you're done!

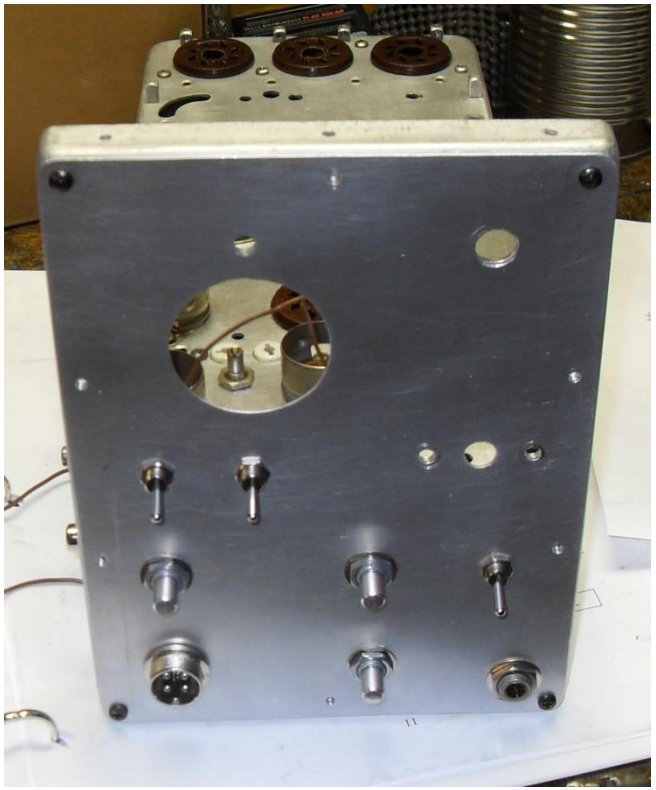
Doing the Metalwork



These pictures show how the cabinet used for the 2X813 linear was made. The same techniques were used for the Octal Tri-Bander and PSSU cabinets.

Doing the Metalwork



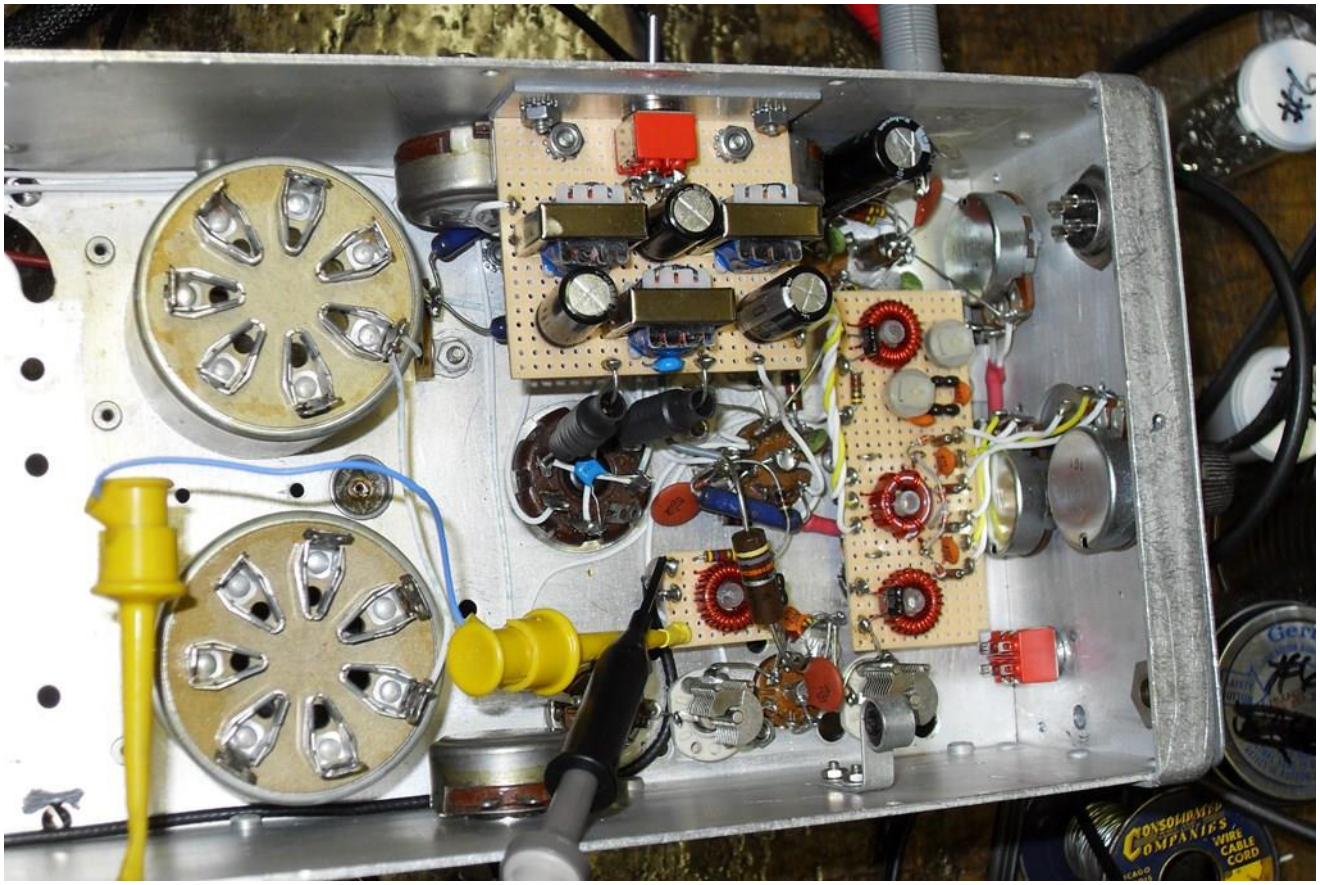


When building a radio on a Command transmitter chassis, I totally strip and clean it first. Then I build from there. These pictures show the 80m Cheap 'N Easy II under construction. Note the new front panel overlay.

