The Vintage SSB Special Radio Set– Part 2

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Note: This is an update that consolidates the articles that originally appeared in Electric Radio (ER) magazine in the summer of 2010. Pictures and schematics appear at the end of this document. - MB

Introduction

This is the second of a two-part article describing construction of a homebrew receiver and transmitter for 20 meter SSB operation. Part 1 of the article covered the transmitter. The matching receiver described here in Part 2 allows transceive operation with the transmitter.

Part 2 – The Receiver

Background

After completing the Vintage SSB Special transmitter I started pondering what might be a suitable receiver to use with it. I initially set up the transmitter with my trusty Drake 2-B, but really wanted the convenience of a transceiver. I knew there weren't any commercial tube rigs that would provide the exact VFO and carrier signals needed for the transmitter, so the decision was made to homebrew a matching receiver. I had an extra Command transmitter chassis and the necessary VFO parts left over from the transmitter project, so this was a good start. In addition, years ago had I picked up a McCoy 9 MHz crystal filter and matching BFO crystals at a hamfest, so a configuration of the receiver began to emerge. I had never built a complete receiver before, and at first thought it should be easy. I soon discovered that receivers present challenges just like transmitters. Although the construction and testing went a little faster than the transmitter as a result of lessons learned, it still took almost five months to complete the receiver shown in Figure 1. This radio shares some of the circuits and construction techniques used in the transmitter. The BNC jacks on the side are physically aligned with those on the transmitter to allow connection for transceive operation using standard adapters. When all was finished the primary mission was accomplished – no need to spot frequency before keying the transmitter!

Overall Circuit Description

The receiver schematic is shown in Figure 2. The top and bottom views are shown in Figures 3 and 4 respectively. The parts list appears at the end of this article. A total of ten tubes are used, with power coming from an external supply. The receiver covers 14.0 to 14.4 MHz and uses conventional design. The 5MHz VFO and 9 MHz BFO/Carrier oscillator are virtually identical to the transmitter circuits. Antenna input at J1 is coupled to the grid of V1, an RF amplifier whose output is fed into the signal grid of mixer V2.

Coils L1 and L2 are peaked to the incoming signal frequency using dual-section variable C2 in what is commonly called a preselector. The 5 MHz VFO signal from V8 is applied to the injection grid of V2, and the resulting 9 MHz IF is coupled to the input of FL1 from the link on L3. The signal at the output of the filter is coupled to V3 via a link on L9. L9, C12 and the 100 pf capacitor are enclosed in a shield due to their proximity to L3.

The filter used in the original build of the radio was a McCoy “Silver Sentinel” unit, with a 6 dB bandwidth of 2.7 KHz. The bandwidth was a little broad for today’s bands, and as a result I was frequently getting adjacent channel QRM. Ten years after the radio was built, I obtained a filter from a Galaxy V transceiver, courtesy of WB0SNF. This filter has an advertised 6 dB bandwidth of about 2.1 KHz, so it did a better job than the McCoy, but it was still a little wide for some ever present QRM on the VSSB net. Plus, as used in the Galaxy transceiver, this filter worked into a special tuned network that may have affected its bandpass. I was unable to duplicate that circuit.

So the final configuration ended up with a modern INRAD #2309 filter that I have used in several other radios with good results. The original McCoy BFO crystals were retained. The INRAD filter specifies 500 ohm input and output impedances, so appropriate resistors are connected across the filter. The McCoy and Galaxy filters have been put away for possible future projects…

Following the filter are two stages of IF amplification provided by V3 and V4. The IF output at L5 is coupled to the grid of V5, the product detector. The BFO signal is injected into the cathode from the link on L8, which also provides the DC return for V5. Those familiar with the R-390A will recognize that the 6C4 mixers used in that famous boat anchor are similar to the product detector circuit shown here. The difference is that the product detector output is at audio frequency. The unwanted RF products at the plate of V5 are filtered out by the RC network and the resulting audio is connected to the top of R1.

The audio at the wiper of R1 is fed into the grid of V6A to provide voltage amplification before going to the audio output stage at V7. V6B was originally used for an S meter circuit that was later modified to use V4 instead, so this tube section is no longer used. At the same time, V6 was changed from a 12AT7 to a 12AX7A to provide more voltage gain.

The output of T1 is sent to a headphone jack and an RCA jack for the speaker. The speaker is cut off when headphones are plugged in. The 6AQ5 used at V7 should ideally work into a 5k ohm primary, but transformers like that small enough to fit under the chassis are hard to find. So T1 ended up being selected from a pile of small, unmarked output transformers obtained at a hamfest. Most were likely from series-string BC receivers, meaning they have about a 2.5k primary.

The VFO circuit is identical to the transmitter with two exceptions. A 6GH8 is used for V8 because it provides more output power to offset losses resulting from driving the loads in both the receiver and transmitter. The output of the VFO is connected to the transmitter through BNC jack J2 for transceive operation. The resulting injection voltage at the transmitter mixer is the same as that coming from the transmitter’s 6U8 VFO tube. The other difference is that only 12 pf was needed across C8 to resonate the trap at 15.9 MHz.

The BFO/Carrier oscillator is also the same as the transmitter, except that the two sections of V9 provide selectable sideband by grounding the appropriate cathode with S1. Trimmers C10 and C11 are also connected across the crystals to allow setting the carriers to the optimum frequencies relative to the filter side slopes. The output of the carrier oscillator is connected to the transmitter through BNC jack J3 for transceive operation.

