New life, for an old workhorse.

(front view of original unit)

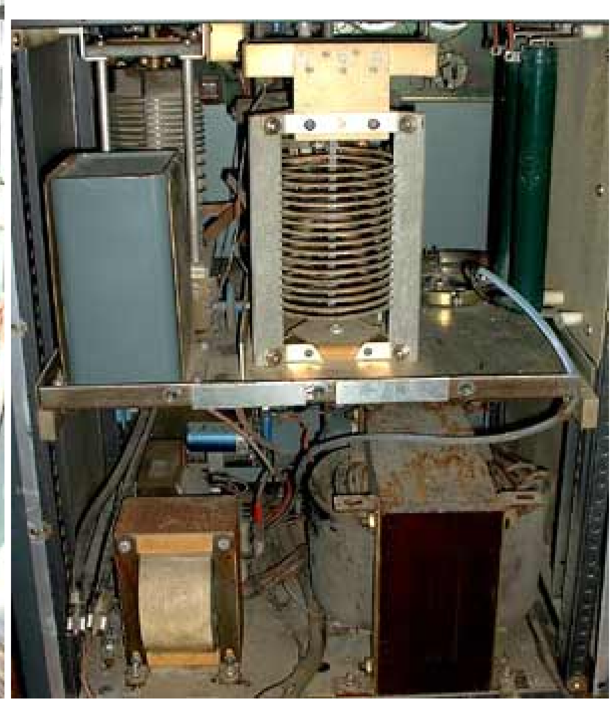
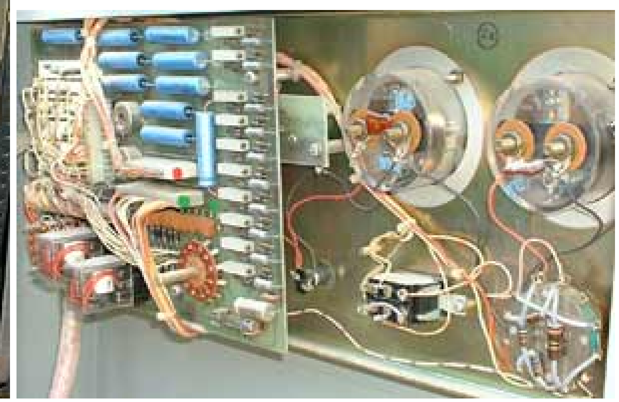
This unit was a "busted" Harris RF-103, I am converting it into something very different from the original design.

Background on these amps:

These amps are designed to operate from 2.0 to 30MHz continuously, at an RF power output level of 1Kw, in any mode, no time limit. It weighs a gut-busting 246 Lbs. It stands 30" tall, 20.6" wide, 21" deep. It uses a single 3-1000Z tube in grounded-grid, cathode driven configuration. About 65 watts of drive will yield 1Kw output. It is tuned manually, or can be configured for automatic "channelized" operation. Below, is a view of the interior of the 103, without the tube or chimney installed.

One of the unique design features of this amp, is that it uses a Pi-output network that has only one tunable component. Unlike most amateur amplifiers, the Harris uses fixed capacitors that are switches in and out of the circuit along with a fixed tap inductor. Tuning is done by the large edge-wound roller inductor, seen at the far right in the picture below. This design allows full coverage of all the HF spectrum from 2 - 30MHz. The disadvantage is that you need a band-switch with lots of positions and banks on it, the band-switch is in the center of the picture. On some frequencies the optimal LC combinations might not be available. But then an amplifier with a tapped inductor and variable capacitors will see greatly reduced output when operated far away from the optimal tap point on a given frequency.

Many of these units were used for "ship-to-shore" phone operations onboard maritime vessels, and off-shore oil rigs. They often did duty on 2.5 and 13MHz marine bands.

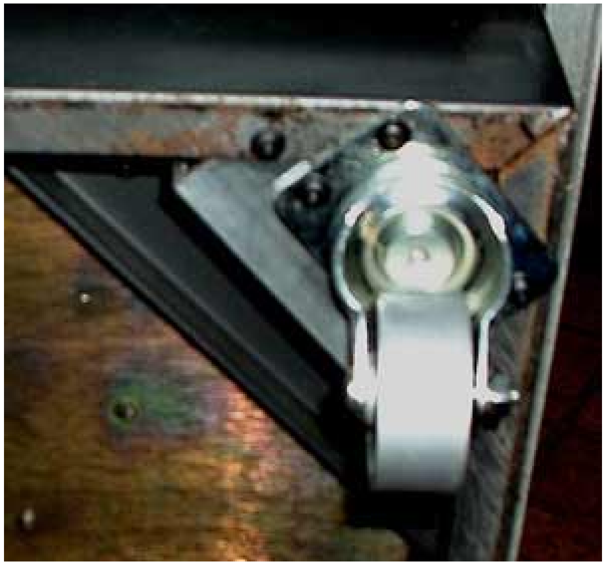
(front view) (rear view) (rear of the front panel)

Above, is a picture of the rear of the front panel, showing the channel controls, and the rear of the front panel meters. The auto-tune channels are set up and adjusted here. Reference voltages are used to set tune point nulls in the servo-controller circuit. There are ten channels, several can be set within each frequency range, or set as single band tune points.

The picture above is of the unit with the rear panel removed for inspection. You can see it is pretty dusty due to being stored in a warehouse for years. The bottom right corner is the HUGE plate transformer, weighing over 100 Lbs. on the left is the HV filter choke, and to the rear of it is the filament transformer. On the upper shelf, left side is the oil-filled filter capacitor (unfortunately this one contained PCBs, and must be disposed of), to the right of it is the fixed tap inductor, and on the far right are a pair of HV bleeder resistors.

Getting started:

One of the first things I did was install a set of heavy duty steel casters to make it much easier to move this beast around. The manual indicates that optional casters were offered, but I would say that they would be as hard to find now, as $1 per gallon gasoline. So, a trip to the hardware store, a bit of drilling with the addition of an aluminum angle stiffener did the trick. Below is a picture of one of the installed caster.



(new caster)

Tube of choice:

(A new 8877)

I have stripped the unit down to bare chassis, and all wiring has been removed. All of the wiring will be new when it is done. The new 8877 seen above, is a "Pro-Tek®" sold exclusively by D & C electronics in Springhill, Florida. These tubes are likely EIMAC O.E.M. versions of the tube. I've tested them and they work fine, just like the genuine article.

Conversion alternative:

A conversion of tube only, that is easy to do, would be to convert the amp to a 3CX1200A7, the only changes required are the socket and chimney. The socket needs to be changed from the stock EIMAC SK-510 to the EIMAC SK-410. The filament voltage and current are the same. Another tube that could be used is the EIMAC 3CX1500D7. This tube uses the same SK-410 socket but uses a 5V @ 30A filament. Either one of these tube conversions is a viable route and requires the minimal level of intrusion. The 3-1000Z tube is a dead-end tube and no longer a reliable source, so conversion to an available type is a concern.

New plate choke:

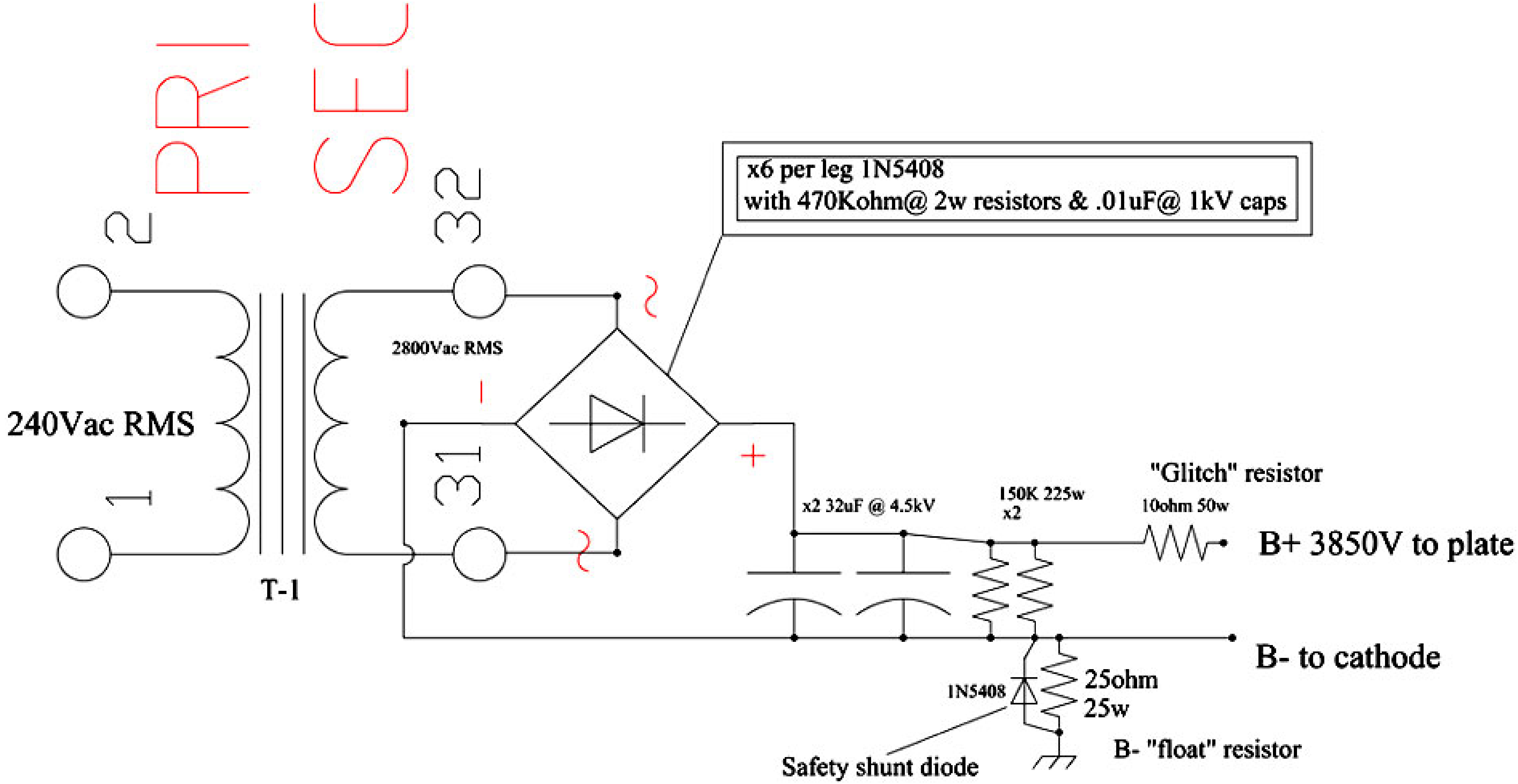
(new plate choke)

The picture above, is the new plate choke I fabricated for the project. It is my design of a ferrite loaded Delrin® rod. Without the ferrite rod, it would be only 40µH, but with the ferrite installed, the inductance jumps up to 365µH but it still has the same distributed capacitance of the original choke. It is wound with 22Ga. silvered, stranded & Teflon® insulated wire. To read more about my choke design, click here.

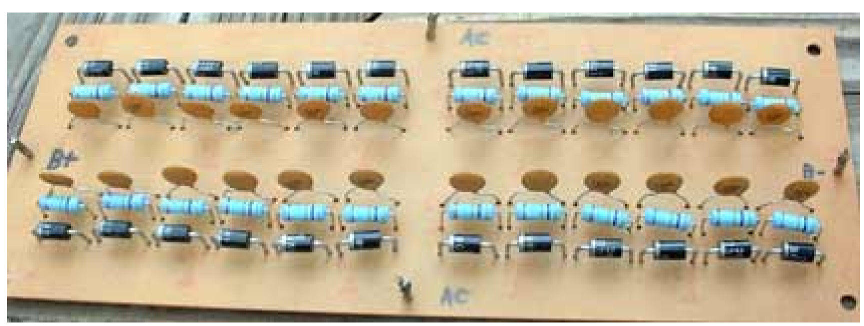
Plate load impedance? :

How does one determine the plate load impedance of an amplifier? Take the desired plate current level, such as 850mA. times the constant 1.8 = 1.53, then divide this into the plate voltage, 3850Vdc = 2516 ohms, round to the nearest even number, and you get 2500 ohms of plate load impedance.

You might wonder how much the RF power output should be for such an amplifier. Take 3850Vdc times the plate current of 850mA. = 3272.5 watts of plate input power. Now, if the tank circuit is well designed in a class AB2 amp, the RF power out should be roughly 60-65% of the DC input power. Using 60% this would be about 1963.5 watts of useful RF output power for this example.



(HV PS schematic)



(HV rectifier stack)

Above, is the HV rectifier unit I will use, it consists of (24) 1N5408 1kV @ 3A. diodes. Each diode is swamped by a 470K ohm 2 watt flame-proof resistor and a 0.01µF @ 1kV capacitor. The resistors equalize the voltage across each diode in the string. The capacitors bypass any diode switching transients which show up as white-noise on the transmitted side-bands. The six diodes in each string are for PIV safety factor, since the string must be able to withstand 1.41 times the maximum RMS voltage of the plate transformer secondary. Each leg of the bridge handles 1/2 of the total 1A plate current, and each of the legs conduct forward for 1/2 of the AC wave, so these operate under full load with lots of headroom. Mounted in the air-flow of a fan, the HV regulation will not suffer due to diode junction heating. The unfiltered DC pulses at the output of the diode stack are 120Hz, or double the 60Hz AC line frequency. These pulses or ripples are smoothed and filtered by the HV filter capacitor.

New HV parts:

I found that the new power supply configuration would place far too much plate voltage on the 8877 using the OEM Harris plate transformer, so I resurrected a Peter Dahl HyperSil plate transformer that had been in storage for years. It is a 2700-2800Vac secondary @ 1A. CCS. Since the unit had been in a damp storage shed for years, I "baked" it in my gas oven on the lowest setting (180 degree F.) for 8 hours, then allowed it to slowly cool for another 12 hours. Then HV leakage tested it. Then tested it in a mock-up test rig with the HV rectifier unit, a filter cap, and bleeder resistors attached. All tested well, delivering a steady 3850Vdc into the load. Next, I sealed the ends of the windings with pure silicone rubber sealer, this will prevent debris and moisture from entering the windings. This transformer is about half the size and weight (58 lbs.) of the Harris OEM (100+ Lbs.) unit. I could not have asked for a better unit to replace the OEM plate transformer.

(plate transformer)

(installed)

Above, the replacement plate transformer is installed in its new home, over the same spot where the OEM unit once sat.

I found the OEM oil-filled HV filter cap is filled with PCB oil, these should be disposed of properly. I replaced the cap with two new oil-filled (non-PCB) type which are rated at much higher capacitance and voltage. I also removed the old filter choke, since the new PS will not need it. A plate load of 2500 ohms calls for a filter capacitance of at least 64µF, the new caps are exactly that when placed in parallel. They are rated at 4500V, so are well above the 3.8kV that will be across them. Below, is a picture of the new caps. A new set of bleeder resistors will go on each cap, 150K ohm @ 225 watts each. Without a choke in the PS, bleeder current can be reduced, which unloads the PS a good amount and gives the PS a nice level of dynamic regulation, since the resistors keep a minimum load on the PS, but do not allow the peak voltage to rise much.

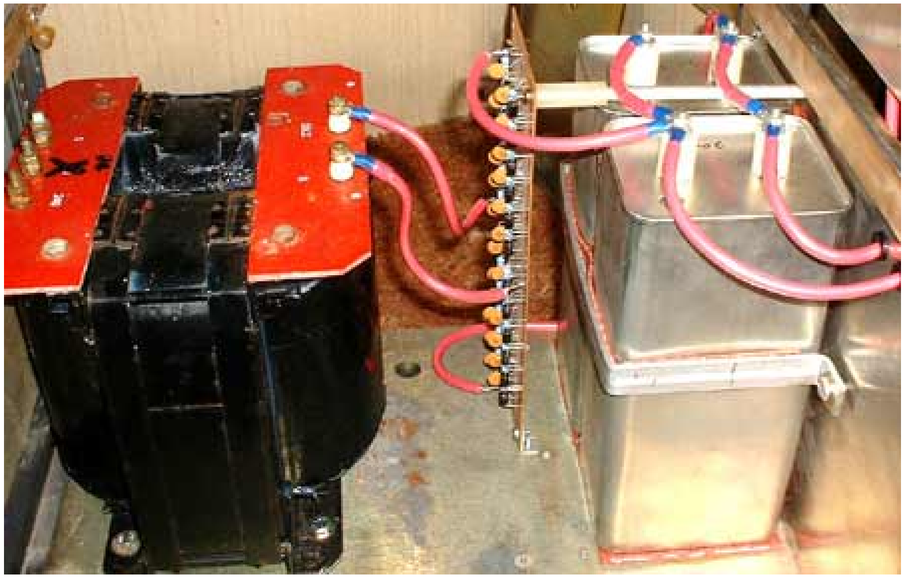
(Installed caps)

Above, is a picture of the new HV filter capacitors installed in the lower cabinet. The red material is neoprene rubber I used to isolate the caps from the chassis. This will help prevent metal-to-metal rubbing as the caps expand and contract as well as the chassis. It will prevent vibrations too. The strap was hand-made from a strip of 3/4" wide, 1/8" thick aluminum. It should hold the caps very secure. There is about 1" of clearance from the terminals to the bottom of the RF deck plate (which was removed for the picture).

Why oil-filled?:

Why am I using the oil-filled capacitors, when electrolytic (computer grade) are cheaper? Oil-filled caps can handle higher current flow as well as higher operating temperatures and will technically last a full life-time. Electrolytic (computer grade) capacitors last 20-30 years, and have a higher ESR (Equivalent Series Resistance), and therefore a higher heat generation level. High heat levels drive the liquid electrolyte out of the plate media of the cap which can cause loss of capacitance, or shorting. Oil-filled caps are non-polarized, and can handle higher levels of AC ripple, and higher heat levels, because the heat can't drive the oil/electrolyte out of the plates. The disadvantage to the oil-filled, is that they are expensive and hard to get. Today, fewer manufactures are making these caps. When I build an amp that is intended to last a lifetime, I spare no expense.

