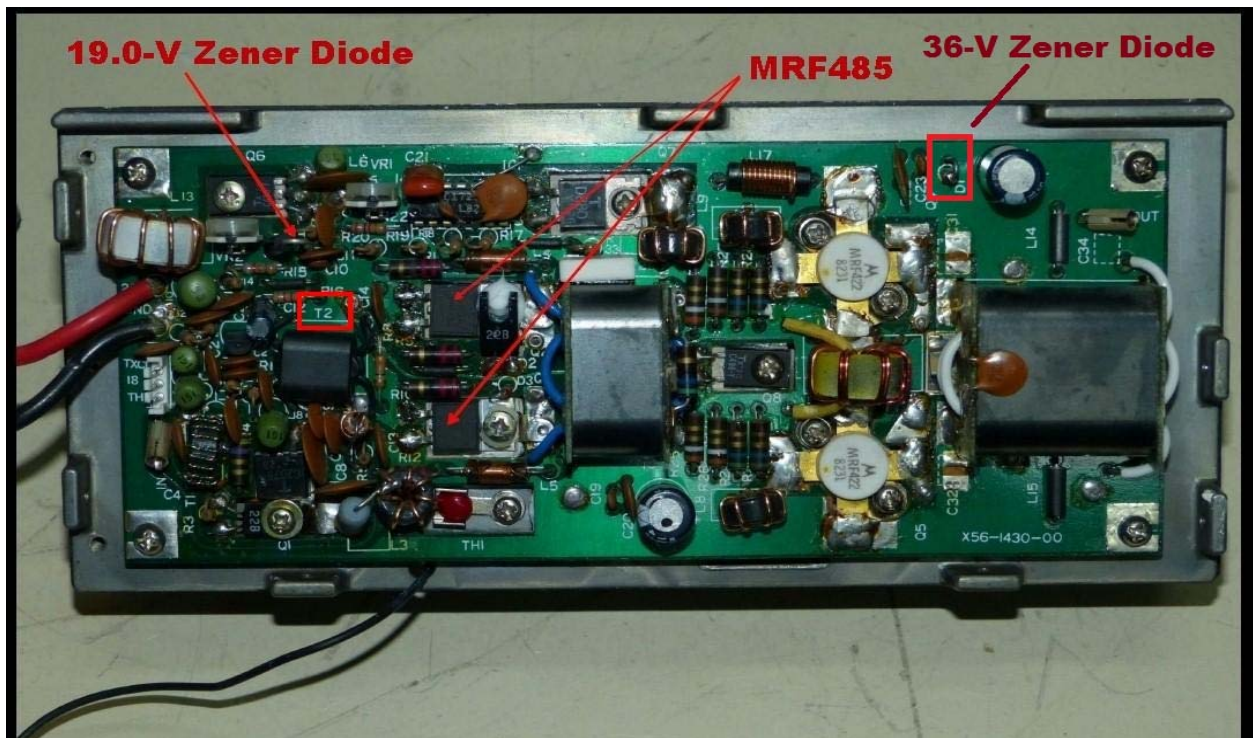


Options for Repairing your Kenwood Power Amplifier

If the RF output in your Kenwood TS-930S or 940S PA is zero, then most likely you have blown drivers. In almost all cases, the expensive outputs will still be good because their maximum V_{ce} voltage is equal to the 40-volt surge that typically destroys the drivers and the 19 and 36-volt Zener diodes, D1 and D5. If in doubt, use the diode test function on a DMM and check the Base-Collector and Base-Emitter junctions as though they were diodes. Unless you unsolder the Collector and Base tabs, the junctions should test as “leaky” diodes because of the Collector-Base feedback loop, and several connections between the two Collectors, including the primary side of T4. But you should see a slightly lower forward voltage in one direction as you reverse the leads. If it’s identical in both directions across one of the junctions, you may have to unsolder the base or collector tab and retest to be sure.

I have four PA’s, and I’ve smoked two of them, one twice, while trying out different drivers and I’ve never ruined a final output “pill”. 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 so they fail.