Building It

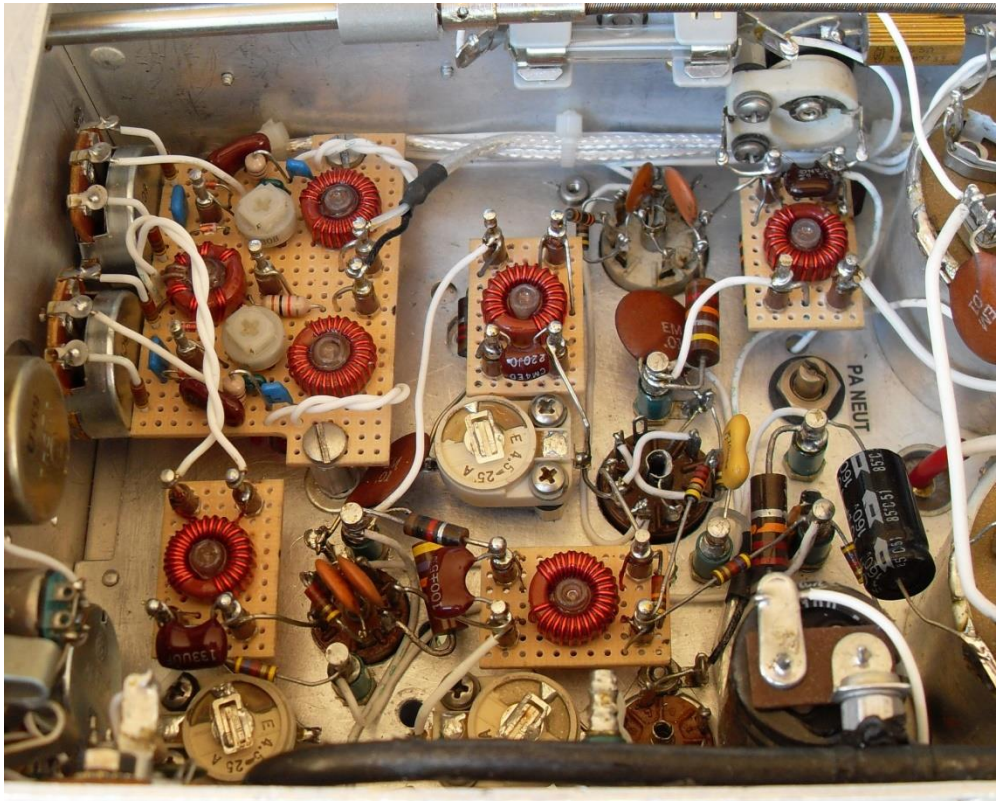
The 80m Cheap ‘N Easy II in the middle of the wiring phase. I always use silver coated, stranded teflon wire, and zip tie it into bundles as required after completion. I find that I have to stop and clean up the bench every so often just so I can find stuff!

Element Testing



Here the audio and 9MHz SSB generator circuits of the 80m Cheap ‘N Easy II are being tested. No sense going any further until this stuff is working!

Tubes & Toroids



Toroids used in the IF and RF circuits of the Vintage SSB Special transmitter. Ceramic trimmers are used to resonate the ones used in tuned circuits.

- I use toroids all over the place in my homebrew SSB tube radios and they work just fine.
- These days you can't find slug tuned coils or coil forms with known characteristics in decent quantities and prices.
- I primarily use T50-2 cores, which are only $.65 each from Amidon Associates.
- Using published formulas, I get actual inductances within 10% of the predicted values.
- Minor annoyances are the need for a variable cap in a tuned circuit, and a method for physical mounting.

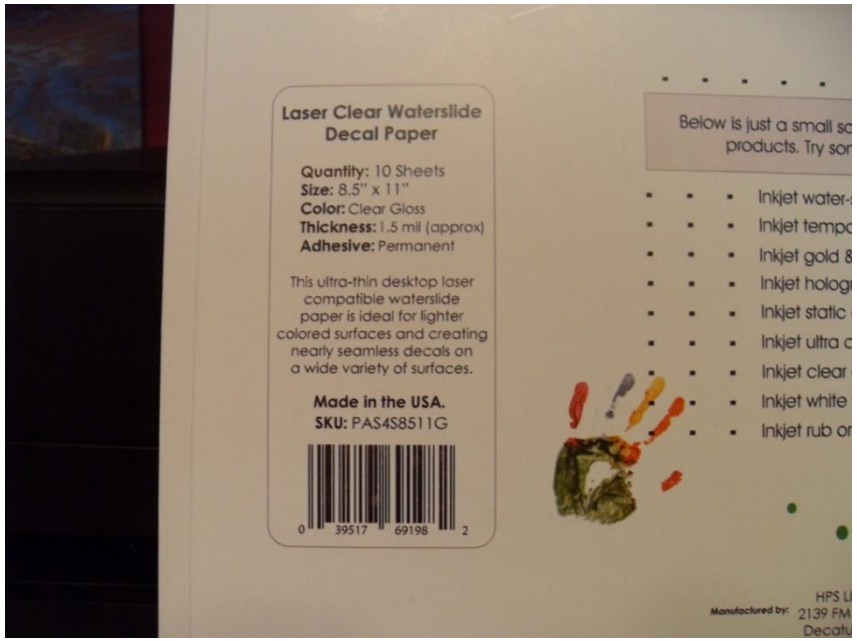
Test Equipment

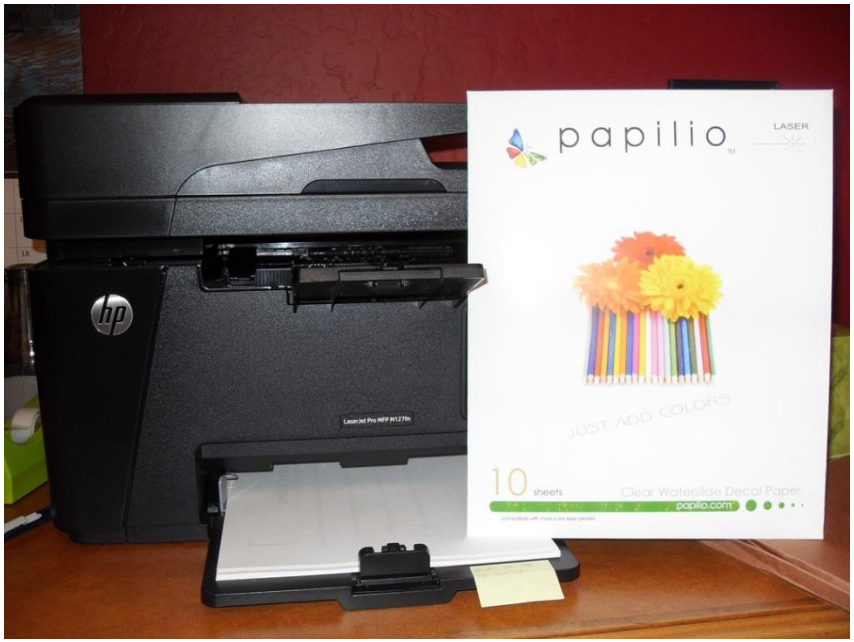
Decent test equipment really helps. For an SSB transmitter, essential are a wideband scope, two-tone audio oscillator and spectrum analyzer. For a receiver a good signal generator is a must. You need a frequency counter for either. The Heathkit lab power supply is useful for breadboard and element testing.