HV PSU installation:



(front view)

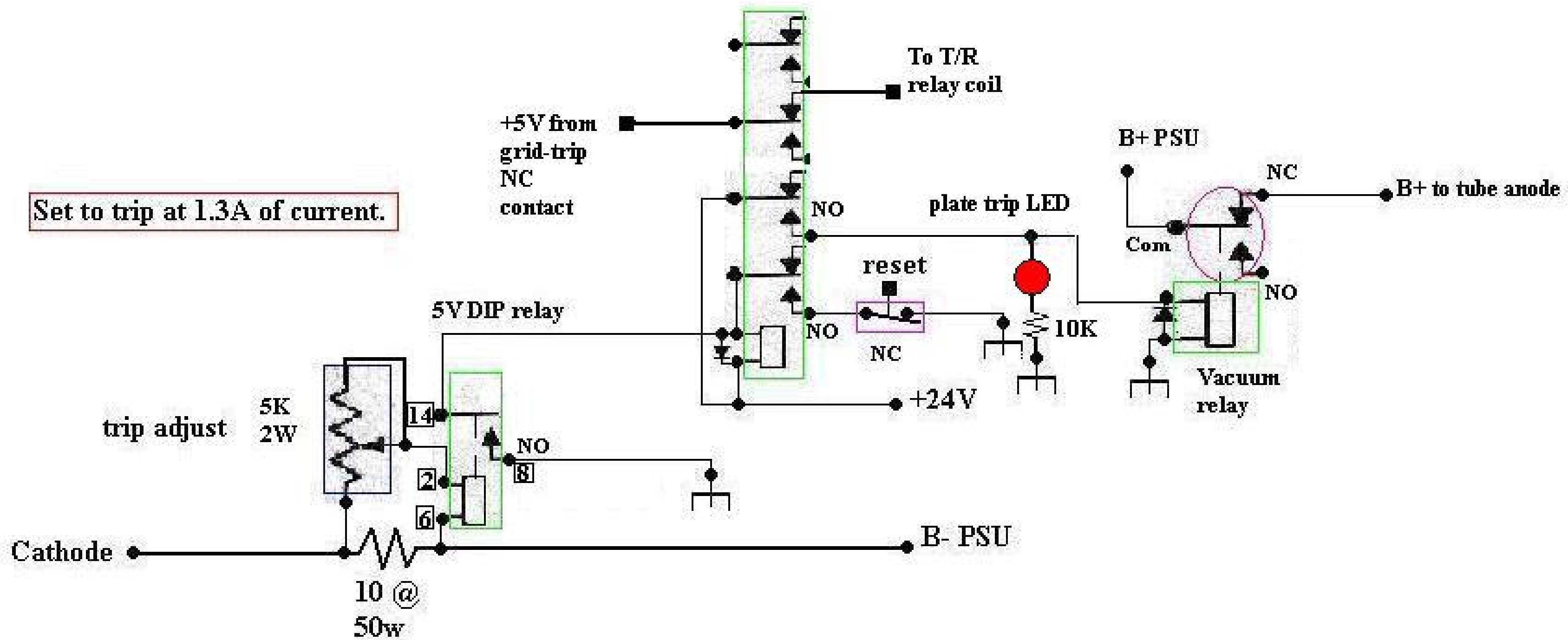
(Rear view)

(HV bleeder resistors)

The pictures above are of the High Voltage section of the power supply. I have not yet completed the final wiring, but most of it is installed. In the rear view, you can see a small resistor bolted to the chassis. This resistor is to hold the B minus line a few volts above chassis ground, this is known as a "floating" B minus line, which I favor for safety reasons, it also makes measuring grid current easier since the grids of the 8877 are grounded directly to the chassis. A single diode across the resistor is a safety device should the cathode voltage suddenly rise to dangerous levels the diode will shunt the current to ground and cause the PSU to trip off-line. The HV rectifier board is mounted vertically next to the filter capacitors. There will be a cooling fan mounted very close to the rectifier board that will pull air into the PSU, cooling the components. The lower end of the board is B minus and only a few volts above chassis so the spacing of the mount is not critical, however the upper end of the board is at very high voltage relative to the chassis so spacing and insulation is critical here. My rule of thumb for HV part spacing is to use a minimum of one inch for 4kV or less, and more for above 4kV. The HV bleeder resistors are mounted on a vertical panel at the top of the RF section. It was the only space large enough to install them. They are a pair of 150K ohm @ 225 watt units wired in parallel across the filter caps via HV wires run behind the panel to the lower PSU section. The effective bleeder resistance is 75K ohm, which will pass 51mA of current at a total power dissipation of 197.5 watts, which is less than half of the total resistor power handling capacity of 450 watts.

The HV wires are Belden® 30kV rubber insulated wire, on which I installed some clear heat-shrink tube to protect the wire jacket from abrasion or cuts. The wire is #18ga. which will handle all the plate current this PSU can run.

I have designed a simple yet effective protective circuit for limiting fault plate current. The picture below shows the schematic for this circuit.

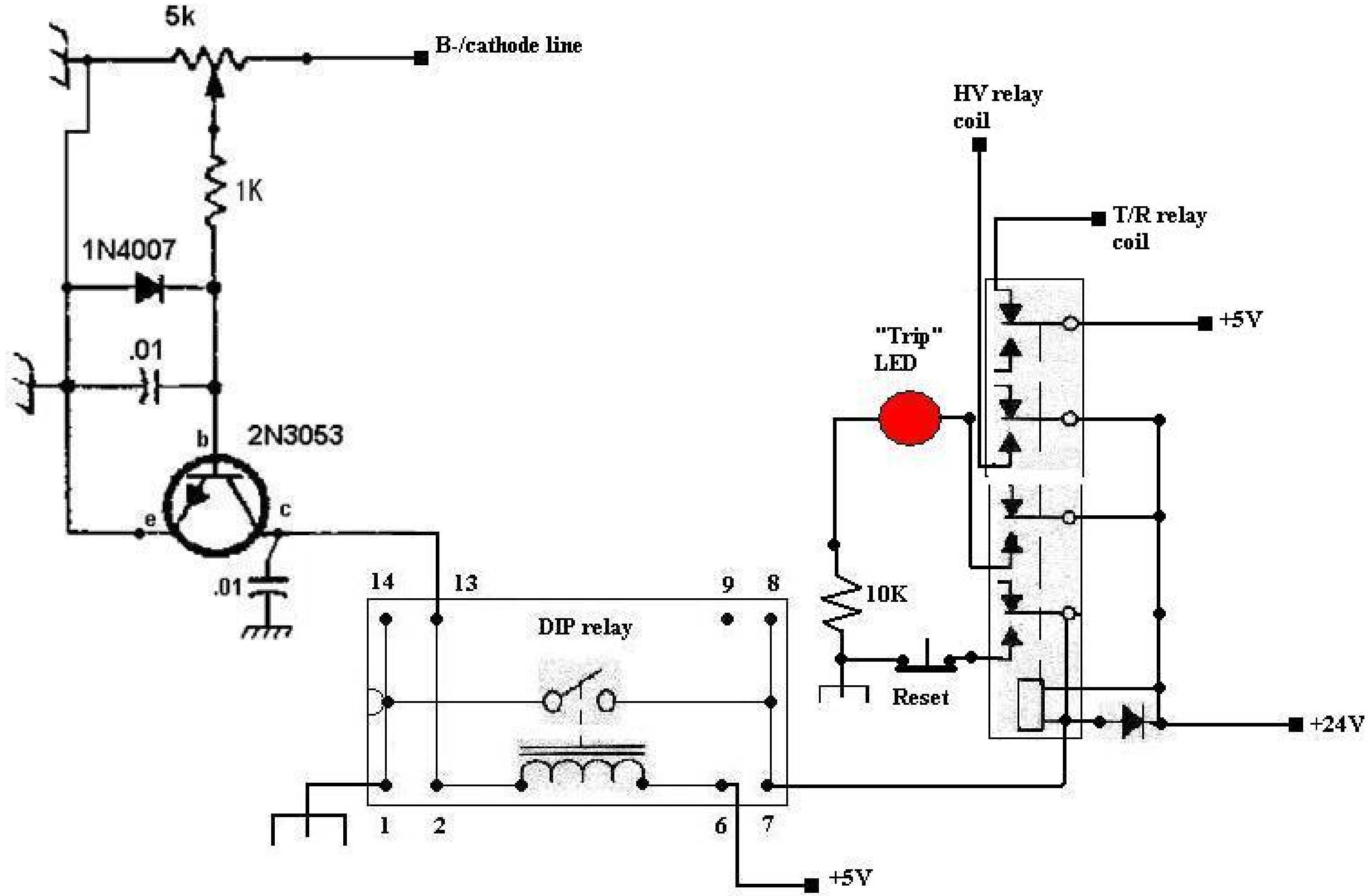


The vacuum relay is a Jennings 12kV type with a 26.5Vdc coil which works fine at 24Vdc. This relay is used as the B+/HV interrupt relay. The voltage drop across the 10ohm @ 50w resistor in the B-/cathode line (for safety reasons) generates enough voltage and current to activate the coil of the 5Vdc relay across it. The coil must have a resistance that is greater than 100 ohms. The pot is used to set the trip current level on the relay. The trip relay grounds the coil of the latching relay which latches closed and sends +24V to the coil of the HV vacuum relay. A red LED is lighted by the latching relay as well. To reset the circuit and restore B+ to the tube anode, the "reset" switch is pressed, which un-latches the relay, and removes DC from the vacuum relay coil, restoring the circuit to normal operation condition. Any time the B+ vacuum relay is activated, an "HV interrupt" red LED will light up on the front panel.

I have tested this circuit on the bench, and it works nicely. It is cheap, simple, and reliable.

Grid over-current protection:

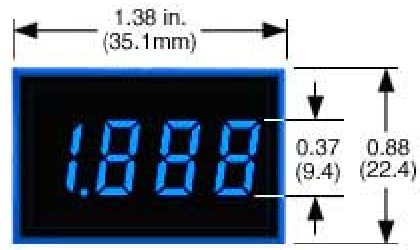
Below, is a picture of the grid-trip unit schematic, that protects against grid over-current.



This circuit will activate the B+ vacuum relay coil as well. This circuit is set to trip at about 100mA. of grid current flow. The DIP relay "triggers" the latching "trip" relay. The relay latches when tripped, and is reset by a momentary switch that breaks the circuit. The trip level is set by the 5K pot. An LED indicates a trip condition on the front panel. This is well known design that is reliable and simple. The "trip" relay also activates the HV "interrupt" relay, and disables the T/R relay system.

New meters:

I will be changing the entire front panel. The meters will all be bright blue LED digital displays, like the picture below. These units are made by Datel Co., and are very versatile.

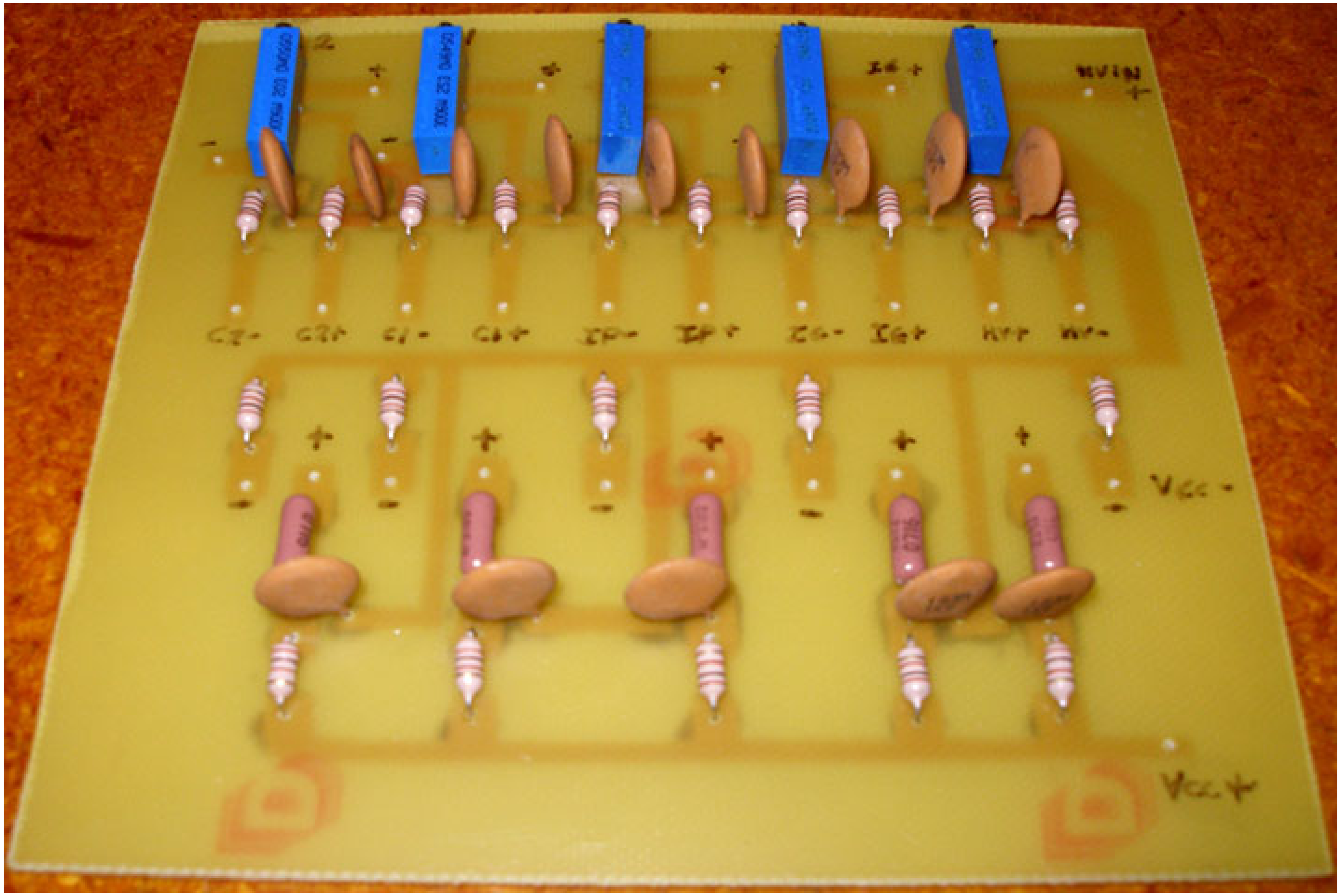


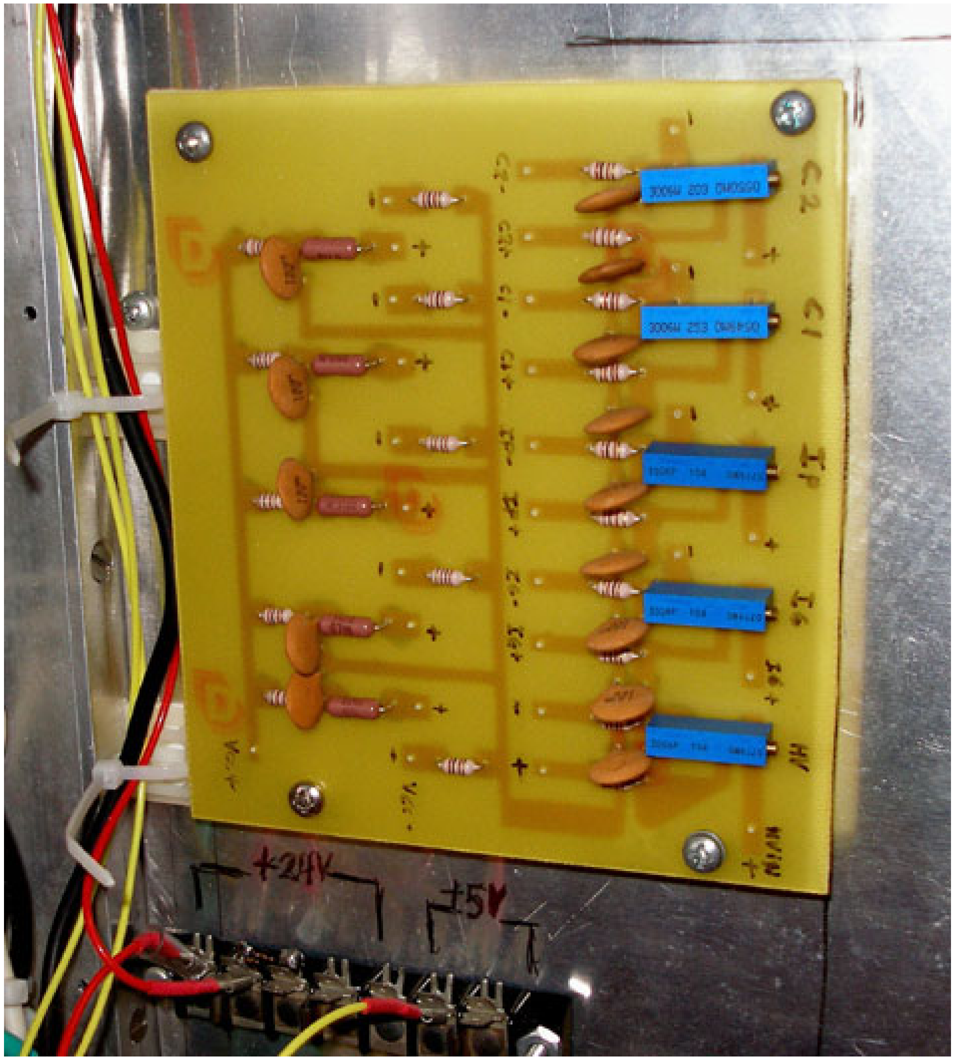
(panel meters, actual size)

I have run bench tests on these panel meters, looking for RFI/EMC susceptibility, and found that using standard RF chokes and capacitor bypassing of all the leads going into and out of the meter, the chance of erratic behavior due to RFI is reduced to nearly none. Grounding to the chassis should be done through an RF choke. The PSU lines should be isolated from chassis in the same manner.

These displays will show all dedicated parameters for; plate current, plate voltage, grid current, and the positioning of the tune and load capacitors. The meters are capable of reading as high as 1999.9 of whatever units I decide to read. That is likely to be mA for plate, and grid current, volts X10 for HV, and relative position for the tuning caps. All indicators and lights will be LED.

An amplifier building project.





Above, the photo shows the meter filter and calibration board. The photo to the right shows the board installed in its final position, but not yet wired. I designed and made this PCB with my own process. It is a simple board but performs a vital function. Since the meters I am using are digital they contain an ADC (Analog to Digital Converter) which can be susceptible to RFI which can cause error readings and or damage to the meter unit. With this in mind, I placed a series of RF chokes and bypass caps on the board which filter RF from the input and output leads on all the meters. The meter DC power supplies are also choked and RF bypassed. The bottom row of devices are conformal type 100µH chokes with .01µF bypass capacitors in parallel on the Vcc+ inputs to the meter units. Just above the caps are current limiting resistors that bring the input down and also the intensity of the LED displays of the meters for longer life span and easier reading. The meter unit Vcc- inputs are also choked individually which is the row above the resistors. Another series of chokes and caps can be seen in the next row up, which are the signal inputs and outputs to the meter units. The last row at the top is the multi-turn calibration pots that set the meter readouts to read the proper levels for the function of each meter.

RF power/SWR metering:

But what about RF power output/SWR, you ask? I have thought of this, I plan to use my old reliable RF Applications VFD, by building it into the front door panel. Below you see a photo of the VFD display.

It has a VSWR alarm function, which I can use to disable the T/R keying system, at the level of SWR I select on the VFD. The VFD has a remote sampling coupler that has a 6ft long shielded cable that will reach to the inside of the amp where the coupler will be mounted at the output of the RF tank circuit. The VFD is fully PEP reading and highly accurate about +/- 10%. Using the VFD will save a lot of time designing, building, and installing a built from scratch power meter and coupler. This unit will read up to 2995 watts output, and reads SWR at the same time. It should be a very nice touch for this amp, and very useful too.

The VFD had an optional board that would lock out an amp when the SWR tripped the selectable level, however I did not order one of them, and they are no longer available. I found that a small SIP/DIP relay with an N.C. contact would work. It needs to be a 5Vdc @ 50mA or less coil with a "snubber" diode across the coil. The four conductor optional board plug has a green and orange wire that can be used to operate the relay coil when the SWR alarm is tripped. When the SWR level is tripped the green wire goes to +5V and the orange wire is grounded, this will open the T/R circuit routed through the relay contact, but only when the SWR alarm is active. When the alarm is deactivated, the relay is de-energized, and the T/R circuit is enabled.

Hour meter:

Why would you need and hour meter? It is a handy device to have installed in an amp to track accurately the number hours you have on a tube in service. Guessing is just not good enough when it comes to expensive tubes, and warranties often depending on the amount of filament "on-time" that a tube has on it. So, it is cheap insurance and a good way to track a tube on-time history, is an inexpensive hour meter. There are basically two types of hour meters, electro-mechanical, and electronic. Within the electronic type meter, there are two types, self-powered (internal battery), and process powered (running on the power that it monitors). I selected for this project a K.E.P. model K-198 LCD PCB mount unit seen below in the photo.

K.E.P. has a large variety of meters, stop in at their web site and check them out. The photo of the meter above is about three times larger than the actual size. This unit costs $27.50 each. It has a non-volatile RAM, and will store the last reading for as long as ten years without power applied to the unit, it also has quartz accuracy and low power consumption. It is a process-powered unit, and electronically re-settable.