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. Eleflow has carried three versions:

1. A low-gain version made by HUAGAO Semiconductor. These had a current gain (Beta) of 22-25. They were a direct swap for the Motorola "red dot" MRF485's. I have a used pair of red dot Motorola's and their Beta tests at 23 and 25. I bought two pair of HUAGAO drivers for my PA's. I regret not buying more before they sold out. They performed identically to the OEM drivers, and I didn't have to change any settings, even AM output regulator VR22.
2. An intermediate gain version with no manufacturer's markings. These had a gain ranging from 50 to 61. I tried a pair of these in a good, working, unmodified PA. They worked fine initially, but they seemed "touchy" when I set the driver and main idle currents, and the moment I increased the output to 60 watts PEP, the case on one of them exploded. However, they work great when used with the PA modifications outlined in Options 2 or 3.

3. A latest version that according to Eleflow has a gain of 70-85. They claim that they have sold them to Kenwood owners and they have not had any complaints. But these will be far too "hot" to use in the 930s without the PA modifications described in Option 3.

NOTE: I'm about to rebuild a fourth PA that will be a hybrid using 2SC1969's that have a super high Beta of 212. The plan is to reduce the voltage to the 1969's to 12 volts as in Option 2, AND increase the negative feedback as in Option 3. If the 2SC1969 can be made to work reliably, then yet another PA rebuild option will be available to 930S owners.

There are probably many ways to make medium to high-gain MRF485's work in the 930S and 940S PA's, but so far I've only tested and used the three PA's shown below. The first two options can be performed without removing the PA circuit board from the heatsink. Basically, you can have:

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. If any of you know of a source for low-gain MRF485's, please let me know.
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.
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. He says that this will allow the 930S PA to run the higher-gain MRF485 drivers 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. I'm running this PA in my rig on a full-time basis now.

The advantage to Merit's solution is that the amount of negative feedback in the driver stage will be proportional to the current gain (Beta) of the drivers used. So his solution should work with Eleflow's latest version of the MRF485, and they recently told me that they can get up to 2000 pieces of that version.

The picture below shows all three options side-by-side. Options 2 and 3 will be described in detail on the following pages. The areas boxed in red show where I made changes.



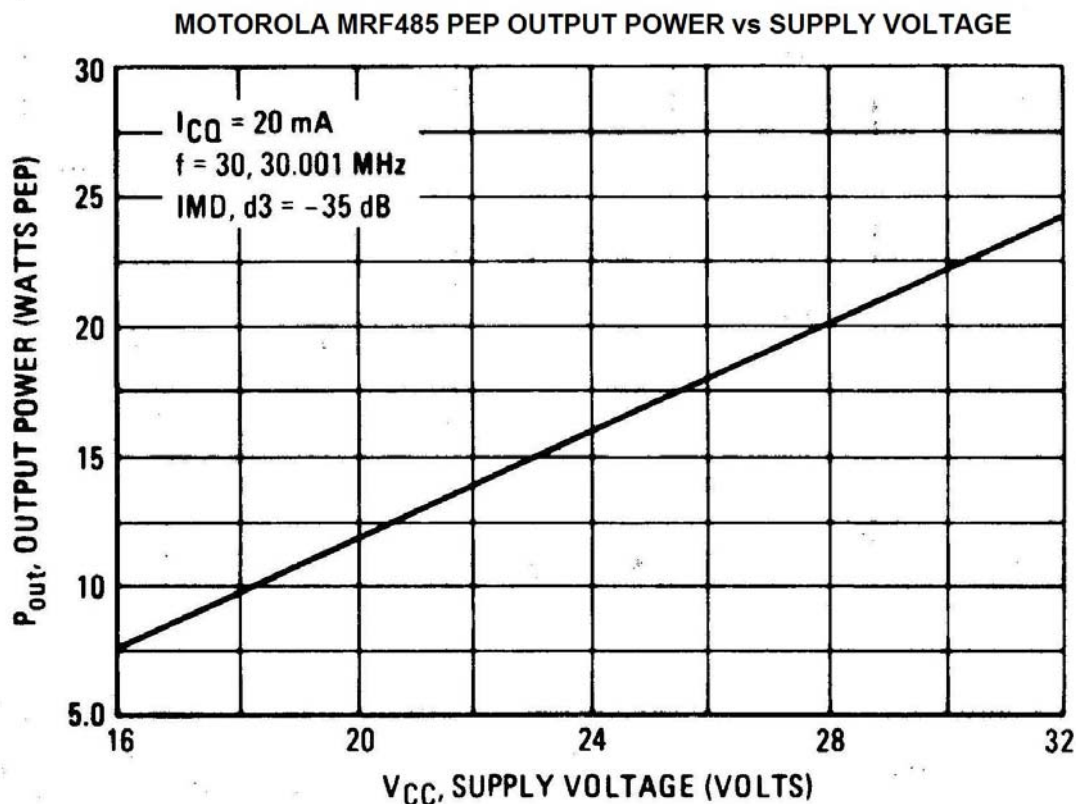
OPTION 1: Use low-gain drivers (if you have or can find them).

