Kenwood TS-930S Repair

<u>Problems:</u>

<u>Primary Issue:</u> The radio was not producing output. Specifically, it was producing very low output, on the order of 2-5 watts. The radio had previously produced full output.

<u>Secondary Issues:</u> The VFO knob was loose, and the frequency readout was erratic. When the VFO knob was rotated, the display jumped around, especially the tenths and hundredths segments. In addition, the band change buttons were "mushy", and the beep sound that accompanied the band changes was weak. Sometimes the display would go blank (dark) until another band button was pushed. Finally, one of the S-Meter lamps was out, and when the "DIM" button was pushed, instead of dimming, the working lamp went out.

<u>Preliminary Tests:</u>

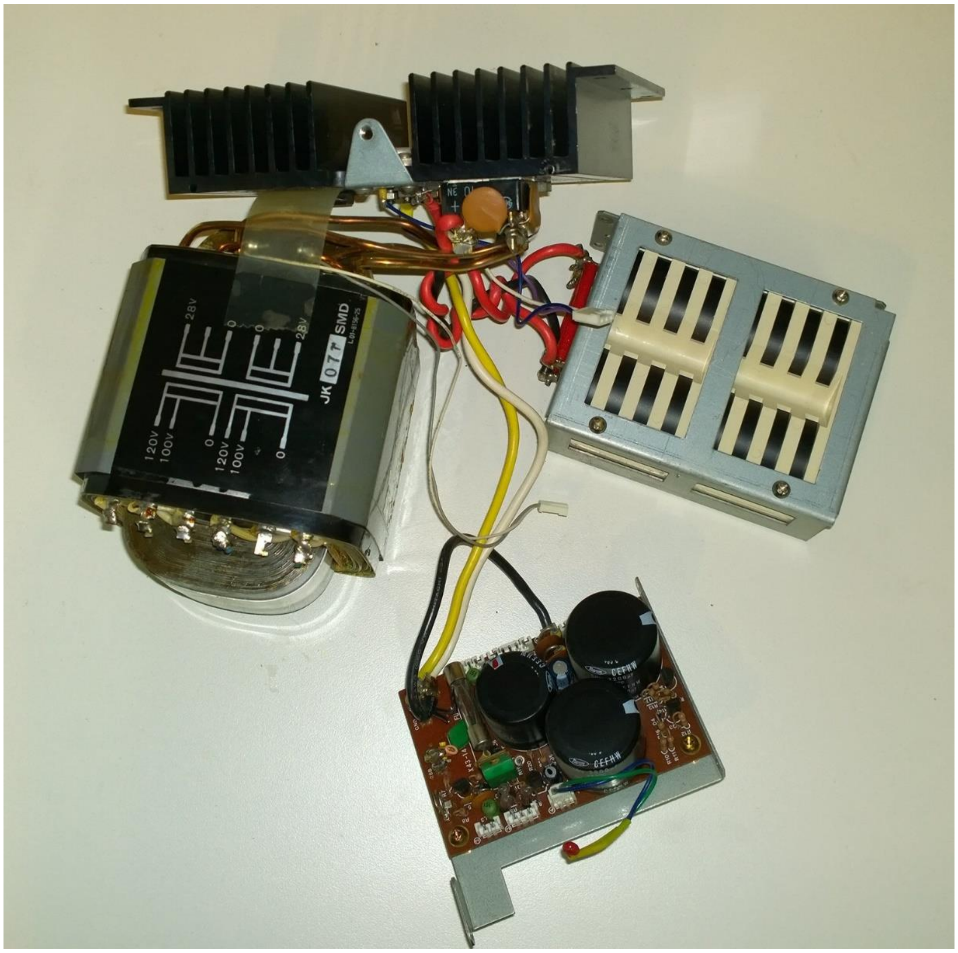
The panel meter and a digital multimeter showed normal voltage (Vc) of 28.5 volts, suggesting that the problem was in the Power Amplifier (PA), so I pulled the PA. I immediately noticed that the PA was an OEM unit with the desirable low-gain OEM Motorola "Red Dot" MRF485 drivers.

Resistance and diode tests showed that the Drivers and Finals were good, so I put the PA in my good, working 930S. It performed perfectly, producing full output. To protect this OEM PA, I replaced it with one of my rebuilt ones for the remainder of my testing and repair work.

During the installation of my spare PA, I moved some of the OEM power supply wires, and upon restarting the radio, it produced full power output, although it was inconsistent. Specifically, TUNE mode fluctuated from 40 to 65 watts. Since the main B+ measured the correct 28.5 volts, the logical conclusion was that one of the sub-voltages on the 21.7-volt line to the signal board and other circuits was incorrect or inconsistent. The fact that the front panel band pushbuttons were sloppy supported this theory. Band changes were weak, as was the beep sound that accompanies the band changes.

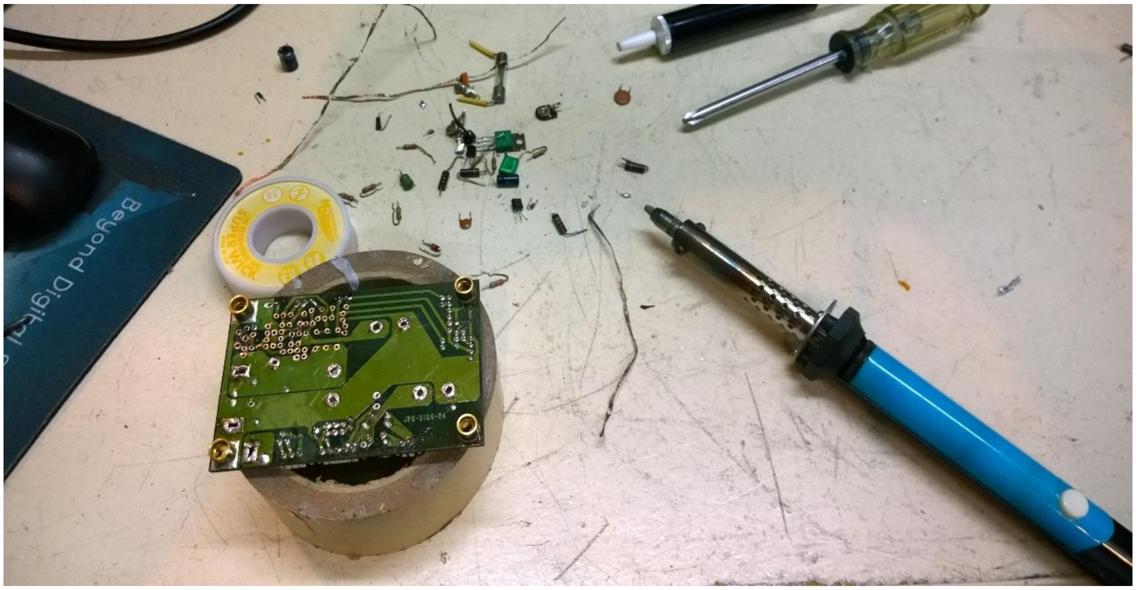
The first order of business was to gut the old power supply in favor of a modern switch-mode power supply from Phoenix Contact. I had just received two of the 20/26-amp models, brand new in the shipping box.

The only parts salvaged from the original power supply were the AVR board, and the Toshiba power transistor, insulating pad, and hardware that Kenwood uses to establish the 21.7-volt branch circuit.

