The ETO Alpha PA-77

By Matt Erickson KK5DR

Background:

The legendary Dick Erhorn of ETO fame, had a direct hand in the design of this heavy-duty desk top HF amplifier from 1972 to 1977, and in later models like the 77D, Dx, S, & Sx from 1977 to 1989. The 77 could operate from 80-10 meters (except 12 mtrs). It used the mighty EIMAC 8877/3CX1500A7 tube. It is a Pi-L output tank circuit, and has a vacuum capacitor for plate tuning, and vacuum relay in the RF output. There were also provisions for full-brk-in QSK keying and electronic biasing of the cathode. There is a tunable input network for a good match on all bands. There are a good many feature circuits that are now standard in many amps built today, but in the time of the 77 were an expensive and rare addition. The 77 could run a full 1000 watts output carrier mode with no time limit, and can easily run 1.5kW on SSB all day long. The HV power supply has an oil-filled capacitor for extra long life span and high capacity. A full-wave bridged rectifier develops about 2400Vdc on "CW" voltage mode, and about 3800Vdc on "SSB" mode.

The later versions (larger cabinet and PS) D,(a later version of the PA-77), Dx , S & Sx differed slightly. The "Dx" version had the addition of 160 meters. The "S" came from the factory as a "two-hole" version. The "x" denoted that the model had the addition of 160Mtrs.

My PA-77:

I have always wanted one of these beasts, but could not afford one back years ago. They were extremely expensive when they were new. It was not until recently that I decided to do what I could to acquire one. The unit I bought came from an estate after having sat for years.

(back panel)

Much to my surprise, when I got my 77, I realized that there is no "standby" switch to allow the amp to be bypassed while still powered up. I was able to add a switch to the back panel, as can be seen in the photo above, point "B", this breaks the relay keying line when the unit is to be by-passed. I had to replace a defective ALC adjustment pot as well, point "A". I upgraded the pot from the original 50K unit to a 100K pot to allow for more adjustment.

You will notice that there is a "muffin" fan on the back panel, this is not a "factory" install. I installed it to aid in cooling the PSU as well as assist the tube blower. The amp comes with an opening that is standard for this size of muffin fans and is pre-drilled for easy installation. I also installed the dust filter. A filter is important, dust accumulation on the tube anode cooler can cause tube failure, or at least damage the chimney and other parts.

The main blower of the 77 is a Rotron® ball-bearing type, and can be adjusted for a low/quiet idle speed via a slider resistor near the blower. A thermal switch on the air outlet will switch the blower to full speed should the air temp rise to a level that would be reached during full duty type modes. I raised the speed to a moderate level to insure cool tube operation. I measured the stable air temperature at the air outlet, it is about 100 degrees F. and rises to about 125 degrees during extended SSB transmissions. There is a "cool-down" mode, when the "OFF" switch is partially pressed, it pops out and lights up red, during this condition the blower remains on and the rest of the PS shuts down to allow the tube to be cooled off. Pushing "in" the "OFF" button shuts the blower off.

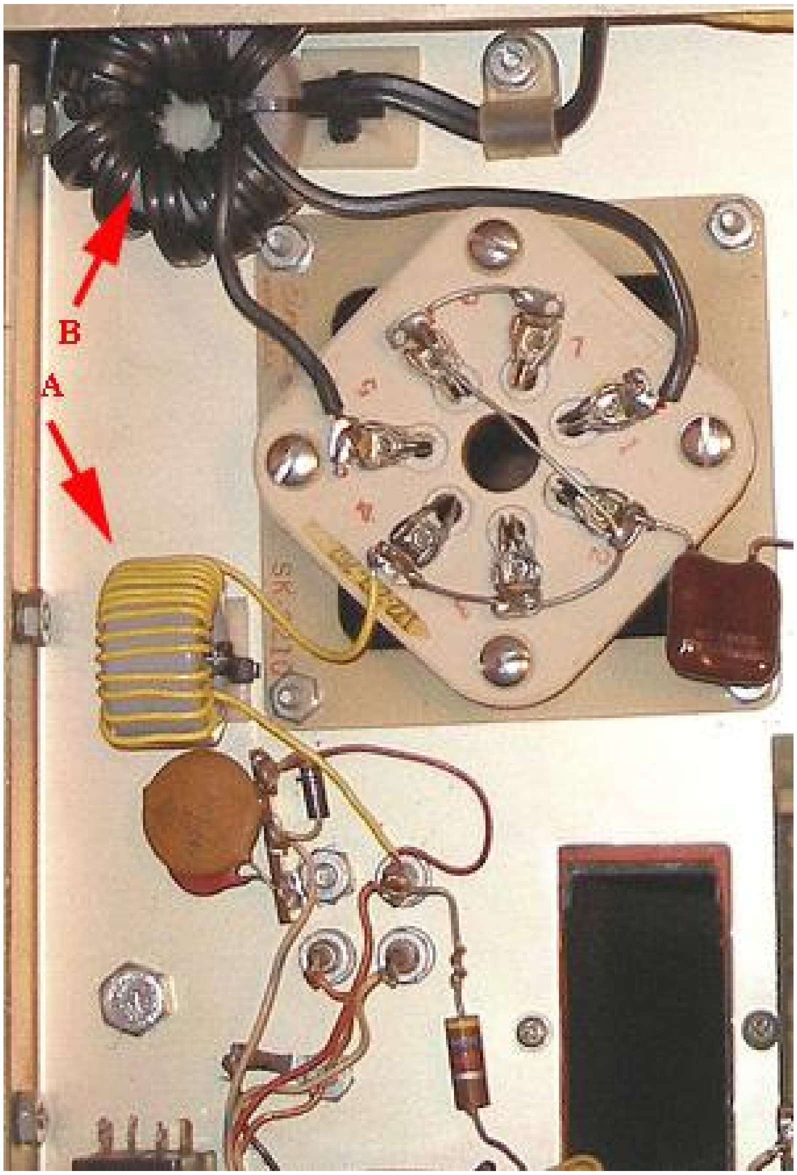
During shipping The tube came out of the socket and did some damage to the tank area, (never ship an amp with the tube unrestrained in the socket). The tube proved to be damaged, the heater filament was open, so I had to install a new tube. Shipping damaged the HV filter cap as well, but I was able to repair it without replacement. Below, is a photo of the repair I did to the capacitor. After cleaning the oil seepage off the case, I carefully glued the loose terminal back onto the metal case, then covered all of it with a thick coat of silicone sealer for added support and vibration damping. The diode board bolts directly to the cap terminals, with no other supports, vibration or impact shock could break the terminals again, so I made some plastic clips that will help hold the the board in place, but still allow removal of the board should it need servicing later. The original oil-filled capacitor is 25µF @ 4kV.