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 have to 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.

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

THEORY OF OPERATION: The Beta (h_{Fe}) 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 the MRF485 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, although having replaced the entire power supply yourself; you should be an “old pro” by now. Still, some prefer not to tear everything apart, and this option has proven to be reliable. 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 input 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 fan screws from your 930S to the hardware store and find a short match. I would get a couple. The 15-ohm shunt for R8 can be simply soldered across the base tabs of the 485 drivers.



MC78T00 Series

THREE-AMPERE POSITIVE FIXED VOLTAGE REGULATORS

SEMICONDUCTOR
TECHNICAL DATA

T SUFFIX
PLASTIC PACKAGE
CASE 221A

Pin 1. Input
2. Ground
3. Output



Heatsink surface is connected to Pin 2.

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

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 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.

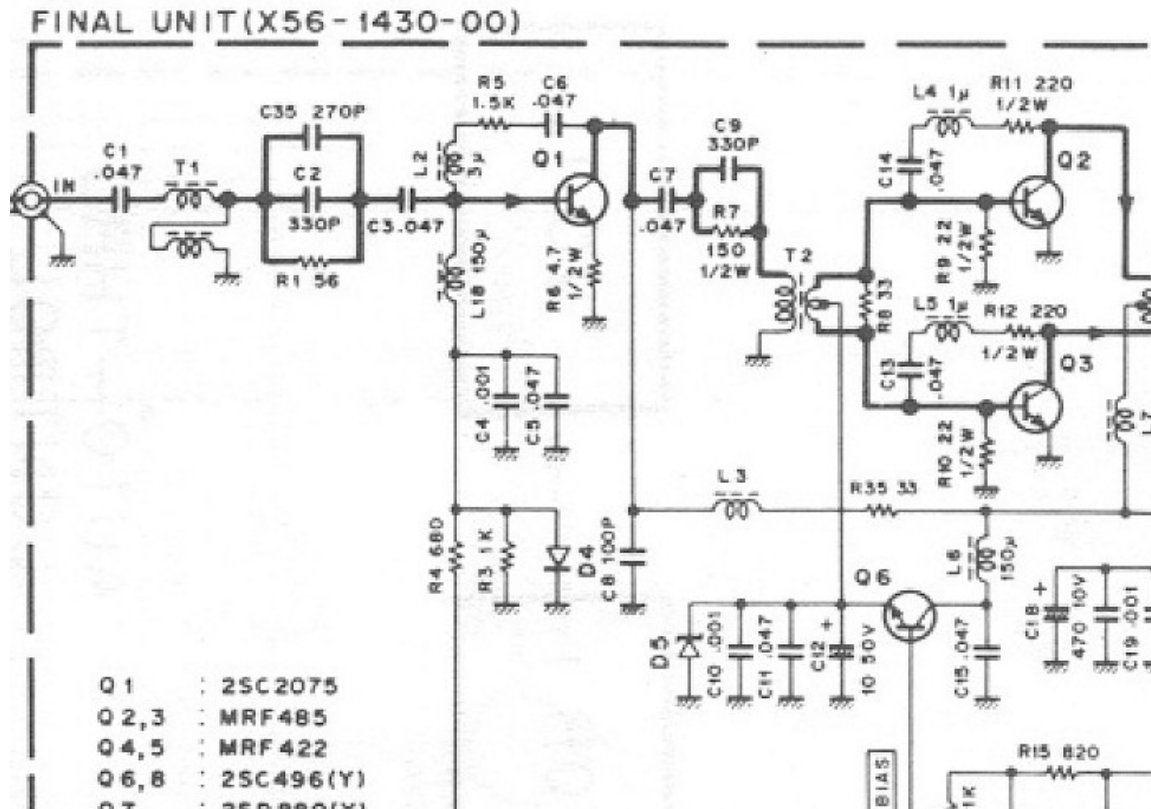


The photo below shows the finished PA board, with the new resistors outlined in red.



