The IC-4KL HF solid-state 1kW amplifier.

By Matt Erickson, KK5DR

User reviews have been published many times on this ICOM amplifier, even though it has been discontinued for several years now. These rare beauties show up for sale from time to time and are quite expensive, even at half the original price of slightly over $6000 new. A solid-state amplifier that weighs over 80 pounds - now that is beefy! The 4KL is built for heavy duty 1kW output operation regardless of mode and duty cycle (one hour). The switched mode power supply and PA are in the larger unit, and the remote control head has the meters and controls on it.

The 4KL uses four push-pull pairs of 2SC2652 (discontinued device) for a total of eight power BJT (Bipolar Junction Transistor) devices in a class-AB linear PA. The DC power supply behind this robust PA is an equally robust 40V @ 60A switching PSU, that can operate on 240/120Vac. AC input voltage is automatically switched by the PSU when connected to the AC mains. If the amp is operated on 120Vac (not recommended!), the output is limited to 500 watts. There is an Automatic Tuner Unit built in as well. It is important to use this ATU whenever the SWR exceeds 1.5:1, so that the PA is properly matched and distortions will be kept low, and risk to the PA devices is also kept low.

There are several protective systems in the 4KL; the most important of these is the ALC system. ALC is the primary protection for any solid-state amp, and many tube-types as well. It MUST be used, and set properly!! The ALC system ties into the SWR protection system and the DC over-current protection. There is also a "protect" mode, which indicates that a PSU fault has taken place, or an imbalance in the divider or combiner networks in the PA.

RF drive is applied to the PA through a 1dB attenuator at the input of the PA splitter/divider. From this attenuator the drive signal is sampled for generation of the ALC negative-going DC signal whenever; (1) the output SWR exceeds 2:1, (2) RF drive level exceeds 70 watts, (3) RF output exceeds 1kW, (4) collector current exceeds the preset limit of 23A. The 4KL switches into "bypass" mode whenever; (1) RF power gain is less than 1:3 ratio (5dB), (2) PA balance is upset (indicates the failure of one or more PA modules and or splitter or combiners), (3) PA heat-sink temp exceeds +194ºF (+90ºC). The cooling fan is activated when the heat-sink temp reaches +122ºF (+50ºC). The bypass system operates independent of the ALC system.

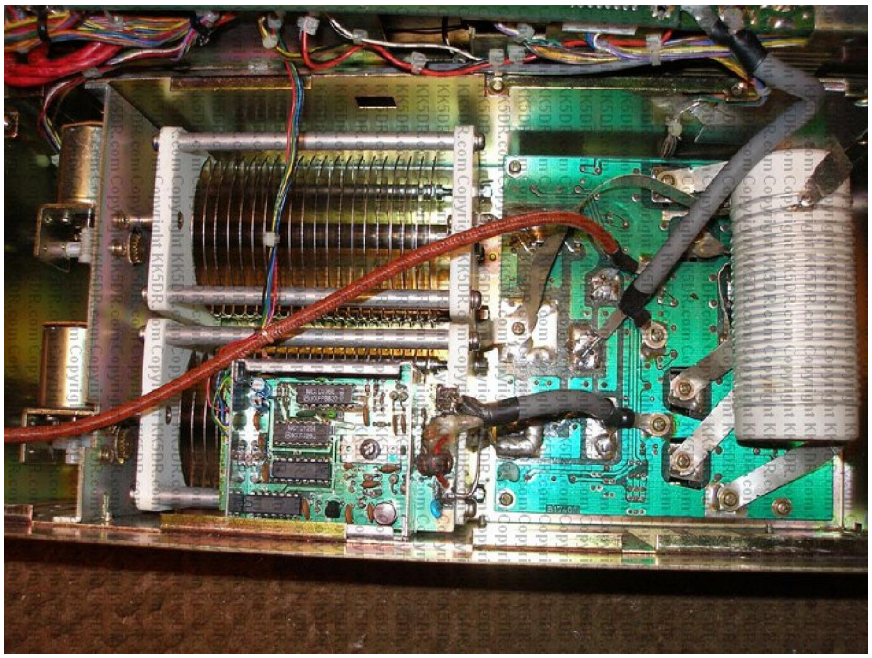
My 4KL:

Serial number 1001, which means that it is likely the first or second unit in the US (All ICOM models begin at serial number 1000), very likely the oldest 4KL most US hams will ever see. Arrived at my station DOA (thanks Internet seller). Battered and scuffed, I have rebuilt it, and it is be better than new.

ATU:

The Automatic Tuning Unit uses relay-switched inductor and two servo-motor driven air variable capacitors, in a T-network. There are additional relay switched capacitors which are used when the amp is operated on the 1.8MHz band, the caps are switched out on all other bands.