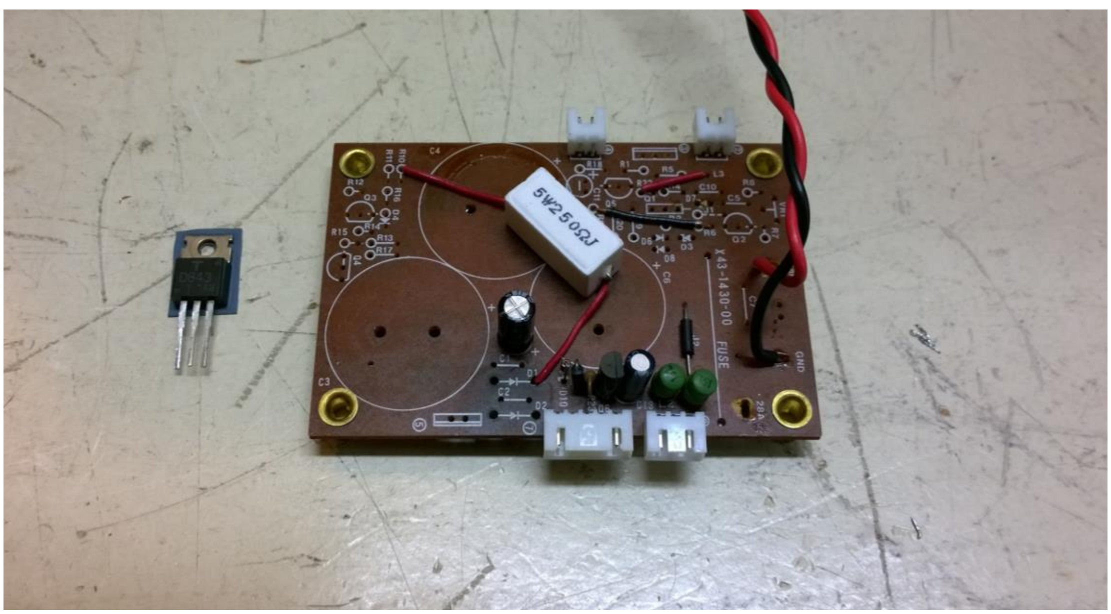


Removing the large heatsink removes the bracket for the left rear top case screw, and with the larger 776 Quint power supply in place, there's not enough room for a new bracket. As a result, that screw cannot be replaced. The top cover of the 930S will press down slightly on the Quint 776 when in place.

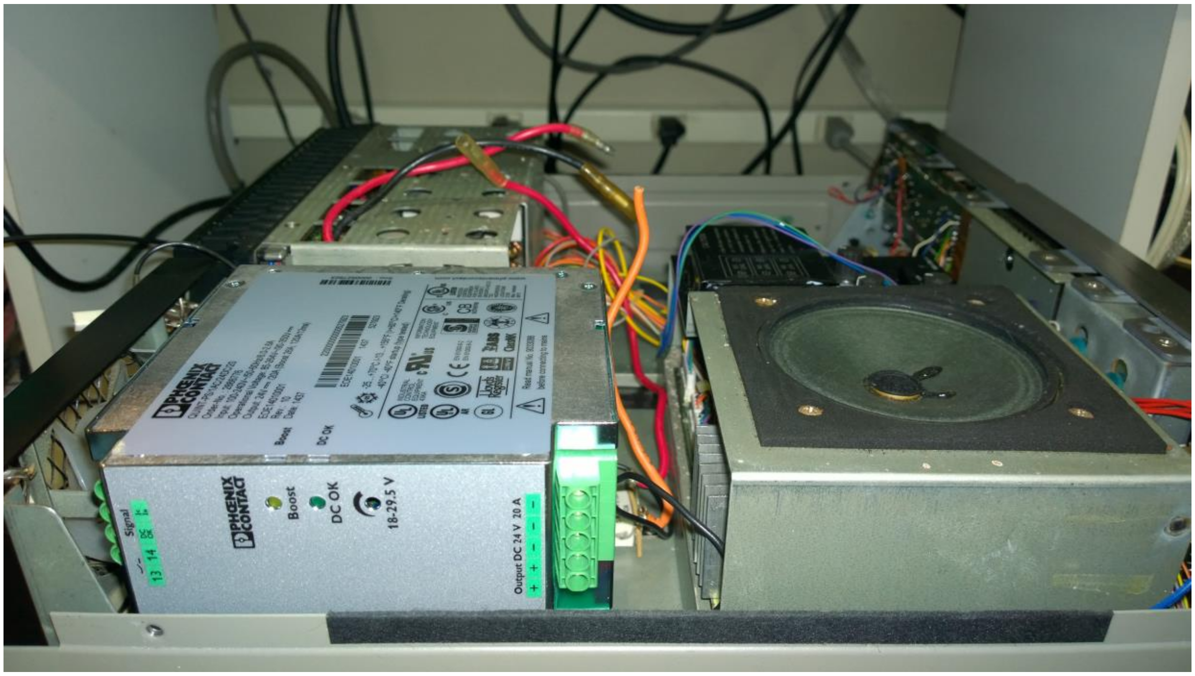
Since my plan was to re-use the AVR board, I stripped of all unnecessary components. I used the procedure outlined in the Compendium. It's a tedious process that takes about 45 minutes.



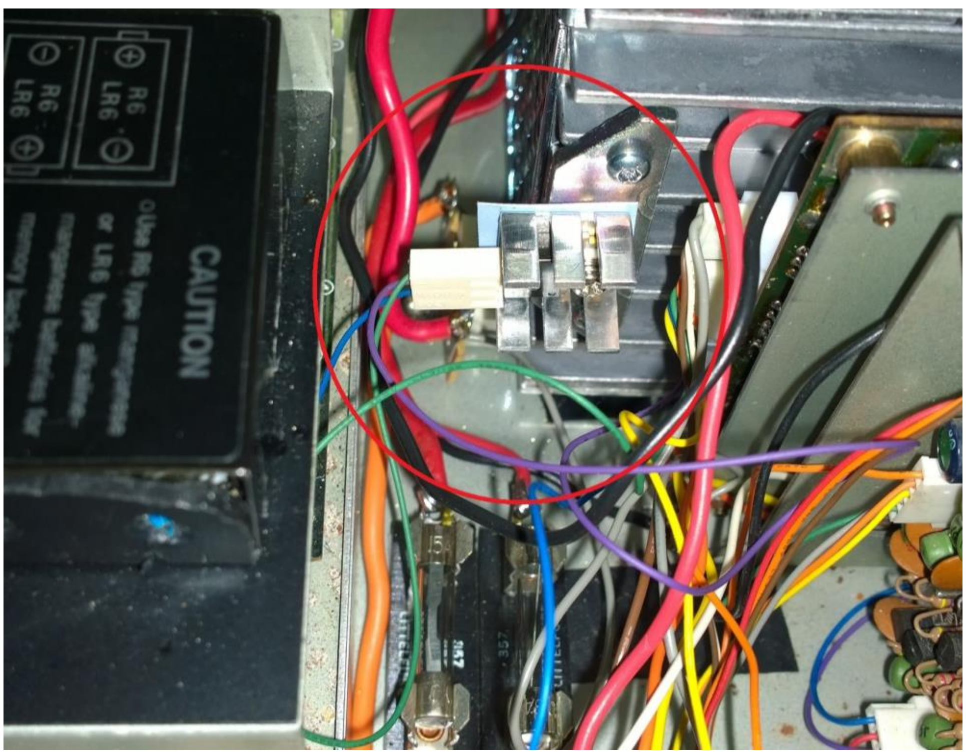
Rebuilding the AVR board per the Compendium and Appendix was easy. The ceramic 5-watt resistor produces almost no heat, so that will be my choice from now on. Clearances are tight with the larger Quint power supply installed so I replaced the original straight connectors with the right-angle ones.