The IF voltage at the primary of L5 is coupled to diodes D1 and D2 to develop AGC voltage. The voltage divider at the cathode of D2 puts about +1.7 volts bias on D2's cathode. As a result, AGC rectification is delayed until the signal at the antenna input reaches about one microvolt. Negative going voltage appearing at the anode of D1 is applied to the control grids of V1 through V4. The AGC voltage is filtered by the .047 µf capacitor connected across the 3.3 megohm resistor in the FAST position of S2. In the SLOW position an additional .15 µf is added to provide more hang to the AGC characteristic. The 22k resistor in series with these capacitors allows some delay in charging them to prevent static "pops" from swamping the AGC. The other end of the 3.3 megohm resistor is connected to the wiper of RF gain potentiometer R2. This control is connected in a voltage divider across the -130 VDC bias. As the RF gain is rotated CCW an increasing negative voltage is applied to the AGC bus, thus reducing overall gain. The R2 I used is a reverse log taper control, which slowly decreases the signal until about S9, then rapidly decreases it to minimum. Of course a regular standard taper can also be used.

To mute the receiver during transmit (i.e., with S3 in STBY and the MUTE line open), the normally grounded end of the 180 ohm resistor in the divider is run through a 12 kohm resistor. The resulting bias on the AGC bus cuts off all the tubes. For transceive operation the MUTE jack is connected directly to the RCVR MUTE jack on the transmitter and S3 is set to STBY.

The AGC and mute circuit are a simplified version of that used in the Collins 75S-3. Some purists might question applying AGC to the mixer, but testing showed that better loop control resulted by doing that. I did note that AGC is applied to the first and third mixers in the Drake 2-B, so it is not without precedent.

V4 is also used to control the S-meter. Negative AGC voltage applied to its grid reduces the current through the tube and the associated voltage at the cathode, which is connected to the negative side of the meter through a resistor network. The positive side of the meter is connected to a fixed reference voltage of +0.7 volts provided by the cathode current of V7 flowing through D3. As the cathode voltage of V4 decreases in response to AGC voltage, the meter reading increases. R3 is used to set the meter to zero in the operate mode with RF gain full CW and the antenna terminals shorted. With 50 microvolts at the antenna the meter reads approximately S9 at half scale in accordance with modern standards. Its calibration is not perfect over the total dynamic range of the receiver, but then what S-meter in a vintage tube radio ever was? Diode D4 limits the voltage across the meter to about 180 millivolts to protect the movement when in standby, or with RF gain at a minimum.

All power comes in through chassis mounted octal connector J7. The radio requires 200 VDC at 120 milliamps for B+, 6.3 VAC at 3.0 amps for filaments and -130 VDC at 3 milliamps for bias circuits. Voltage regulation for both oscillators is provided by V10. Sharing the Heath HP-23 transmitter power supply was originally considered, but the added power requirements of the receiver would have been too much. A separate power supply for the receiver was constructed using a modern Antek toroid transformer. The power supply schematic and parts list are shown in Figure 6. It was packaged along with a four inch speaker into in a repurposed cabinet from a HP 204 audio oscillator, as shown in Figures 7, 8 and 9. Besides taking care of the speaker problem, the separate supply allows listening to the receiver without having the transmitter powered on.

Construction Details

Much of the construction information detailed in the transmitter article applies to the receiver and won't be repeated here. For the receiver, the 1625 sockets are removed by tapping the rolled edge lip with a small chisel and hammer. After enough perimeter is bent inward the socket can be pulled out. If care is exercised the sockets will still be in reasonable shape if you want to use them for something else. Like the transmitter, to provide mounting for the miniature tube sockets .125 aluminum sheet was cut to size and installed over the octal socket holes at the rear and the large holes from the 1625 sockets.

Looking at the top view of the chassis in Figure 3, starting at the front V1 is adjacent to the dual section variable C2. On the other side of the chassis is V2 behind the AF Gain control and AC switch. V10 is directly behind C2. In the center of the chassis is V5, with crystal filter FL1 next to it. V3 is directly behind FL1, with V4 in the center and V9 behind BFO crystals Y1 and Y2. At the rear behind the VFO shield are V7 in line with FL1, V6 in the center and V8 on the other side.

The general layout at the front of the chassis was driven by the need to incorporate some kind of frequency dial. In addition C2 had to be mounted in a practical position. In the pile of Command transmitter parts that had been accumulated was a front variable capacitor with a broken stator but otherwise usable for the dial. All rotor and stator parts were removed so that the only thing left on the frame was the worm gear and the dial gears. The frame was mounted at the front using the original holes so the dial and VFO driveshaft arrangements remained the same as in the original transmitter. With no stator or rotor there was enough room inside the frame to mount the sockets for V1 and V2 as shown in the chassis bottom view at Figure 4. Besides making use of all available space and providing a dial, using the frame in this configuration provides a measure of shielding for the two RF stages.

During build up and testing of the RF and IF stages it became apparent that shielding would be necessary between the various circuits. The various vertical shields that were used are shown in Figure 4. Horizontal shields were removed for this photo to show the circuitry underneath.

It is especially important to keep the grid and plate circuits of V3 and V4 shielded from each other. Besides the main shield running vertically between L4 and L5, a small shield made from brass sheet was bent into an "L" shape around pin 1 of V4. The shield was soldered to the center pin of the socket and grounded to the chassis. The 33 ohm grid resistor from the previous stage was then fed through a small groove in the bottom of the main shield. Additional horizontal shields were added over V4, V5 and BFO circuits. Stray signal from the BFO circuit must be kept away from the IF amplifiers or it will get amplified and fed into the AGC detector. This is turn will reduce the gain of the receiver. The BFO injection to V5 was fed through a wire that fits under a groove in the main shield. At V1, the L1 tank circuit is isolated from the plate and L2 by the frame of the stripped down variable capacitor described earlier. The 33 ohm grid resistor was passed through a small hole at the bottom of the frame as shown.