(HV filter capacitor)

Input re-work:

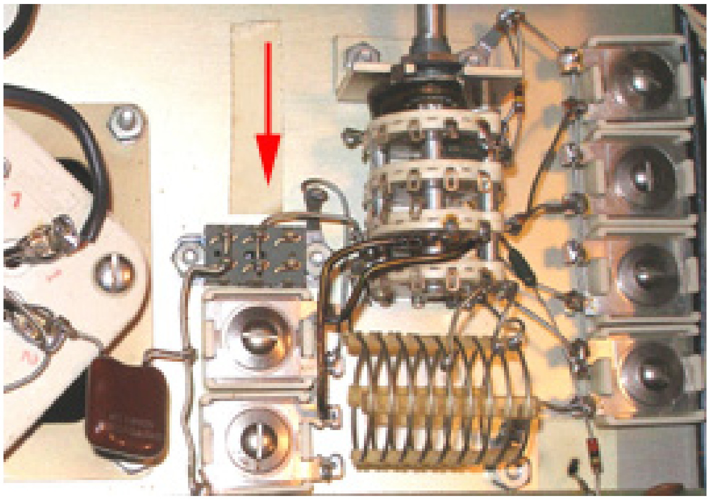
I found a few issues with the input area. The original cathode choke, which prevents RF from propagating back down the B- line and damaging the bias circuit, was a bit small for my liking so I fabricated a new toroidal choke with heavier wire and much higher inductance. The original is a 15µH @ 1A. slug type. The new choke it 2.5mH and can carry over 2A. The arrow point "A" shows the new choke installed. My reasoning for replacing this choke, is that at the level of inductance of the original part is too small for RF at 80 meters, which could easily propagate through the choke and into the cathode circuits causing damage and or erratic operations. This would become especially important if 160 meters is add to the amp.

The 77 was not equipped with a heater/filament choke. This is not an absolute necessity, but I installed a toroidal choke wound with bifilar 16ga wire, to prevent RF from ever coupling with the heater supply. My new choke serves dual purposes, one is to block RF from the supply line, the second is to reduce the filament voltage by a small amount. Originally, the heater voltage was outside the max allowable level of 5.25Vac. With the new choke installed the voltage at the socket is now about 5.1Vac, which is slightly high, but within the allowable range. The choke windings get only slightly warm. The arrow marked "B" points to the heater choke.



(input side of the socket)

The tube socket is the "Septar" type, 7 pin, which is also used on the 829B tube. You will notice that several pins are connected together, these are all cathode pins, wiring them together is standard practice. The higher the frequency that the amp is designed for, the heavier the connections on the cathode need to be. At VHF, the pins are usually connected with a solid copper plate.



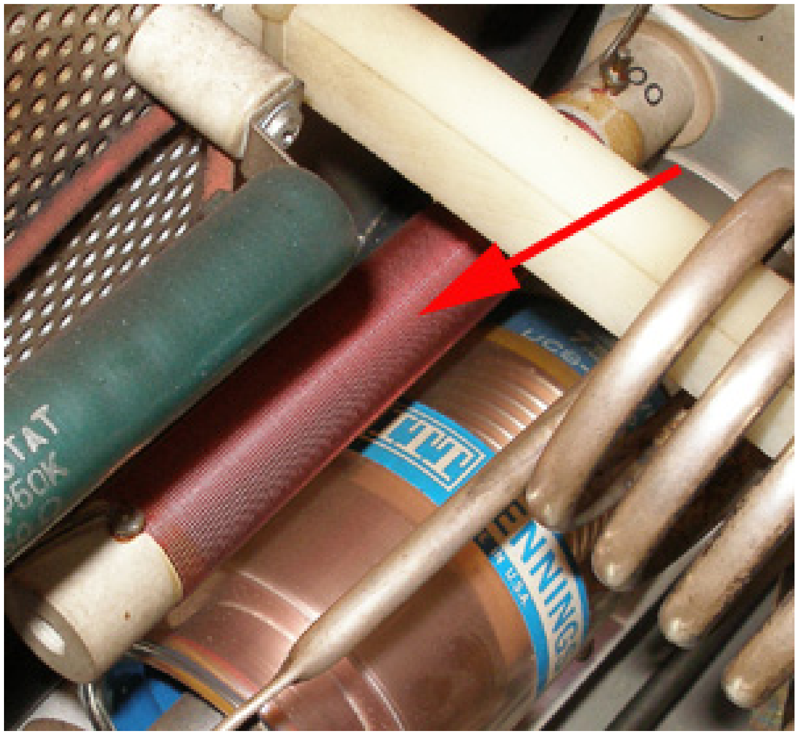
(tuned input network)

