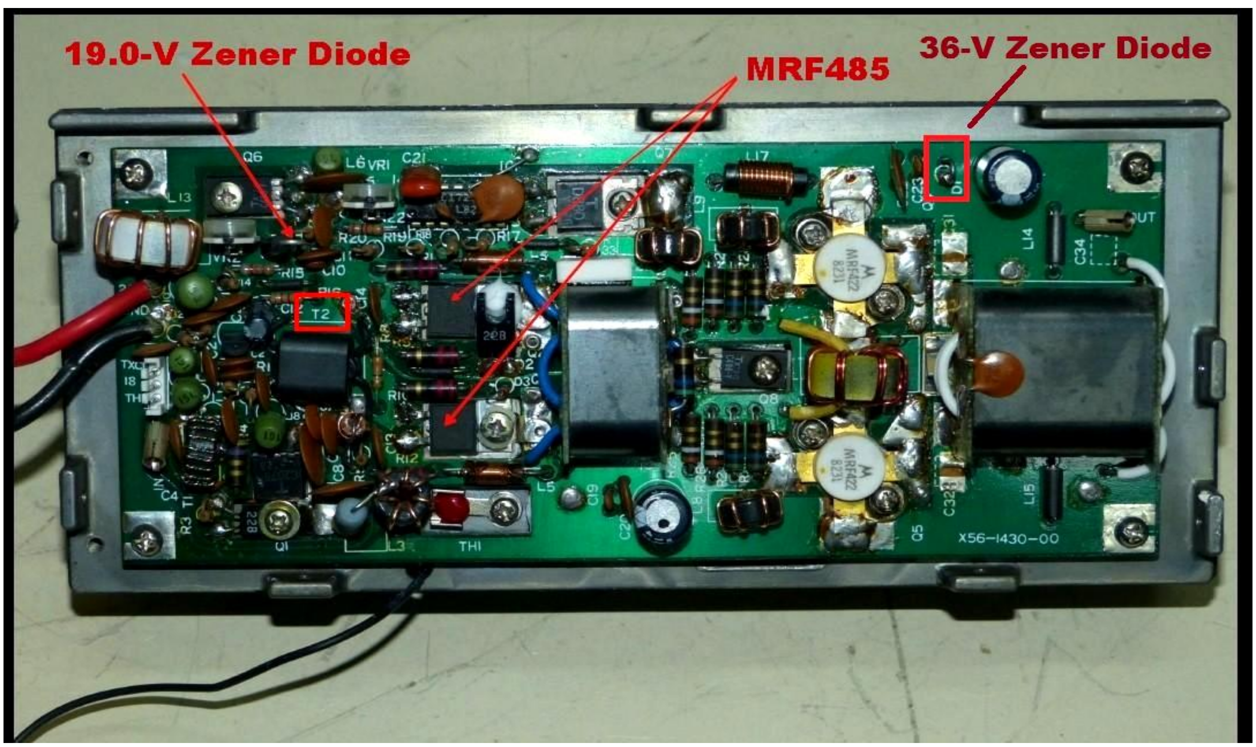
Options for Repairing your Kenwood Power Amplifier

Rev. 10/30/2020 (Important notes regarding Options 2 and 3)

If the power output from your 930S is zero, or close to it and you are certain that the problem is not in your Signal Unit, then you probably have one or more blown drivers. I say "one or more" because I've encountered several PA's that had one open driver, but the other was good. In the case of my own rig, which I bought on eBay, the cause was using the higher-gain Motorola "yellow dot" 485's instead of the red dot version. More information on this can be found in "anatomy of a working Kenwood PA" on this website. I recommend reading it before you tear into your power amp. But once you identify that at least one of the drivers are bad, it's time to remove the PA and in most cases the circuit board and get down to it. Repairing your own power amp is as easy as installing a Quint power supply.