Its all about air-flow:

During my disassembly and inspection of the unit, I found that the squirrel cage blower had become froze up, so a replacement would be needed. The cabinet exhaust fan had bearings that appeared to be going bad as well, so it will be replaced. I plan to add a fan for air intake on the rear panel, which will cool the HV PS section while pressurizing the cabinet with 65 CFM air-flow. This will force feed air to the new 68 CFM blower, and the exhaust fan which is another 65 CFM "muffin" fan, which pulls the now warm air out of the cabinet exhausting to the rear. The flow drop due to back pressure in the blower should be around 60-63 CFM, so the flow should be nicely matched. Exhaust air is routed through a plenum that covers the HV bleeder resistors, the air flowing over them will keep them nice and cool during operation. The exhaust plenum can be seen in the photo below. The open end will be covered by the front cover plate.

(Exhaust plenum)

(new blower and fan)

The "muffin" fan used is the Radio Shack® cat.# 273-0241. These are some of the smoothest and most quiet fans I have ever used, I use them extensively. The blower is a Dayton 4C940 available from Grainger®. These units are high temp, ball-bearing type.

(Rear panels)

Above, is a photo of the current rear panel area. The upper panel is plated steel and is original along with the fan port, that has been reversed for operation on the left hand side, the right hand side was the original position. This is the exhaust port. The lower panel is new, fabricated to fit the opening left by the scrapped original panel. The fan in the lower panel has been added, this is the intake fan, notice the filter installed, these are available from Jameco.com PN/ 196817. The filter media is washable/reusable. The two holes on the right side were originally the input and output coaxial connectors, but will not be used in the current installation and will be covered. There will be no other openings in the rear of this unit.

I don't wish to lecture, but too many amp builders design cooling that is bare minimum air-flow to keep the unit quiet, but I say you can have it both ways. Careful selection of blowers/fans, and careful design of air-flow to maximize cooling of as many components as possible with the flow available, will keep the amp alive for decades. The air-flow I have designed into this unit is roughly twice as much as the bare minimum level required for the tube, but the noise level is the same as the lowest allowable flow required. You must remember that your not just cooling the tube, but all other heat producing parts in the amp. Time and thought are needed to design a proper cooling system for your amp.

Study the component layout, and the air-flow that will be needed to keep as much of it cool as possible. Next, select fans/blowers that have noise figures below 40dB, 38dB is pretty soft, but can flow enough air to cool effectively. If you do it right, the results will last a lifetime, under **any** duty cycle. I would say that the original Harris design was "adequate" but not optimal. I have taken the design to the "next" level.

I have tested the fan system, and it works perfectly. It is very quiet, as good or better than any of the **Alpha** amps that I have had or currently own. It is by-far the quietest, most efficient system I have ever designed. It will also be the coolest running system as well. All the hard work and difficult design has paid off.

Plenum "air box":

(socket, chimney and plenum box)

Above, is a picture of the plenum box I fabricated for the 8877 socket. It is to be bolted to the upper side of the RF deck. There will be a slightly larger box mounted on the underside of the deck as well. These boxes will keep the pressurized cooling air from escaping, with the only exit through the tube socket area, and out the chimney. Inside the box will be the cathode RF choke, filament choke, cathode coupling capacitor, and RF input line. This will insure maximum RF shielding of the tube input. Maximum shielding of the tube input goes a long way toward helping prevent parasitic oscillations and feed-back paths.

The 8877 is much shorter than the original 3-1000Z, so placing the box on top of the deck will bring the top closer to the tank circuit connections. Keeping the lead lengths as short as possible and as heavy as practical improves the amp stability and efficiency. Many of the original lead lengths and component placements made for very long lengths, which can contribute to instability and RF feed-back. I will move some parts for a more efficient layout. There is always room for improvements.

(blower intake)

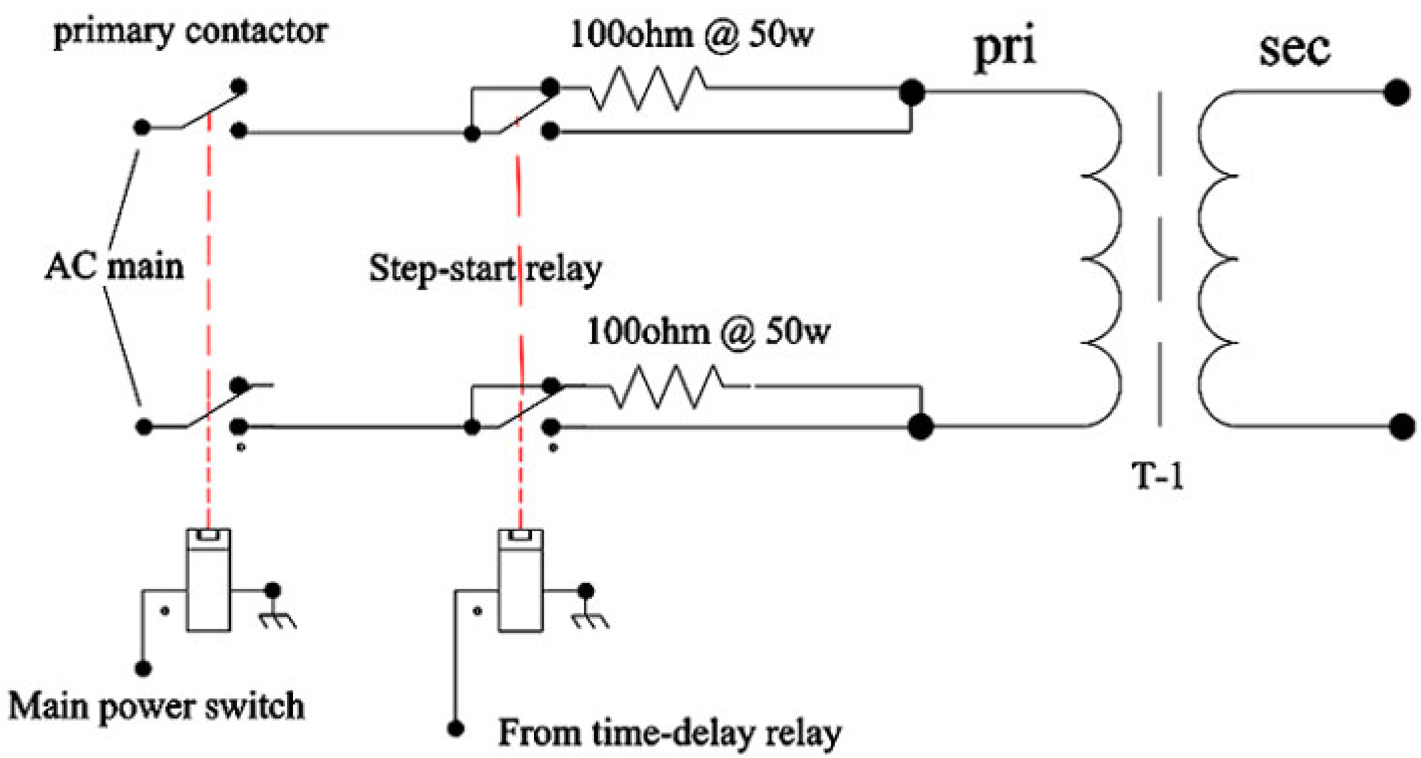
(blower motor end)

The pictures above, are of the finished plenums and the mounted squirrel-cage blower. The picture on the right is the view from the right side of the amp looking left. The left side of the picture is the front side of the amp. You will notice a feed-through cap, this is the B-/cathode line connection. The BNC connector is the RF input to the tube cathode. Inside the plenums, are the cathode choke, heater choke, and mica coupling capacitor for the cathode. The tuned input network is a separate unit, connected by a short length of RG-58A/U coax cable with a BNC connector. The picture on the left is the air intake side, and shows the upper plenum box with socket & chimney installed.

HV step-start system:

I found that the original main AC power contactor was not usable, and there is no "step-start" circuit, so I installed one. Below, is a picture of the new 30A DPDT relay, of which there will be two. One is the primary contactor which will be activated when the warm-up time-delay is finished, it feeds main power to the step-start relay which is exactly the same type of relay, but is on a 5 second time delay with a set of resistors across it to soften the current in-rush to the HV PS. At the end of the 5 second time delay, the contacts close and short the resistors out of the circuit. The large capacitance of the HV filter presents a near dead short when fully discharged, so to prevent burn out of the HV rectifier stack, the in-rush current can be controlled by the voltage drop across the step-start resistors which are only in the circuit for 5 seconds, then shorted out. AC power is then feed directly to the plate transformer which in-turn charges the filters. The time-delay, and the resistor value can be changed to adapt to any given PS level.

(new power relay)



(The schematic of the step-start circuit.)

During initial testing of the HV PS, I calculated that my desired step-start resistors would need to be about 100 ohms @ 50 watts, in-line for about 5 seconds. The test confirmed that the resistance is perfect. During the first stage of start-up, the HV slowly rises to about 1900V, then to 3850 when the step-start relay closes. The HV bleeder resistors do get warm in a few seconds, so the cabinet exhaust fan will be mounted near them to help remove the heat. It takes about 30 seconds for the HV to bleed down to zero after the PS is shut down. Due to the high level of filter capacitance, I wanted a smooth and soft HV start-up, this circuit will do just that.

(HV step-start and primary circuit)

The picture above shows the main HV step-start circuit wired into the primary. The time-delay relay and control wiring has not been installed in this photo. The terminal board at the right is where the AC main is connected to the circuit. Then the AC lines go into the EMI/RFI filter (the silver box near the center of the photo). You will notice the two yellow devices that look like capacitors attached to the terminals of the filter input, these are NOT caps, they are MOV's Metal Oxide Varsistors which are voltage surge suppressors. The step-start resistors are mounted on the relay bracket. The relay on the right is the primary power contactor which closes first and feeds AC power through the resistors to the HV transformer primary. The relay on the left is the step-start relay which closes after about 5 seconds, shorting the resistors out of the circuit, and feeding AC power directly to the HV transformer primary. The wiring is all 12ga., and the connectors are crimped on, and then soldered for the lowest possible loss. I mounted all the relays and resistors on the vertical bracket so that the circuit takes up far less space and makes for a nice compact unit that can be removed easily for servicing later.

The step-start system was tested and works perfectly. There is no step-start required for the filament PSU since it is a switcher and that feature is built-in. However, a step-start was required on the heater side of the PSU, (see more details below).

I should mention that it is important to "balance" the AC load as well. If the primary load is drastically uneven, it could cause many "false" overload trips of the primary circuit breakers. So, some thought should go into how much each device draws on the main AC lines. Since a 240Vac circuit consists of two 120Vac lines relative to ground/neutral, the load should be balanced between these two lines. If a 120Vac device is placed on one of the primary lines, an equal load should be placed on the opposite line. The load balance should be kept within a 1-3A. margin.

On the topic of circuit breakers, I use magnetic/hydraulic type circuit breakers exclusively in the home-brew amps I build. These units trip very fast! The older/cheaper thermo/bi-Metallic strip type are much too slow to prevent damage from an overload condition or a dead short.

(circuit breaker)

The picture above is a typical gang breaker. I can speak from personal experience that these things work great. They should be the very first device in the AC input line of the amp power supply. Believe me, spending a few more dollars on these will save a bunch later if and when the unit trips due to a fault in the PSU.

Below, is a photo of the circuit breakers installed in the front door panel.

Time-delay relays and more PSUs:

The photo below, shows the installed time-delay relays, latching starter relay, and the remaining switcher power supplies. These are all to the right of the HV power relays. The photo was taken prior to the installation of the wiring for an unobstructed view.

(time-delays and power supplies)

The relay at the top is the latching starter relay. This relay when wired to the main power switches will latch in the (ON) position when the main power (ON) switch is engaged. Should there be an outage on the AC line, the relay will release and shut down the entire power supply, thus protecting the unit from possible line surges resulting from the AC main line re-energizing improperly. I have seen the damage that can happen when an amplifier is "locked" (ON) and the line voltage drops out and comes back quickly, the surge can cause massive damage to the unit. This circuit also allows the main switches to carry only the small relay coil current, and not the full load current of the entire power supply. The starter-relay energizes all of the switching supplies, which then power all of the time-delay relays in sequence, which in-turn energize the coils of the main power relays. The fans and blower are also powered by the starter-relay.

The yellow relay below the latching starter-relay is the warm-up time-delay relay which will hold off the main HV supply for four minutes until the tube heater is at operating temperature, then the relay will initiate the step-start sequence for the HV supply. This relay also locks the amp in the by-pass mode until the unit is ready and warmed up. Testing showed that the warm-up delay is about 3.5 minutes.

The two small switching power supply modules below the yellow relay are auxiliary power supplies. One is a 12Vdc unit that will provide DC power to the PWM unit which drives the capacitor tuning motors & the auto-tune input network. This is its only job. The second module is a low current 5Vdc module, which will provide power to the meter display units, and the exciter keying line, as well as a few of the front panel LED indicators.

The switcher PSU at the bottom is the main control PSU providing 24Vdc for the main band-switch drive motor, most of the relay coils in the amp, and most of the LED indicators.

The two white relays on top of the control PSU are the step-start control relays, they are identical and run from 0.1 - 10 seconds delay time adjustable by the knob on top. One relay will control the heater step-start relay, the second relay will control the main HV step-start relay.

I mounted these relays to the top cover of the control PSU, this saves space, but care must be given that none of the screw heads that secure the relays to the cover come in contact with any of the parts inside the PSU. I used flathead screws for this purpose.

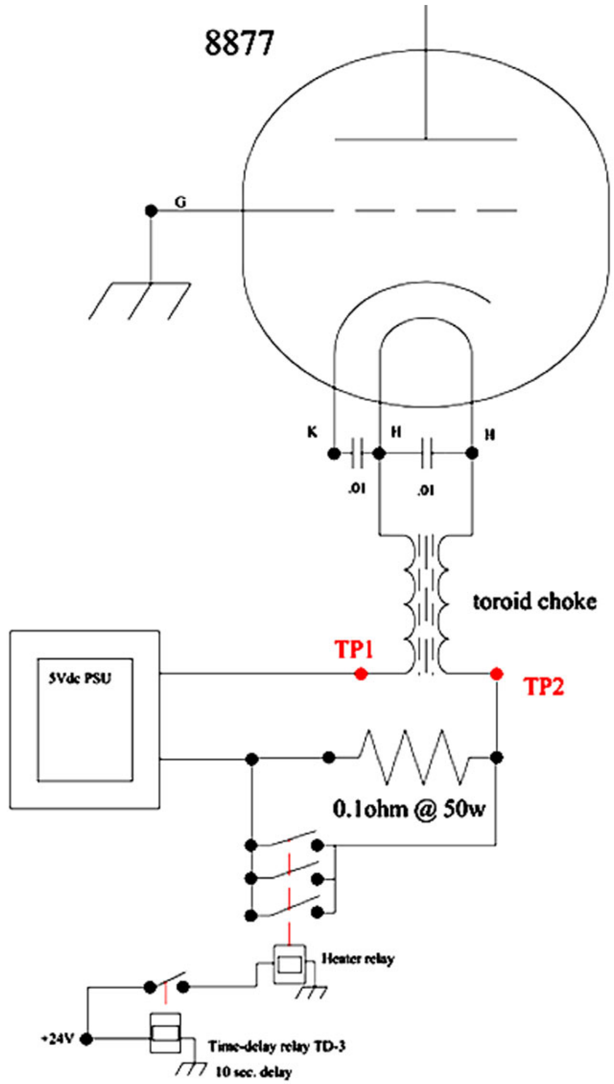
Cathode heater step-start:

My plan to use a 5Vdc @ 12A. switching power supply on the cathode heater, in the place of an AC transformer had an unexpected problem. The new power supply has short circuit protection, and the very low cold heater resistance of the 8877 presented a near dead short to the PS, and it shut down. So, I placed a 1/8th ohm resistor in line with the PS, and the tube heater, this allowed the heater to slowly heat up and its resistance increase to the point which the PS can operate directly into the heater. Since the operating resistance of the 8877 heater is about 0.10 ohms, I have placed a resistor of .10 ohms @ 50watts in the heater line, and short it out with a relay after about 10 seconds.

I had a small problem with the first circuit design I used. The voltage drop across the relay contact was excessive, so I had to change to a relay with more contacts and wire all of the contacts in parallel so that the voltage drop would be much less. The wire used in this circuit is 12Ga.

Such is the problems of a low voltage/high current step-start circuit.

Below, is a diagram of the step-start for the heater.



(heater step-start schematic)

(finished heater PSU & step-start circuit)

The picture shown above, is of the finished and installed heater circuit minus the time-delay relay and primary wiring. The terminal strip on the left side is the "test points" shown in the schematic above. The tube connection was disconnected for an unobstructed view of the circuits.

The heater should be RF coupled to the cathode, to prevent arcing due to the RF voltage differential between the two elements. However, DC current must be blocked from coupling between the elements. Capacitors couple the RF between the elements, and a choke in the heater power leads blocks the RF from moving into the power supply. The picture below, shows the choke I built for this purpose.

(heater choke)

The choke is at the center of the picture, the AA battery is shown for scale. The choke is wound with 12Ga. Teflon® insulated wire. The core is a toroid, gray mix. Believe it or not, the inductance is a whooping 750µH, more than enough to block any RF. The RF coupling caps can be seen to the left on the socket. A toroid choke will also be placed in the cathode line as well. It will be about the same size, but wound with 22Ga. wire.

The test points are outside the air plenum, so it is easy to check and adjust the heater voltage. Pervious tests prove that the full load voltage drop across the heater RF choke is 0.1V, so with this in mind I can adjust the test point voltage to read 5.000V, so the heater voltage at the socket of the tube under full heater current load should be 4.900V, perfect. I tested the system, and it runs cool to the touch.