The photo above shows the tuned input network including the band-switch. The red arrow shows a by-pass switch which allows the input network to be by-passed. I have removed the by-pass switch from the circuit, there is really no valid reason to have this feature, so I wired around it. The only instance where this switch might be needed is when the amp is used outside the amateur bands, but since I have no plans to ever do that, I by-passed it.

Tuning the input network can be done without putting the unit on the air. I used a small carbon resistor of 54 ohms (equal to the cathode Z of the 8877). I soldered it from the tube cathode to chassis ground, then applied 24Vdc to the RF input relay, K-4, then connected my MFJ-259 analyzer to the RF input port, then dialed the frequency I wanted to adjust the input for. Then I adjusted the compression caps of each band for a flat input SWR. This method is much more safe and effective than doing a "powered up" adjustment with an exciter providing RF drive signal. Later, an "on-air" check confirmed that the adjustments were perfectly on target. The input match is good across the entire band when set at center band.

WARC? :

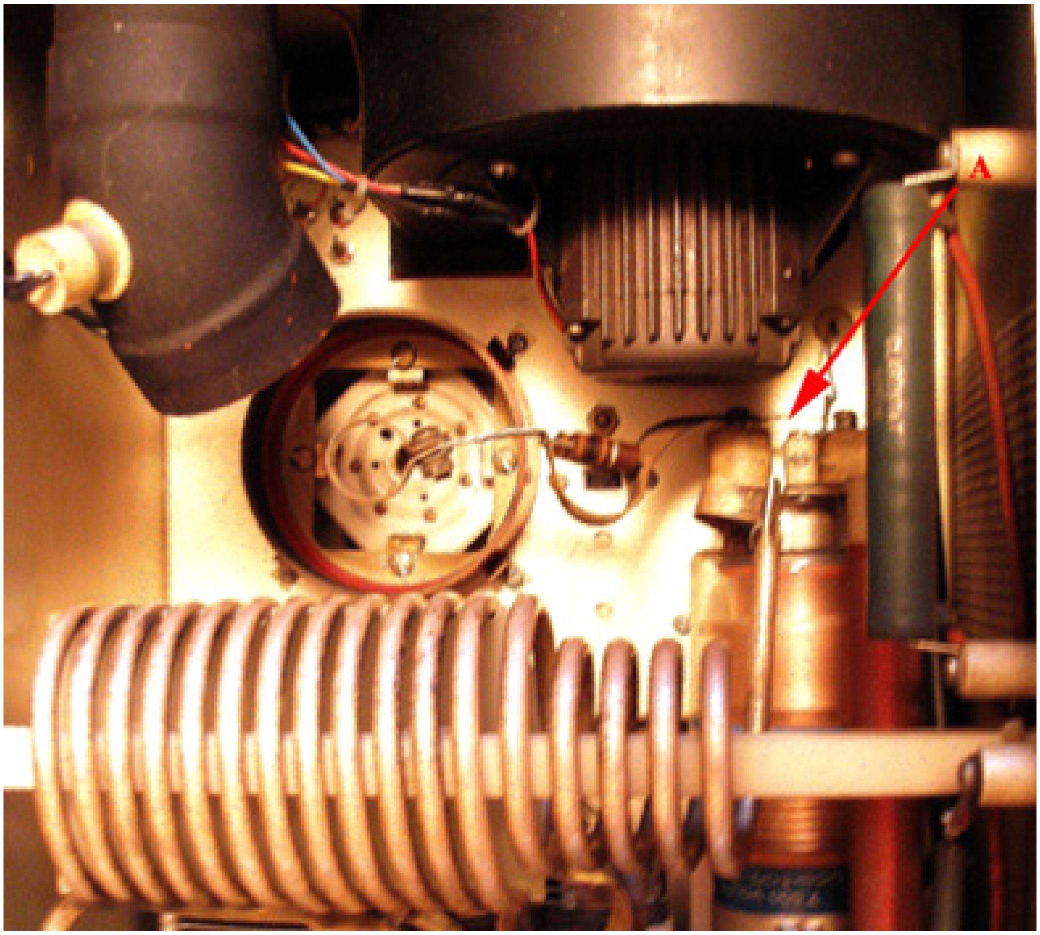
These amps are much older than the WARC bands, but can be used on some of them. ETO Alpha stated in the operation manual that the unit could not be used on the 24MHz band. The reason for this is the problem of the plate choke being series resonate at about 25MHz. If used on about 24.9MHz, the plate choke smokes or goes "BANG!". This problem is simple to fix. Replace the OEM choke with a choke from RF Parts Co. # RFC-3, or use my ferrite loaded design.