Panel and Chassis Labels

These labels were made with water slide decals printed on Papilio stock with an HP laser printer. The labels were designed using Microsoft Visio software. The front panel was oversprayed with clear matte finish from a rattle can. The chassis labels were brushed with polyurethane semi-gloss.

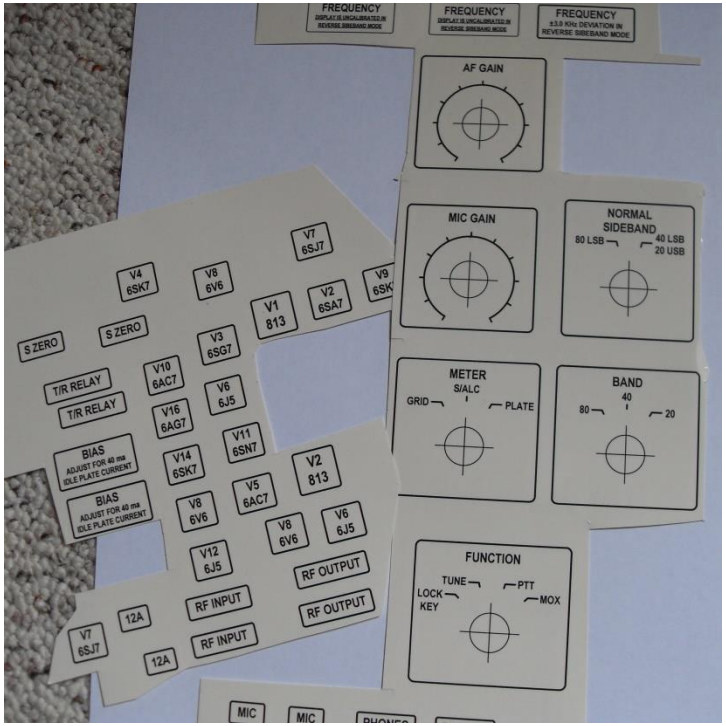
Panel and Chassis Labels

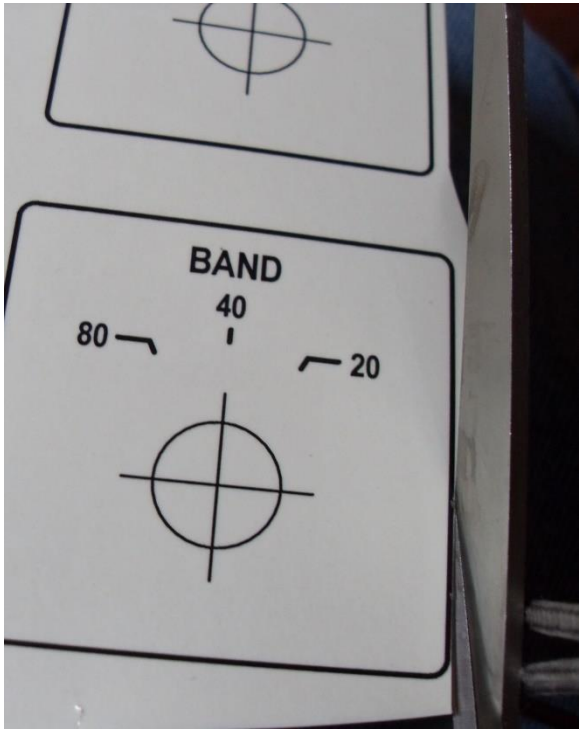




The decal stock is very inexpensive and is available from papilio.com. They make decal stock for inkjet and laser printers. With an inkjet you have to spray Krylon or similar on the sheet to keep water from dissolving the ink. But you can do color with an inkjet printer. With laser stock no overspray is required. If you have access to a color laser printer, that will make color decals too.

Panel and Chassis Labels





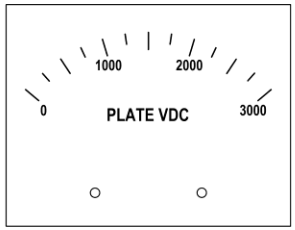
A good pair of sharp scissors is used to cut out each decal. Putting a box around each decal makes the transition on the panel less perceptible, and provides a way to line up the label parallel or perpendicular to an edge.

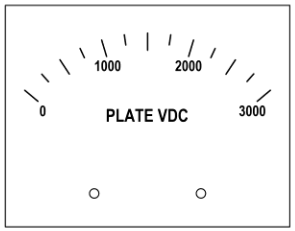
Panel and Chassis Labels

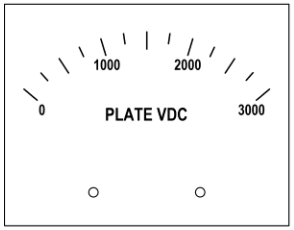
Overall Process:

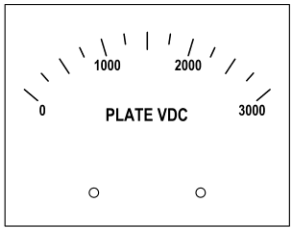
- For front panels, spray unfinished panel with Rustoleum light gray primer.
- Design decals using Visio or other software.
- Use Papilio Laser Clear Waterslide Decal Paper.
- Print decals using laser printer and plain paper setting.
- Cut out decal and dip in warm distilled water for about 30 seconds.
- Slide decal off backing and apply to panel or chassis. When lined up squeeze water out with paper towel.
- Allow to dry for 24 hrs. For front panel, place in middle rack of oven at 275° for 15 minutes to remove splotchy areas.
- Overspray front panel with Rustoleum clear matte finish.
- For chassis labels, brush with polyurethane matte finish.
- Do not use lacquer or acetone based finishes!