Should your 4KL fail to recall tuner settings, this usually means that the back-up battery is depleted and needs replacement. This is likely to happen about every ten years. If the battery voltage reads 3Vdc or more, it is fine, check it again in a few years.

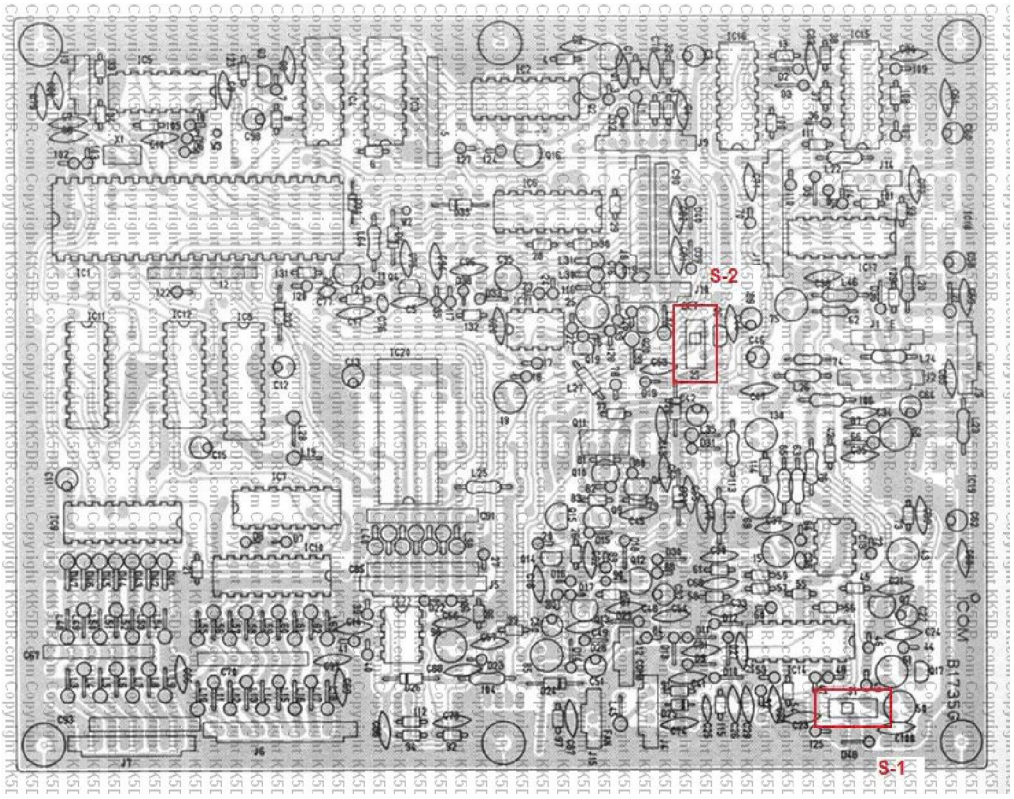


The tuning unit is designed to handle a maximum SWR of 3:1 or 16.7 to 150 ohms. It has an insertion loss of 0.5dB after tuning, which means that at 1kW output there will be a fair amount of heat will be generated in the ATU. For this reason there is a fan installed to draw cooling air through the ATU. This is a small "muffin" fan that cools the ATU section. During ATU operation at 1kW output into an SWR of 3:1, there is a significant amount of heat that will be dissipated in the ATU circuits, so cooling air is needed.

10/12m enabling?

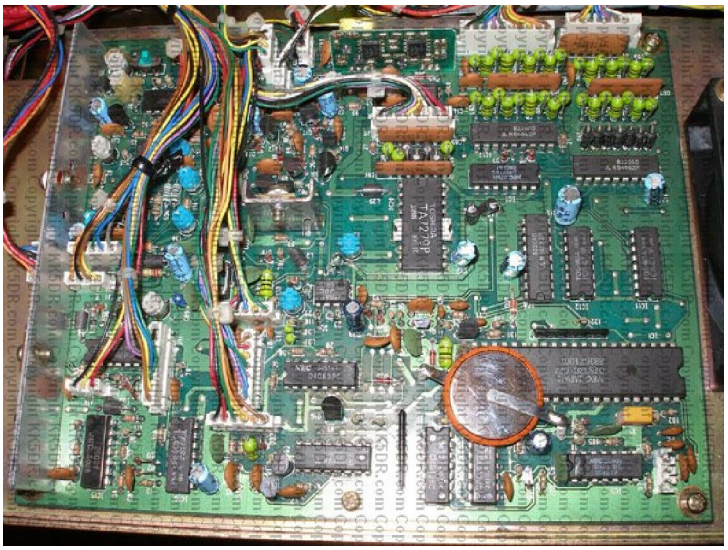
The 4KL was built during the era when the FCC had a misguided rule that no linear amplifier sold in the USA could have the 24-30MHz bands enabled at the time of sale

without verification of a general or higher ham license. The US version of the 4KL came without the 10/12m bands enabled, it does not even have an LED indicator on the control head front panel. All others versions did. There is very little documentation on enabling the 10/12m bands. The info I have gathered says that the main unit PCB must be found and switch "S-2" is switched to enable the bands (switch shown in the 10/12m enable position). Below you can see a picture of the main board and switches S-1 & 2 are highlighted. "S-1" is a selector switch for 500/1kW output levels (switch shown in the 1kW position). This switch is likely for certain European countries which have a 400 watt power limit, and also for service alignment.