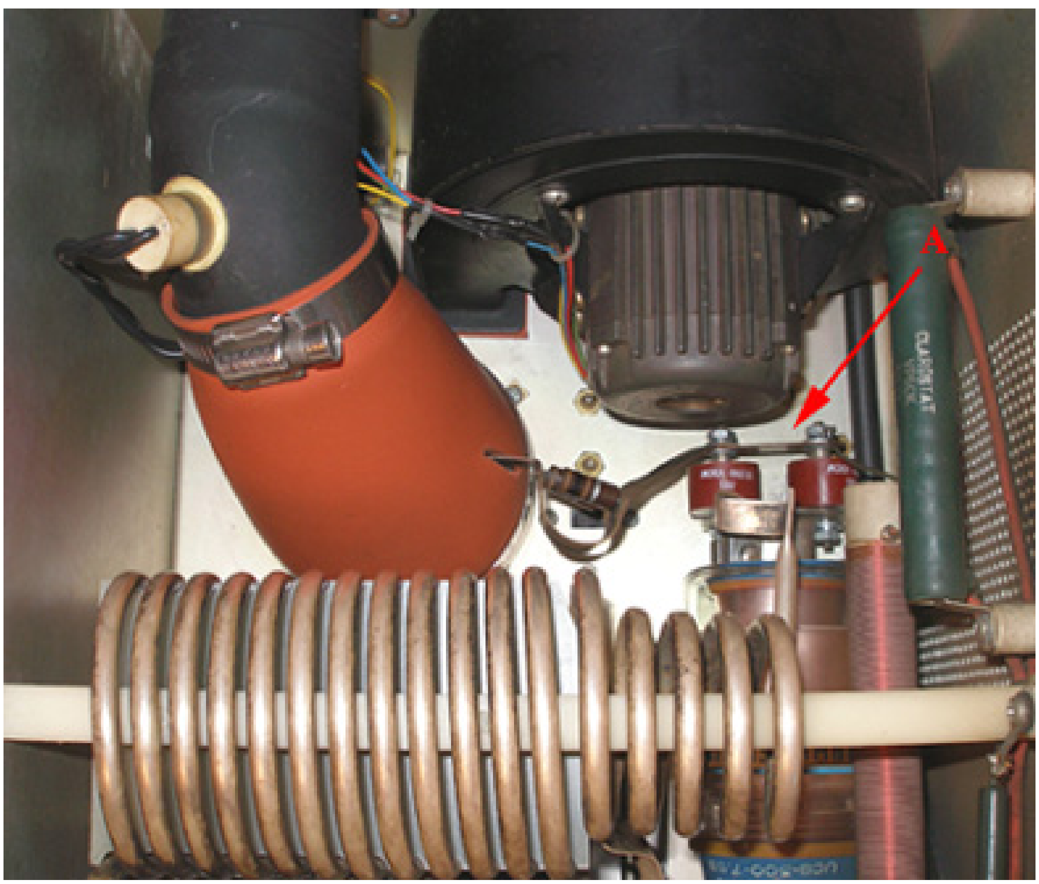


(plate choke)

The picture above shows the OEM plate choke, which is a B&W model 800. Below the choke you can see the plate tuning capacitor, a 300pF @ 7.5kV vacuum unit. It is highly unlikely that this cap will ever arc while tuning.

ETO Alpha PA-77, inside and out, old and new.





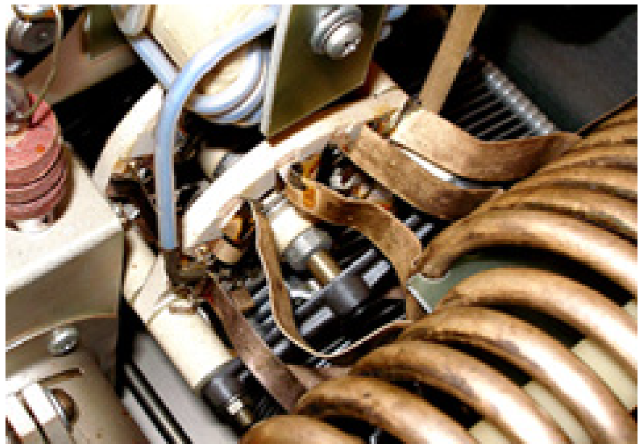
Coupling caps:

The two photos above are of the tank circuit section, the arrow marked "A" shows the plate "coupling" capacitors, there are two in parallel. The photo on the left shows the factory installation, the caps are .001µF @ 5kV door-knob type. As a "rule of thumb" the plate coupling caps should be rated for at least 2 times the B+ voltage, more if possible. Serious damage could be done if the caps ever shorted. I replaced the caps with new 10kV plastic encapsulated door-knobs. Another "rule of thumb" is that for HF operation the caps should have a total capacitance of not less than 1000pF, and not more than 4000pF. This is so that the maximum amount of RF current will be coupled to the tank. If too much capacitance is used, the tank will be de-tuned and efficiency will suffer, in addition the amp could become a robust oscillator. Too little capacitance will cause a limited amount of RF current to be coupled. Many times a single cap will not pass enough current without overheating, so many manufacturers use two or more.