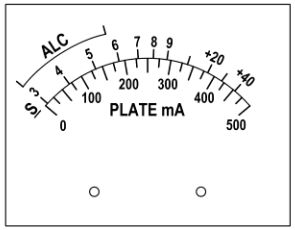
Custom Meter Scales

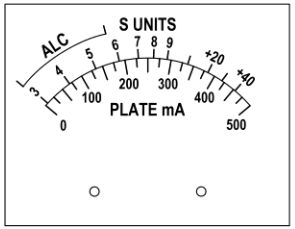


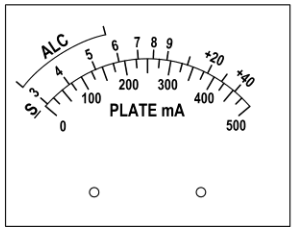


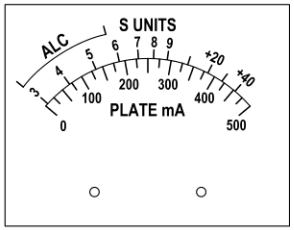










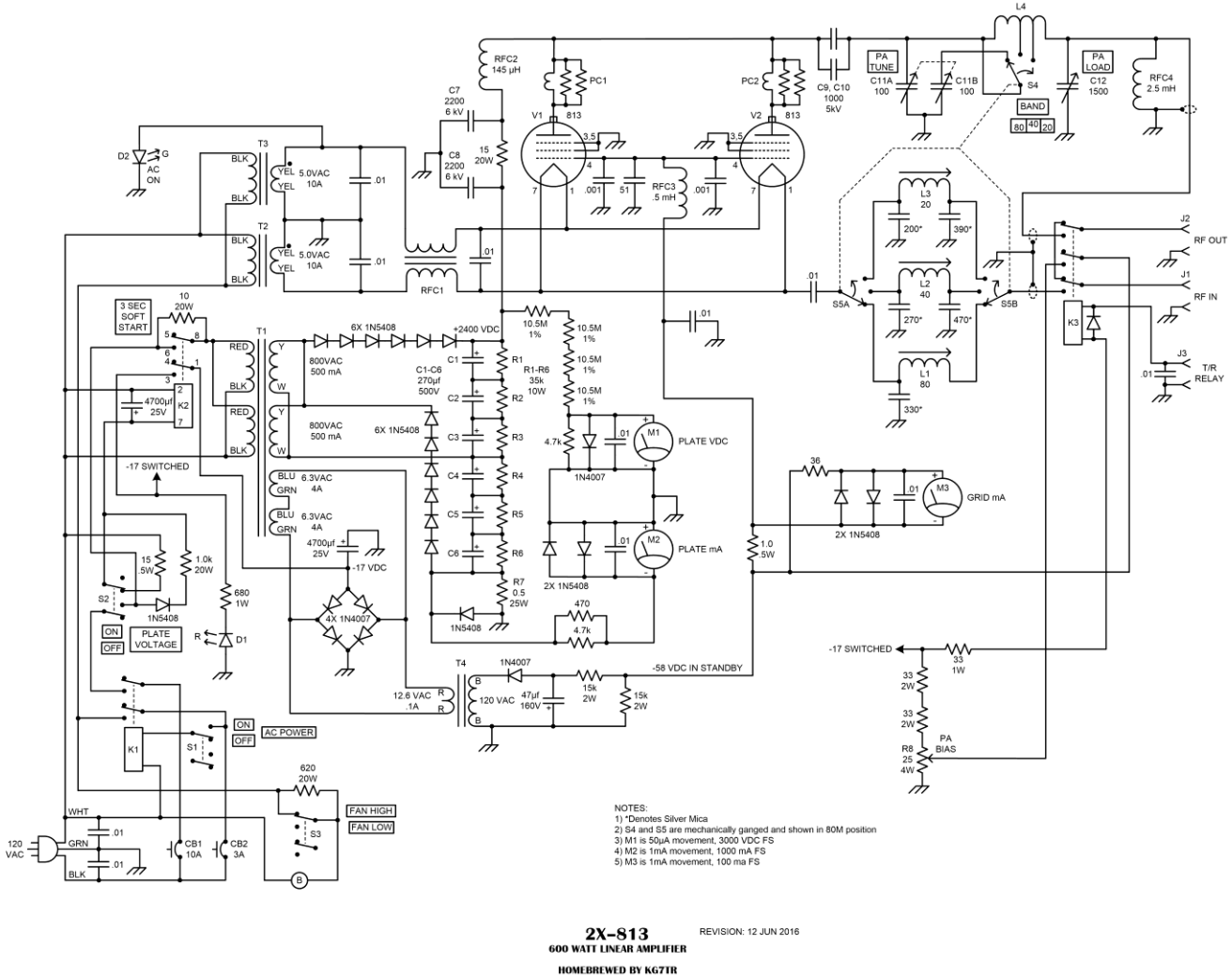


- Meters were carefully disassembled and original scale plates painted white.
- Custom scales were designed using Visio and printed on plain paper.
- New scales were aligned and glued over the painted plates
- Meters were carefully reassembled, paying attention to FOD.

Documentation

- During build and test, rough schematics were scribbled down if I knew tracing them out would be difficult.
- When the radio was completed and I knew there would be no more changes, I drew up formal schematics using Microsoft Visio.
- Once I had defined all symbols for the VSSB Special, I was able to reuse the symbols on all the other radios.
- By defining my own symbols, a resistor looks like a good old resistor instead of a rectangle!
- See next page for a typical schematic.

Documentation – Typical Schematic



- Open Discussion

Why don’t hams homebrew anymore??

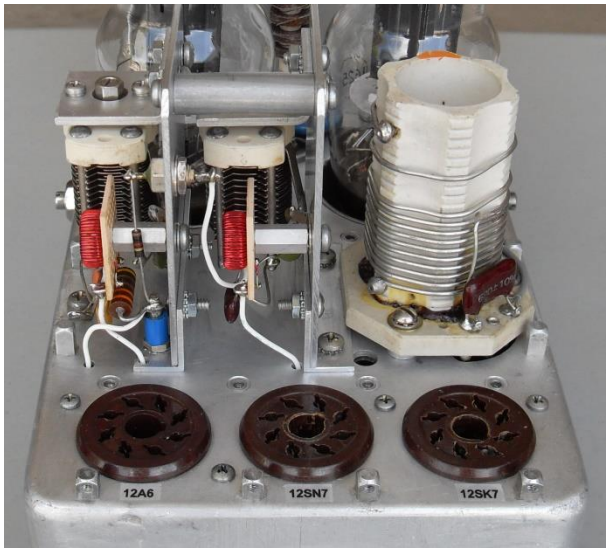
Potential Obstacles to Tube DIY

- Real Interest?
- Finding Time for Homebrew!
- Basic Theory for Tube Circuits?
- Finding Projects & Tech Data
- Finding Parts, Making Substitutions
- Sheet Metal Work
- Required Test Equipment
- “Elmers”

- Thanks for your interest
- Be sure to visit kg7tr.com for more info
- Send me an email if you think you might want to give it a try (bohn48@msn.com)