Once the AVR board was ready, it was time to install the Quint. My original plan was to re-use the Toshiba 7-ampere power transistor that Kenwood used. The 21.7-volt output is set by a Zener diode connected to the base of the Toshiba in that design. Eventually, I chose to replace this transistor with a 5-amp DC-DC converter board because it produces virtually no heat. Although the Toshiba transistor gets hot, I used that system for most of the diagnostic and testing work.



The advantage of the large 776 Quint is that the heat sink has threaded holes that were originally used for the rail mounting system. I repurposed two of them to secure the 21.7-volt branch circuit system.

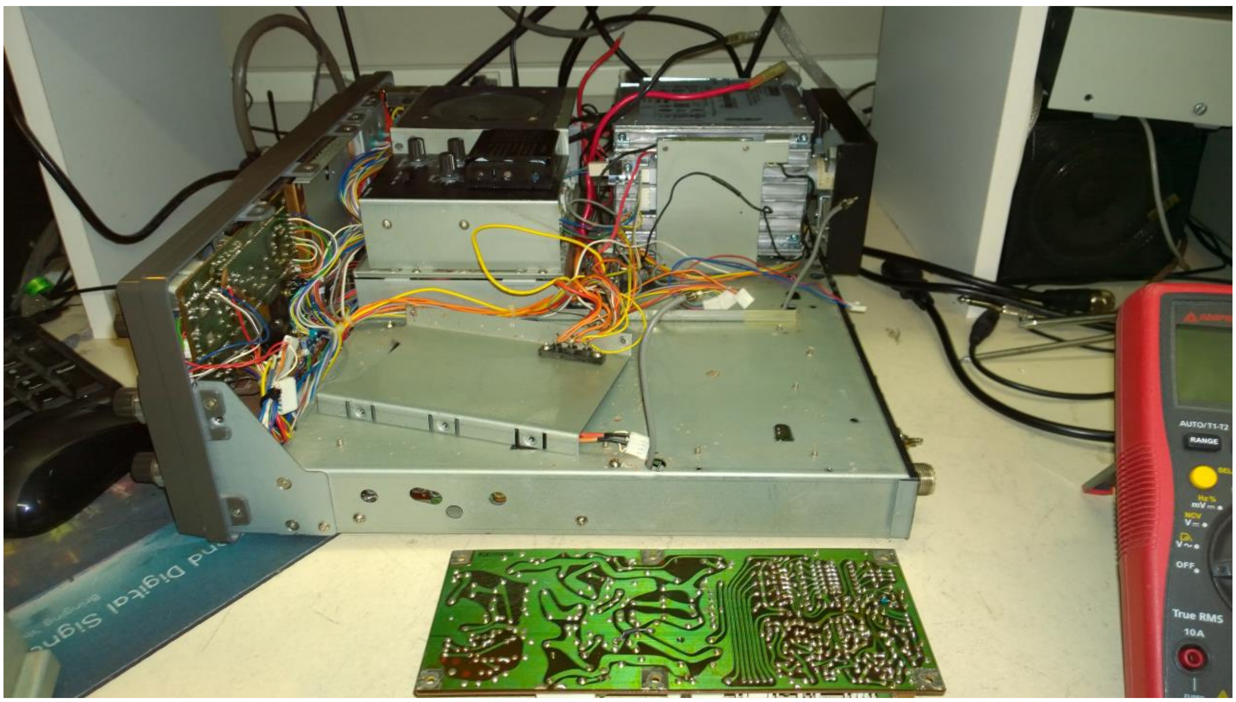


After the new power supply was in place and all the sub-circuits were connected, I reconnected the power amplifier cables and tested the radio. Power output was solid and consistent at 120-125 watts, with great modulation. It appeared that other than replacing my test PA with the OEM unit, dealing with the secondary issues mentioned above, and installing some wire ties, the radio was good to go. I decided to put the rig on the air for testing. 9Y4D (Chris) was on the air down in Trinidad and Tobago, and I reached him easily.

He’s a frequent contact of mine, so I told him about the radio and we engaged in a ragchew session. However, after only a couple minutes or so, the power output level began to fall off quickly. It dropped to around 65 watts, and began fluctuating wildly, down to as low as 20 watts. I told Chris that I was losing power and we ended our QSO, although he said my signal was still quite clear.

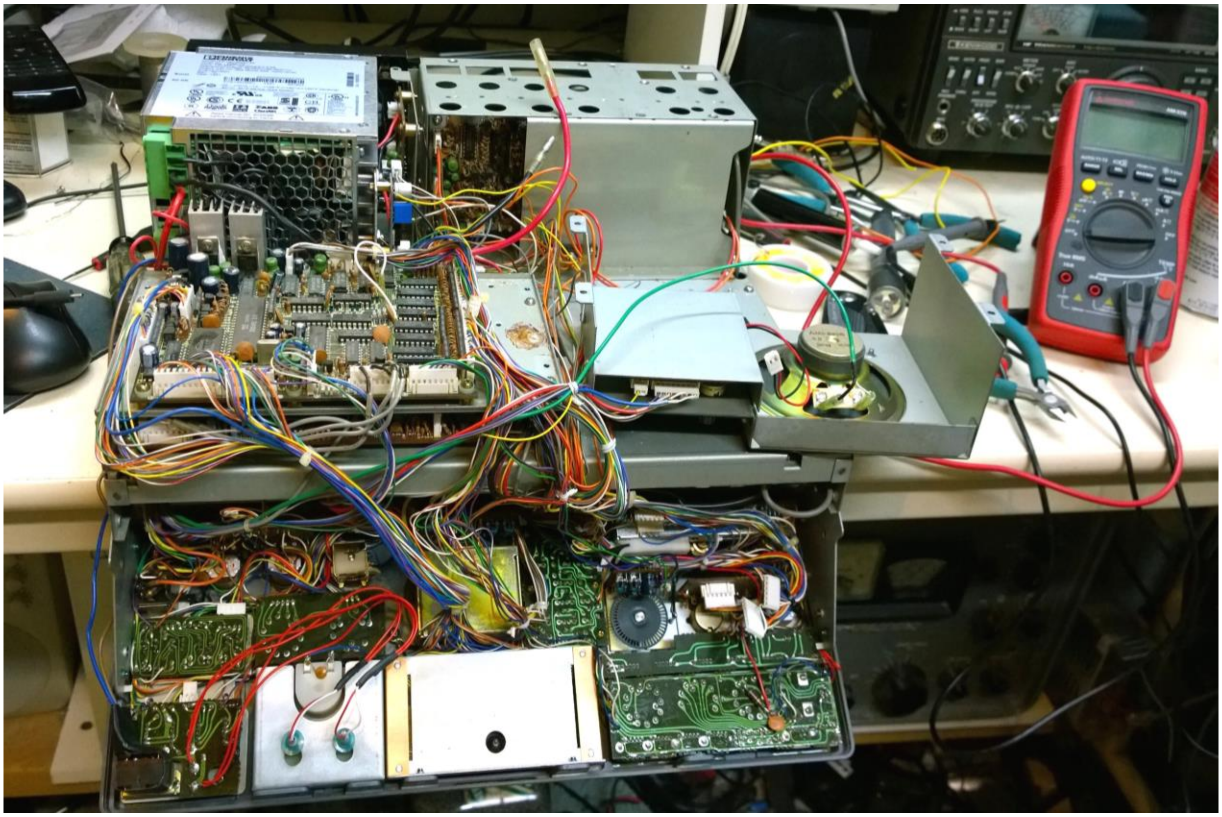
Believing that my rebuilt PA was malfunctioning, I replaced it with another good, rebuilt PA but the problem remained. I removed the PA completely, and began conducting tests on the circuits leading to the power amplifier, including the Signal Unit the Low-Pass Filter, and all the cables between them.