Things have changed quite a bit since I wrote my first paper on repairing the TS-930S Power Amplifier. I've acquired four complete power amps, and I have all four up and running using different solutions for the drivers. The first three involve using MRF485's with varying gains, but the fourth one uses the 2SC1969. The 2SC1969 has a gain over 200, yet simple changes to the power amp will allow it to work with absolute stability. And there are other TO-220 power transistors that will work, provided they have the classic B-C-E pinout configuration. Dave Phillips and I are constantly experimenting with new drivers, including some MOSFETS.

The picture below shows the locations of the components that are most likely to fail. From my experience, the drivers and Zener diodes are the only parts that blow when the OEM power supply fails. The drivers open, the diodes short. Since the Quint power supply has a maximum let-through voltage in failure mode of 32 volts, Zener diode D1 which clamps voltages over 36 volts, can be tossed. D5 is also optional. Both are intended to protect the PA from the over voltage from a blown OEM power supply, but they are too small, and their clamping response time is too slow. By they time they short, one or both drivers are gone.



At one time, finding replacement drivers that would work in your PA wasn't that difficult. When I first wrote this paper, Eleflow Semiconductors Ltd had over 200 MRF485's in stock with the same low gain as the original Motorola "red dot" 485's. Shortly after Google and others started listing my paper, Eleflow informed me that they had sold out of the low gain MRF485's, and there would be no more production runs. This is unfortunate, but it doesn't spell doom for your 930S. They have higher-gain versions that will work with some minor mods to the circuit board, and there are other drivers that work well. You'll just have to tailor your repair approach to the type of driver that is available to you.

On rare occasion, someone lists a set of Motorola “Red Dot” MRF485’s, or an aftermarket brand with a current gain of 25 or less on eBay. If you find some of those, then Option 1 will work for you. For MRF485’s with a gain of 25-60, Option 2 works well, with an important caveat (below). When hFe (gain) reaches 60, I recommend Option 3, and for alternate drivers with lower voltage requirements and high gains, Option 4 is the way to go. One important note is that you cannot use the published current gain (hFe) shown in the data sheet for the drivers because the gain varies widely with the voltage and application configuration. Some standard DMM’s claim to be able to test hFe, but I have yet to find one that’s reliable. If you truly want to test your drivers, buy one of those $12-$15 “Mega” 328 testers that you see online. They test the semiconductor without restraint, so the gain that they show will be the highest that the device will probably do.

The following pages describe four options for rebuilding your Kenwood PA. The first two options can be performed without removing the PA circuit board from the heatsink. Basically, the options are:

1. An "OEM" PA, using low-gain drivers such as the ones made by HUAGAO. These have the same current gain as The Motorola OEM "red dot" drivers. This option works well with drivers whose gain is between 15 and 30.

2. A modified PA that uses a Motorola MC78T12CT to provide 12 volts @ 3A to a pair of Eleflow 485's with a gain of 50-60, along with a reduced value of R8 to "throttle back" the input to the drivers. A 15-ohm shunt resistor across R8 works well. The shunt resistor can be soldered across the MRF485 base terminals. **IMPORTANT NOTE:** This option results in a PA that can be “hot” above 25MHz, especially when using CW. See notes below.

3. A PA that uses mods suggested by Merit Arnold (W6NQ) of RF Parts. His solution reduces the Base-to-Base shunt resistor R8 that is across the secondary of T2 from 33 to 10 ohms, and halves the value of the 220 ohm collector-base negative feedback resistors R11 and R12 to 110 ohms. This will permit the 930S PA to run drivers with a gain of 80 or lower without stability problems. I completed this mod recently, and it works great. I only had 100-ohm resistors on hand, so I used those instead of the 110’s.

4. A PA that uses a combination of options 2 and 3, described above. The drivers in this case are either 2SC1969’s, or MRF485’s with a current gain of 80 or greater. It’s best to run these higher-gain drivers at 12 volts using the MC78T12CT regulator from Option 2. I have seen a few PA’s for sale online that use the 2sc1969 drivers with nothing more than reduced voltage. I strongly recommend the feedback modifications as well. The PA in this example had 2SC1969’s at reduced voltage with no other changes, and one of the MRF422 output “pills” was open.