The photo on the left shows the tube socket with the tube removed. The photo on the right has the tube and exhaust duct installed. You will notice the strap connected to the tube anode has a "U" shaped bend in it, and a pair of resistors shunted across it, this is a parasitic choke. The 77 is entirely stable on all bands, there is no evidence of any parasitic oscillations.

There are no settings shown in the manual for the 17 meter band, since this band was not active yet in the era when this amp was designed. Finding a resonant point would take a great deal of time, and could damage the tube in the process. So, to take the "guess work" out of it, I did a calculation to establish the resonant tank impedance of the output network. My calculation indicated an impedance of about 2500 ohms. To verify this, I placed a 2500 ohm carbon resistor from the tube anode to chassis ground, then applied 24Vdc to the RF output relay from an external bench PSU, and connected my MFJ-259 to the output port, dialed it to a known frequency that the amp works on and confirmed that the 2500 ohm impedance is correct. Next, I moved the band-switch to the 20 meter band, and applied a 17 meter signal to it from the MFJ-259. Then I tune the plate and load caps for a 1:1 SWR on the analyzer. I found that the 17 meter band works well on the 20 meter band-switch position, but not in the 15 meter position, this is a little unusual since most amps do just the opposite. An "on air" test confirmed all of the above procedure was correct.

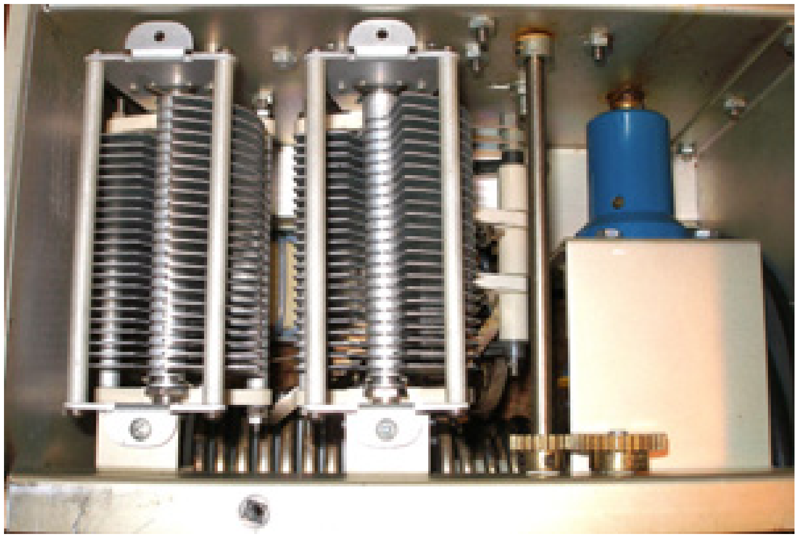
<How do you calculate the plate impedance of a tank circuit?> Take the maximum plate current times 1.8, then take the product of this function and divide it by the plate voltage. The result should be rounded to the nearest whole number, this will be the plate impedance or pretty close to it.



(Band-switch)

Above, is a picture of the main band-switch, it is a Radio-Switch Corp.® model 86, now made by Multi-tech industries Inc. These are very heavy duty switches, you really have to grossly mis-tune the amp at extreme power levels to arc one. There is one extra "open" switch position marked "A" on the knob, the "B" position does not connect to anything since there is no switch contact in this position. The open switch position can be used to add 160 mtrs.

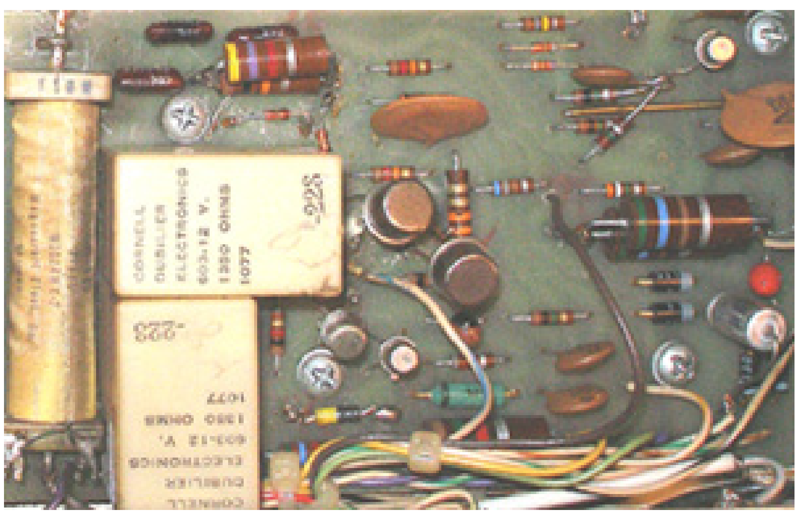
Loading capacitors are a synchronized pair of air variable caps, driven by an intricate chain system. The loading caps are shown below in a view from the bottom-side of the RF deck. The tuned input drive shaft can be seen near the center of the photo.



(loading capacitors)

Ahead of its time:

In the days when the 77 was designed, it had several features that were very advanced for amps of that period. Some of these designs were, warm-up time delays, step-start, & electronic bias. All of these features were controlled from one board, seen below.