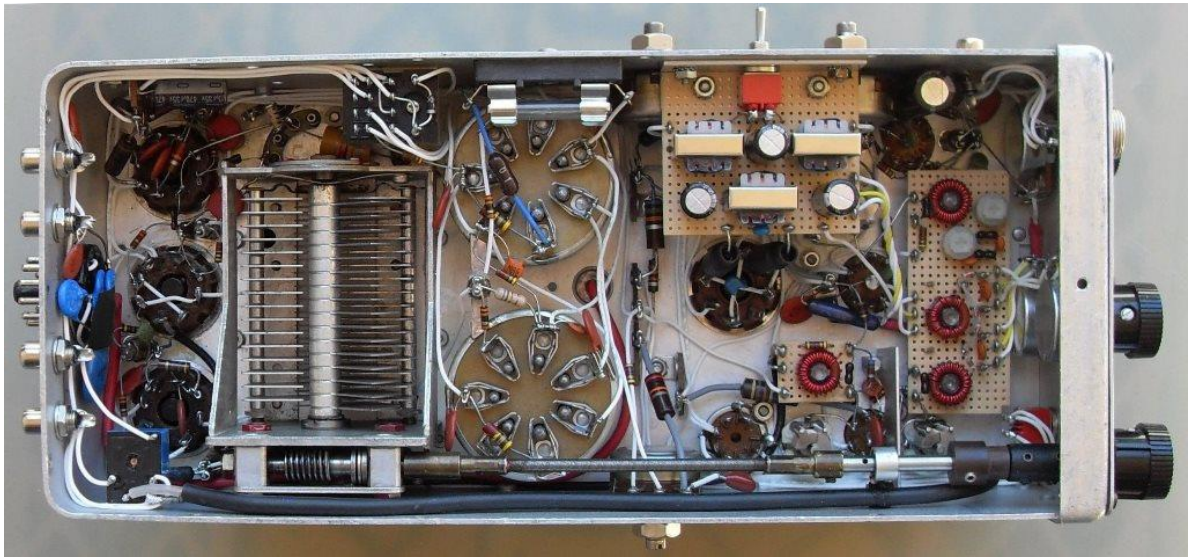
- Backup Slides

80 Meter Cheap ‘N Easy II



- Pretty much a clone of the 20m version
- Replacing original ARC-5 range set variable frees up space for driver coils
- Now owned by NU6X

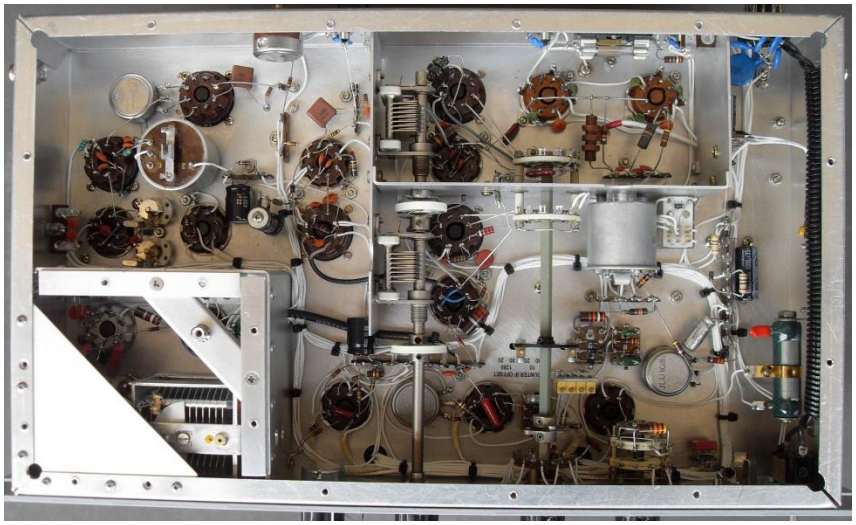
80 Meter Cheap ‘N Easy II

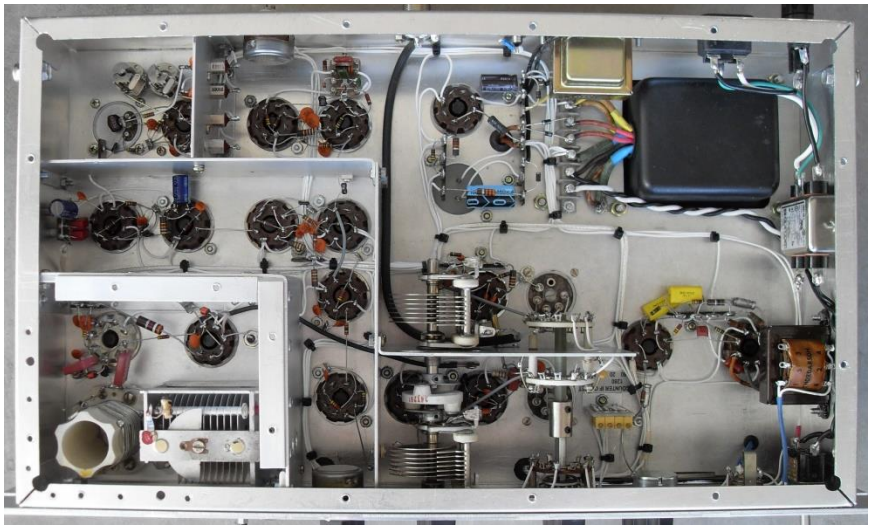


Octalmania!

- Inspired by hamfest acquisition of a whole bag of octal sockets plus lots of leftover Command set parts
- Transmitter and receiver use 12 octal tubes each
- Transmitter is stacked on top of receiver and picks up receiver VFO signal from below
- Radios cover 80m LSB and 20m USB with single bandswitch
- Both radios use INRAD 9 MHz filters with 2.1 KHz bandwidths
- Radios shown on top of HB-600 linear – a 25 inch tower of homebrew, hollow-state SSB!

Octalmania!