As with the transmitter, VFO variable capacitors C6 and C7 were not installed permanently until everything was completed. The three main shields were also designed so that they could be temporarily assembled as a group and then slid down into place for testing. Grooves were filed into the bottoms of the shields where needed to clear wires or hardware. After final wiring was completed the shields were mounted securely. If a larger and wider chassis were being used it would probably be possible to lay everything out so less shielding would be required.

The various tuned circuits in the receiver use toroids and ceramic trimmers assembled and mounted using the same methods as the transmitter. One chief difference is that instead of a standoff terminal on each corner of the perf board, a small piece of tinned 18 gauge wire was bent into a half loop and the ends pushed through adjacent holes in the board. This turned out to be much easier and faster to do, plus it was a snap to add another loop when an additional connection point was needed.

Shielded wires were used for the audio and RF circuits as shown on the schematic. The AC switch wires from J7 to S4 are a shielded twisted pair. The cabinet and front panel were constructed and finished in the same manner as the transmitter and so will not be described here.

The Front Dial

Because a new front panel was fastened to the front of the radio the Command set dial contacted it when installed in the original manner due to the extra thickness, thus preventing rotation. Attempts to cut some metal off the back of the original dial to compensate for the panel thickness were not very successful. So as plan B a large flat dial disc from an old knob was mounted to a large washer that just fit over the dial gear threads. The dial was fastened to the washer with three countersunk screws. A cursor was fashioned from a .125 piece of Lucite, which was scribed in the center and mounted on spacers to hang over the dial. A slot was cut in the bottom of the pilot lamp jewel so light could shine into the cursor. These details are shown in Figure 5. A temporary paper dial was taped to the disc for rough alignment and check out.

After preliminary alignment the final dial calibration was performed. The dial disc was removed, sanded and painted black, then remounted to the radio. The Lucite cursor was removed and a temporary metal fixture was crafted having a vertical surface in the same position as the cursor scribe. This fixture was mounted to the spacers and a dental pick was carefully pressed against its vertical surface to cut a line into the paint at the desired calibration points. Long lines were scribed for the 100 KHz points, medium lines for the 50 KHz points, and short lines for 10 KHz. Calibration was performed with the radio thoroughly warmed up and the sideband select switch in USB. The dial drive runs at about 9 KHz per revolution and the BFO crystals are about 3 KHz apart, so the position of the sideband selector definitely makes a difference. If a lot of QSY is anticipated a spinner knob is a must. After calibration the dial disc was removed and rub-on numbering transfers applied at the 100 KHz points. The disc was then sprayed with matte clearcoat and reinstalled.

The Digital Frequency Display

In July, 2022, an outboard digital frequency display was added to the receiver. The counter/display module is housed in a plastic box, and sits on top of the radio as shown in Figure 10. Associated circuitry is shown in Figure 2. A connector pair with .1 inch spacing is used to connect the display to the radio, with the female side passing through the top cover. This allows the display to be removed if only the analog display described previously is preferred. In this case, the female connector can simply be pushed into the grommet in the top of the cabinet for storage. This connector must also be pushed all the way through the grommet in order to remove the top cover of the radio, and pulled back through to reinstall it.

RF voltage from the VFO is sampled through a capacitive divider, and fed into the counter through a shielded cable. The shield also provides the ground for the power to the counter. 6.3 VAC filament voltage is half wave rectified and filtered to provide about 8 VDC. RFC4 keeps high frequency noise generated in the rectifier diode from getting into the receiver circuits.

There is an oval hole cut into the back of the display case to access the programming buttons. The display instruction sheet is currently available on the mpja.com website. The counter/display module is programmed with an IF offset, such that the displayed frequency is the measured VFO frequency plus the IF offset. Display resolution and brightness are also adjustable via these buttons.

Note that only a single offset can be programmed with this unit, and it can only be set to the nearest .1 KHz value. Therefore, it is set up for the most predominant mode of operation, which is USB, in the transceive mode with the transmitter connected. The end result is that the offset is set to 8998.6 KHz. The BFO was tweaked within this range to get about 10 to 20 Hz accuracy. The bottom programming button can be used to toggle between 100 Hz and 10 Hz resolution (i.e., one or two decimal places). With 10 Hz resolution the first digit (“1”) will go away. So instead of “14.xxx.x”, you will see “4.xxx.xx”.

Final Alignment and Testing

Setup and alignment of the receiver is pretty easy. When all is ready connect a speaker and apply power. Assuming a successful smoke test, glowing filaments and B+ in all the right places, turn up R1 and touch the high side of it with a screwdriver. You should hear hum if the audio circuits are working. For IF and RF alignment a signal generator with decent stability is required. The receiver S-meter can be used as a peak indicator and should be initially adjusted as described earlier. The VFO is setup as described for the transmitter. The tap on L6 should be adjusted to give the desired bandspread. With V8 and V9 removed from their sockets, the IF circuits are aligned first by injecting a 9.0 MHz signal into pin 1 of V2 and peaking C3, C12, C4 and C5 for maximum S-meter reading. The receiver needs to be in the operate mode with RF GAIN turned full CW, and the injected signal needs to be within the FL1 passband. As always, there should be two peaks observed in a full rotation of each trimmer.