This was a particularly odd case, because the output pill worked until signal power was applied. The PA output in TUNE would start to swing up, but then it fell right back to zero. I went over that board with a fine-tooth comb and could find nothing wrong. I finally traced the TUNE signal through the PA with an Oscilloscope, where I saw a strong output waveform on one pill, but next to nothing on the other. A quick shot of freeze spray uncovered the problem. The PA would work as long as I kept that 422 pill ice cold. Of course, I had to replace both pills.

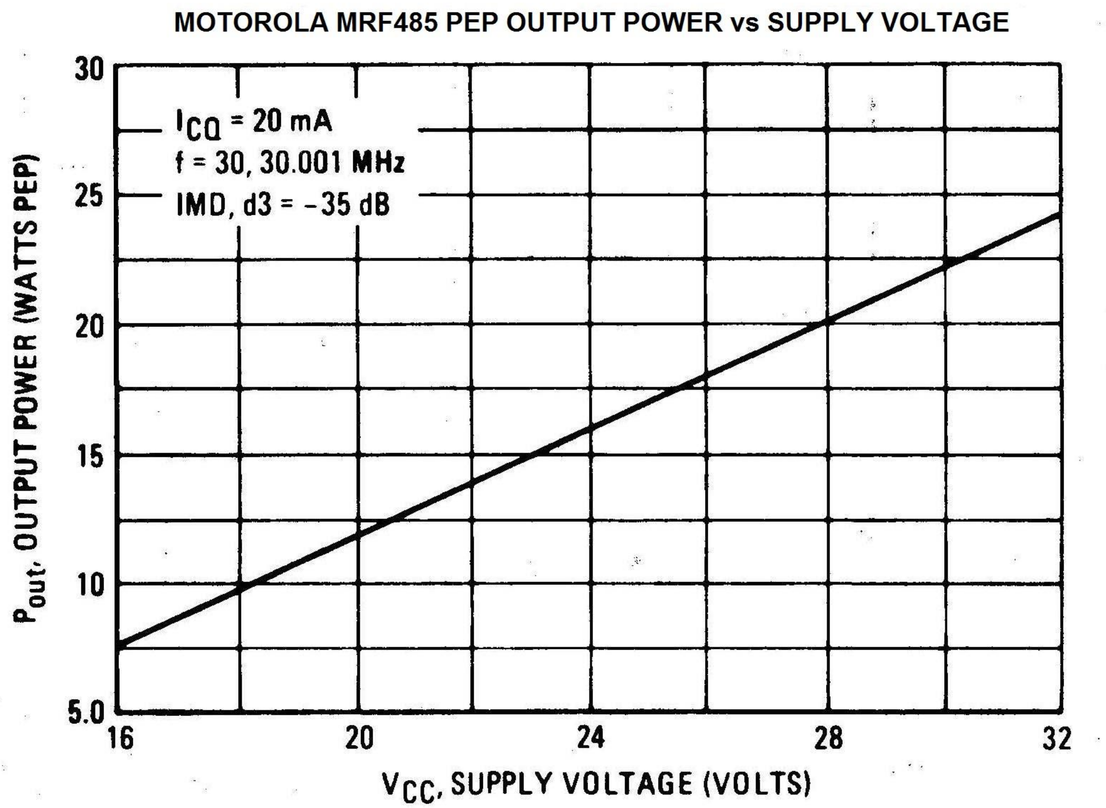
OPTION 1: Use low-gain drivers, if you have or can find them.

This option is the easiest. You simply remove Zener diodes D1 and D5, and the old drivers. I remove the screws and insulating washers that hold down the drivers, bend the tin collector contact up, and then unsolder the base and emitter leads one at a time. Unless you plan to replace your drivers many times for testing, you can just bend back the collector contact up and then back down after you install new heat sink grease and you’re ready to solder in the new drivers. I’ve worked on my PA’s so many times that I must unsolder those tabs so metal fatigue doesn’t break them.