(switching heater & control PS)

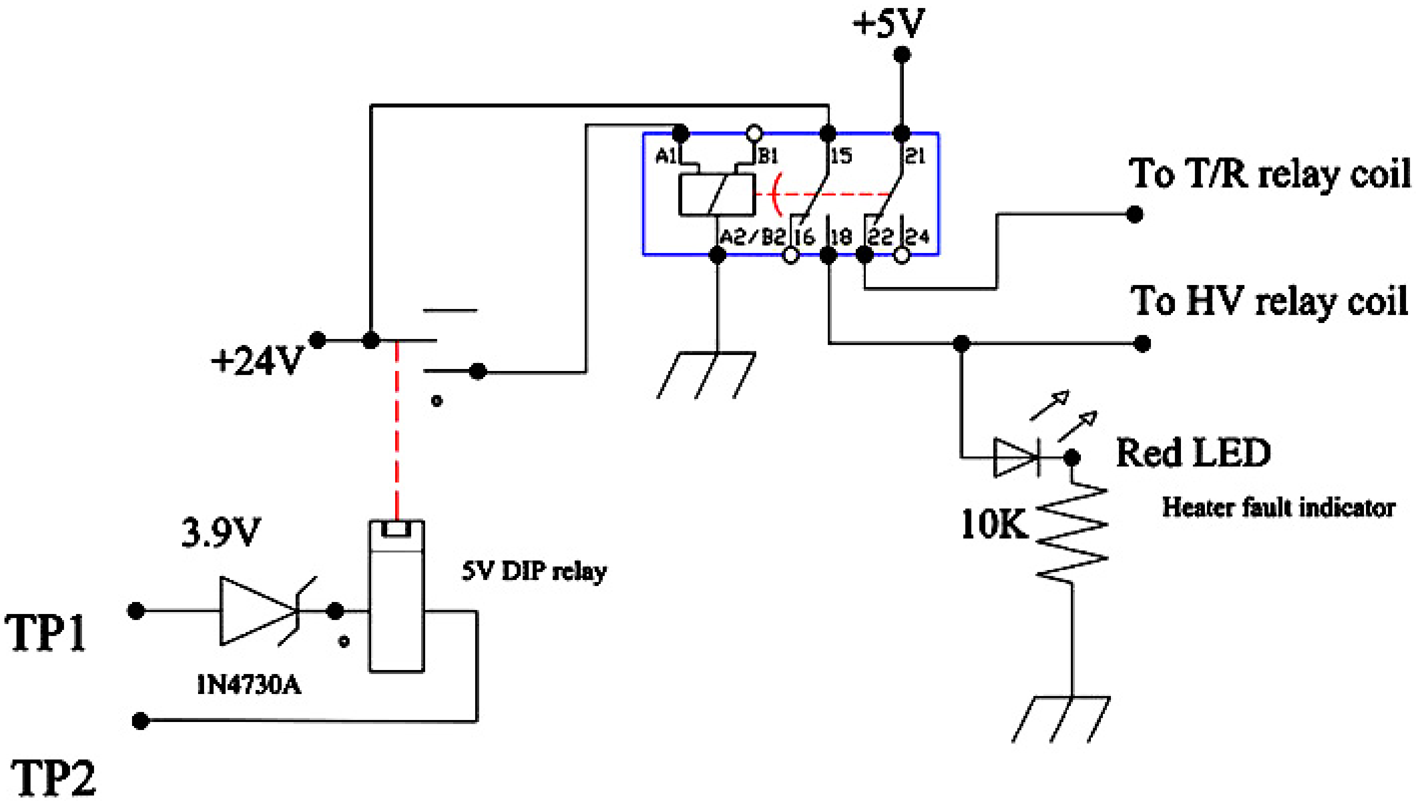
Above, is a picture of the switching power supply (shown actual size). Some of the reasons I like to use these are; they are small and inexpensive, they work with either 120/240Vac input, they have great output regulation (0.5% typical), and the output voltage is adjustable within a 10% range, they are fully protected. They run cool and quiet. I use switching power supplies for control circuits as well.

During start-up, a time-delay relay will hold off the plate supply for about 4 minutes allowing the tube heater to be fully warmed up before HV is placed on the tube. A second time-delay relay will hold the 0.10 ohm @ 50 watt resistor in line with the PS and the tube heater for about 10 seconds, then the relay will short out the resistor allowing the PS to be directly connected to the tube heater. This gently warms up the heater, so there is no massive in-rush current that can cause damage or heater failures. It will extend the life of the tube heater. DC current on the heater will also extend the life of the heater, by how much, I'm not sure, I'll let you know in about 30 yrs. as to if it was worth it. Another reason to use DC rather than and AC heater PS, is the fact that the AC magnetic field causes the element structure to vibrate at 60Hz, this vibration can't be seen by the naked eye, but over time shortens the heating elements lifespan. A DC current is steady, so the element does not vibrate. Nearly all large broadcast tubes use computer controlled switching power supplies for filament/heater current. The voltage and current of these PSUs is ramped up slowly to prevent damage to the large heater elements which draw huge amounts of current.

Heater protection:

There is a potential problem should the voltage of the switching PSU drop off or fail. Without heater voltage, or a drastically reduced voltage, severe damage can take place inside the tube, as arcing can happen if HV remains applied to the anode of the tube, and even a small amount of RF drive signal is applied to the cathode under these conditions.

I have designed a circuit to help prevent such damage and trip the amp off-line, thus protecting the tube. Below, is a schematic of the design.



A one watt zener is used as a voltage reference, which activates a very sensitive 5Vdc DIP relay, which in-turn activates an open-frame relay that remains closed as long as proper voltage is fed to the DIP relay. If the heater voltage falls below the level of 3.9Vdc, the zener diode (1N4730A) will stop conducting and the DIP relay will open the output contact which deactivates the 24Vdc relay, this disables the T/R line, and activates the HV "interrupt" relay, and lights a "Heater fault" LED inside the front door (as seen above).

This circuit was bench tested and works fine, it should prove reliable and simple.

New band-switch motor :

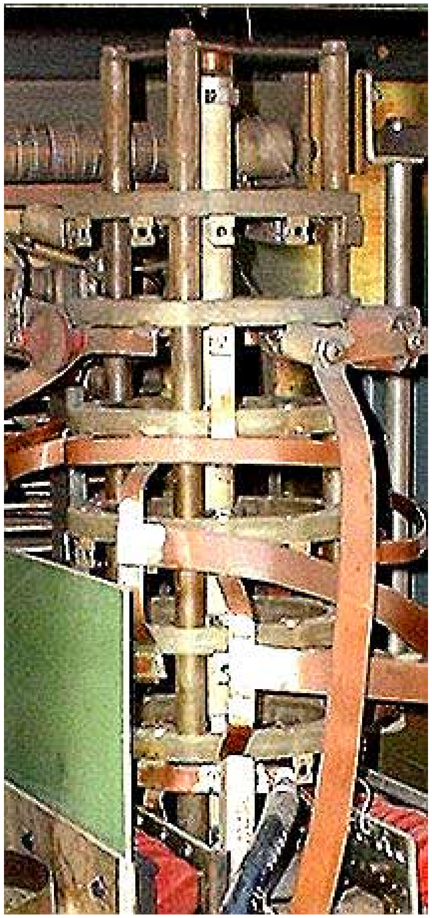
(old band-switch motor, and new motor)

Above, on the left you see the old band-switch drive motor, which was damaged and needed to be replaced. It is an old 24Vac, "C-frame" type motor (above left), and has a small gear cut into the end of its shaft, so it would be virtually impossible to find a good replacement. Instead, I purchased an inexpensive gear-head motor that operates on 24Vdc (above right), it turns at 65 RPMs no-load, which is a bit too fast and does not have enough torque to turn the huge band-switch well. I had a worm-gear right angle drive with a 50:1 ratio which brought the RPMs down to about 1 RPM but the torque level was multiplied many times. The new motor and angle drive are mounted under the tuned input network cabinet. The terminal end of the motor points out toward the front door of the amp. This motor is controlled by the junction control board which drives the motor via a relay to the proper position. Once at the correct switch position the junction board detects this from a sub-band-switch contact, then the control board releases the relay and the motor stops. My new design will retain this feature although it will be reconfigured somewhat. Timing is critical in this motor drive circuit. The motor must stop when the band-switch rotor contact is fully engaged on the proper stator contact. Since the motor is controlled by a relay, a timing capacitor is placed across the relay coil, which holds the relay closed just long enough for the band-switch to reach the proper position after the control has disengaged. When the cap is discharged the relay opens, and due to the torque level in this system the motor stops turning nearly instantly.

Big band-switch!:

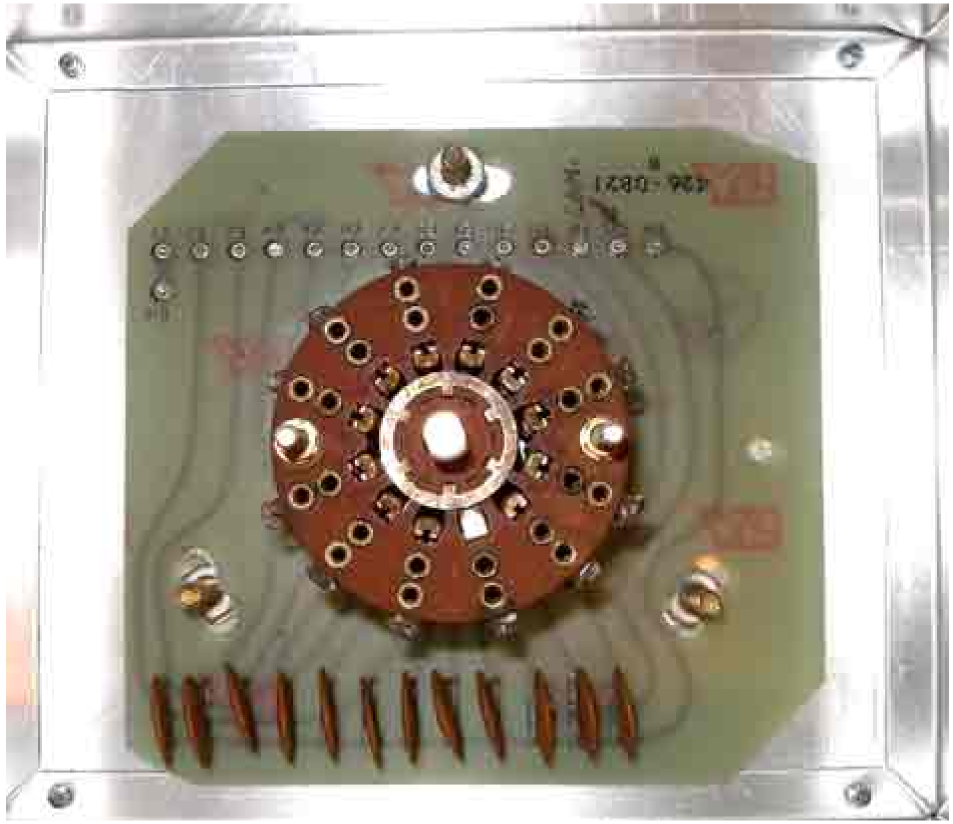
The RF band-switch itself, is similar to the Radio-Switch® Model 88, rated at 13kV and 30A. These switches are now made by Multi-Tech Industries Inc. Below, is a picture of the original band-switch set up. I have since removed it and stripped it clean for re-configuration. I checked the price on replacement units, and they are currently about $500 each. There should be little need for that, since it is virtually impossible to arc or damage these brutes under normal operations. It could handle an amp of about 10kW output with headroom to spare. It would be more likely to do mechanical damage to it, that is why alignment and regular cleaning and lubrication are critical for long service life. All moving contact surfaces have been treated with Pro-Gold® for good corrosion inhibiting and excellent electrical conductivity.

You will notice that the number of banks/wafers are half of the original on the reconfigured unit. The new tank circuit design requires a much less complex switching system. The Pi-L network and tuning capacitor system needs only three banks, not the six of the original unit. I saved the extra banks and parts as spare parts should the new switch need repair at any time in its future.



(band-switch, original) (cleaned & reconfigured)

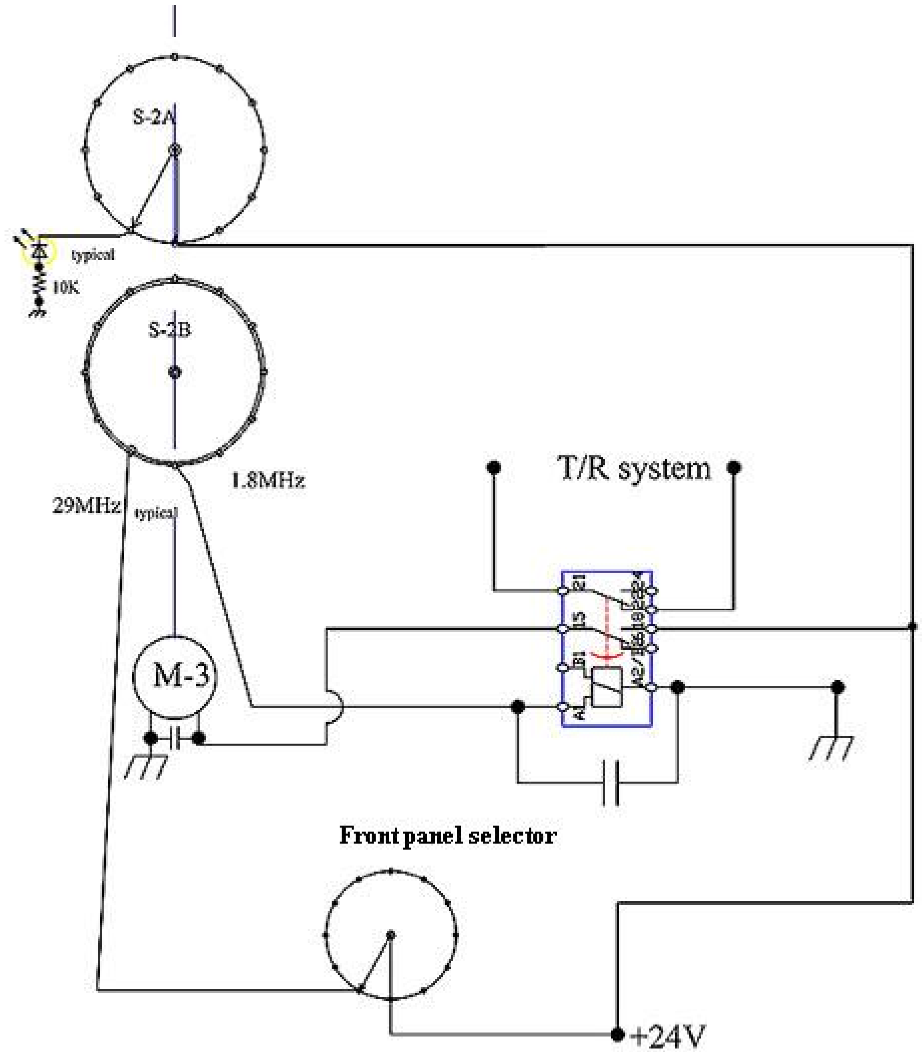
Sub-band-switch:



(sub-band-switch)

The picture above, shows the sub-band-switch mounted in the enclosure that the main band-switch sits atop. This sub-switch consists of (4) wafers on a common shaft from the main band-switch, two wafers will not be used.. The wiring has been removed in this photo, prior to reconfiguration. One wafer is used for controlling the band-switch motor-drive, another wafer is for LED position indicators on the front panel. A series of disk capacitors can be seen in the lower portion of the photo, these are for RF by-pass of the DC control circuits.

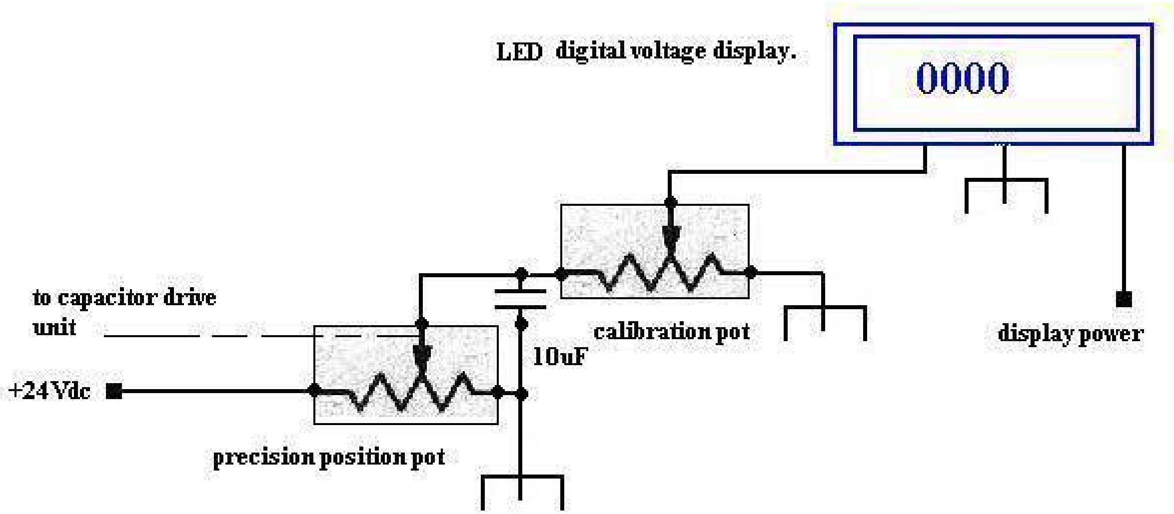
The schematic below, shows the typical wiring of the motor control and LED indicator circuit of the sub-band-switch.



Switch section S-2B is a normally open contact type, shorting all unselected positions, this way it stops at the selected band position because the motor drive circuit is opened as it reaches that position. There is a "timing cap" across the relay coil, that holds the contacts closed long enough for the the rotary switch to reach the proper position before opening and stopping the motor. The motor is fed DC power by the relay, so the rotary switch contacts don't actually carry the motor current. The switch will always rotate in the same direction until the selector switch circuit is opened. An additional set of relay contacts disables the T/R keying system while the rotary switch is in motion to prevent any arcing in the DC or RF sections of the band-switch. Switch section S-2A is a normally closed type, all unselected positions are open, this section is for lighting the band-switch position indicators. These are blinking amber LEDs that will indicate the current band selection. All of these switch sections are driven by a common drive shaft that turns the RF tank circuit band-switch as well. The front panel selector switch is a small rotary switch that allows the operator to select the desired band for the amp to operate on. "Select and forget", is the way this system should work. It takes about 45 seconds for the band-switch to make a 360 degree rotation.

Tuning display:

The caps will be tuned from the front panel with a pair of three position switches. Limit switches will prevent over run and damage to the caps, they will also light up LED panel indicators. Relative position of the caps will be indicated on a digital LED display, which takes the place of the old "turns-counters" and metal shafts. A speed controller will allow for fine tuning control of the caps. Below, is an schematic of the cap position display.