Next reinstall V8 and V9 and monitor the RF output at J3 with a VTVM and RF probe or a scope and 10X probe. Set C10 and C11 to mid-range and adjust C9 for maximum signal, then go a little beyond this point down the side of the slope where V9 continues to oscillate. Switch to the other sideband and make sure V9 still oscillates. Note that when connected for transceive operation, this trimmer may need to be reset to reestablish oscillation due to the additional load impedance of the transmitter. At this point it should be possible to hear a beat note from the signal generator in the speaker with R1 turned up. Now remove the 9.0 MHz signal and inject a 14.2 MHz signal into J1. It should be possible to get a beat note with the VFO set to around 5.2 MHz. Peak C2 for maximum signal, then C1. Repeat this adjustment. Now try signals at 14.0 and 14.4 MHz. At each endpoint it should be possible to peak the signal with C2 to the same strength on the S-meter. Little or no readjustment of C1 should be required.

The BFO crystal settings are somewhat a matter or preference. The usual rule of thumb is to set the frequency 20 dB down the filter slope. If you are using a signal generator with a calibrated attenuator this can be done by peaking the test signal in the passband and noting the S-meter reading. Then zero beat the signal and increase the generator attenuator by +20 dB. If you get the same S-meter reading as before, the BFO crystal is set to the 20 dB point. If not, adjust the crystal trimmer until this happens. If you move the crystal frequency too far into the filter passband you may go past the AGC threshold and see some S-meter movement. You will also note that the farther down the slope you put the BFO the tinnier the audio sounds. Conversely, as you move closer to the passband the audio will get more bassy. So the optimum setting is somewhat subjective. These adjustments should also be made in the transceive configuration if that will be the predominant mode of operation.

Transceive Operation

For transceive operation the BNC jacks are connected using male-male adapters and the switches in the transmitter are placed in the transceive position. Note that both the transmitter and receiver need to be set for the same sideband. It was noted that if the BNC jacks are connected and the transmitter switches are in the NORM positions, a constant beat note will be produced in the receiver due to feed through from the transmitter’s oscillators. So if separate operation is desired, the BNC adapters must be removed. The transmitter carrier balance is very sensitive to the phase and amplitude of the 9.0 MHz carrier being injected into the balanced modulator, so if the opposite sideband is selected or the normal/transceive mode is changed it will be necessary to rebalance the carrier. I also recommend aligning the transmitter’s balanced modulator, and C9, C10 and C11 in the receiver for the primary mode that will be used. For me this is transceive mode on USB.

When the radios are in the transceive mode the carrier can be nulled by placing the transmitter in the SPOT mode and adjusting the balance controls for minimum reading on the receiver S-meter. I have found the best way to make the final adjustment of the balance controls is to key the transmitter with MIC GAIN set to zero and adjust for zero forward power on the SWR meter. This really gives a sensitive adjustment with the linear on and the SWR meter set to low range.

Overall Receiver Performance

It was never the objective of this project to create the hottest radio ever made. The circuits were mix and match taken from radio handbooks and commercial rigs. Those well versed in receiver design would probably advise use of a low noise tube at V1, better coupling methods between stages to get more gain, and various other hints and kinks. What I do know is that even without such refinements a very weak signal on this homebrew receiver doesn’t sound much different when tuned in on my 75S-3, so I don’t think the radio has any major sensitivity problems for practical use. I didn’t make any sensitivity measurements, but as built the AGC threshold is around 1 microvolt. The selectivity with the INRAD filter is adequate for vintage radio QSOs. The stability of the receiver is the same as the transmitter and is very good. After a 15 or 20 minute warm up I can listen to a QSO from modern synthesized rigs and not have to touch the main tuning for a long time. The AGC response and hang characteristics work fine for SSB. And the operating convenience in the transceive mode can’t be beat. When the microphone is keyed the transmitted signal only changes by about 10 Hz from the receive frequency based on measurements. That’s not bad for a tube radio.

In Conclusion

From start to finish it took one year to complete the Vintage SSB Special Radio set, including drawing up the schematics, taking photos and writing the two part article. Once in a while my patience was taxed, but overall it was a lot of fun to build and document these gems.

Parts Lists for the Vintage SSB Special Receiver

C1, C3, C4, C5, C8, C9	4.5-25 pf ceramic trimmer, NPO or Type A temperature characteristic	
C2	Dual section 15 pf variable	Hammarlund HFD-15-X
C10, C11	7-45 pf ceramic trimmer, N750 temperature characteristic	
C6	Command Xmtr VFO variable, rear unit, 150 pf	
C7	Command Xmtr VFO variable, range set, 180 pf	
C12	5-20 pf ceramic trimmer, N300 temperature characteristic (or same as C1)	
D1, D2	1N914 or 1N4148	
D3, D5	100 PRV GP silicon, 1N4002 or similar	
D4	1N270 germanium diode	
FL1	9 MHz SSB Crystal Filter, INRAD #2309 used here	
J1	SO-239 UHF Jack	
J2, J3	BNC jack, chassis mount	
J4, J6	RCA phono jack, chassis mount	
J5	Phone plug, shorting type	
J7	Octal chassis mount plug to mate with power supply cable	
L1	18 turns #24 on T50-2 toroid form, primary link 3 turns #24 over cold end	
L2	18 turns #24 on T50-2 toroid form, primary link 5 turns #24 over cold end	
L3, L5, L8, L9	22 turns #24 on T50-2 toroid form, secondary link 5 turns #24 over cold end	
L4	22 turns #24 on T50-2 toroid form	
L6	Command Xmtr VFO Coil, 7.0-9.1 MHz, modified; see text and photo in transmitter article	
L7	28 turns #26 close wound on .25 inch insulated rod	
M1	0-1 ma meter, 1.5 inch diameter, dial custom made	
M2	6 Digit LED Frequency Counter/Display, available from mpja.com or other internet sources, blue color LEDs used here	
R1	Panel mount, audio taper, with SPST switch	Mouser 31XP601-F
R2	Panel mount, reverse log taper used here, linear taper also suitable, composition	Mouser 31VA401-F is linear taper
R3	Miniature panel mount, linear taper, composition	Mouser 31CN201-F
S1-S3	Miniature toggle, SPDT	
S4	Part of R1	
T1	Audio output transformer, 5K ohms plate to voice coil	