Installation of the replacement drivers is pretty straightforward. Whether I replace the drivers without removing the PA circuit board from the heat sink or not, I install them with the circuit board screwed back down to the heat sink. I cut off the center (collector) lead, and then bend the Base and Emitter leads upwards at about a 30-degree angle. After the drivers are screwed down, it’s easy to push each lead down onto its respective terminal. The advantage to this practice is that the heatsink will now offer some protection to the driver’s junction as you solder each lead down because much of the heat will be transferred from the junction to the sink. Alternate soldering the leads down: Do the base on one, then the base on the other, etc. That minimizes the heat that reaches each junction.

<u>OPTION 2</u>: Reducing the bias to the drivers to 12 volts using a NEC 3-Amp, 12-volt MC78T12 voltage regulator, <u>and</u> decreasing the value of R8 to 10 ohms by shunting it with a 15-ohm resistor.

THEORY OF OPERATION: The Beta (hFe) is the DC current gain at a certain temperature, current and collector bias. While I have been unable to locate a graph of Beta vs supply voltage, I did find the one below, which shows the supply voltage vs output power in PEP watts of a Motorola MRF485. Note that at 28 volts bias, the graph shows a PEP power output of 20 watts (about equal to the 14 watts RMS shown in theMRF485 data sheet). At 16 volts, it's down to 7.5 watts. I tested the Eleflow MRF485's at 12 and 16 volts. Since the PA performed admirably with a driver supply voltage of 12 volts, and 3-amp, 12-volt regulators are easy to obtain, I settled on that option.



The advantage to this option is that you can do the work without removing the circuit board from the heatsink. <u>The disadvantage is that the original feedback loops in the driver circuit are left unchanged, resulting in a PA that can be very "hot" on 10M.</u> The extent of this problem will depend upon the current gain of the MRF485's that you use, and the characteristics of your rig, but the drivers in mine tested in the 50-55 range, and my PA pins the Ic needle on 10M unless I reduce the Carrier control or adjust the MIC level so that the ALC remains in the red zone on the meter. Operation at such a high current level can cause spurious emissions and may damage your PA. At the very least, it will blow the PA fuse. Still, some prefer not to tear everything apart, and this option appears to be stable at frequencies below 25MHz.

The black wire to the center ground terminal of the voltage regulator is not really necessary, but I put it in to be safe. The blue wire to the <u>input</u> terminal of the regulator is connected to the 28-volt tab where RF choke L7 was once soldered. The red wire carries 12-volts back from the 3-amp regulator to the collectors of both drivers via the end of L7. I used 1-inch pieces of insulation to protect against shorts, but heat shrink tubing also works, and I used red and blue solid conductor wire to keep track of what goes where.

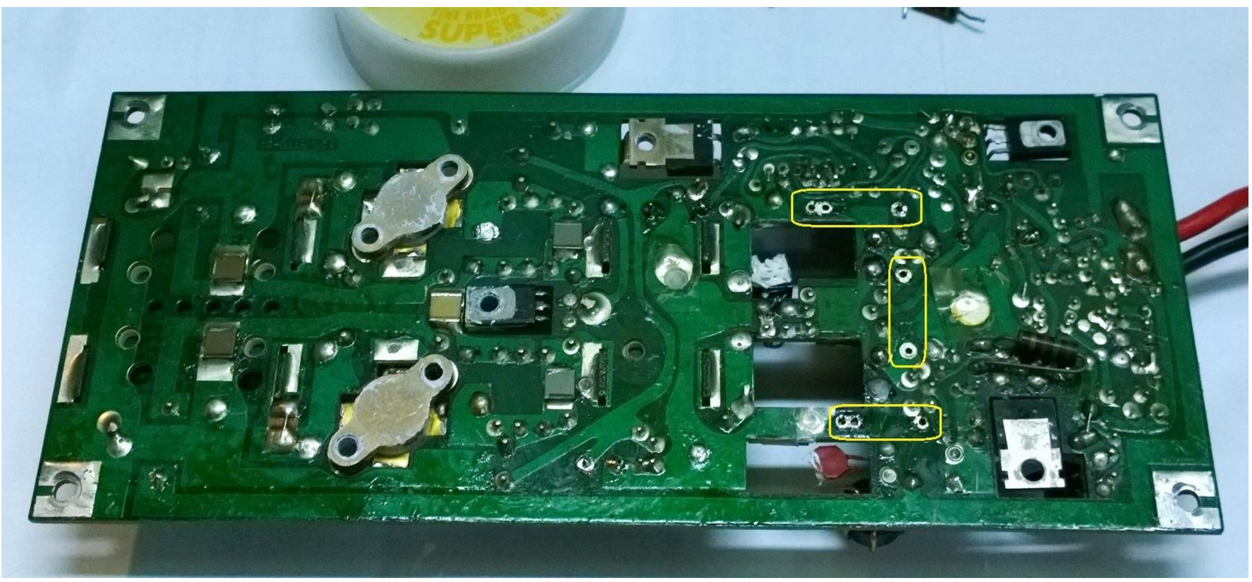
Here's a photo of the changes, with the areas where I made changes boxed in red. The screw used to secure the voltage regulator came with a computer hard drive kit, or you could take one of the PA mounting screws from your 930S to the hardware store and find a short match. I would get a couple. It's a fine threat machine screw. The 15-ohm shunt for R8 can be simply soldered across the base tabs of the 485 drivers.