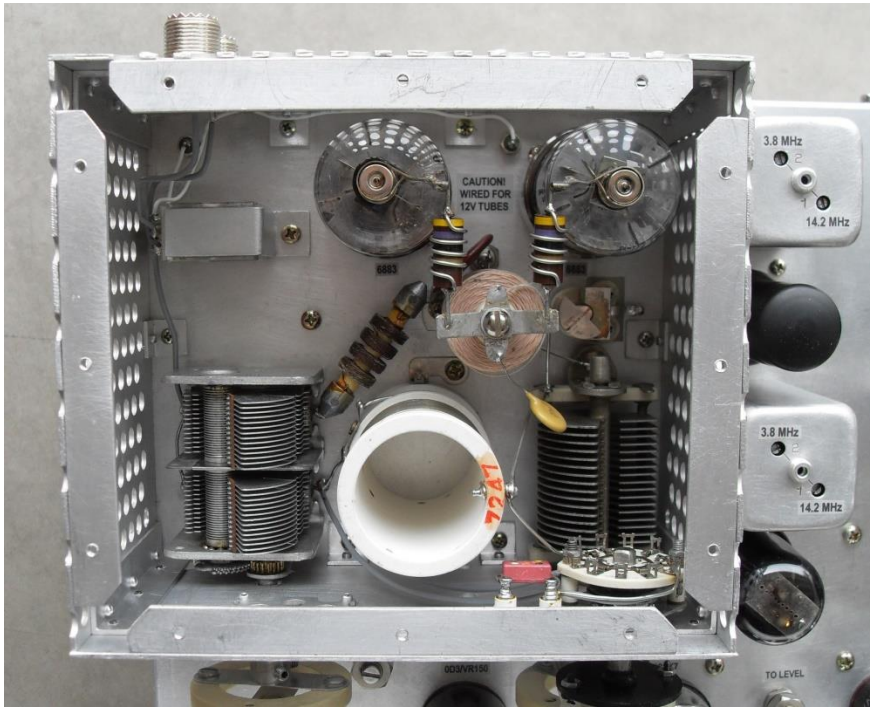




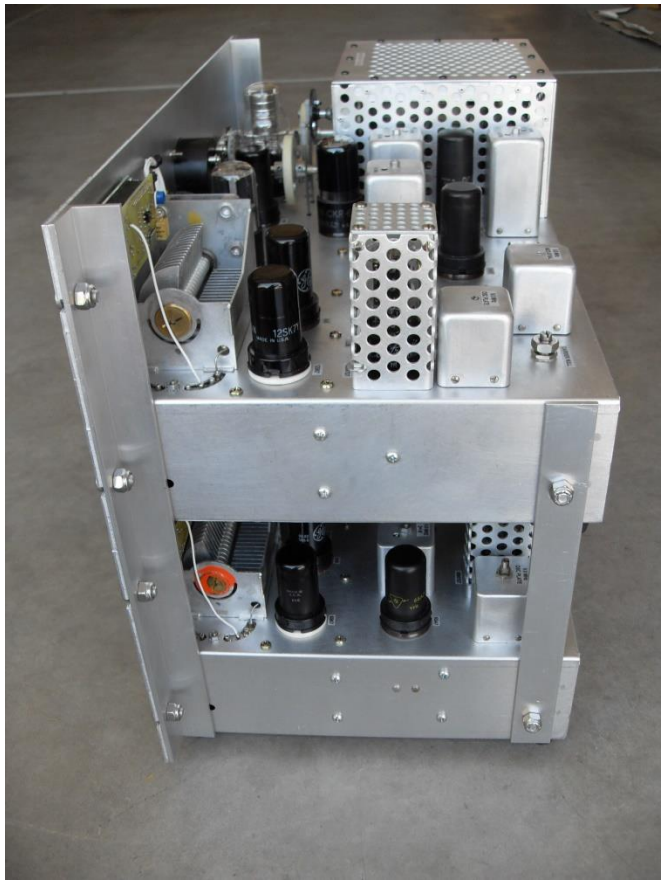
Transmitter Top & Bottom

Receiver Top & Bottom

Octalmania!



Inside PA Cage. Pair of 6883s (12 volt version of 6146) deliver 100 watts PEP. Coil wound on ARC-5 PA form. Antenna relay is at upper left.

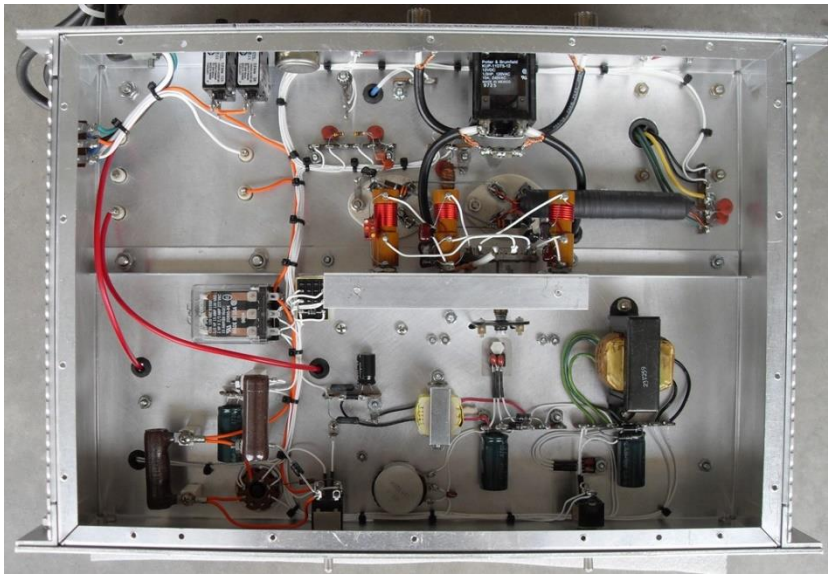


Side view shows simple stacking method.

HB-600 Linear

- Basically a Heath SB-200 clone
- Pair of 572Bs in grounded grid put out about 600 watts PEP
- Cabinet designed so Octalmania pair can sit on top