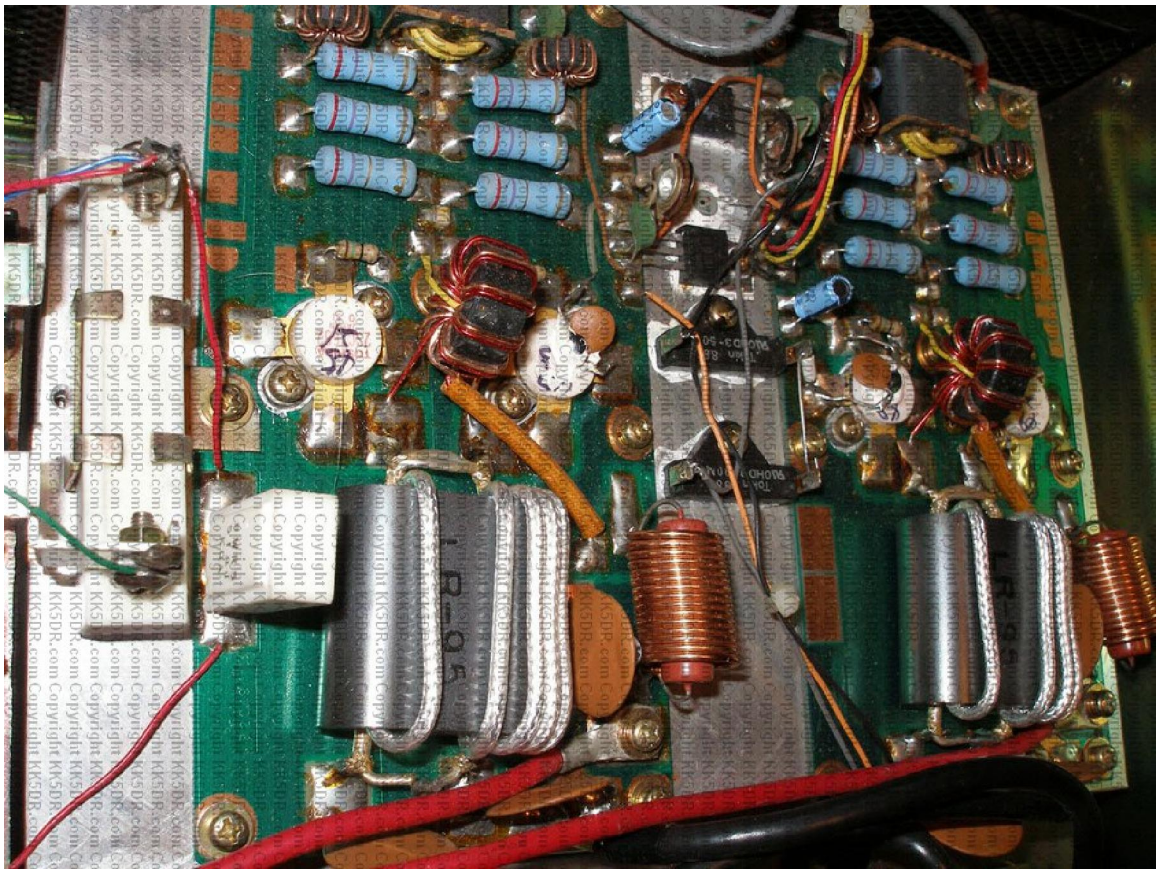
Enabling the 10/12m bands in a US version is pretty easy. However, since the unit does not have the indicator LED for those bands on the control head, when those bands are used there is no indication for the operator to see and verify the band selection. The best way to know that the 10/12m band are currently selected, is to verify that info from the exciter's operational frequency, and remember that there should be no band indicator LED lighted on the 4KL control head.

CPU:



Above, you see the main control board where the CPU can be found, under the back-up battery (orange & silver round part).