<u>OPTION 3</u><u>: Increasing the amount of the driver stage's negative feedback (Merit Arnold, W6NQ):</u>

This option reduces the Base-to-Base shunt resistor R8 that is across the secondary of T2 from 33 to 10 ohms, and halves the value of the 220-ohm collector-base negative feedback resistors R11 and R12 to 110 ohms. I used 100-ohm resistors for R11 and R12, and they work great. In fact, I recommend using them as an extra margin of safety.

THEORY OF OPERATION: The output signal of a grounded-emitter transistor amplifier is amplified and inverted with respect to the input signal. So, you can control the gain of the stage by "looping" some of that negative signal from the collector back to the base. The Kenwood PA uses a 220-ohm resistor to reduce the amount of the signal, in series with a choke to remove RF, and a disc capacitor to block DC and pass only the signal to the driver's base. For driver Q2 the loop consists of R11, L4, and C14. For Q3 it's R12, L3, and C13. The advantage to increasing the amount of the feedback is that the greater the gain of the MRF485 that you install, the greater the reduction in gain generated by the feedback loops. This option works well with drivers whose current gain is 80 or less, but I recently had a pair of MRF485's with gains of 83 and 85 short out, torching L5. If the 485's that you plan to use have gains higher than 80, I recommend using them with reduced voltage as in Option 4.

This photo shows a PA board with the three resistors – R8, R11, and R12 – removed, and the areas highlighted in yellow. Solder wick does an excellent job of assisting with the removal of the old solder and components.



The photo below shows the finished PA board, with the new resistors outlined in red.

OPTION 4: Decreasing the voltage to high-gain drivers, AND Increasing the amount of the driver stage's negative feedback:

This option allows the use of high-gain drivers like the 2SC1969 by reducing the supply voltage, and adding the negative feedback loop changes described in option 3. I would use this option for any driver with a gain of 80 or greater.

THEORY OF OPERATION: See Options 2 and 3 on the previous pages.

This photo shows the PA board with the areas where parts were changed highlighted in red. Obviously, the drivers were also changed. Their gain tested 212, yet this PA is a super stable. This one belongs to Luis, K4BTA.

Once everything is in place, I recommend that you perform some resistance and diode tests before applying power.

You can't use the diode test function on a DMM to test the Base-Emitter and Base-Collector junctions on the drivers as diodes, because the readings will be skewered by the associated sub-components, especially the RF transformers. An almost dead short will appear between the emitter of the driver bias regulator Q6 and ground, as it will also be across the Emitter-Base leads on both drivers. The reason is that the ends of T2, the RF coupling transformer to the drivers are connected to the bases of Q2 and Q3. Since the emitters are grounded, and T2's secondary is grounded on one end through a 22-ohm resistor, the circuit appears to be almost shorted. However, I've found some tests that will help verify that your efforts are a success.