When I first removed the case to this radio, I found a fair amount of chassis rust and a grey wire underneath that had corroded and had been repaired with black vinyl tape and solder by another owner, so there was a strong possibility of a similar failure in a wire or connector between the signal board, the low-pass filter, or the power amp. This led to a complete strip down of the radio.



The board in the foreground is from the Low-Pass Filter (LPF). The LPF controls the power output of the PA through several different circuits, so a malfunction can shut down the PA.

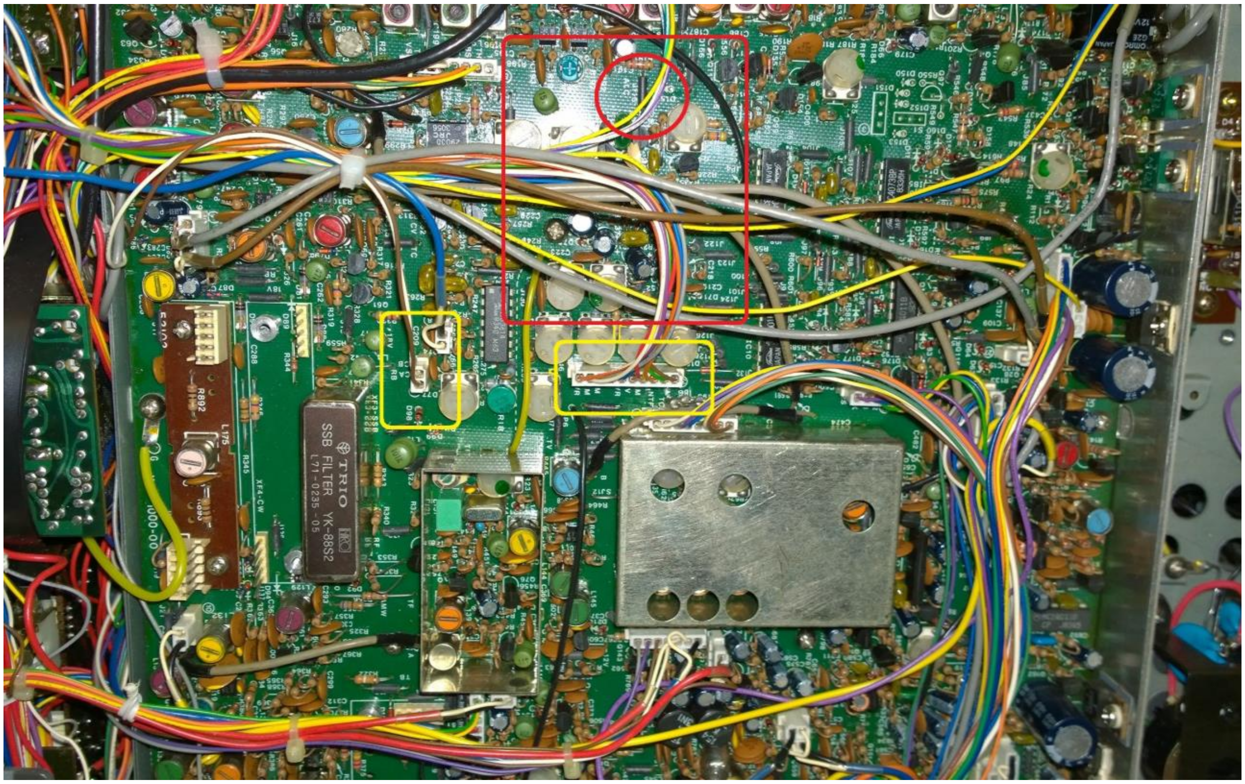
To access the circuits behind the front panel, including the VFO circuits and the band switch push buttons, I tilted down the front panel. This is easier than one might think. The advantage to this is that it’s absolutely the best way to access the controls and circuits behind the panel. It’s also the easiest way to change the S-meter lamps. The disadvantage is that both halves of the case must be removed.



Circuit tracing and continuity/voltage tests at the board connectors indicated that the cables and connectors were OK, so I reassembled the radio for further live testing and diagnostics.

During the QSO with 9Y4D, I noticed that as the output power plummeted, the ALC went to full scale, and it could not be adjusted. The ALC level is controlled by a feedback circuit from the Power Amplifier and the LPF. The specific circuits are circled in red on the next page. The connectors are outlined in yellow. The larger one is the Automatic level Control (ALC) from the LPF. It reduces the drive from the Signal Unit to the PA as the SWR increases, and it will shut the drive down completely if it believes that the SWR is too high, there's a short at the antenna terminal or there's a fault somewhere else in the output circuit. A simple test is to remove the ALC plug from the right side of the LPF with the power off. The rig is then turned back on. With the carrier control "off" (fully counter-clockwise), the rig is set to SEND, and the carrier slowly increased. If the output power climbs to 100 watts or more as the carrier control is advanced, then the problem is in the LPF, or in the ALC circuit in the Signal Unit. Care is needed here because the power can go over 150 watts with that plug removed, which could damage the finals.

The other power control circuit is the current limiter (ICA and ICB) which comes from the connector on the AVR board. This circuit, which shuts down the drive to the PA in the event of a current overload, is maintained while rebuilding the AVR board after the Quint conversion. This circuit receives the main voltage and a slightly lower one from the voltage drop across that 0.05 ohm power resistor in the PA supply line. The gray wire from that resistor goes to the 3-pin connector on the AVR board, through one of the green inductors, and then down to the signal unit via the brown wire. The 28.5V B+ goes passes through the other green inductor down to the Signal Unit via the white wire. A simple test to see if this circuit is malfunctioning is to unplug the two-wire ICA/ICB connector (with the power off). The rig is set to SEND and the carrier control slowly eased in. If the power returns to normal, then the problem is either in the voltage output from the AVR board, or a bad component on the Signal Unit board.



Unplugging the LPF connector had no impact on the power output. Unplugging the ICA/ICB connector resulted in a slight increase in the output, but it was still under 10 watts. Voltage and signal tests indicated that there was a problem in the ALC circuit on the signal board, but it was intermittent. Full power output would return, and the ALC operation and meter indication would return to normal, usually for only a few seconds. The ALC could be "tricked" into allowing some power output by adjusting the ALC control VR13 fully clockwise, but the fact remained that there was a problem in the ALC circuit that was throttling back the signal to the PA to such a degree that the output was almost zero.

At this point, I made an adapter cable that allowed me to view the output from the signal board to the PA input, and connected it to my Tektronix AN-USM 488 scope because some of my planned testing involved locking the radio in SEND mode and turning it on and off, which might damage the PA. By watching the output waveform as I turned the radio off and then on, I could visually determine if the ALC was clamping down on the output, or if the output was low due to a fault somewhere else on the signal board.