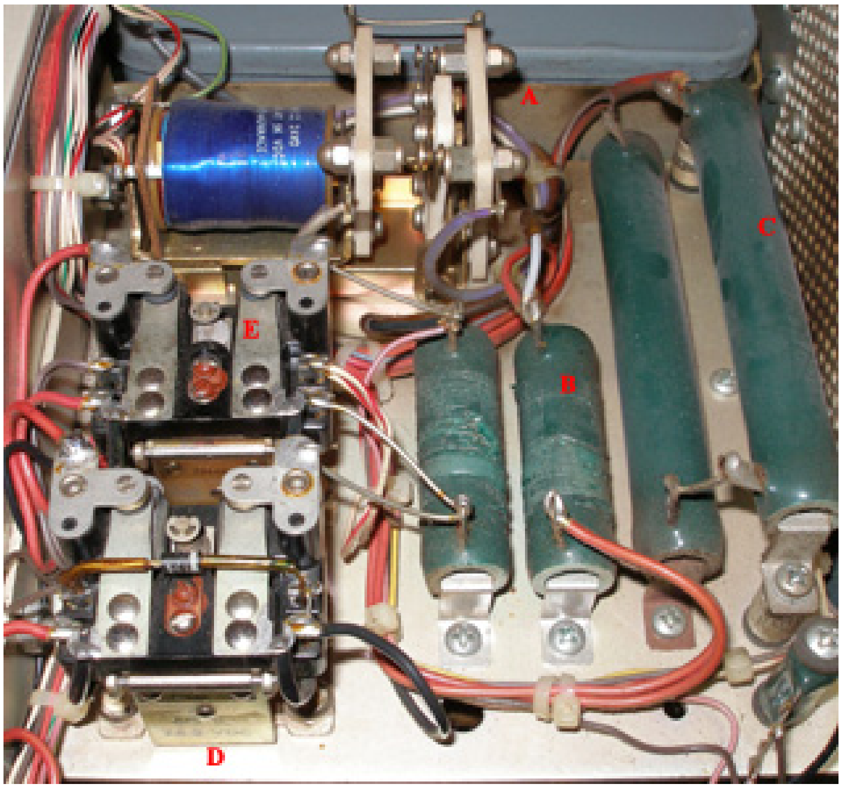


(control board)

The RF input relay is on the left side, warm-up delay relay to the right of it. The electronic bias portion of the board is near the center.

Electronic bias switches the operating bias on and off at an audio rate by sampling the RF drive signal. This brings the plate current level to cut-off between voice syllables or CW tones. If the timing capacitors are not carefully selected for the circuit, electronic bias can introduce "compression" type distortion to the output signal. I tested the signal on the air, and found no evidence of this on the air, so the circuit was well designed, and works fine.

Step-start:



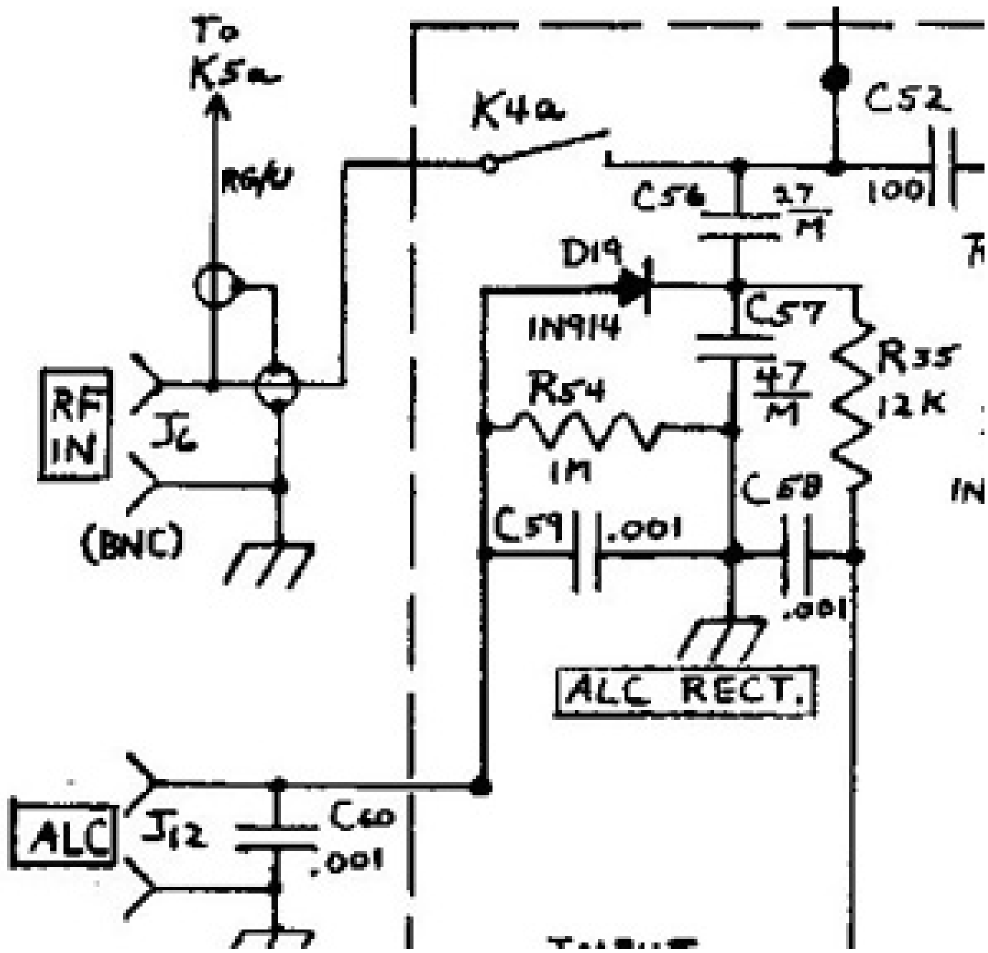
(step-start circuit)