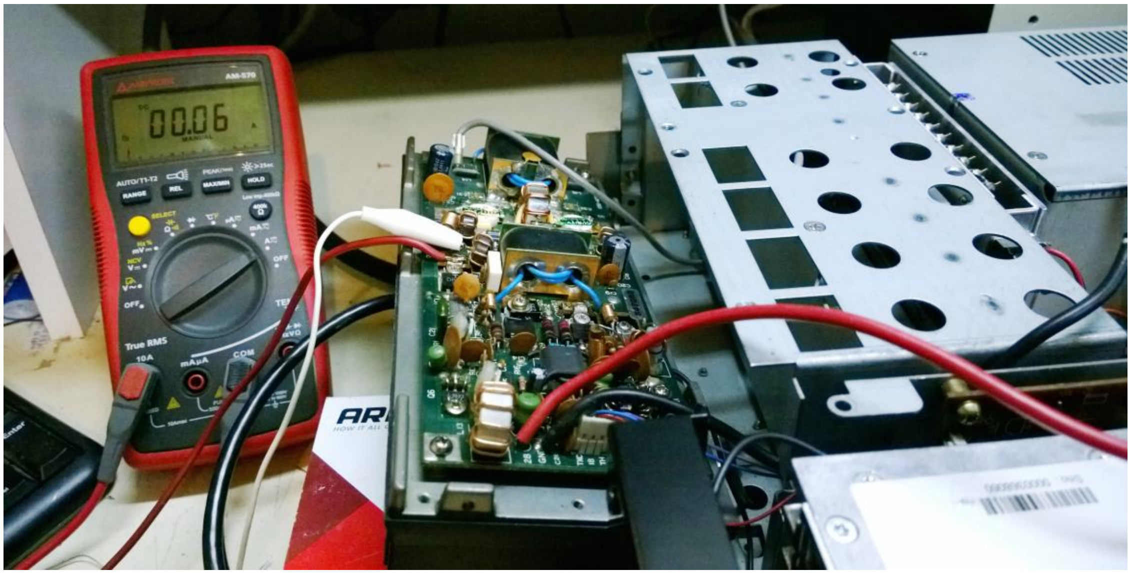
“Pre-Flight” Tests

1. Check with a DMM to make sure all the collector tabs that should be grounded are, and those that aren’t, are not. Check the shoulder washers on the collector tabs of the drivers and voltage regulators (Q6 & 7) to make sure they are insulating those components from the heat sink/ground.

2. Put the negative lead from your diode tester on each driver’s collector tab. Then touch the positive lead to the base lead, and then to the emitter lead. You should “see” a diode reading of about 0.577 volts at each. Don’t use the screw that pins the collector tabs to the heat sink because it’s a dead short to ground. Now reverse the leads. You should see either “OL”, or if you’ve selected Options 2 or 4, something high, like 2.80V. As mentioned above, you will not be able to test the Base-Emitter junctions because T2’s secondary will appear as a dead short.

3. Set your DMM to diode test. Connect the red lead to the black cable or the PA heat sink, and the black lead to the red power lead. You should get about the same reading (0.566 – 0.577) as you did in test 2, above. Reverse the leads now so that the negative meter lead is to ground (the black lead) and the positive is on the red power lead. You should see either a high voltage (2.800V or more) or infinity. If your meter reads a short or the same reading in **both** directions, find out why before you apply voltage to your newly rebuilt PA. (See the APPENDIX for test pictures and more info)

Much more detailed information on testing your PA can be found in “Anatomy of a working Kenwood PA”. Once you are ready, it’s time to apply voltage and adjust the PA idle current, and the idle current to the drivers. The PA must be connected to the rig but sitting out with the 3-pin transceiver control and in/out cables connected as shown below. It’s the best way to adjust the driver’s idle current. You will have to unsolder L7 and connect a set of wires to the end of L7 and the 28-volt source tab to which it was soldered.



If you used Option 1 or 3, you can set the PA idle currents as per the Kenwood service manual. Despite what the manual says, I set the overall PA idle current to 1.20 – 1.30 amps using VR1 first, which ironically is the one farthest from the power leads. Then I adjust the driver bias to 70 mA using VR2, which is the one farthest from the drivers!