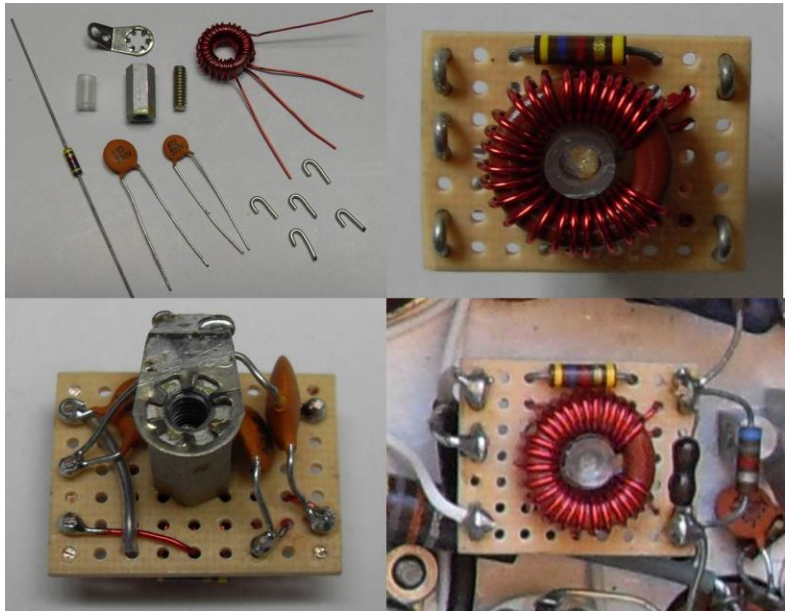
HB-600 Linear

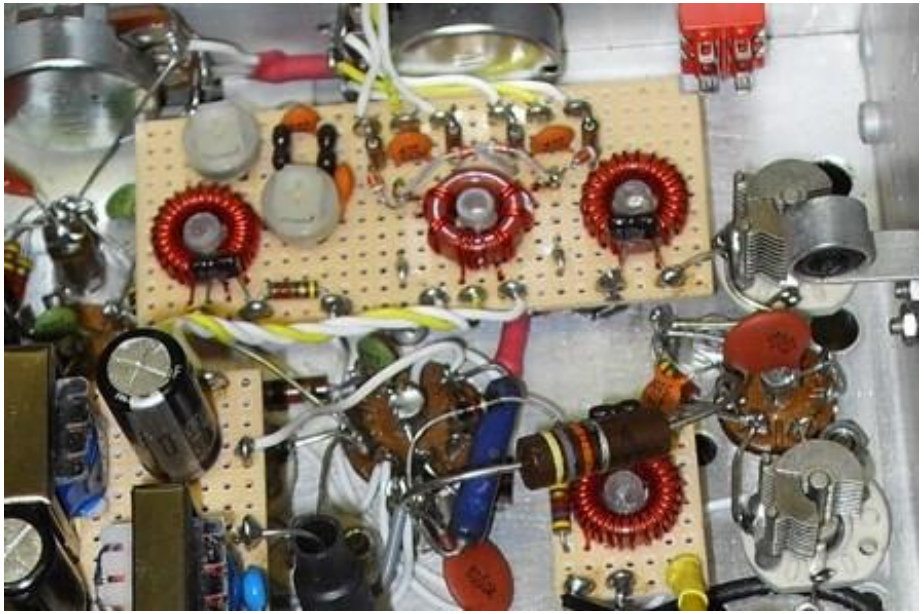


Voltage doubler delivers about 2,700 VDC no load. PA coil is wound on a form from a TU-5 unit. Bandswitch is heavy duty unit made by Radio Switch Corp. Plate transformer was a NOS military unit from Surplus Sales, but they are now out of stock.

Input is tuned by bandswitched pi-net circuits. A 3 second soft start circuit is used in the HV supply. The filament choke was made from an Amidon kit.

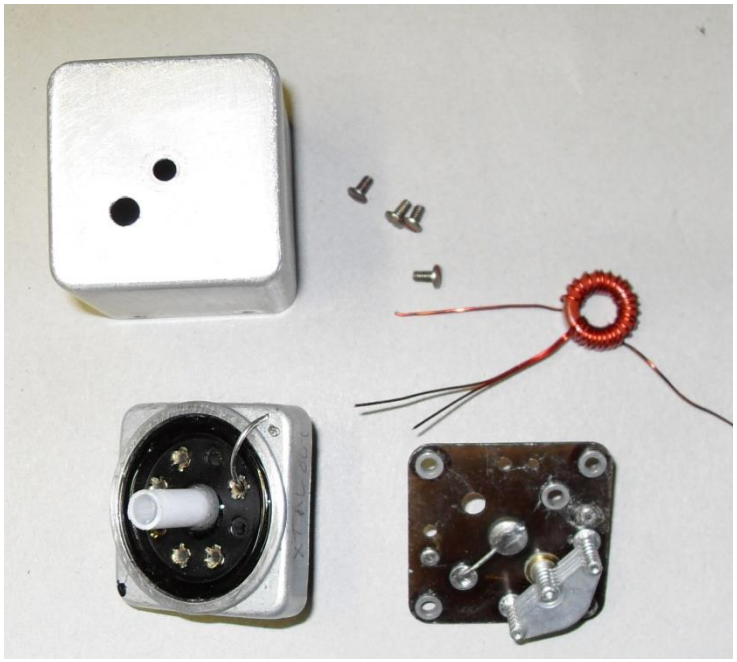
Tubes & Toroids

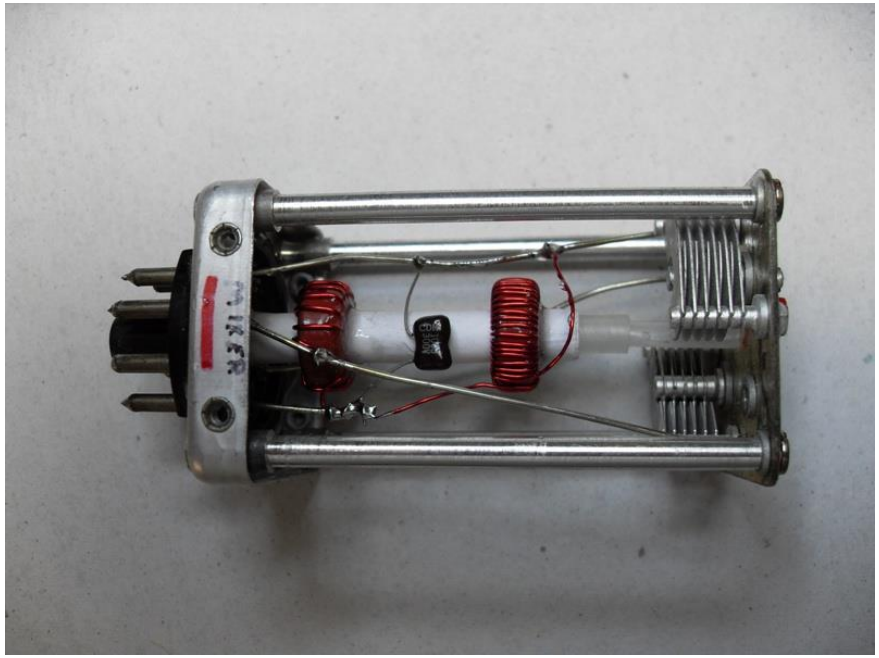




Perf board and threaded spacers provide one way to mount toroids. You can also mount ancillary parts on the board. Simple loops of tinned #18 wire can be pushed into the board and used as terminals for external connections.