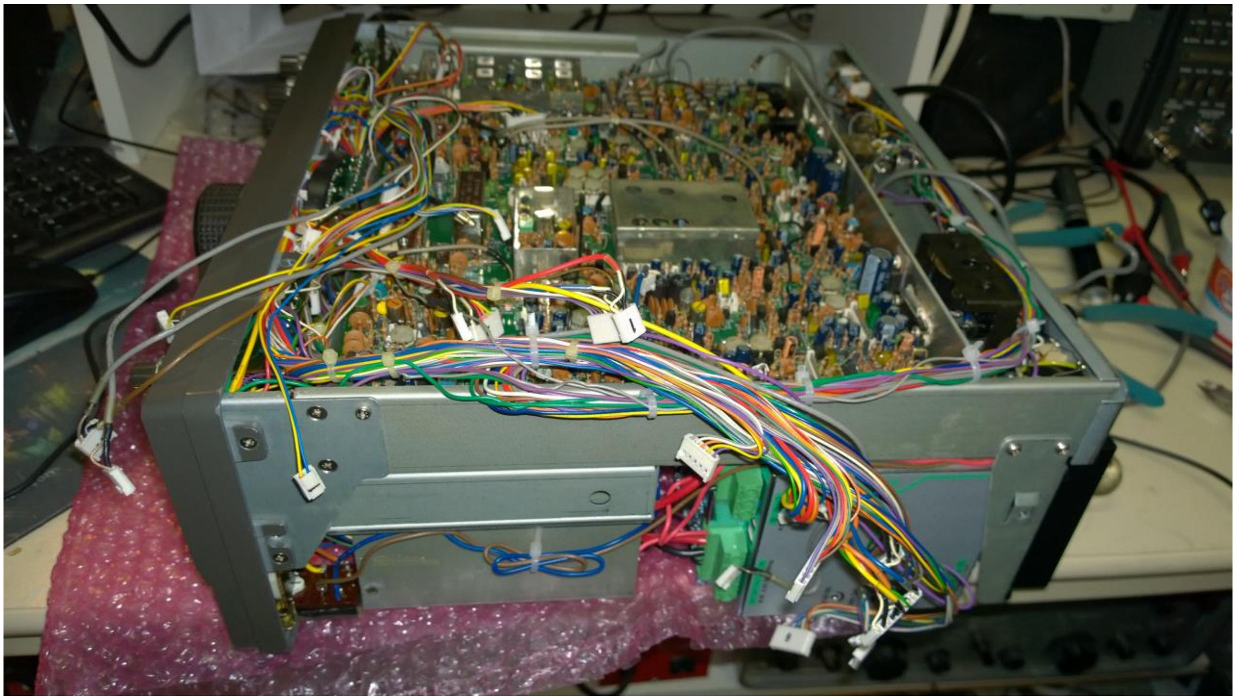
When the radio was turned on in SEND mode, the output from the signal board started at the specified full no-load peak output of 3.5 volts RF, but the ALC immediately kicked in, throttling it down to a fraction of a volt. At the same time, the ALC meter readout went from normal to pinned all the way to the right – maximum ALC action. I made two videos of the ALC activity: One shows the OFF-ON test and the other shows the action when the power output and ALC action would intermittently return to normal. The videos can be seen at the Youtube links below:

ON-OFF ALC Test: https://youtu.be/8GaSpT0E3mg

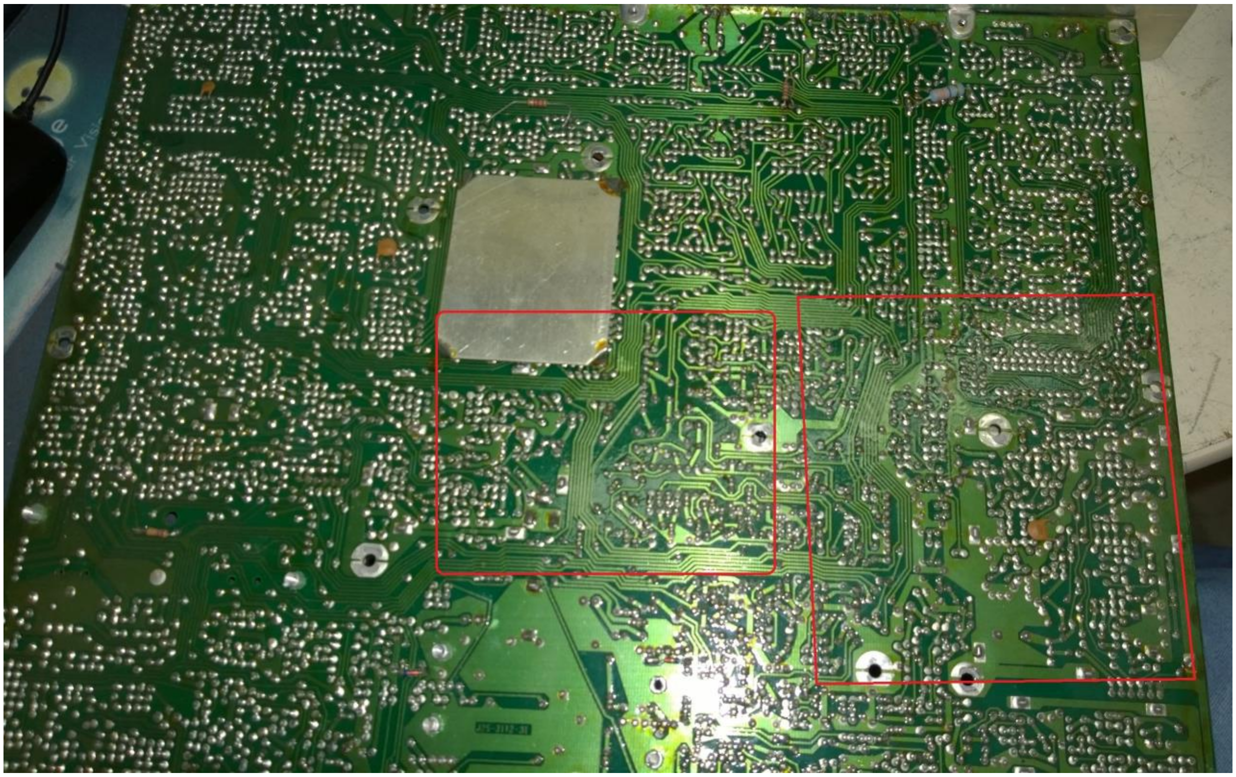
Intermittent ALC Action: https://youtu.be/bx_OSdpKj5M

Attempts to pin down the exact location of the fault using a heat gun and cold shot were unsuccessful, so I decided to pull the signal unit. By good fortune, I had a known good signal unit courtesy of a donation from contributor Dave Phillips, so if I could not find the fault, my plan was to swap out the signal board.