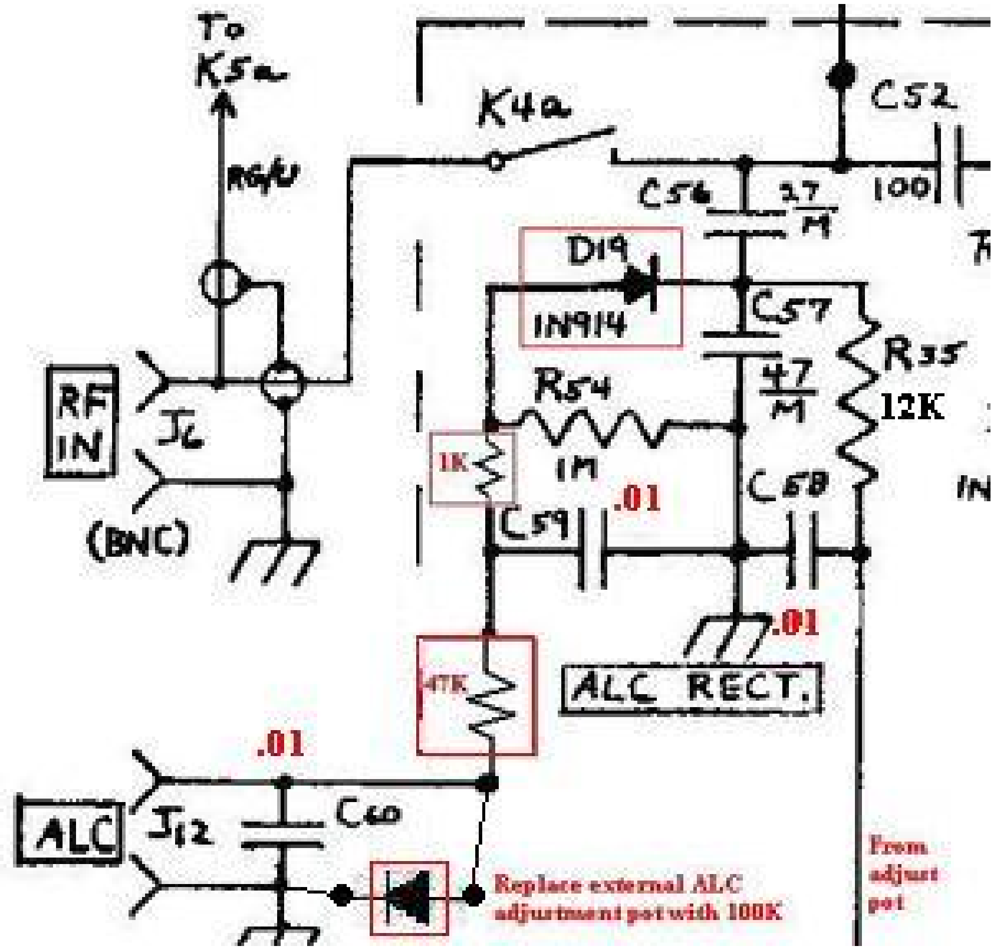
Above, is a photo of the step-start circuit and a few others. The primary relay of the step-start is at "D", the secondary relay is marked "E". The large relay marked "A" is the HV "transfer" relay, which changes the HV from low to high and back. "B" marks the step-start resistors. The HV bleeder resistors are marked "C". The time-delay of the step-start is fixed at about 1/2 a second.

Defective ALC:

After operating the 77 for a while with my ICOM exciter, I found that the ALC seemed defective, because The amp was being driven beyond the level of which it should normally be driven with the RF drive setting on the exciter. I suspected that the ALC circuit was leaking positive DC instead of the negative-going DC as it should be. It is likely that after so many years (30+) of service, the diode, and or capacitors in the ALC circuit have begun leaking.

Research confirmed that a positive DC voltage on the ALC input of an ICOM exciter can cause an "over-ride" of the RF drive level setting. This is the exact indication that I was seeing during operations.