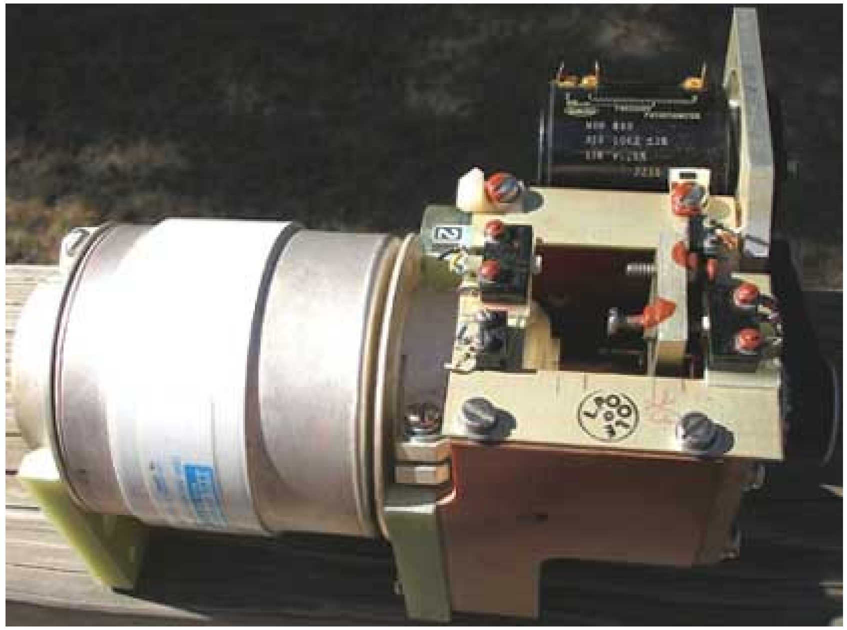


(cap position display schematic)

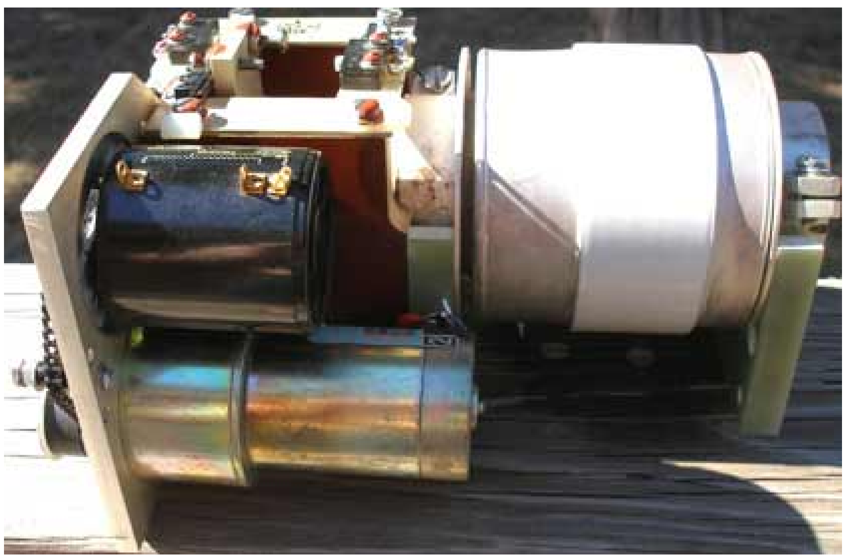
(capacitor tuning switch)

Tuning capacitors:

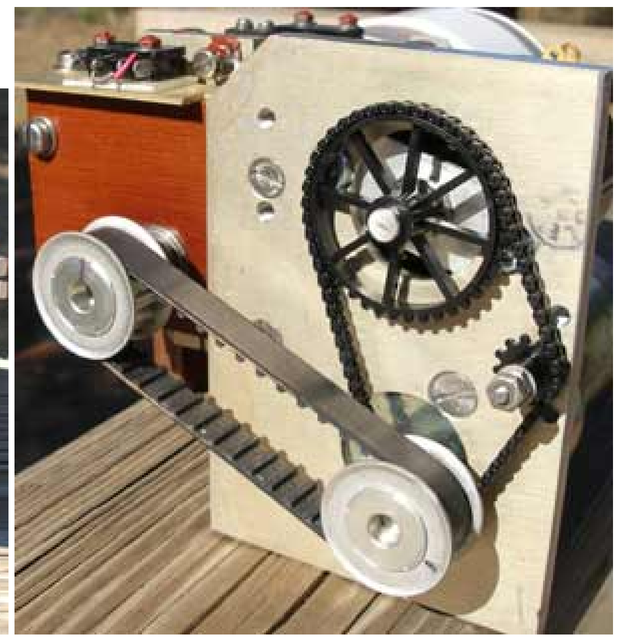
The plate tuning cap (C-1) is a 10kV @ 500pF - 12pF Jennings unit. The loading cap (C-2) is a 7.5kV 500-12pF unit mounted in a motor drive fixture. Both caps are 25 turn units. Vacuum cap voltage ratings are DC to 60Hz ratings, when used on HF they are "de-rated" for RF service to 60% of the DC-60Hz rating, which means that 10kV = 6kV in RF service. The DC to 60Hz rating is for peak voltage, the RF rating is a working RMS voltage level. The plate tuning cap has high RF voltage on it, but relatively low RF current on a given frequency. The loading cap is inverse, having relatively low RF voltage on it, but very high relative RF current flowing through it. So, the loading cap can have a much lower voltage rating than the plate cap.



(C-2, loading capacitor drive unit.)

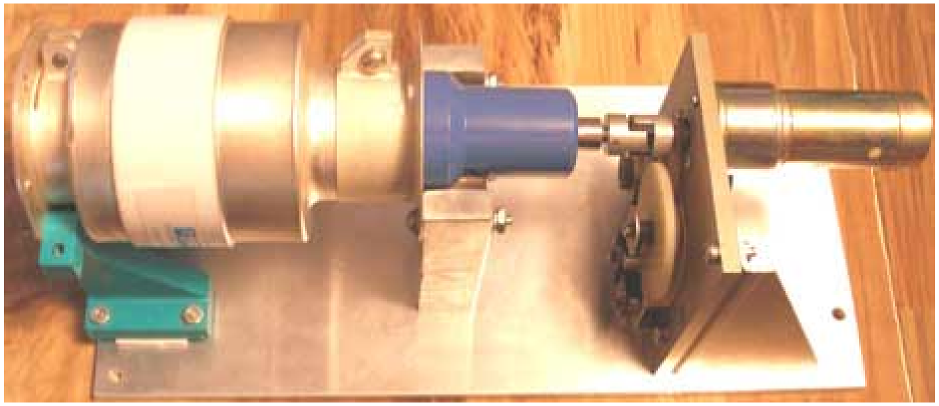


(Motor drive and position pot view)

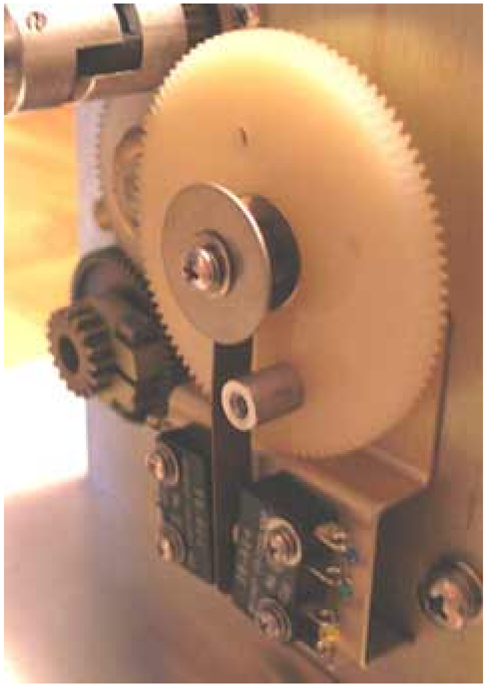


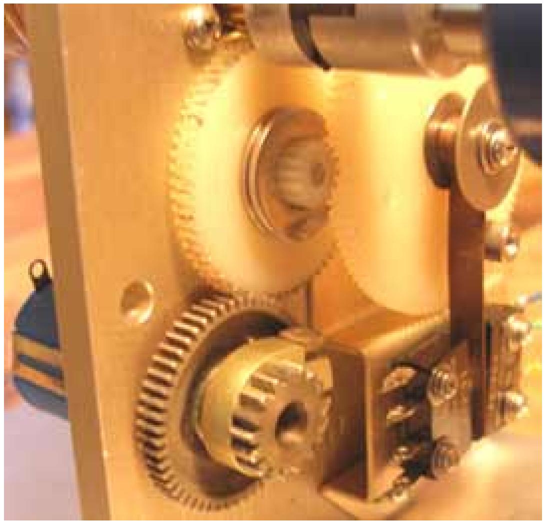
(Drive belt & position pot chain drive view)

Above, is the "C-2" loading vacuum variable capacitor. It was salvaged from an ITT Mackey marine antenna coupler. The motor limit-switches can be seen on the top. The lead screw drives the capacitor piston in and out, the stop is attached to the piston, which activates the limit-switches as it travels from each extreme of travel. The motor drive can be seen under the 10 turn position indicating potentiometer. On the right, you can seen the belt drive from the motor, as well as the plastic chain and sprocket drive for the position pot. The turns ratio of the sprockets changes 25 turns of the capacitor, to the 10 turns of the pot. The small idler sprocket is adjustable to maintain proper tension on the chain. The motor drive belt is sized perfectly, so no idler is needed for the life of the belt, I have spares. Backlash is minimal, if non-existent. The C-2 assembly will be mounted on an aluminum plate much like the one seen below on C-1. The loading cap has far less RF voltage placed on it during operation than the plate tuning cap, so spacing and insulation are less critical. You will notice how tightly spaced the C-2 cap and drive unit components are compared to that of C-1, which has extreme levels of RF voltage on it.



(C-1, plate tuning cap and motor drive)





(Two views of the limit-switch & position indicating pot, gear drive assembly)

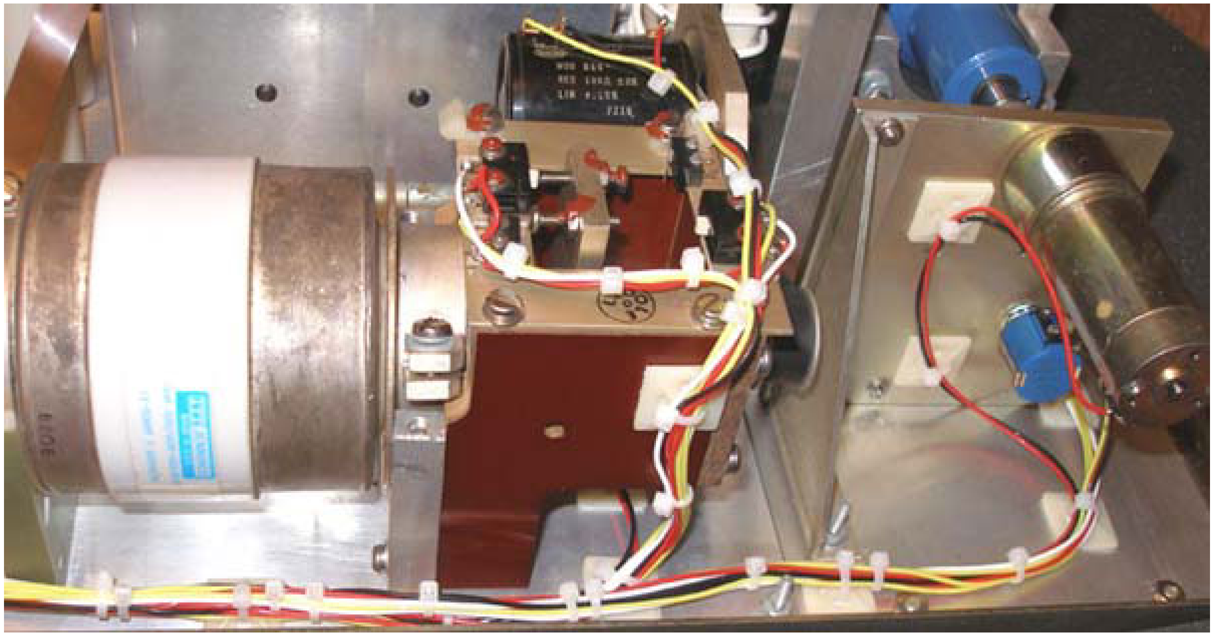
The pictures above, show the built C-1 plate tuning capacitor and motor-drive unit, as well as views of the motor limit-switches and position indicating potentiometer. The capacitor, motor, and gear assembly were salvaged from an old Harris antenna coupler. The gear-drive changes the turns ratio from 25 turns at the cap & motor shaft, to 10 turns at the pot, and 1 turn at the limit-switches. All of it was built on an aluminum plate that will bolt to the RF deck plate, which can be removed for servicing later. Wiring and Molex® plugs will be installed later.

A good way to test a vacuum cap without a "hi-pot" tester handy, is to turn the drive shaft in the "out" direction, the resistance of the turning shaft should be progressively stronger as the bellows are drawn outward. This would indicate that the vacuum is intact. This would not work for a gas filled cap, which must be hi-pot tested. Also, if a vacuum cap is no longer sealed, the capacitance will no longer be the same as the name plate on it states. The test procedure for vacuum caps can be found on the Jennings web site.

Most vacuum variable capacitors have a life time operating (when tuned from each extreme of adjustment) of about 2.5 million cycles. This is a very long life span. However, this can be radically shortened by a shock load such as a drop to a hard surface, which these will not tolerate well. Forced adjustments at either end of the range of adjustment will likely cause premature failure as well. End stops and or limit switches should be used to prevent such damage. Limit switches can be seen in the picture above.

I priced the capacitors when new, the ceramic is about $500. I'll say I paid far less than that for these.

One would ask why use vacuum capacitors, aren't air variable caps good enough? Well, yes, air caps are good enough with amps operating at B+ voltages below 3kVdc. However, when plate voltages are above 3kV, the possibility of arcing in the cap plates becomes much greater, and the spacing required for these high voltages makes the physical size of the caps become unreasonable. Large capacitors have higher minimum capacitance and inductance as well. Vacuum capacitors give large capacitance ranges and voltage ratings, and are un-affected by humidity and temperature. The inductance levels remain constant. The hard part of using vac caps, is that most are multi-turn units, and the relative position must be indicated in some way. Mechanical turns-counters are the most common method for indicating. The mechanical system must have a shaft that drives the turns-counter and the cap, this can create problems with mounting and space constraints. Using a motor-driven system has its own difficulties. The best way is to use an electrical reference voltage from a precision potentiometer that is mechanically connected to the drive mechanism. A more complex system is to use a digital rotary encoder that is read by a decoder which converts the signal into a form that can be displayed on an electronic display like LEDs. A system like this could be controlled automatically as well. Perhaps at some later time I'll design a controller that can do this, and be interfaced into the existing system. However, a digital system will need to be very RF resistant to be reliable.

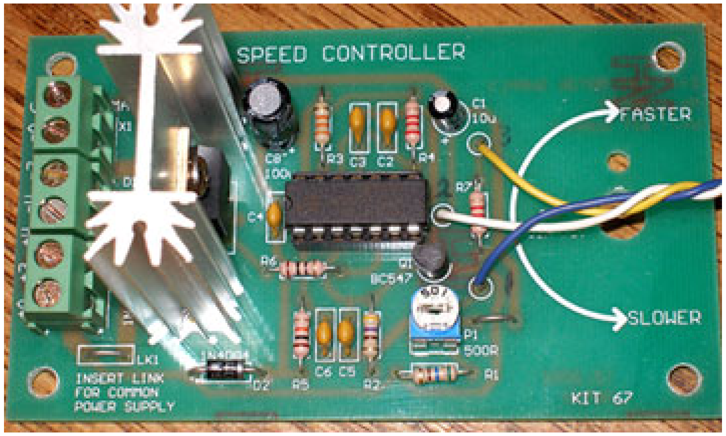


The photo above shows the wiring harness for both the tuning capacitors. There are limit switches to prevent over-run, and to light indicators on the front panel. Each cap has a precision pot for relative position indication. A pair of Molex plugs on the end of the harness allow for removal and servicing of the system.

PWM:

PWM, (Pulse-Width-Modulation), speed controller for the tuning cap motor drives. How does PWM work? A PWM converts the DC power into square-wave pulses of adjustable width. The L-C of the motor windings have a smoothing effect on these pulses.

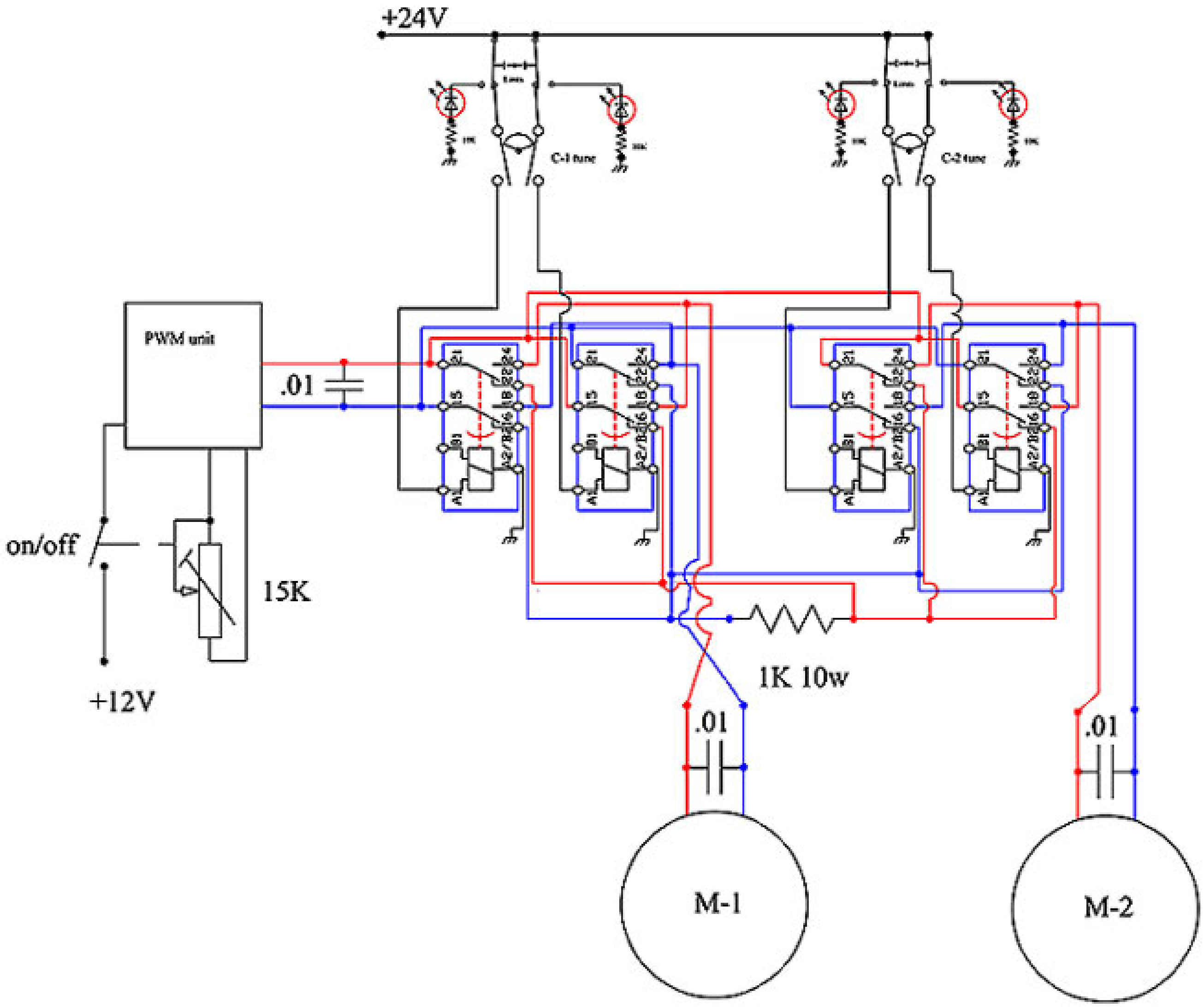
I bought this PWM motor speed control kit and built it some time back, it works nicely and drives the motors even at super slow speeds, under full torque loads. Jameco PN/ 120539CM. Below, is a photo of the PWM unit.



The speed adjust pot was mounted on the board, but I have remote mounted it at the end of the three wires seen above. The inputs and outputs are on the left-hand side of the PCB. One problem with the PWM unit, even at the slowest setting, the output signal is enough to make the motor "sing", emitting a high pitched whine, so the relays will route this signal to a resistor that will substitute for the motor windings when the motor is not actually being driven. The speed adjust pot also has a power switch, so when it is adjusted to the slow end of the range, DC power can be cut to the unit. The PWM operates on 12Vdc. The PWM is capable of driving the motor up to 120% of max RPM rating, or so slow that the finest of adjustments can be made in tuning. Why PWM and not a variable DC supply? With a DC supply the motor loses torque with the drop in voltage, PWM's don't.

The PWM unit is not the only part of the motor controller circuits, there are a set of relays to control the direction of the motors. (See below)

Motor control:

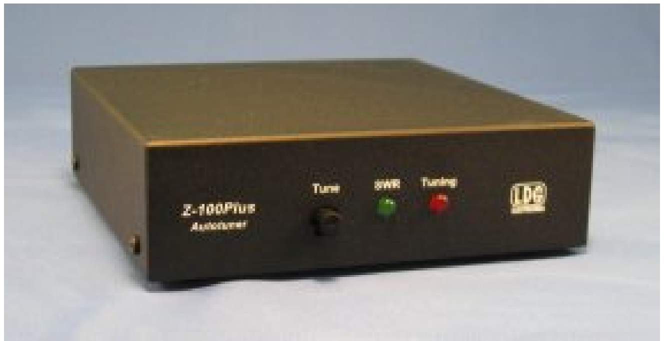


(Motor control schematic)

Above, is a schematic of the tuning cap motor drive control circuits. The motors are gear-head type, 9Vdc units. The caps across the motor inputs are for RF bypassing, there is also a cap across the output of the PWM unit. The tuning switch (seen in the Tuning display section) applies +24V to the relay coils which drives the appropriate motor in the chosen direction, should a travel limit-switch be reached, it will open the circuit to the tuning switch, and light a red LED on the front panel. Motor travel in the opposite direction is the only possible selection in this situation. When the tuning caps are not actively being tuned, the PWM will be powered down to prevent possible EMC/RFI problems.