Y1, Y2	LSB and USB crystals to match FL1, 9001.5KHz and 8998.5 KHz, INRAD possible modern source	

General Notes for Receiver Parts:

1. Fixed capacitors: Capacitors marked with an asterisk are silver mica, 500 volt rating. Capacitors with a plus sign are electrolytic. AGC time constant capacitors are mylar or polyester film, 100 volts rating. All other capacitors are disc ceramic, 500 volt rating.
2. Fixed resistors: Unless otherwise noted, all resistors are 0.25 watt, 5 percent tolerance, carbon composition or carbon film. 0.5 and 1.0 watt are 5 percent tolerance, carbon composition or carbon film. 10 watt is wire wound.
3. RF Chokes: All chokes except RFC4 are miniature epoxy coated, Mouser/Fastron type 434-23-xxxJ, where xxx is the inductance. RFC4 is 36 turns #26 on FT50A-43 ferrite toroid form.
4. Ceramic trimmers should have rotors connected to low side of circuit.

Figure 1: The Vintage SSB Special Receiver.

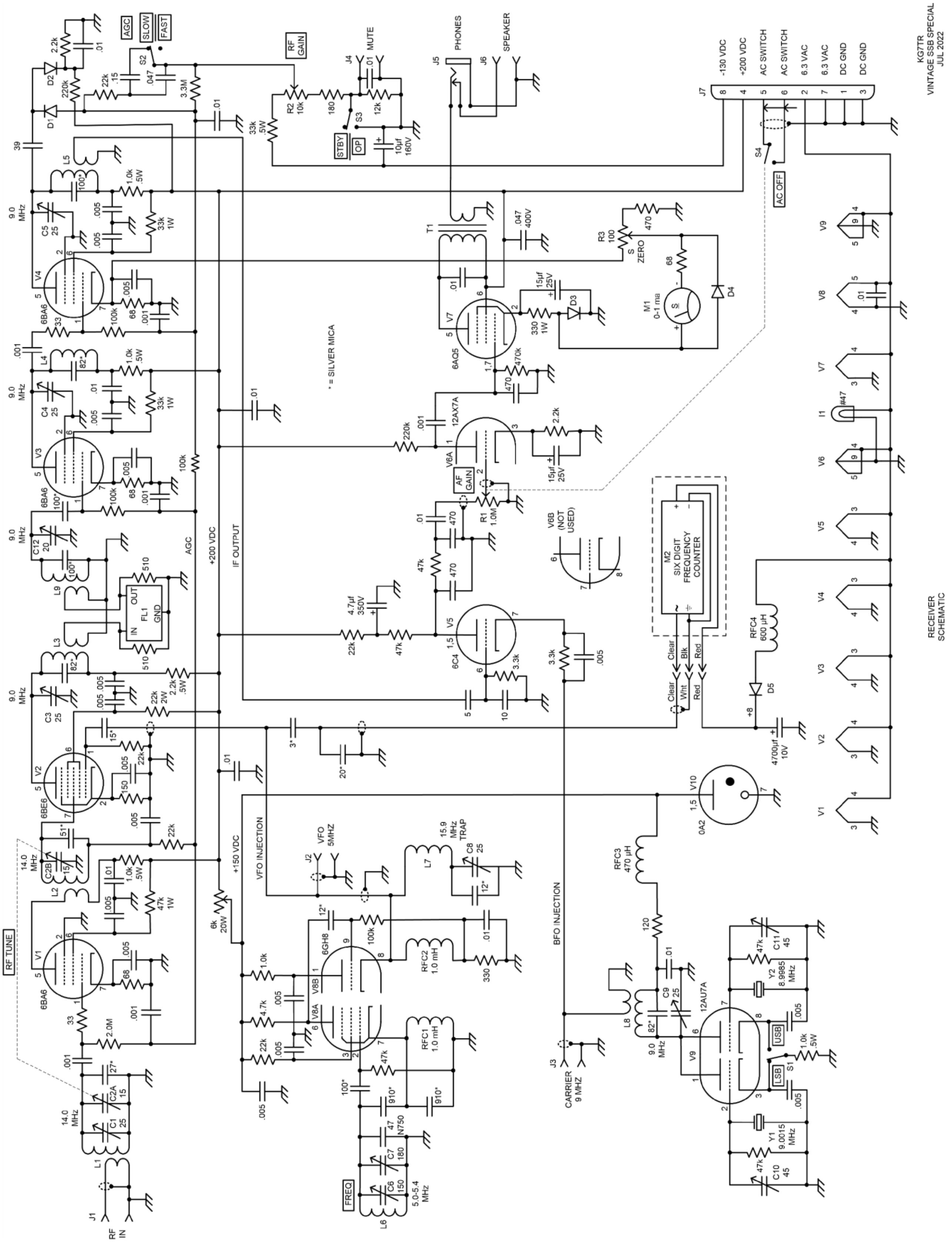