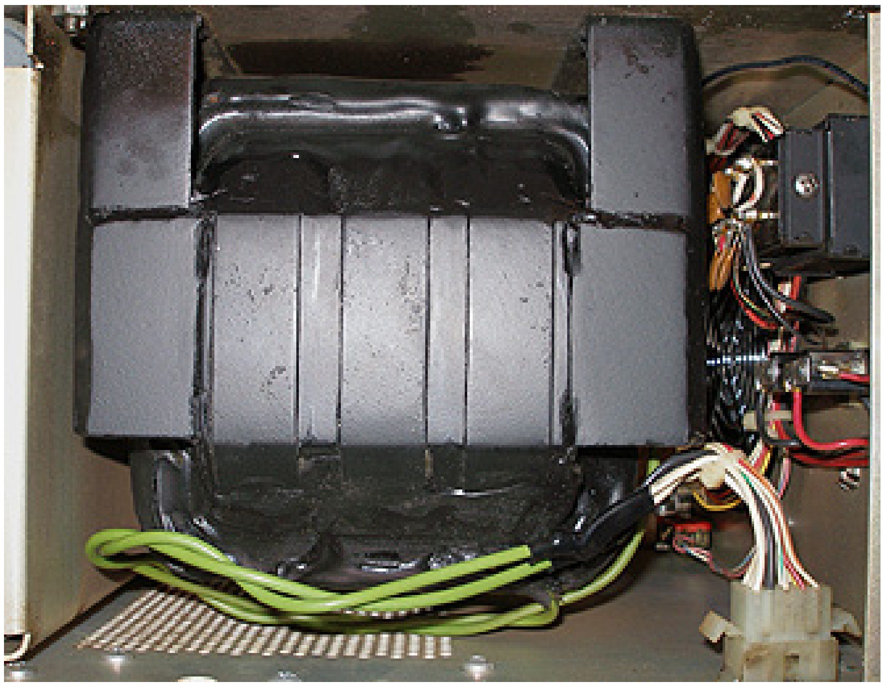


The schematics above shows the main ALC circuit. The drawing on the left is the original factory design, the drawing on the right shows my modifications to the circuit, which bring the voltage down to a level more comfortable for today's radios. Diode D19 was replaced, since this is likely the primary cause of the defect. The two resistors in the red boxes were added to circuit. The component values shown in red indicate changes from the original. The original external ALC adjustment pot was damaged, so I replaced it with a 2 watt 100K ohm pot, this would allow greater adjustment range for operation with a wider variety of exciters. The diode placed near the ALC output port is for positive voltage protection. Should the DC voltage output of the circuit ever go positive, the voltage would be shunted to ground by the diode, thus preventing positive-going DC from ever being allowed to appear at the output port. I tested the modified circuit and found that a very small level of positive voltage appears at the output, so low that the protective diode does not conduct. A level this low is not likely to harm or influence the exciter.

Power transformer:

The power transformers used by ETO Alpha were custom made for them by Harold Johnson Co. until recently.

They used high-silicon, grain orientated steel cores, otherwise known as "HyperSil". The windings are flat tape-like copper wire with Teflon® insulation. They are very compact and very powerful. Most are dipped in epoxy sealer to prevent moisture from entering the windings and causing an arc-over. Below is a photo of the bottom side of the power transformer. The green wires at the bottom of the photo are the heater/filament supply lines.



(power transformer)

A little history regarding "HyperSil" core transformers. They were designed by Nicola Tesla and patented by Westinghouse Co. in 1930, for which Tesla worked for a time. Years later the patent expired and many companies began building HyperSil core transformers.

The advantage of using HyperSil over a standard iron core is that the size and weight can be reduced but the power output remains the same as the larger iron core. This is because HyperSil can handle a much more dense magnetic flux in the core without overheating. For example, an iron core transformer with an output of

3kVa might weigh over 90 lbs., but has the same output as a HyperSil core which would likely weigh 50-60 lbs. A considerable savings in size and weight, which equals more money in the pocket of the builder.

Things to watch for:

Due to the advanced age of this model, there are certain things that need to be watched for and checked.

(1) Arcing in the load capacitor, band-switch, and any part of the HV PS section.

(2) Wire insulation that has become hard and cracked, any of this should be replaced ASAP.

(3) Relays with seriously pitted contacts, replace as needed.

(4) Flaky, intermittent switches, clean with contact cleaner and treat with Pro-Gold or DeOxit.

(5) Oily leakage from the HV filter capacitor, replace as needed.

(6) Dust accumulation on the tube anode cooler, remove yearly. Install a washable filter on the air intake to reduce dust accumulation internally.

Possible modifications:

A common issue with the PA77 is that the panel lights dim and flicker when the amp is transmitting. There a couple possible ways to deal with this issue, (1) install a three leg voltage regulator in-line with the +55 and +24Vdc lines. If you do this, reduce the +55V line to +48Vdc with the regulator and set the +24V line to +22Vdc with a separate regulator circuit. A voltage regulator will only work properly when the output line is set a few volts below the input line. It isn't very important that the voltage output be set to the factory ratings, as there is a wide allowable range, it is more important that the line be well regulated. (2) replace the panel lights with LED lamps and the properly selected current limiting resistors. All LEDs should be wired in parallel and connected to the line through the current limit resistor. The typical LED draws 20mA at full load, so add up all the LED and multiply that by 20mA for the total current draw of a string of LEDs which will tell you how high the wattage rating of the resistor will need to be. For LEDs in the +24Vdc line a 10K ohm resistor will work, on the 55V line a 24K ohm resistor will be required. Replacing the lamps with LEDs will have two effects, first the current load will be dramatically reduced, and secondly the LED will last far longer than the original lamps, practically forever. The user has a wide choice of colors when LEDs are used.

If you have difficulties with your PA-77, or have other questions about it, let me know, I'll try to help out.