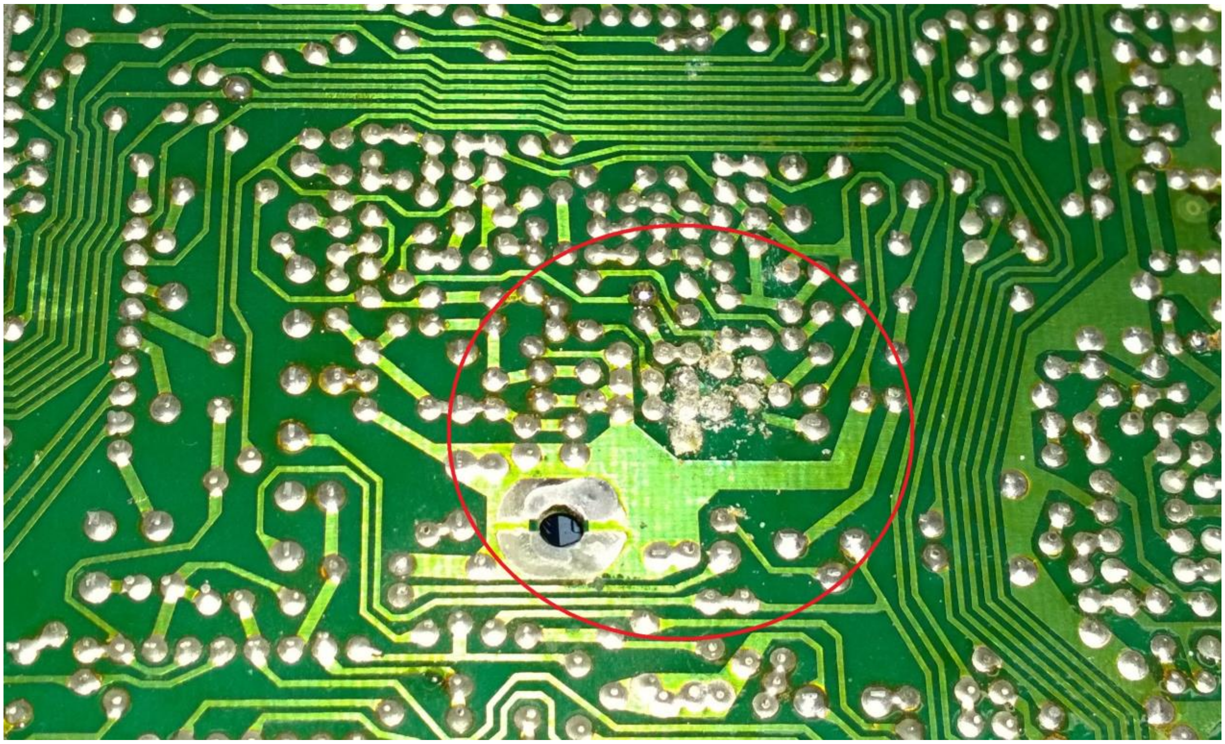
Removal of the signal unit board takes time, but it's not especially difficult. The most important thing is to take plenty of photos of the connectors and their locations. Most of the cables and connectors fall back into their places, but some have only two or three wires, and do not have "wire memory". Plugging one into the wrong board connector may cause serious damage. This is a photo of the old board coming out.



As soon as I flipped the old board over to look at the foil side, I saw the problem. The foil side had a visible white deposit on it. The deposit was particularly heavy under the ALC components.



The solder joints in the corroded areas had a grainy appearance, as did some of the foil traces. When I tried to retouch some of them using a fine-grade solder, the solder refused to "take". The flux simply bubbled up with a greenish tint. I scraped up some of the deposit for testing. Since I didn't have an accurate PH meter here in my shack, I did what any technician or engineer would do – I tasted it. It was salty.



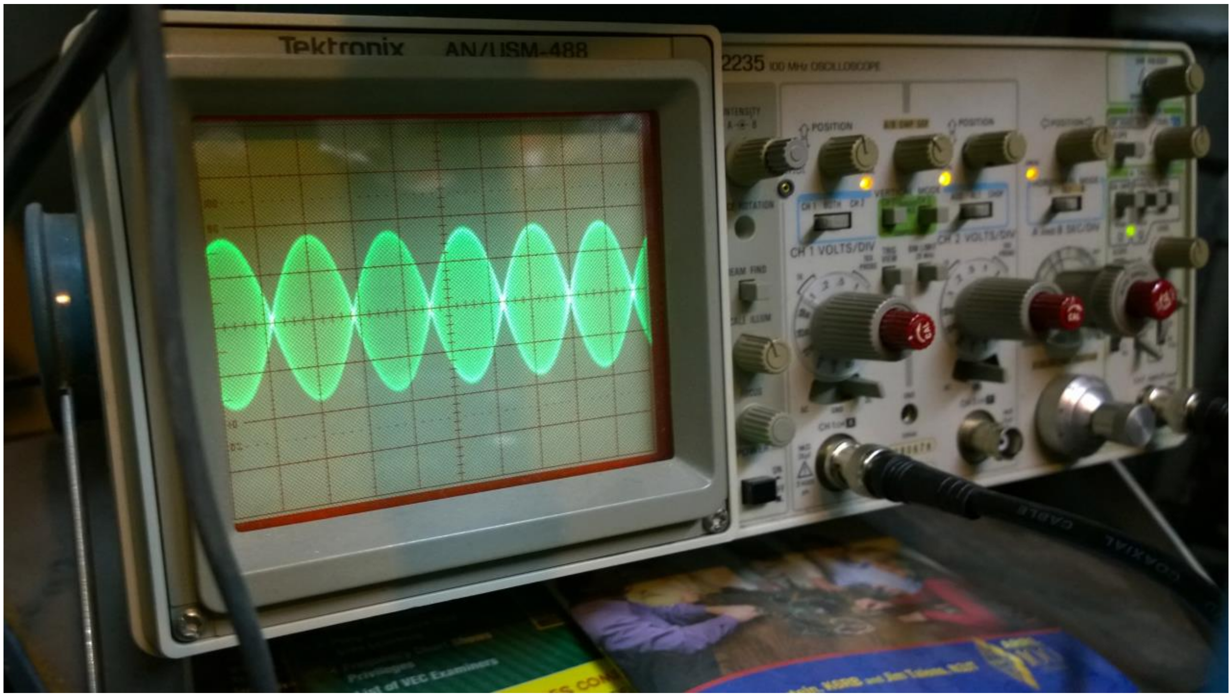
At his point I decided to install the Signal Unit that Dave had donated months ago. It worked perfectly. Power output was spot-on, as was the ALC. The only headache was that despite the fact that it was removed from a working TS-930S, it was out of alignment with respect to this radio. While that was a bit of a hassle, it was far less of one than cleaning off the salt deposits on the original board, re-soldering the connections, reinstalling the board to see if there were any faulty components, and then possibly having to pull it back out for more testing. I've discovered during my various PA tests that the board connectors can only take so many plugging and unplugging cycles, so I decided to leave in the replacement board and perform the alignment.

There were several small glitches along the way, one of which was that the collector current (Ic) reading on the panel meter didn't work, and in that switch position, the S-Meter didn't register. After some circuit tracing, I discovered that the voltage for ICA at the ICA/ICB connector was out of range. Flipping the connector resulted in a reading and restored the S-meter reading, but the numbers weren't right, and the setting on the meter could not be properly adjusted.

Suspecting that I did something wrong when I rewired the AVR board, or that my Compendium contained an error, I pulled the AVR board. While performing resistance and voltage tests, I discovered that one of the little green 151 uH inductors was burned. This is the first time I have ever encountered this. Fortunately, I had some spares. In fact, I had an identical inductor left over from my stripping of the AVR board. The board contains three of those inductors. Once I installed that one, the Ic reading was restored, the meter reading could be adjusted properly, and the S-meter operation returned to normal.

While I lack some of the test equipment listed in the Kenwood TS-930 Service Manual, I was able to align the board. I do have an RF signal generator with crystal control, several high-bandwidth scopes, two accurate frequency meters, and a good audio sine/square wave generator. And I also have a good, working TS-930S that I use for comparison. The results of the two-tone tests and the calibration were quite satisfactory. On-the-air tests with other HAMS resulted in many "great sounding rig" comments.

The desirable "Eggs on a Rope" waveform from the two-tone test (Dave's description)



Frequency readings at 14.20000 MHz.