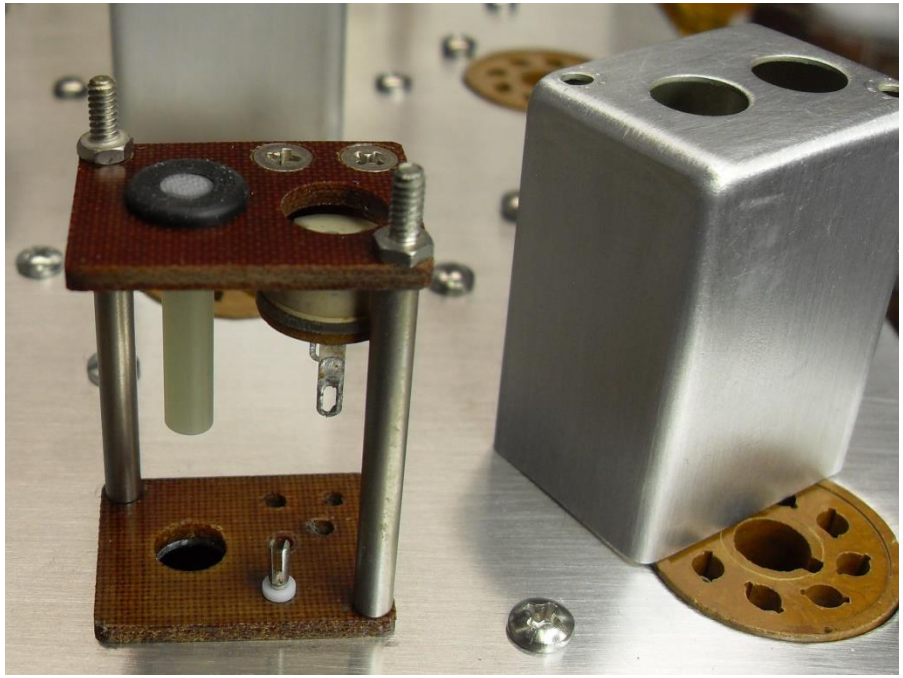
Tubes & Toroids

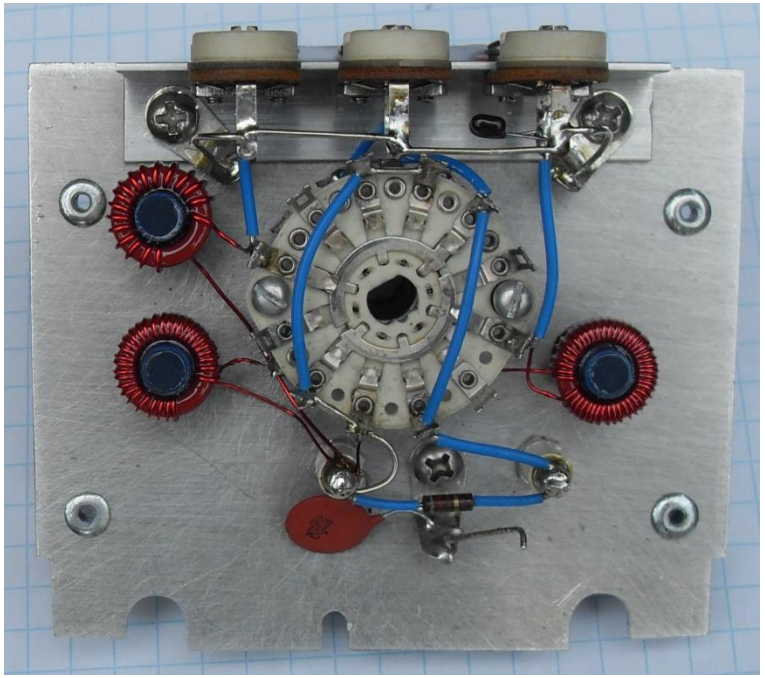




Examples of ways to make a shielded coil using a coil can from an ARC-5 receiver. Most of the Octalmania coils were made this way. Note that the original air variables are used to resonate the circuit.

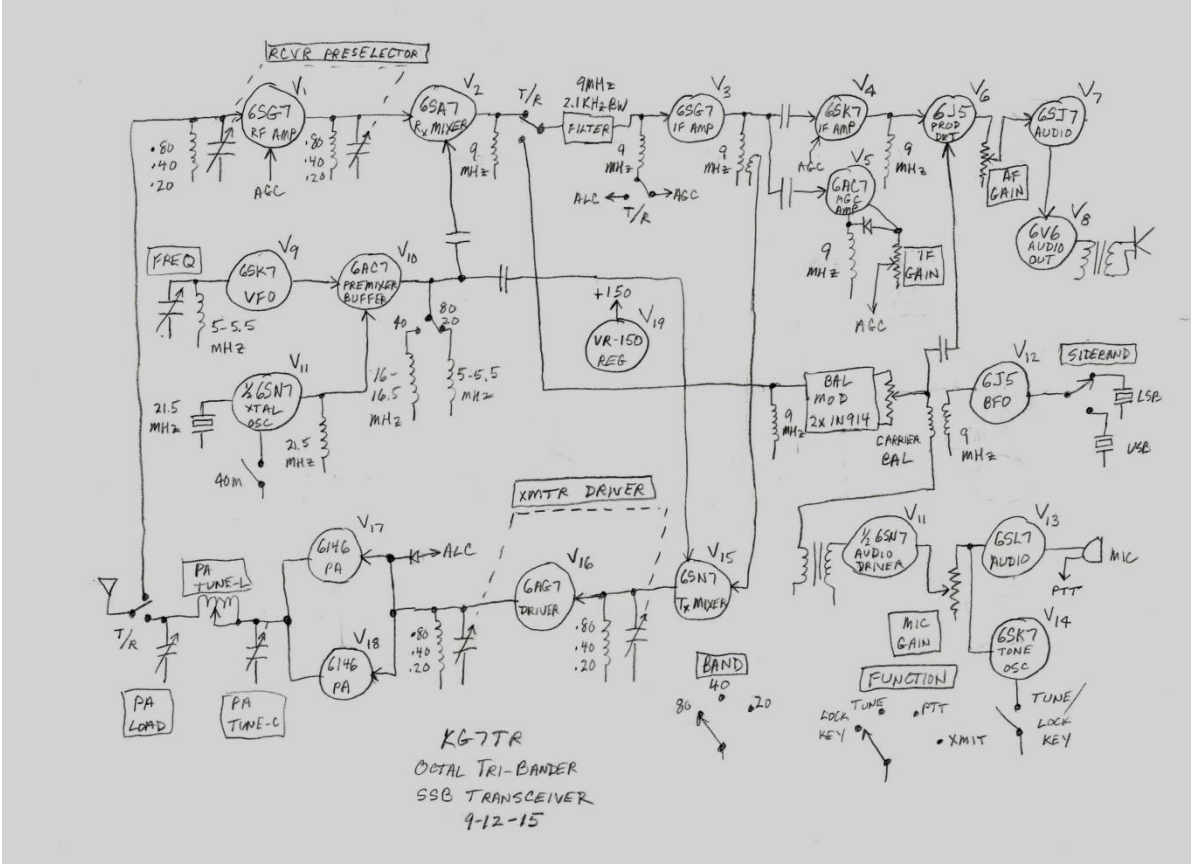
Tubes & Toroids





Coil construction used in the Octal Tri-Bander transceiver. At left, coil can and internal parts are from an airborne transceiver. Fiberglass peg is pushed into rubber grommet. Toroid will be epoxied to peg and ancillary components mounted on standoffs on bottom fiber base. At right is shown a removable bandswitch section. Fiberglass pegs pushed into a grommet are used here as well. In both cases, diameter of the peg is increased with masking tape to make a snug fit of the toroid.

Block Diagram



If the project will be complex, I sketch out a block diagram of the major parts and circuits. This is the rough diagram I used for the Octal Tri-Bander.