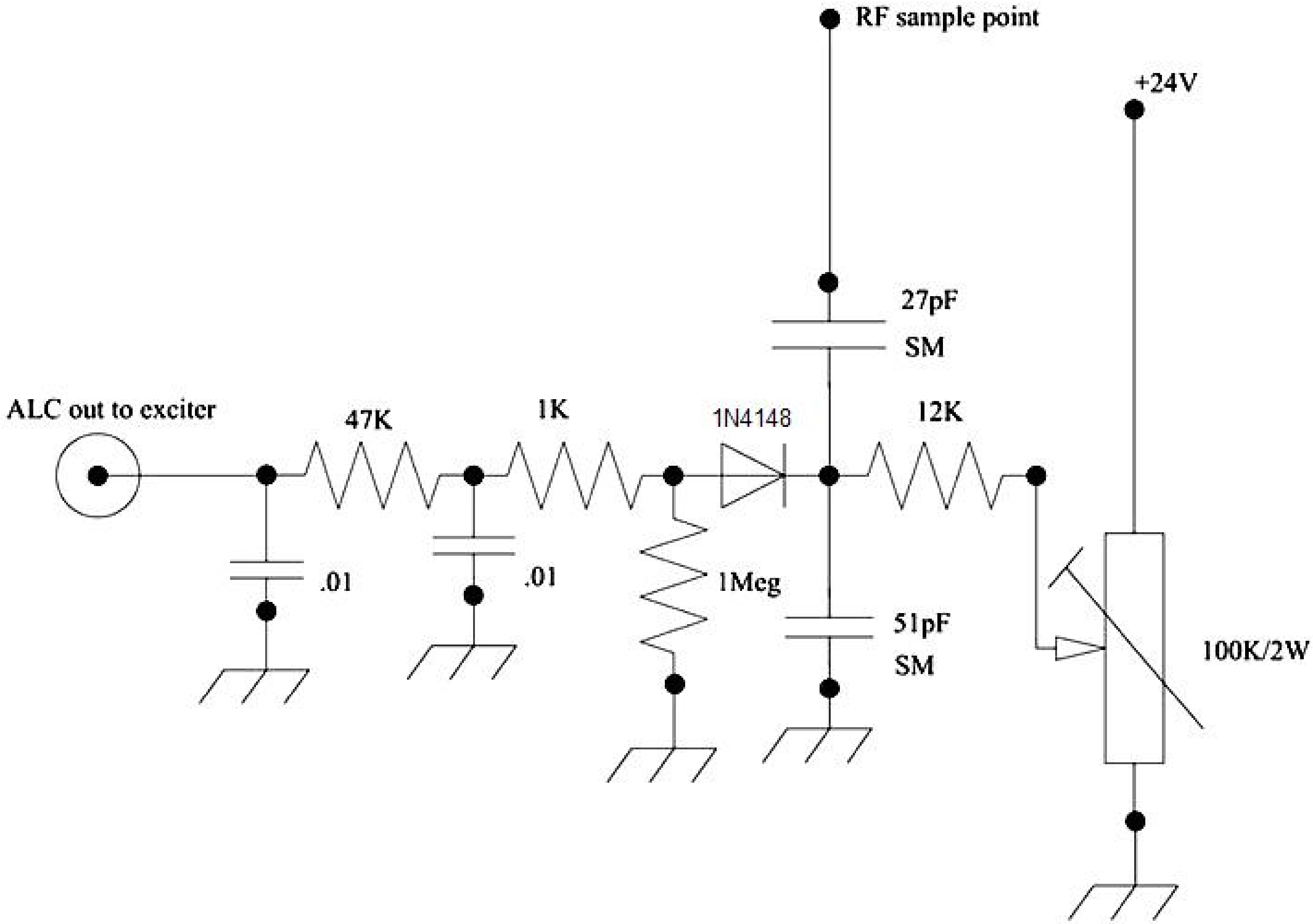
Tuned input network?:

Instead of using the standard inductor/capacitor tuned input network like that found in most amps, I have opted to use the LDG Z-100Plus, which uses latching relays, and does not require DC power after a tune cycle has been run and the parameters have been stored. Modifications would need to be done to use the switch control and the LED indicators on the front panel of the amp. This unit can be mounted on the exterior of the amp if desired. The coax cable from the ATU to the input of the amp should be kept as short as practical, typically one foot or less. A few strips of Velcro hold it nicely horizontal or vertically.

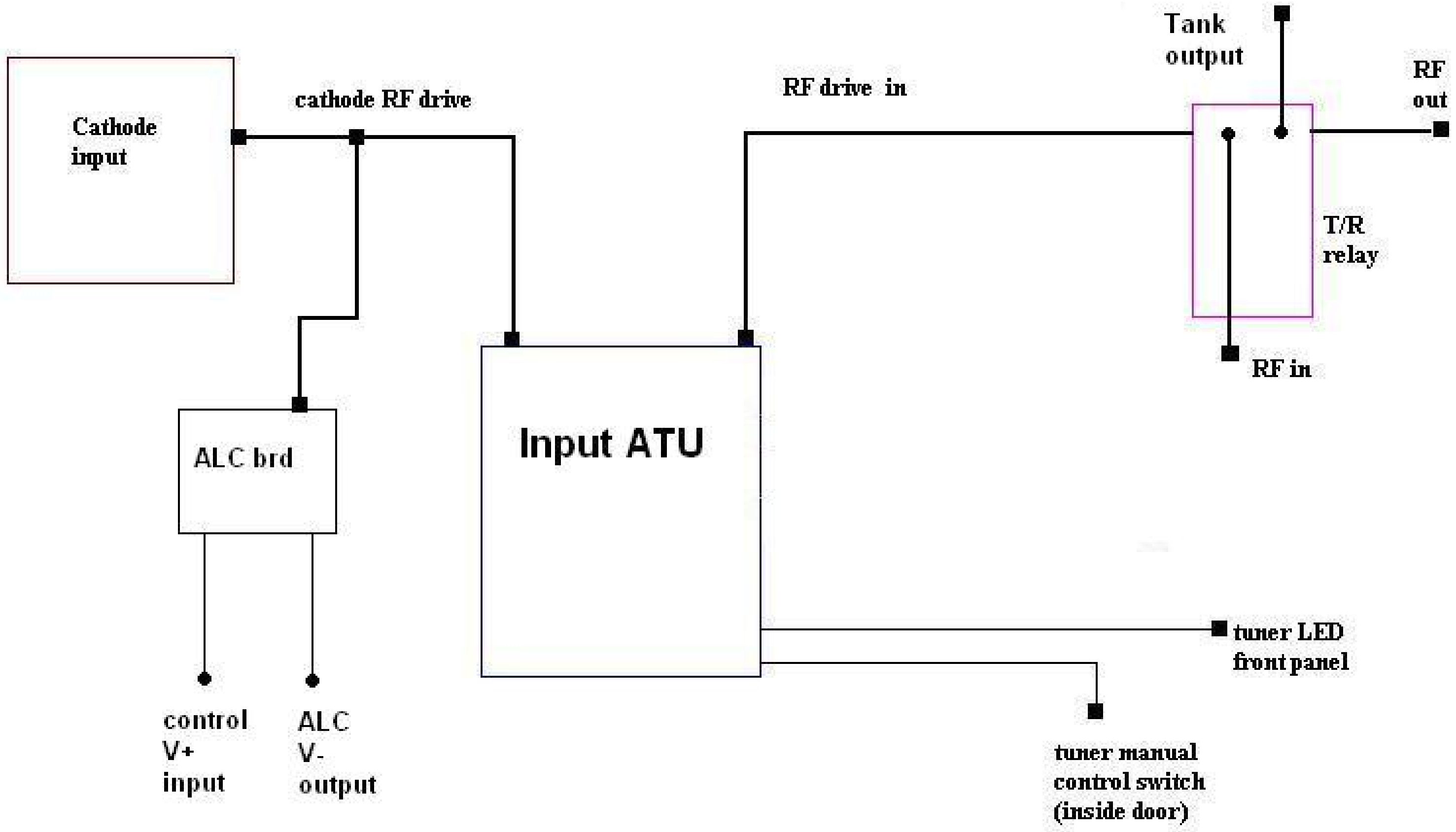


ALC:

The schematic of the circuit I use is shown below.



(ALC circuit schematic)

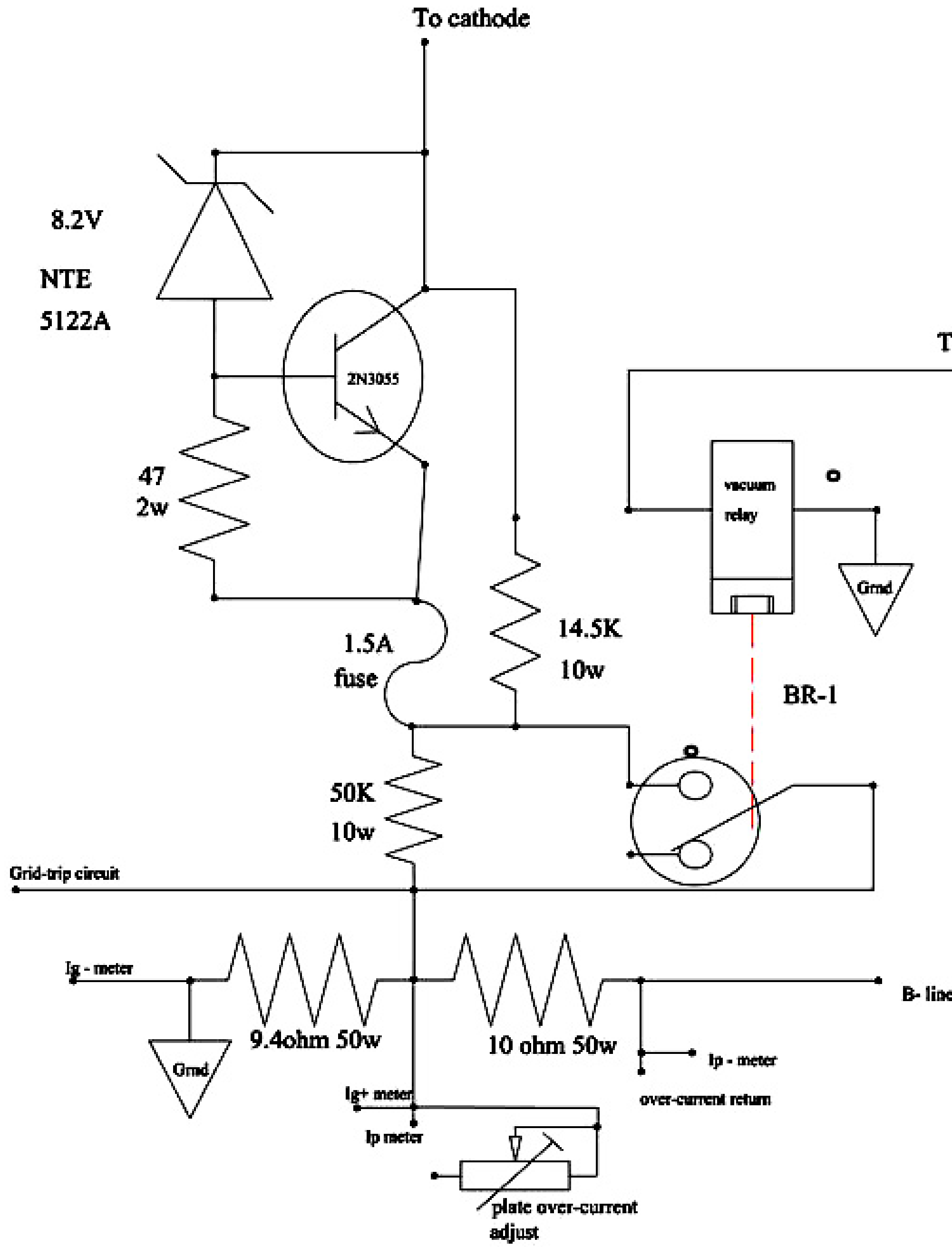


(Block diagram of RF and ALC system)

These circuits are reliable, and stable, I use them on all of my amp projects. The builder that does not use ALC is asking for trouble, in prematurely failed tubes, and other damage. The ALC output level is adjusted by the 100K pot. Any amp that has tube(s) that require less than 100 watts of drive for full output should be protected by an ALC system. If you use a tube that requires more drive, then you need not use ALC. Examples of these tubes are; 3CX3000A7, 5000, etc.

Cathode circuits:

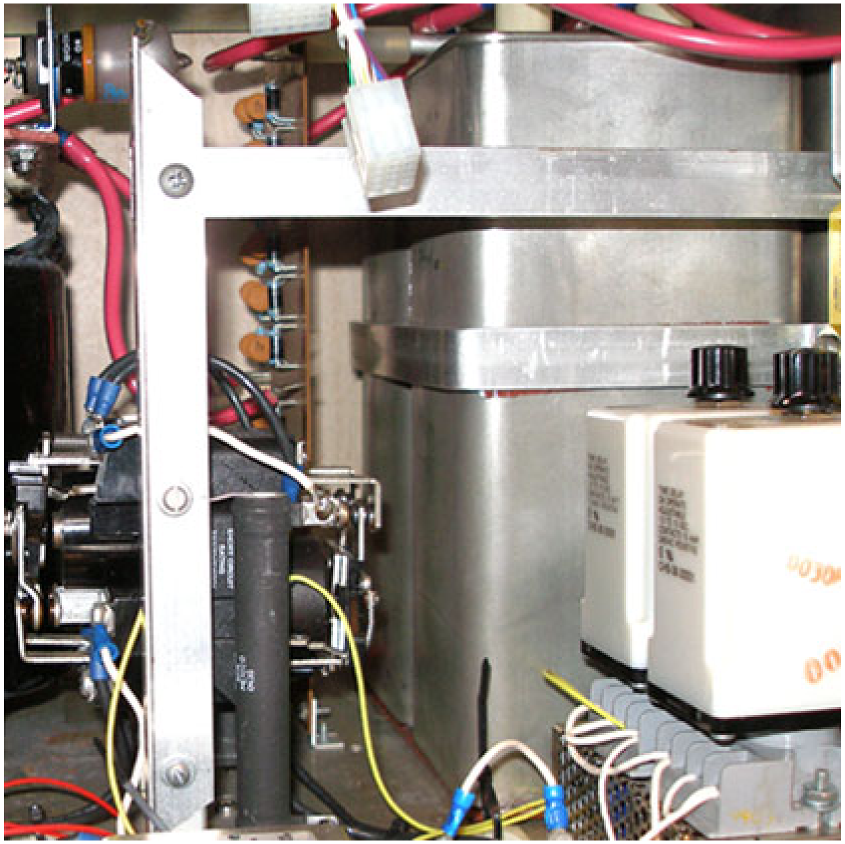
Several circuits will be combined on a single board that will go in the B-/cathode line. A "pass-element" bias circuit will regulate the cathode current, it consists of a single 2N3055 transistor and a 1 watt zener diode (NTE5122A) that controls "operational" bias. Standby, or "cut-off" bias is provided by a 50K ohm resistor that is shorted out when the T/R system is energized. The 14.5K ohm resistor is a safety resistor which comes into play only if the safety over-load fuse opens, the resistor biases the amp to near cut-off, by-passing the zener unit. When the fuse it replaced the bias will operate normal again. Plate over-current is measured from the large resistor in the B-/cathode line. This resistor develops a voltage across it when current passes through it, this voltage/current is routed through the coil of a relay that will close when enough current is present. In-turn this relay energizes another relay that "latches" closed and locks the T/R system off-line and also the HV interrupt relay, and lights a warning/fault LED on the front panel. A reset switch re-activates the T/R, & HV/B+ system. Below, is a schematic of the circuits that will be contained on this board.



(cathode/B-)

There are other associated circuits and components that are located in other areas of the PCB. The heater fault circuit is also on the same board, but does not connect to the cathode or grid circuits, it is placed on this board to conserve space in other areas of the amp. The grid-trip circuit is also located mostly on this PCB as well. The heater fault circuit is located on the same board but not connected to the cathode or gird circuits.

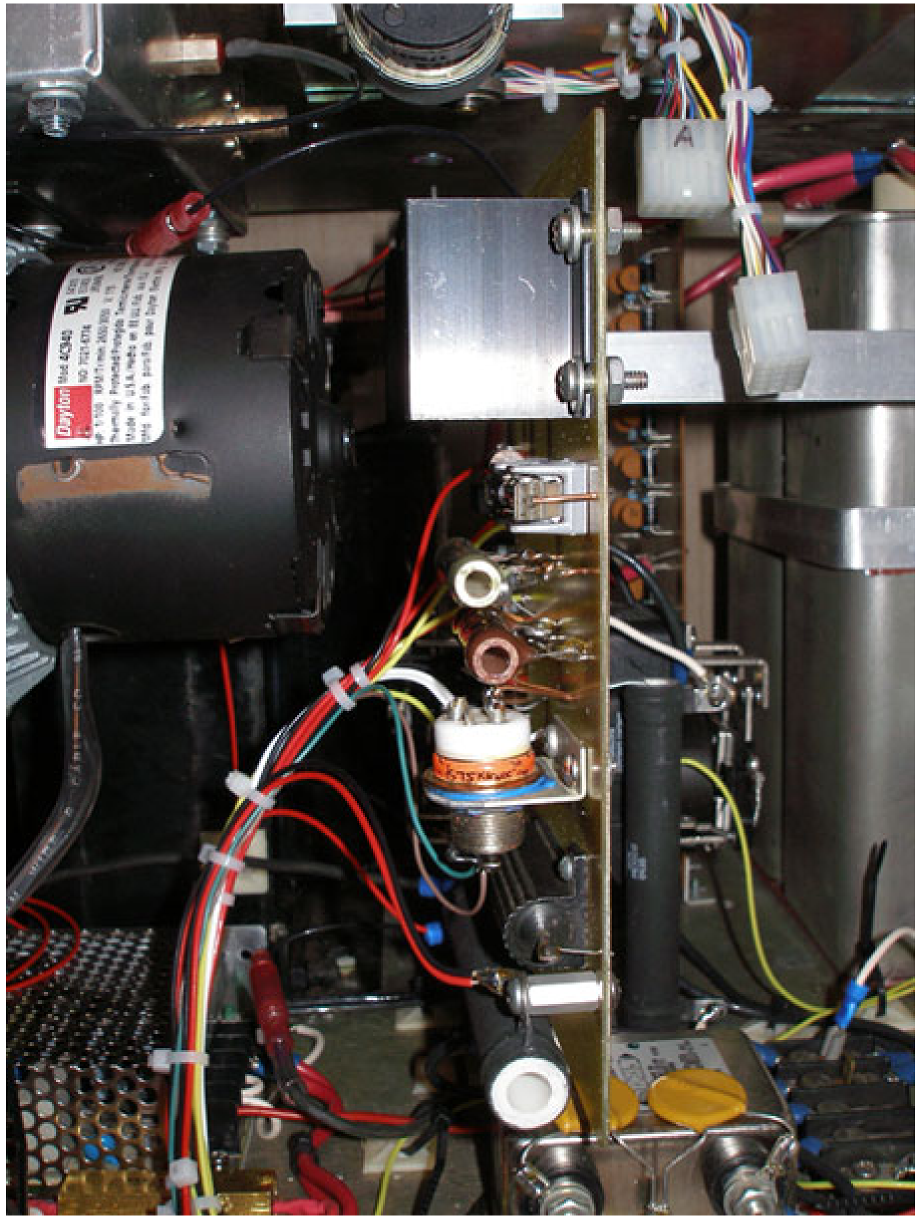
The frame which the cathode board will be mounted is seen in the photo below. In the upper left corner of the photo you will see the HV interrupt relay. The frame is mounted to the primary step-start relay bracket, the relays can be seen behind it.