If you used Option 2 or 4, then the PA idle current can still be set to 1.2 or 1.3 amps, but for the driver current at 12-volts has not been established. I set mine at 50 milliamps, but a better option might be to set it at the 70 milliamps Specified by Kenwood but take the measurement at the INPUT to the 3-amp voltage regulator. I’ve done it both ways.

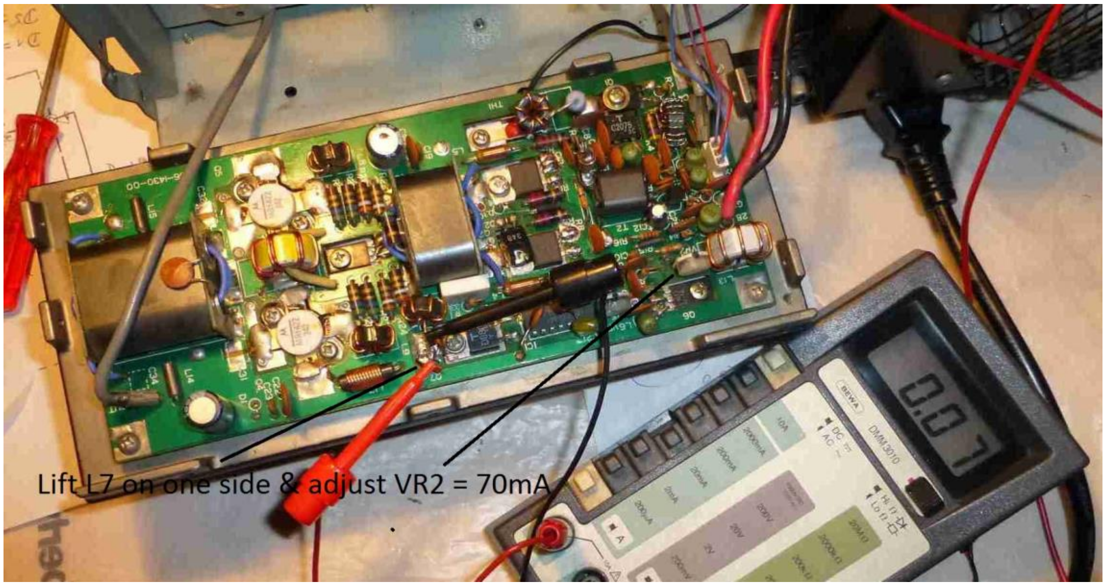
Once you have made those adjustments you can test the PA in TUNE mode or even on the air and check for hot spots or other signs that something is amiss. Carefully touch the drivers with the back of your forefinger. If something is more than just warm, find out why. The final outputs will get HOT in TUNE mode.

In my original paper, I was in a hurry to get my 930S back on the air and I failed to take pictures of the adjustments, so, I posted the excellent pictures and info submitted by Marcel, ON7DY on the next page. I have since taken my own pictures, but I'm going to continue the tradition. His readings are for Options 1 and 3.