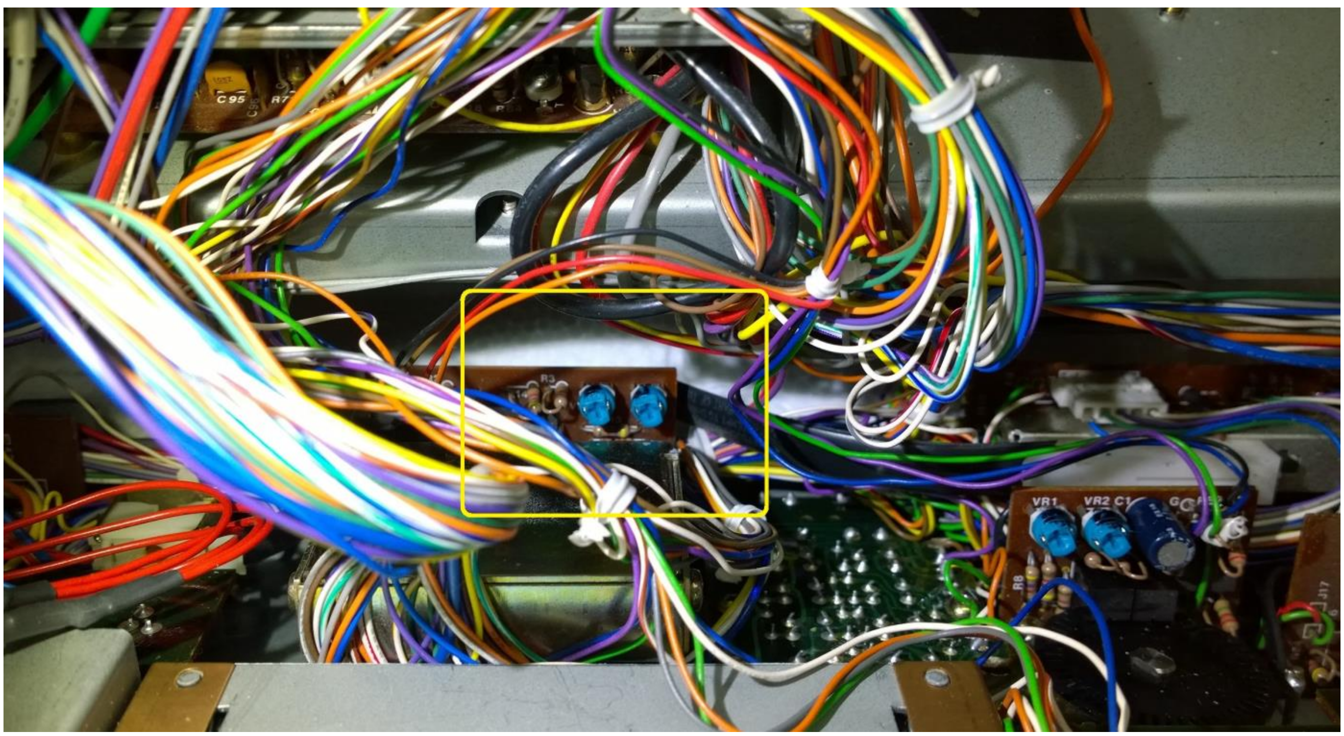
OTHER ISSUES

VFO: There were two problems with the VFO when I received the radio. The main tuning knob was loose. With the radio's top cover off, the VFO could be seen moving. This turned out to be a simple loose main nut behind the tuning knob. The second problem was that as the knob was turned, the readout on the display jumped around, especially the tenths and hundredths digits. This is a frequent problem with the 930S. It's caused by component drift in the VFO encoder, especially in the light output from the encoder's LED.

There are two ways to fix this: The hard way, and the easy way.

The hard way is to remove the encoder, provide power to it, connect the shaft to an accurate drive motor set to 300 RPM, and watch the output on a scope while adjusting the two voltage regulators shown below. I have a Unimat SL that I could use for that, but it's packed away at the moment.

The easy way is to make small adjustments in the regulators until the display snaps back into proper operation. I used the easy way and it worked perfectly. I only had to move the two VR controls (outlined in yellow) about an eighth of a turn counter-clockwise to restore proper VFO operation. The black marks on the controls were put there by Kenwood. I tried clockwise first, but that made the problem worse. Some HAMs have reported that all they had to do was spray some contact cleaner into them and turn them back and forth to restore their display, but that wasn't effective. I moved both controls the same amount.

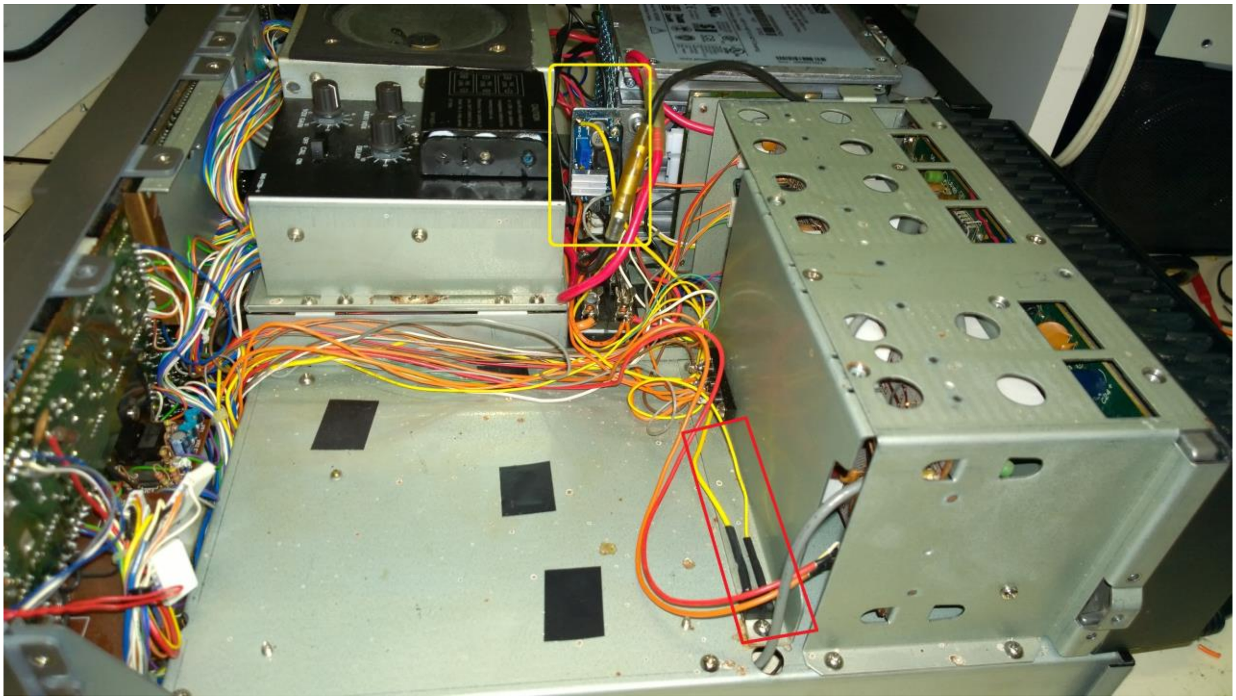


Band Switching/PLL: After restoring the VFO, I decided to tackle the band switching problem. It was logical to assume that since some of the circuit boards and controls were suffering from salt deposition and corrosion that the problem was in the push buttons. As evidence, the foam surrounding the switch assembly was completely disintegrated. While I had the front panel tilted forward, I removed the assembly and dribbled DeOxit Gold into the contacts.