Once everything is in place, it's time for some resistance and diode tests. I used the schematic from Kenwood as a guide. A large version is in the APPENDIX. I've also included a picture of a PA heat sink with the insulating washers in their proper places as an aid.

If you use the diode test function on a DMM to test the Base-Emitter and Base-Collector junctions on the drivers as diodes, the readings will be dramatically affected 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, and it will also be across the Emitter-Base leads on both drivers. None of my PA's show the exact same reading, but 12-13 ohms is typical. The schematic below shows why. Bias regulator Q6's emitter, along with D5, C10, C11, and C12 are connected to the center-tap on the secondary of RF transformer T2. And the ends of T2's secondary 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.



“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. 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. Test for a diode relationship across the main power input leads to the PA. Typically you'll see about the same reading here as you measured between the collector tab and the emitters in step 2 in the forward direction, and infinity in the reverse. If you see a short or a low resistance in **both** directions, find out why before you apply voltage to your newly-rebuilt PA. (See the APPENDIX for test pictures and more info)

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 on pages 23 and 24. In fact, it's the only 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. **Confession:** I've performed the above adjustments with the PA in the rig. It's not that hard. I'll post some pictures in the Appendix.

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, then the PA idle current can still be set to 1.2 or 1.3 amps, but 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.

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 due to a contest that was underway. I failed to take pictures of the adjustments, so, I posted the excellent pictures and info submitted by Marcel, ON7DY on page 23. His readings are for Options 1 and 3.

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

1. **A HOT RESISTOR.** There's a 2-watt resistor in the 28-volt supply line resistors in the PA that runs at 1.95 watts, sandit 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'm going to try to fit a 3-watter in there. If it fits, I'll add the information to this Compendium.
2. **TO PIN OR NOT TO PIN.** 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. Look at the pictures below. The option is yours. I just thought I should mention it.

"PINNED"



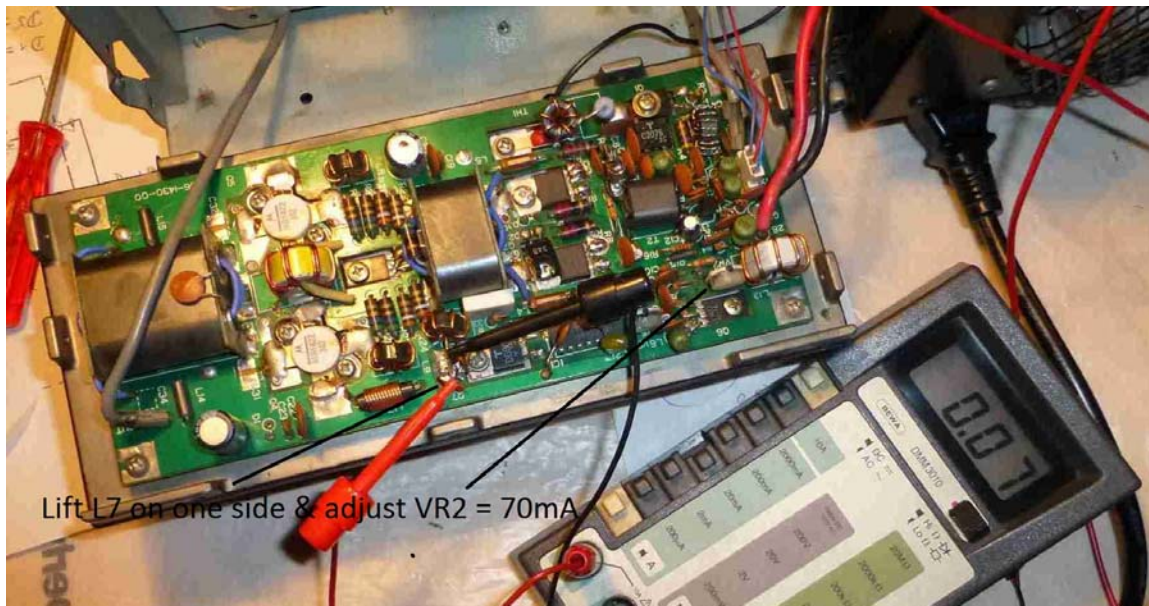
"NOT PINNED"



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. Extreme care needs to be taken here not to short anything out.. The main idle current measurement shown below is much easier.