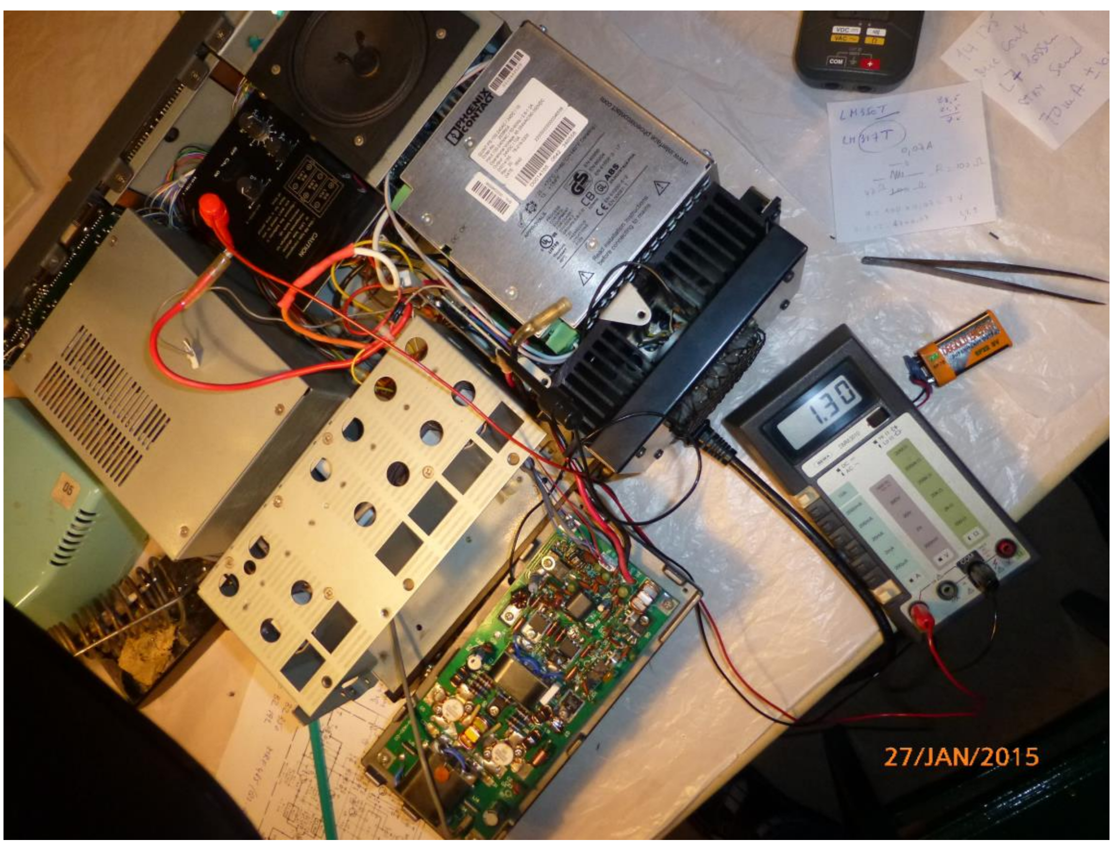
Marcel, ON7DY

"After delivering 40V to the PA not only are the MRF's blown, but most of the time the Zeners D1 and D5 are shorted, remove them but you don't need to replace them due to the self protection function of the new Quint power supply.

John told me: since I adjusted my PA idle current = 70mA, I haven't experienced the "flickering" dial light phenomenon that he mentioned in his earlier paper."



Note how Marcel lifted the side of L7 near the regulator to set the idle current. Care needs to be taken here not to short anything out. The main idle current measurement shown below is much easier.



<u>A COUPLE OTHER ISSUES.</u> There are a couple other things to consider while you have your PA out of your rig.

1. <u>A HOT RESISTOR.</u> There's a 2-watt resistor in the 28-volt supply line resistors in the PA that runs at 1.95 watts, and it gets finger-burning hot. It's R35, that 33-ohm resistor that stands on its end, soldered in series to a choke, right between regulator Q1, and thermistor TH1. I've never heard of one failing, but it bothers me, so I replaced mine with a new 3-watter. It was about the same size, so it fit easily. The new one still gets hot though.

2. <u>TO PIN OR NOT TO PIN</u>. When you take your PA out of your radio and begin to remove the drivers, you will notice that driver Q2 has a "20B" thermistor pushed down onto the tab screw, covered with thermal paste. The thermistor has a U-shaped end so it *could* be pinned down to the tab, but it's not. There's a second thermistor at regulator Q1, but that one IS pinned down. Pinning it down should result in better thermal transfer. So why didn't Kenwood do it for Q2 also? Who knows, but the screw at Q2 isn't long enough anyway.

   Dave Phillips and I kicked this around, and we both have adopted the practice of installing a longer screw, and pinning the thermistor down. But that's more work, and you can't crank down on that screw. Also, you have bend the thermistor leads back so that it will fit. Look at the pictures below. The option is yours. I just thought I should mention it.

<u>"PINNED"</u>

<u>"NOT PINNED"</u>