The cleaning improved the action of the buttons, but the display still went blank during certain band switches. To further confuse the issue, the display only blanked when switched in one of two specific and inverted patterns. I had never experienced this before, so I wrote to Dave Phillips for advice. After thinking about it for a while, he recommended that I re-align the Phase-Locked-Loop (PLL) system, which involves the alignment procedure found on page 58 in the Service Manual. Basically, the procedure requires adjusting inter-stage transformers on the PLL board and coils on the Signal Board to achieve certain target voltage levels at the extreme ends of each band. Performing steps 1 through 7 completely eliminated the display blanking problem and resulted in crisp band changes.

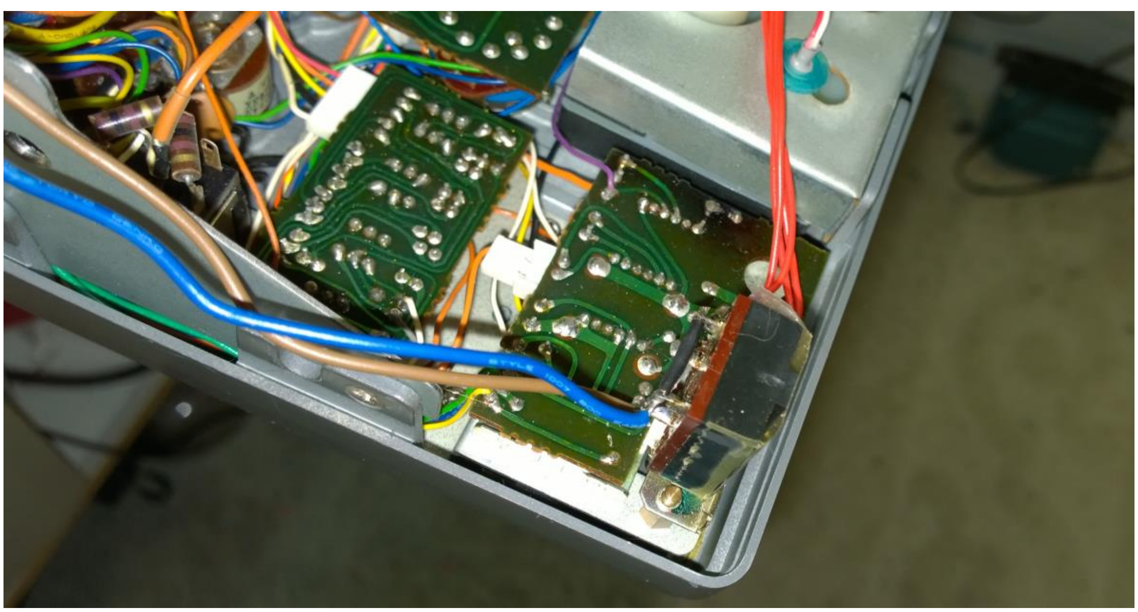
S-Meter lamps: While I had the front panel tilted forward, I measured the voltage from the DIM switch in the DIM and NOR positions. In the DIM position, the voltage dropped down slightly to 24 volts as designed, but under load, it dropped to 0.5 volts. After cleaning the switch, the problem remained, although sometimes the switch would work properly. The digital frequency readout dimmed normally. To avoid replacing the DIM switch (if one could be found) I simply installed commonly-available 12-volt “pea” lamps and drove them from an inexpensive 3-terminal 3-amp NEC regulator that I installed near the LPF. This resulted in a very pleasing, natural illumination for the S-Meter, and it will allow future lamp replacements using readily-available 12-volt pea lamps rather than the much harder to find 28-volt variety.

The 12-volt regulator can be seen in the picture on the next page, boxed in red. The item boxed in yellow is the 5-amp adjustable regulator that supplies power to the 21.7-volt sub-system.

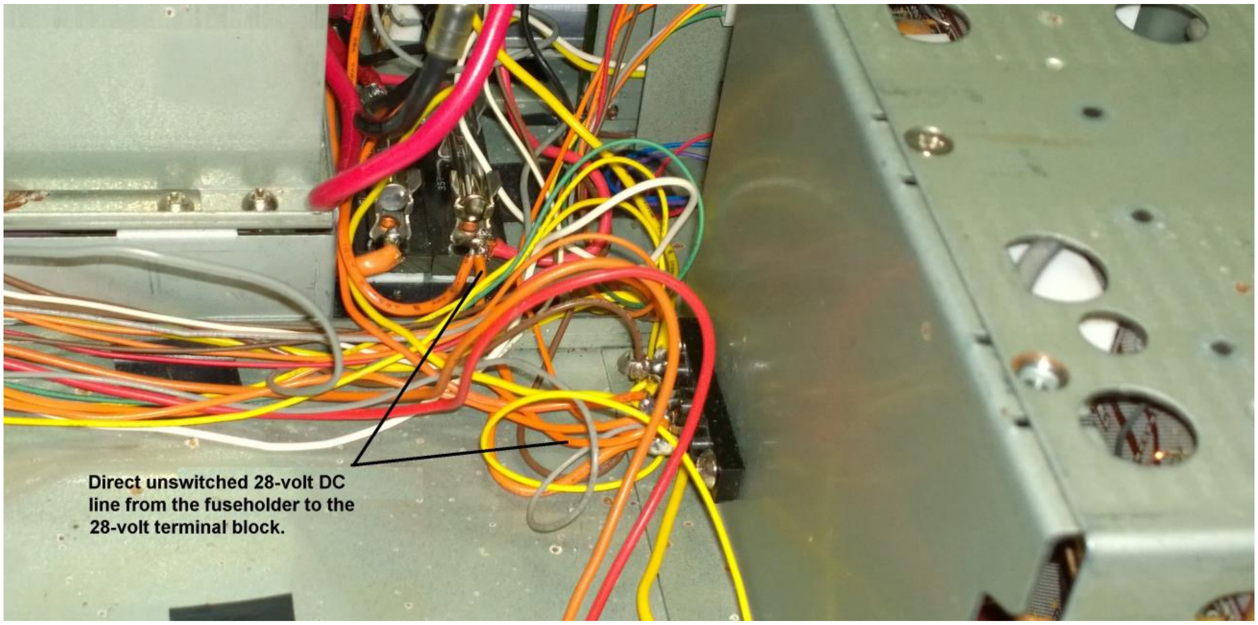


One final issue. Ever since Paul Groothoff wrote about and possibly pioneered the Phoenix Quint power supply conversion, there has been a debate on how to wire the AC circuit to the front panel switch. The Kenwood system simultaneously switched both the AC power to the transformer, and the DC output from the AVR board by using a double set of independent contacts in the front panel switch. The DC circuit disconnect was apparently designed to prevent a power surge to the radio as the AC entered the transformer windings on start-up. Since this is not an issue with the Quint, Paul and others have recommended removing the DC wires and bridging the contacts so that the two sets handle the AC load. The DC wires consist of a yellow wire up to the switch, and an orange one back to the 28-volt terminals. These wires could be simply clipped at the switch and pulled back to the power supply section. An orange wire can then be connected from the end of new receiver fuse holder to the 28-volt terminals at the back of the LPF. That's how I wired this radio as shown below (blue and brown wires).

AC connection (Blue and Brown wires)



DC Connection (Direct wire to the new fuseholder for the receiver section)



After I did this, I decided to modify my own 930S in the same manner. However, I notice that with the 20/26-amp Quint power supply, the DC output drifts down as the power to the Quint is cut, rather than shutting off instantly. As a result, the radio’s audio and dial lamps do not shut off “crisply”. With the smaller Quint models, the DC simply drops out. I’m not sure why this happens in the larger model, but I find the effect annoying. If I had it to do over again, I probably would have left the DC disconnect system in place, even though the system recommended by Paul and others is probably more reliable.