Figure 2: Receiver Schematic

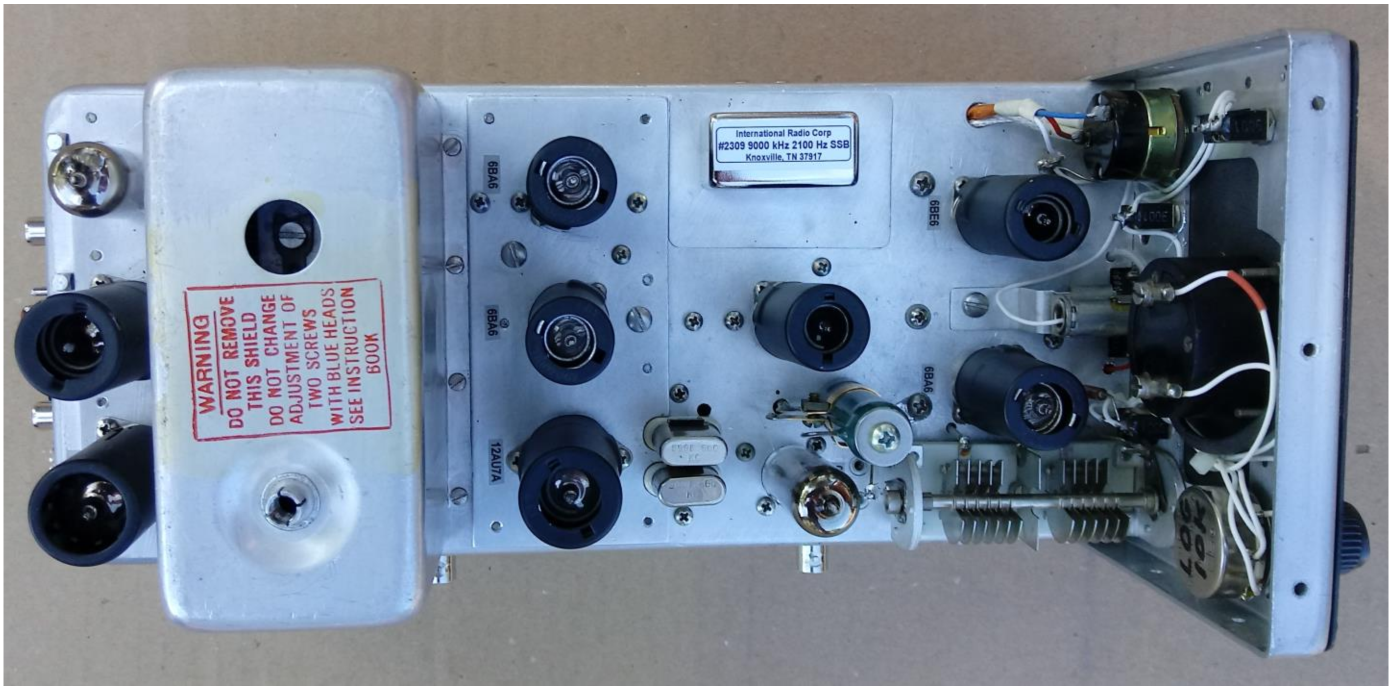


Figure 3: Chassis Top View

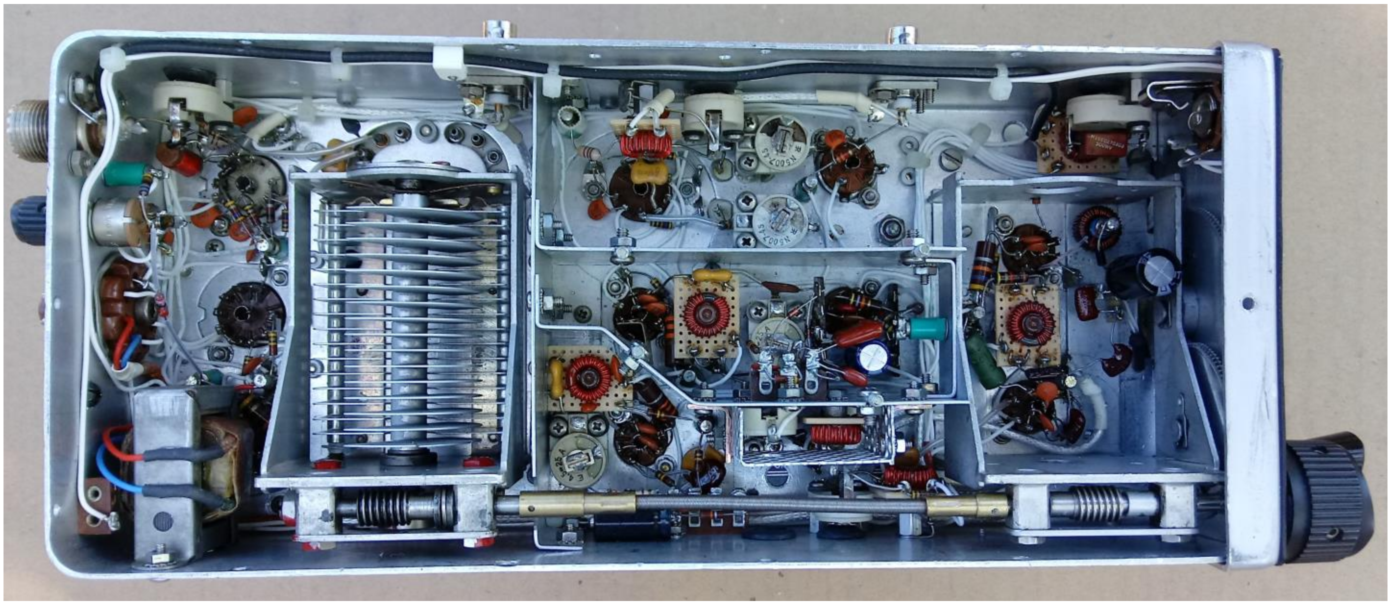
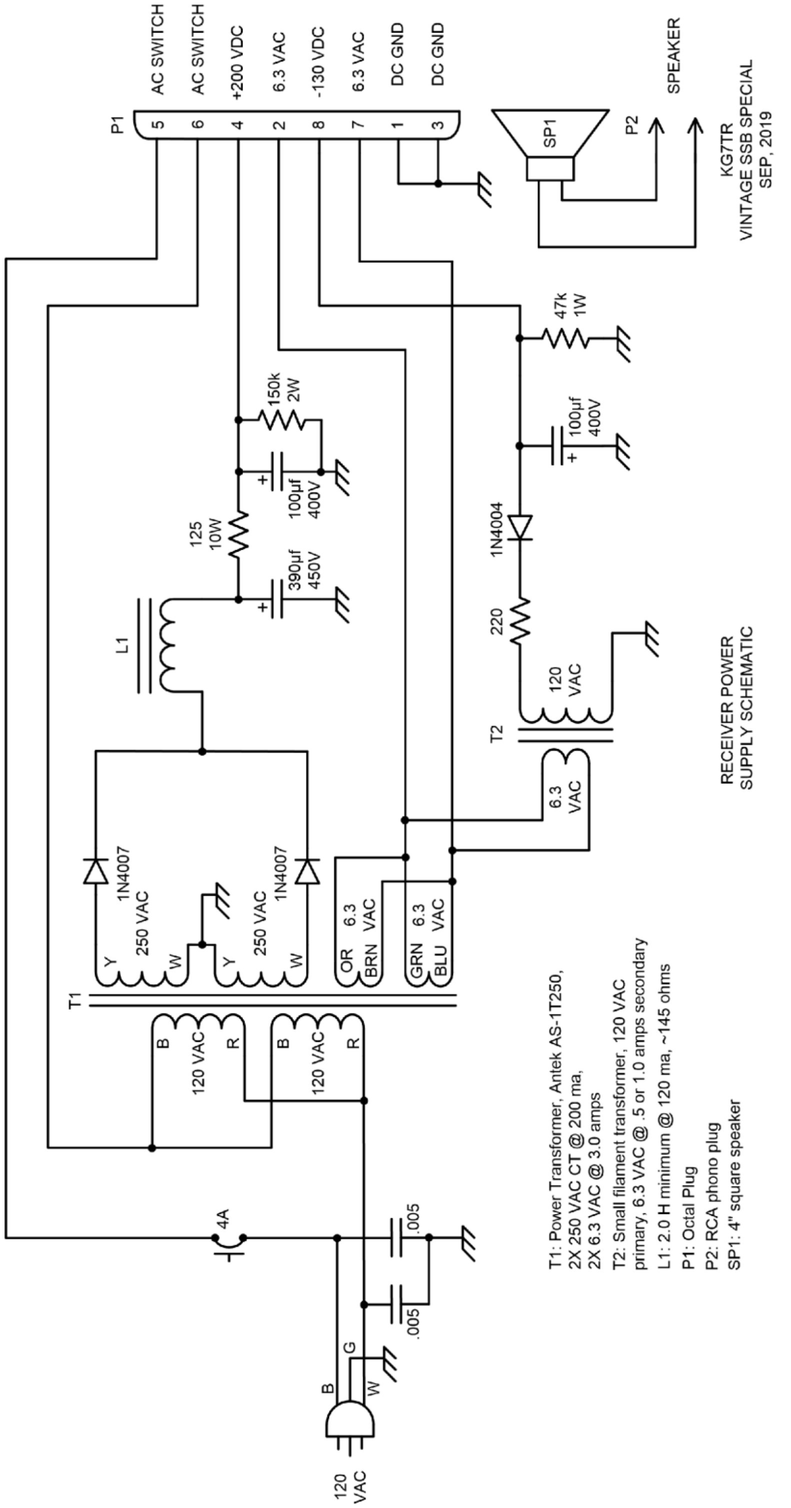


Figure 4: Chassis Bottom View (horizontal shields removed)

Figure 5: Custom Frequency Readout Dial



T1: Power Transformer, Antek AS-1T250,
2X 250 VAC CT @ 200 ma,
2X 6.3 VAC @ 3.0 amps

T2: Small filament transformer, 120 VAC primary, 6.3 VAC @ .5 or 1.0 amps secondary