(cathode board mounting frame)

(Cathode control PCB, shown actual size)

Above, is a photo of the cathode control board, which contains the circuits described in the previous paragraph. The PCB is not fully wired, but is ready to be installed in the amp. Cathode/B- line input is at the bottom of the board, under the large resistor. The cathode/B- output is at the top of the PCB just above the large transistor. Grid current DC return is through the resistor second up from the bottom, and connected to chassis ground through a solder lug connected through the hole at the lower left side. The grid return resistor is also the meter shunt for the grid current meter. The board itself, is mounted vertically on the left edge of the frame, with only one edge of the board secured to the frame. The edge of the board that points out toward the viewer is "free-floating". This is not ideal for mounting, but was the best I could come up with since the requirements for the board are rather strict. Those requirements are; **Heat dissipation;** (50-100 watts), so it needs to be in air flow for cooling. You will notice that the board will be in direct line with the cooling fan mounted behind the HV rectifier board (near center of the photo). **Proximity;** The board needs to be as close to the tube cathode as physically possible. The connection point for the tube cathode is about 6" away from the output of the board.



(Cathode PCB installed)

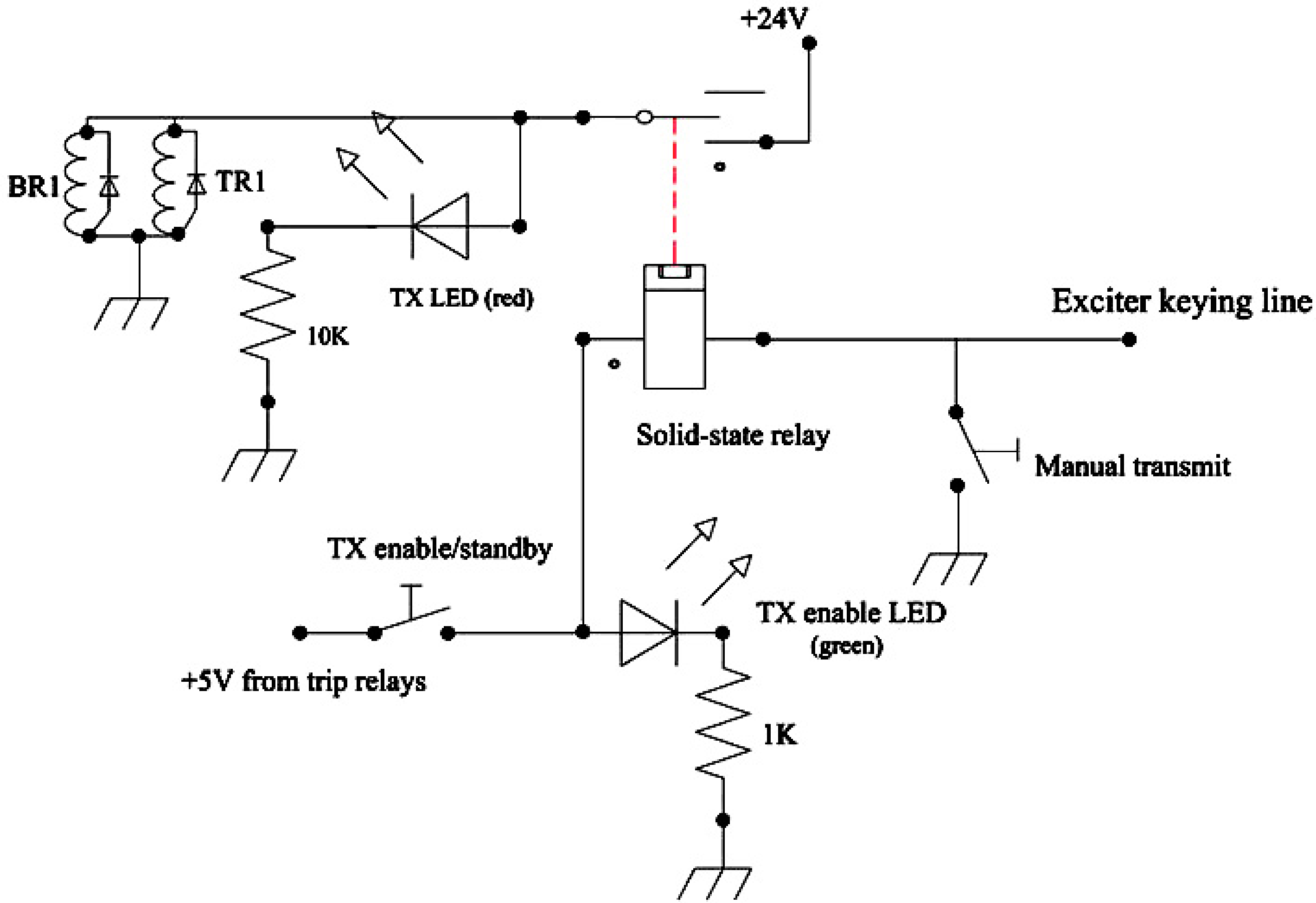
The photo above shows the cathode board installed in its final position, with wiring harness attached. The vacuum relay mounted on the board is designated BR-1, this relay switched when the TR system is operated, and switches the cathode bias from cut-off to operate by shorting out the 50K resistor just above it. I used a vacuum relay because I had it laying around, and I wanted a fast relay with very good reliability. An open-frame relay can be used for this purpose, but will become tarnished or pitted over time. It is unlikely the vacuum relay will ever fail.

T/R:

(RF T/R relay, shown actual size)

The photo above shows the main RF transfer relay. It is rated for 1kW @ 50MHz CW. It can handle lots more power on 30MHz and below. The coil is 26Vdc. It is not designed for "full QSK", but then I never operate CW with my amplifiers. There is more info on this type of relay on the Dow-key web site.

This relay will be controlled by another relay that is actually activated by the exciter.



(T/R relay system)

The schematic above, shows the Transmit/Receive relay control system. BR-1 is the coil of the bias switching relay located in the cathode circuit. This relay is a Kilovac vacuum relay similar to a Jennings RJ1A type relay. I have tested this system on the bench, and it works nicely. The manual Transmit switch is a momentary contact switch located on the front panel of the amp to allow the amp and exciter (only ICOM HF radios can be keyed from the amp keying line) to be keyed at the same time for testing and tuning purposes.

More shielding:

The original cabinet consists of an outer "shell" cover, and an open frame skeleton that supports the outer shell and all the internal parts. I felt that there is a need for inner panels that will form added shielding and provide a foundation to mount new parts. Structurally, the panels will add to the strength by stiffening the frame.

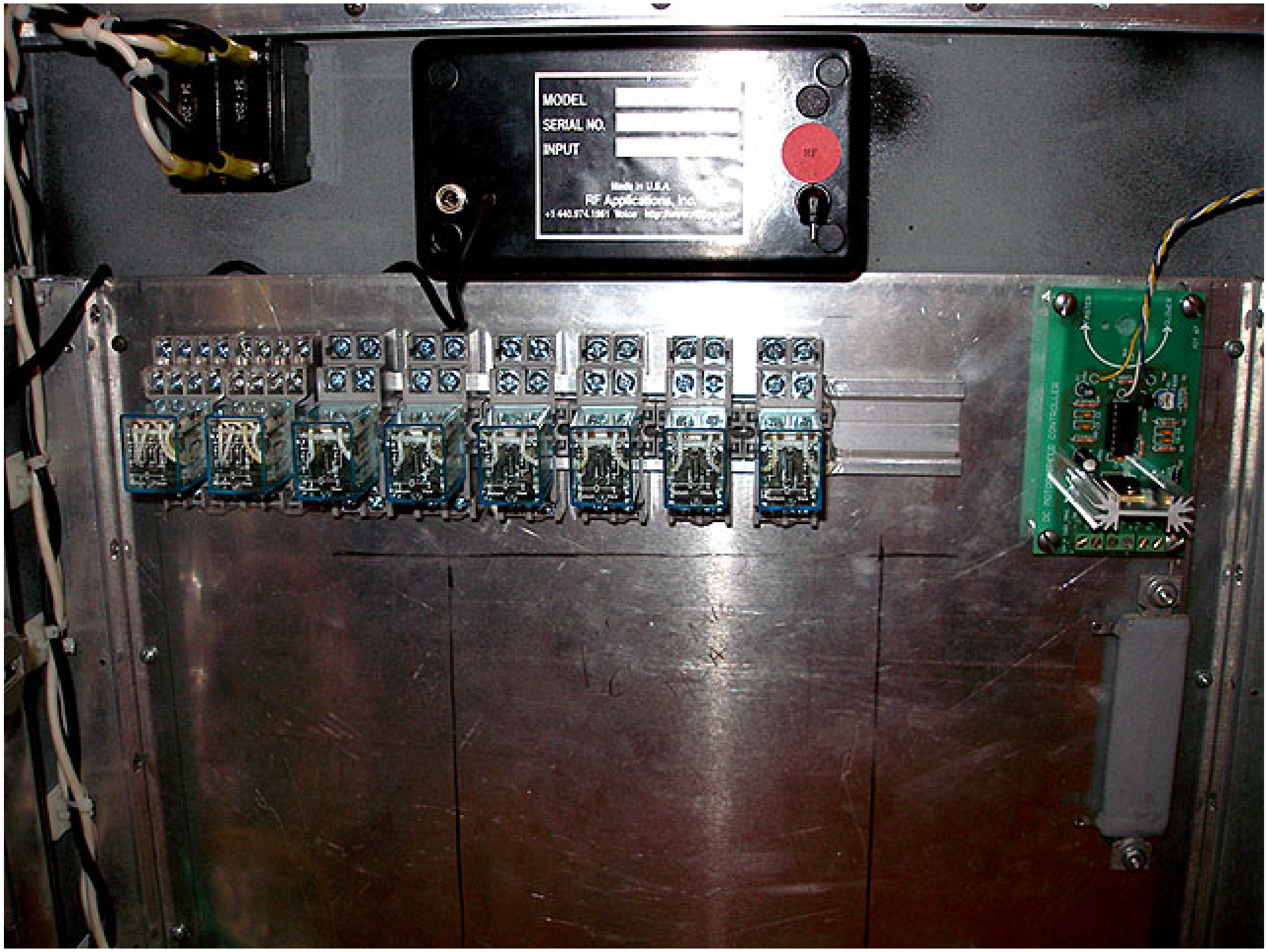
(Inner panels installed in the frame, side and top views)

(Inner Front panels)

The outer shell is a very thin cover that slips over the frame, it does not add much to the structural strength, it is mainly for appearance. I will be re-finishing the shell since it is pretty scuffed up. An added benefit of these panels, is that some of the wiring can be routed through the space between the outer shell and the inner panels, this will avoid the wires having to pass through the area of maximum RF field inside the RF deck area. There will not be that many wires routed in this fashion but the ones that are routed here will be shielded from picking up any RF. The front view of the unit shows the inner panels that will be covered by the outer shell and front door. Cabling has not been installed in this photo.

The Front door:

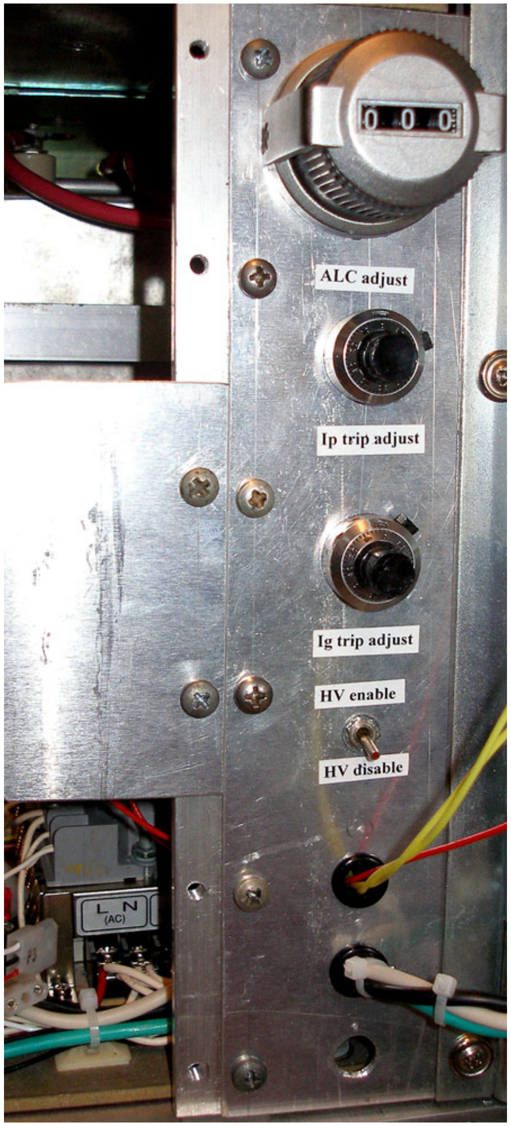
Above, are photos of the Front door/control panel for this amp. As seen they are not complete, but have the blank panels installed and the VFD unit installed. As seen from the front, the upper blank panel is for all the amp controls and indicators, the lower blank is for much of the control circuitry. At the bottom left of the inside door is the main AC power entry twist-lock type 250V @ 25A. plug. The holes at the bottom will allow access for the various cables to enter and leave the unit, they will also allow just enough air flow to cool the low power circuits that will be housed in this area. There will be more photos of the door when it is finished.



Above, is a photo of the inside door panel with the controller relays mounted. These relays are plug-in type using DIN rail type mounts. All but a few PCB mounted relays are on the rail. The PWM tune speed module can be seen to the right, and below it is the load resistor that is switched to the output of the PWM whenever tuning is not taking place but the unit is powered up, this prevents the motors from "singing" and overheating in the idle position. The rectangular area that is marked on the panel is the area where the ATU input unit shield cover is positioned when the front door is closed or operations. The marked area is a low clearance area where there is only one inch of open clearance.

The black wire on the back of the VFD is for the DC signal from the RF coupler. The coaxial connector next to the wire is the 12Vdc input to the meter. On the right side of the VFD is a mono-phone plug I installed for the SWR lockout circuit, it has a 90 degree plug in it, in the photo. This circuit will cause the T/R system to default to bypass condition whenever the SWR alarm level is tripped on the VFD.

Below, is a photo of the Auxiliary control panel inside the front door on the lower section of the main cabinet. This panel has the ALC adjustment control, plate over-current trip adjustment, and grid over-current trip adjustment controls. The small toggle switch at the bottom is the HV enable/disable switch which allows the HV section of the PSU to be shut down while leaving the rest of the PSU operating. This will allow testing, & maintenance of control circuits without the danger of the HV PSU being energized at the time. It would also be useful for "conditioning" of tubes that have some gas contamination and would flashover if the HV was fully on the plate. This panel also serves as a cable/wiring penetration point for various circuits that pass in and out of the main cabinet, to and from the front door control unit. The Aux panel is not a frequently used control panel, and is concealed behind the front door most of the time.

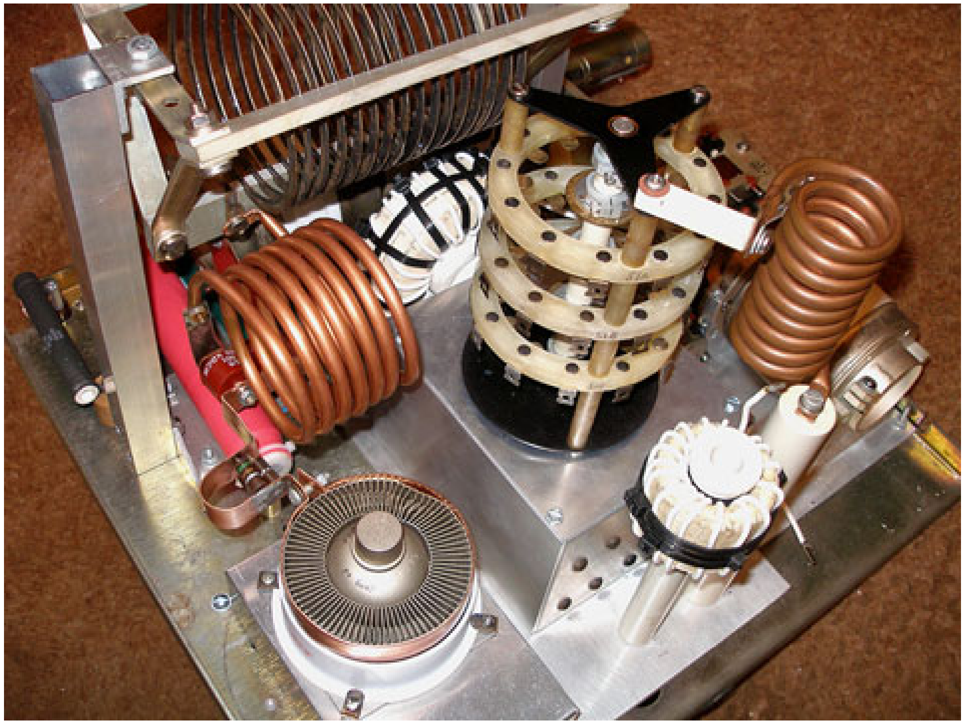

ALC adjust
Ip trip adjust
Ig trip adjust
HV enable
HV disable
L N
(AC)

Above, you see a photo of the front control panel with all the parts installed but not yet wired. From left to right, the LED indicators are blinking ambers for the cap limits, green LEDs for the tune power, input status and band-switch position indicators, Red LEDs for the various "trip" condition indicators. The LED above the power ON button and Standby/Enable button are Bi-color red/green type. The warm-up RED/GREEN is lit at all times when the amp is operating with main power ON. If the LED goes clear the amp is powered down. The Standby/Enable LED indicates three states, clear is T/R disable state. Green indicates Enabled RX state, or PTT "active", Red indicates TX state or the amp is in a "keyed" operation, transmitting. The meters along the top row are all 3-1/2 digit segmented LED meters, they are very bright blue when powered up. The HV meter will read only 3 digits with a x10 multiplier, in other words the actual plate voltage of 3850Vdc will be indicated as 385 on the meter. The grid current meter can read 0-1999 mA, the same for plate current. The tuning position readouts are only a relative position reading, the higher the number displayed, the higher the capacitance setting. A blinking limit LED will indicate that a drive limit has been reached and that direction is now disabled electronically. The cap can only be driven in the opposite direction from the limit LED. The tune-speed control consists of the LED power indicator and the speed adjust control. Tune power is turned off when not actively tuning to prevent PWM module over-heating and possible RF leakage in the circuit. The control pot has an on/off switch at the slow end of its travel. The band-select control is simple, the desired band is selected with the knob, the motorized band-switch moves to that position, stops, and lights the appropriate LED on the control panel. The input tuning LED and switch are as indicated on the front panel, these are the external controls and indicators for the LDG input auto-tuning unit. The unit can be bypassed or set into various other states by a series of button presses. The LED indicates the state by lighting steady (normal operation in auto-mode), or a sequence of flashed codes for each state, such as bypass, and manual tune over-ride. No incandescent or neon lamps will be used anywhere in this amp. This is done to keep current consumption down, and reliability up. These LEDs will be operating far below their maximum limits so they will last a very long time, in the area of 40 years.

The image below shows the LED displays powered up for testing, which should give you an idea of how they will look in operation.

The DC power to the display modules has been dropped to about 4Vdc by a dropping resistor on the filter PCB, but they are still very intense, easily readable from across a room.