L1: 2.0 H minimum @ 120 ma, ~145 ohms

P1: Octal Plug

P2: RCA phono plug

SP1: 4" square speaker

RECEIVER POWER
SUPPLY SCHEMATIC

KG7TR
VINTAGE SSB SPECIAL
SEP, 2019

Figure 6: Receiver Power Supply Schematic

Figure 7: Receiver Power Supply and Speaker

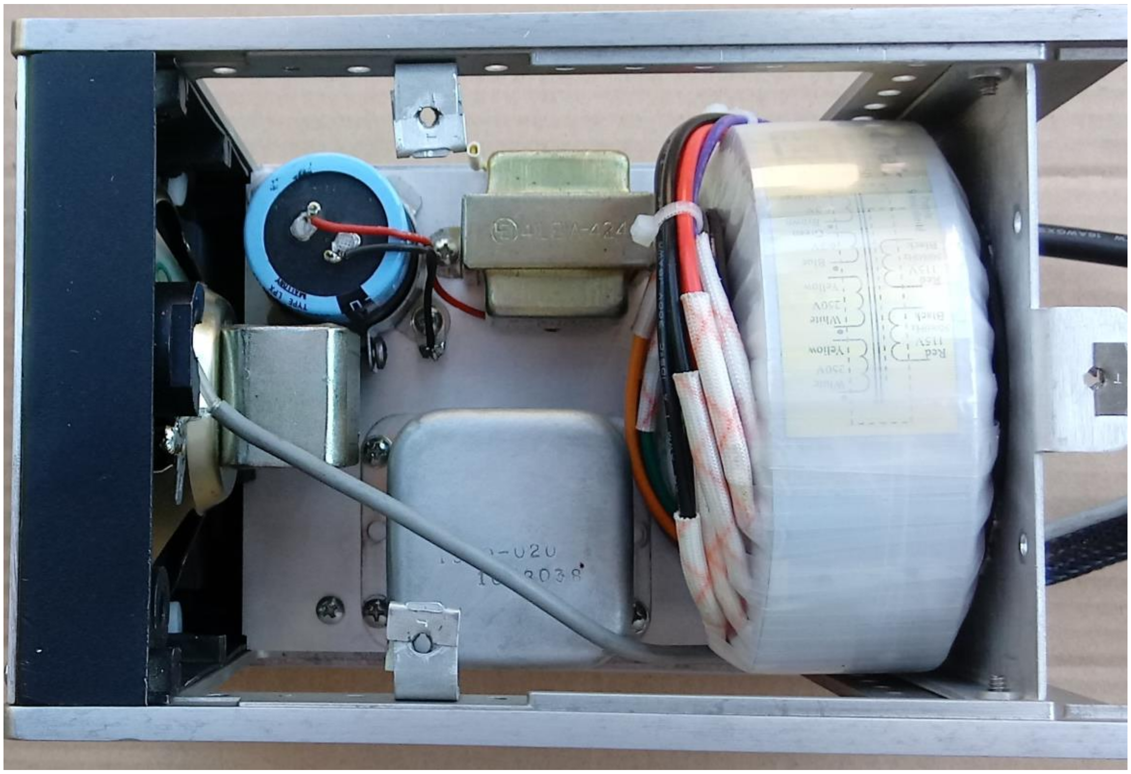


Figure 8: Receiver Power Supply Top View

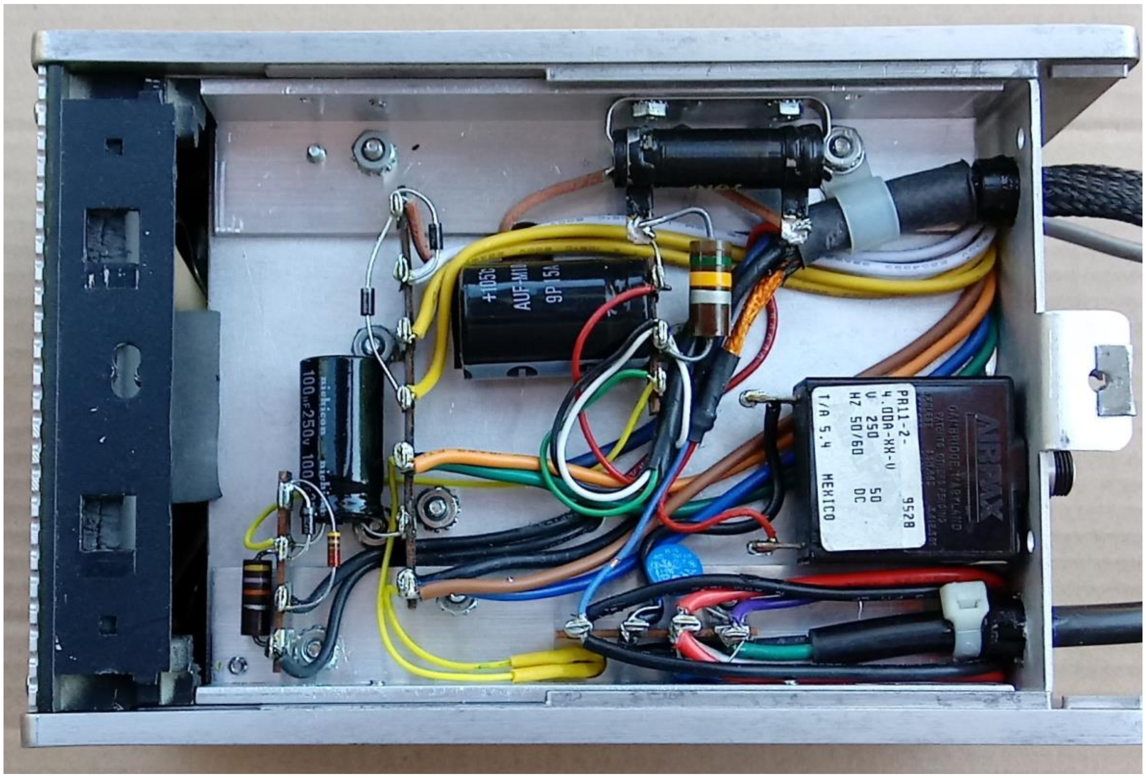


Figure 9: Receiver Power Supply Bottom View

Figure 10: Digital Frequency Display