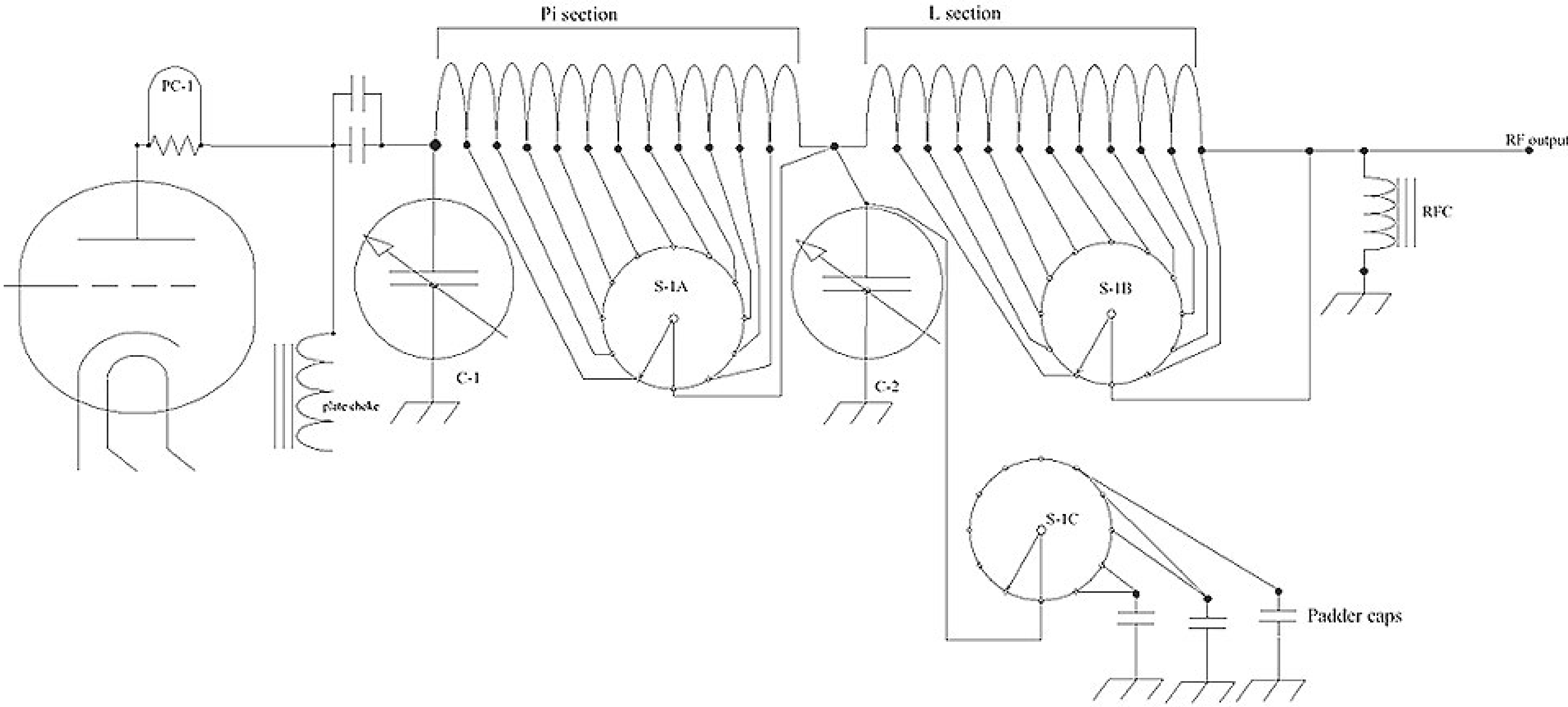
Building a "Tank" circuit:



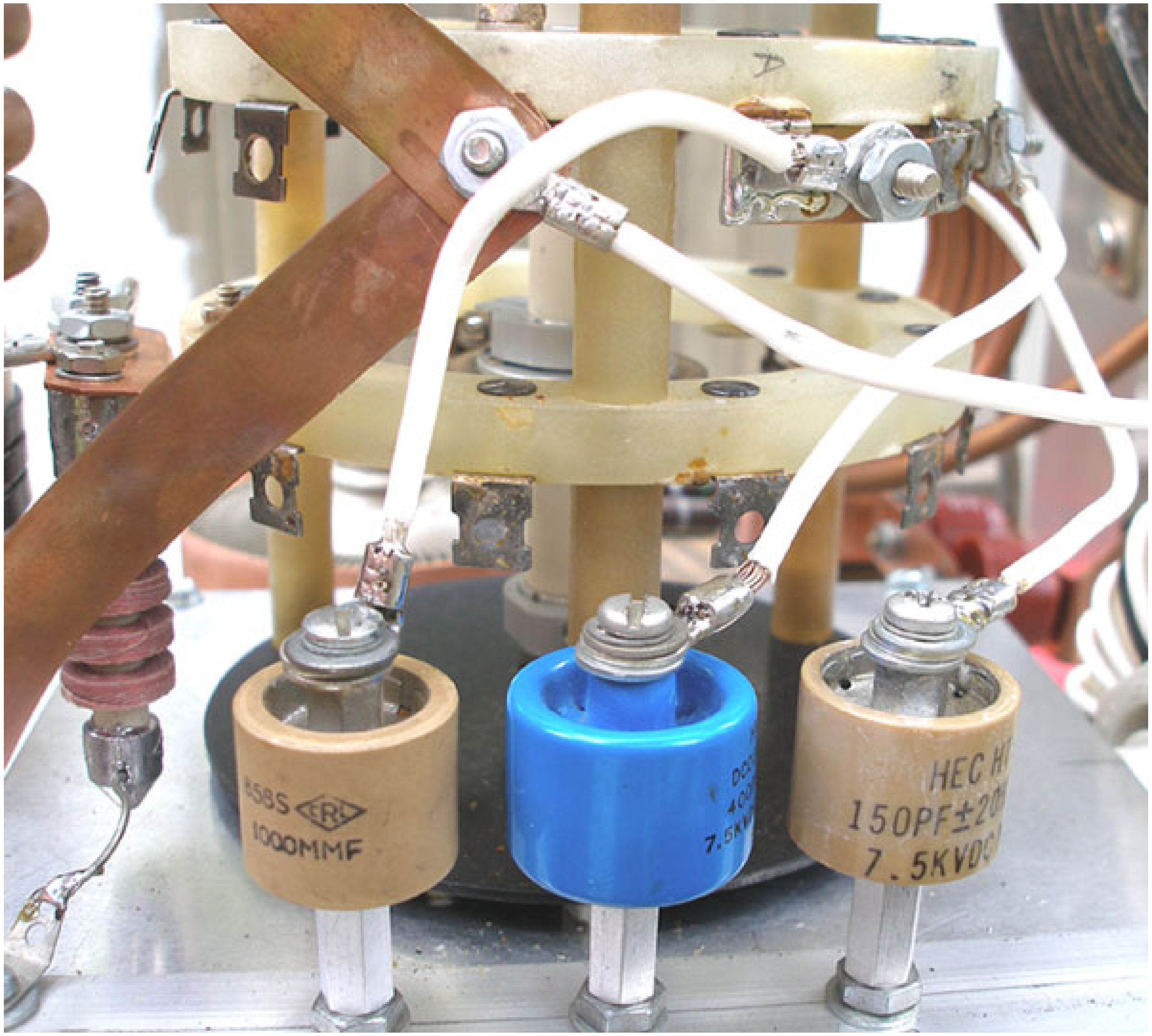
The photo above, shows the tank coils installed. The interconnections & coil taps are not installed in this photo. I wanted to retain the removable RF deck feature that was original to the Harris, this would make it very easy to build and service the RF section of the amp, but would also mean design and construction problems that would have to be overcome. All hardware in the RF deck had to be mounted on the deck itself, no parts could be mounted on the side walls. I came up with this main coil mount seen above. All five coils that make up the Pi-L output network can be seen in the photo.

At a plate impedance of 2500 ohms, and a coverage of 160 meters to 10 meters requires a Pi section inductance of 40µH and an L section inductance of 11µH, which is divided up between copper tubing coils, flat wire coils & ferrite toroids. The maximum C-1 (plate tune) capacitance for 160 meters is 260pF, and C-2 (antenna loading) capacitance of 1300pF. Taps on the main band-switch will switch in fixed door-knob type caps for additional capacitance with C-2 for 80 & 160 meter operation. The large copper tubing coil on the left in made of 0.25" O.D. copper tubing available at many hardware stores. This coil covers 10-15 meters, a companion coil covers the same bands in the output "L" section of the tank. The large flat wire coil in in the "Pi" section and covers 17 - 40 meters. Under the flat-wire coil is a large iron powder toriod which consists of two stacked T-400 "Red mix" cores, insulated with fiber-glass tape from 3M®. The wire is 12Ga.stranded with Teflon® insulation, this coil covers 80 - 160 meters in the "Pi" section. A companion coil in the "L" section is made of T-200 "Red mix" toroids, triple stacked, fiber-glass insulated and with the same wire coils. This coil covers 20 - 160 meters. Hopefully, the "Q" of the tank circuit will be around 12, which will be a good level to aim for in this type of amp. The "Q" may climb as high as 15 on 10 meters, but will not harm the circuit efficiency more than 5%.

The schematic below shows the typical Pi-L tank circuit configuration. The switch section marked "S-1C" is for switching in additional capacitance for the lower frequency bands, this often happens because C-2 does not have enough on its own. This can also be done to C-1, if it does not have enough capacitance, however, the switch sections must not be common, but rather separate from C-2. The configuration below is what was need for my unit. Both C-1 & 2 are 500pF. C-1 is more than enough , but C-2 needs a good deal more capacitance for operation on 160 & 80 meters.



Padder capacitors:

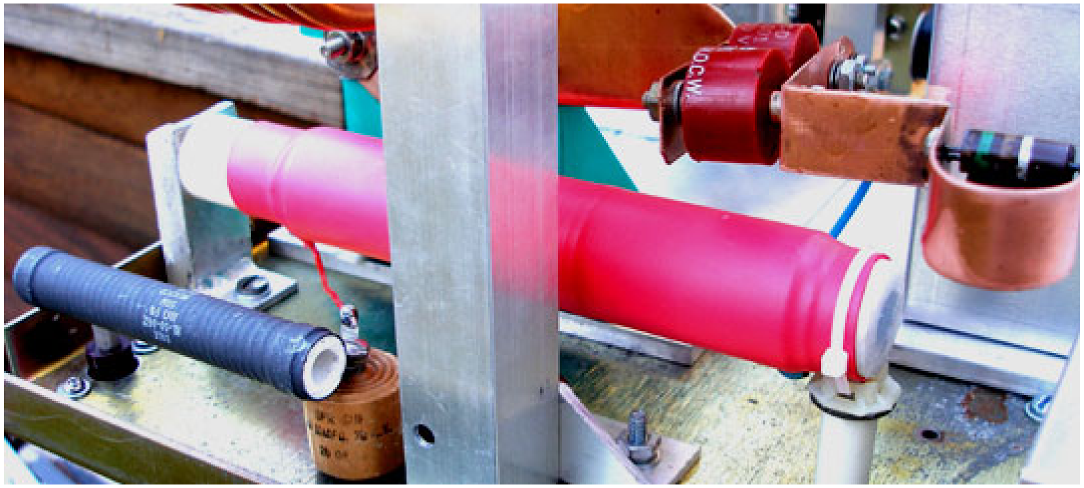


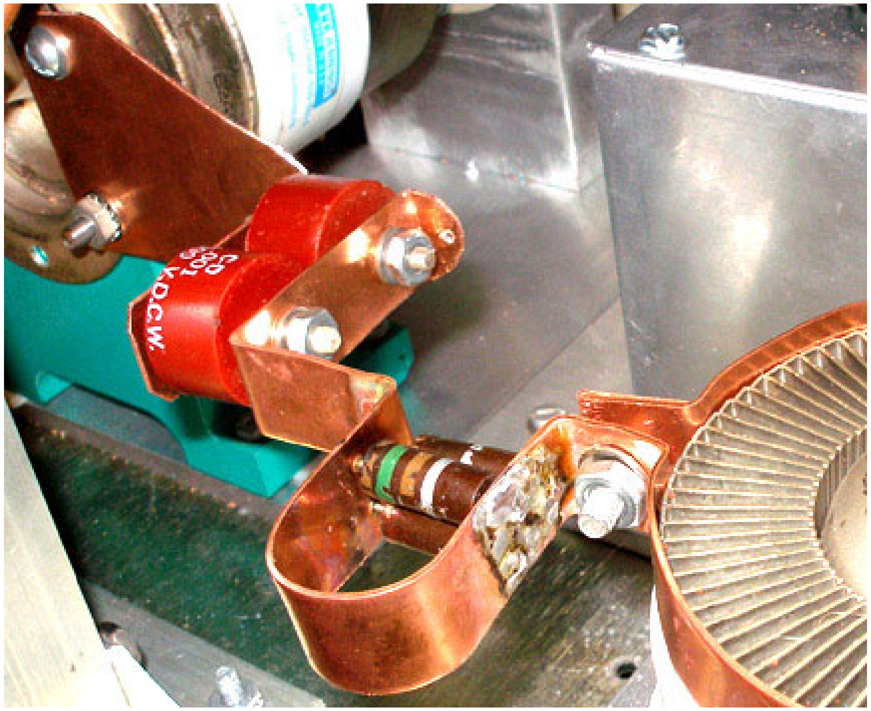
The photo above shows an extreme close-up view of the "padder" caps. Padder caps are used in this design for additional loading capacitance on 160, 80, & 40 meters, since the variable cap does not have enough capacitance on its own. 1000pF is added for 160 meters, 400pF is added for 80 meters, and 150pF is added for 40 meters. All the padder caps are 7.5kV door-knob type.

The tank output point can be seen in the left, behind the large copper strap. An RF choke of 2.5mH @ 300mA is grounded to the chassis from the output terminal. This choke is for safety, should plate DC voltage ever appear on the tank circuit, the choke will short it to ground and cause the HV PSU to trip off-line. The choke also shunts to ground any static buildup on the antenna, and shorts it to ground when the amp is keyed into transmit.

If the plate tuning cap does not have enough capacitance the same method can be use to add capacitance, but are connected on the band-switch bank that connects to the plate tune cap.

The photo below shows from left to right, the B+ "glitch" resistor connected to the HV/plate voltage at the far left end. The opposite end of the resistor is bolted to a 500pF @ 20kV RF bypass door-knob cap. The B+ is connected to the plate choke at this point. The red rod in the center is the plate choke, it is made using my [ferrite loading design](), it has an inductance of about 365µH, but the distributed capacitance of a 90µH standard choke design. This choke is wound with 22Ga. stranded Teflon® insulated wire. Just above and slightly right of the plate choke is the plate coupling, or decoupling capacitors, if you will. These are epoxy encapsulated door-knob type, rated capacitance of 1000pF @ 10kV each. The B+ connects to the anode at the copper strap bolted to the plate caps (see the blue wire below the caps). At the far right of the photo is the parasitic choke, more on this below.





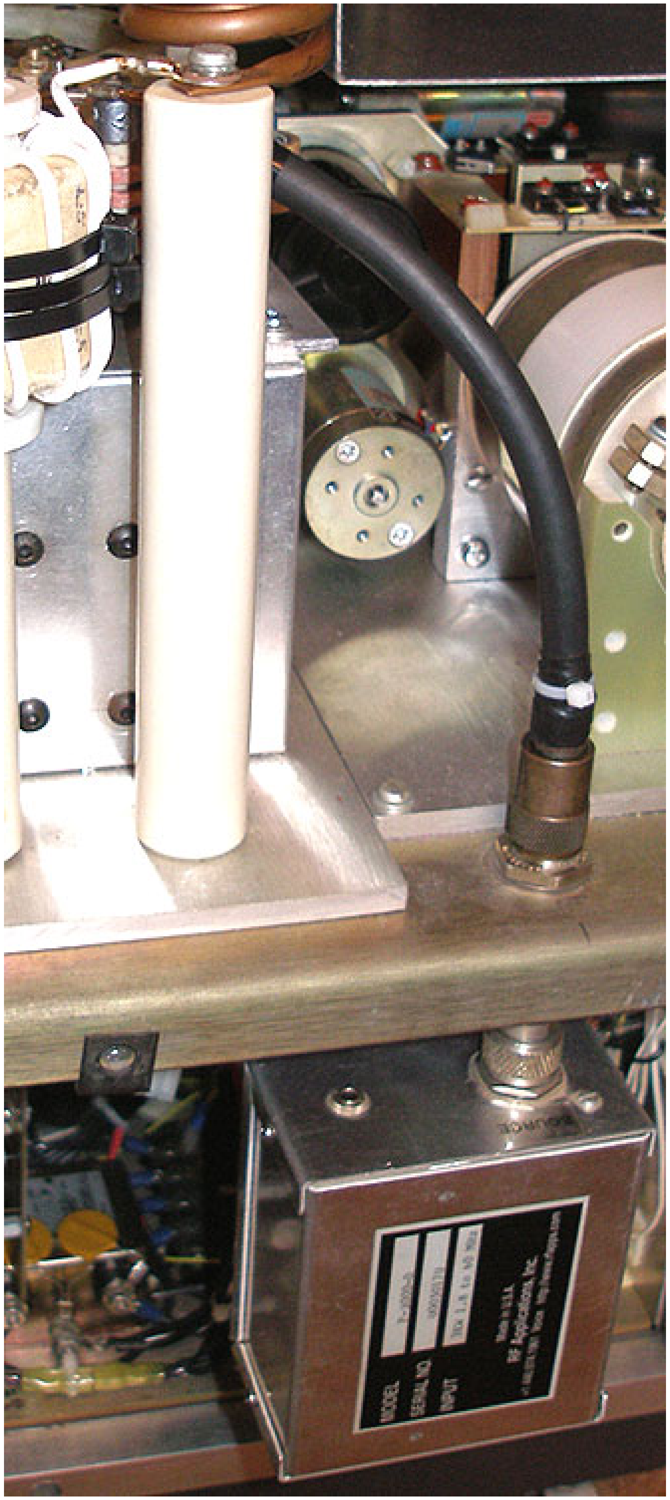
The photo above shows the copper strap anode clamp mounted on the tube in the socket. In the center of the photo is the "**U**" shaped parasitic choke with three, 3 watt, 150 ohm carbon resistors across it. I copied this design from my Alpha PA-77, it works fine in that amp, so I decided to use the same design in mine. The strap forming the clamp is made from a single strip of copper to insure the best possible low resistance conductor for both DC and RF. To the left of the choke you see the plate coupling caps and the strap connecting them to C-1 plate tuning capacitor. The copper has been cleaned and coated with clear acrylic enamel to preserve it. The areas of physical connections were not coated.

Plate choke testing for series resonance; I used two set ups for this test, the first test is "out of circuit" where the choke is tested alone, the second test was done with the choke installed in its operational position, as you see above. I used my signal generator to inject a test signal, sweeping it from 455kHz up to 150MHz, using an oscilloscope and a field strength meter to detect any resonance. The out of circuit test showed a resonance was at 1.6MHz and no where else.

RF output and measurement:

To measure the RF output from the amp, I will be using a retro-fit RF Applications "VFD". The photo below shows the RF output line from the tank circuit. The actual T/R relay is not located within the amp itself, it will be located in the front door with coaxial cables routed into and out of the amp for RF input and output. The coax port on the bottom of the VFD sensor is connected to the output coax that runs to the T/R relay. The VFD sensor also will have the ability to lock out the T/R system if an SWR alarm trips.

A bulkhead coax connector penetrates the RF deck plate. This should keep the RF where it needs to be. The coax cable runs to the main band-switch where it is connected to a common mount with the tank inductor and an RF choke that drains any DC voltage buildup in the tank or antenna line.



The small port on top of the sensor is for the signal pickup line that runs to the VFD control head which will be mounted in the front door. The sensor is secured only by the coax coupler, and can be easily removed for servicing.

There will be much more to come on this unit, stay tuned...