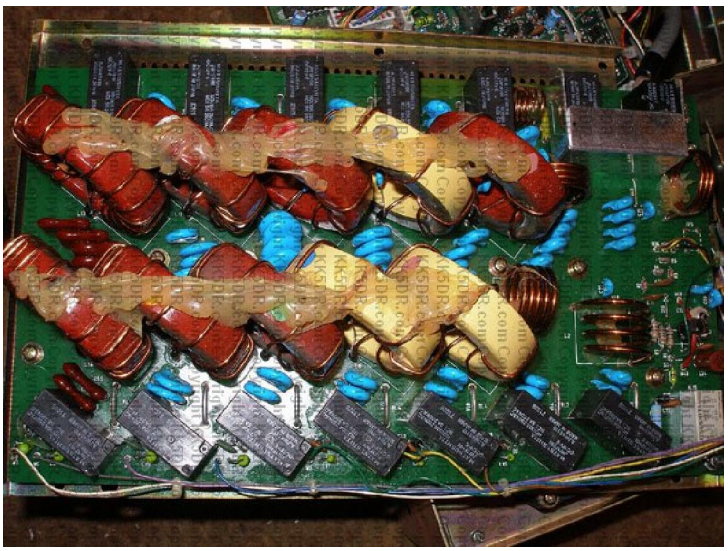
PA modules:



The photo above shows two of the four PA modules with their input and output transformers. The black objects in the center are the temperature sensors that sense heat-sink temp to activate blowers, and protective circuits. The other two modules are on the opposite side of the heat-sink. The design of the heat-sink is a "flow-through" cooling system, small but very efficient. Forced air goes through the heat-sink and exits the rear of the RF deck.

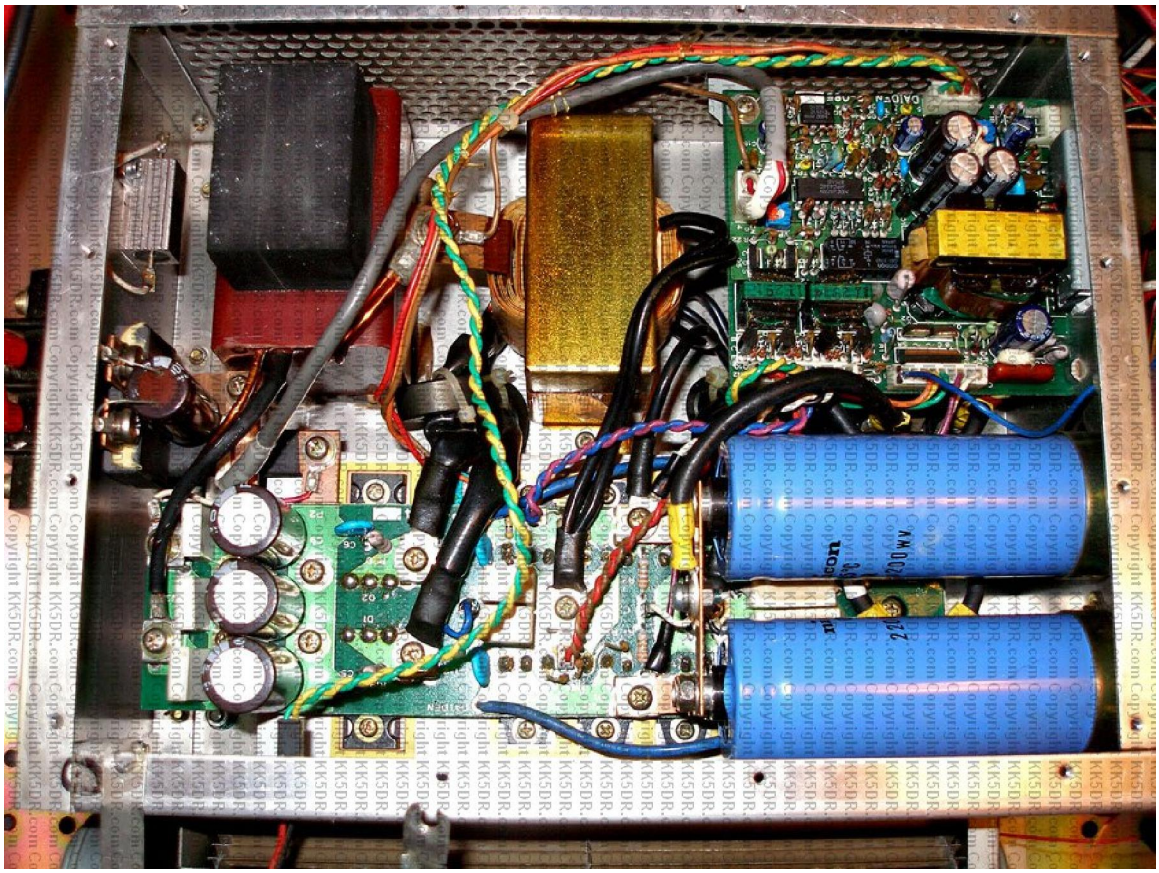
Filters:

Broad-band amplifiers require a set of low-pass filters to attenuate harmonics. Below is a photo of the LPF section.

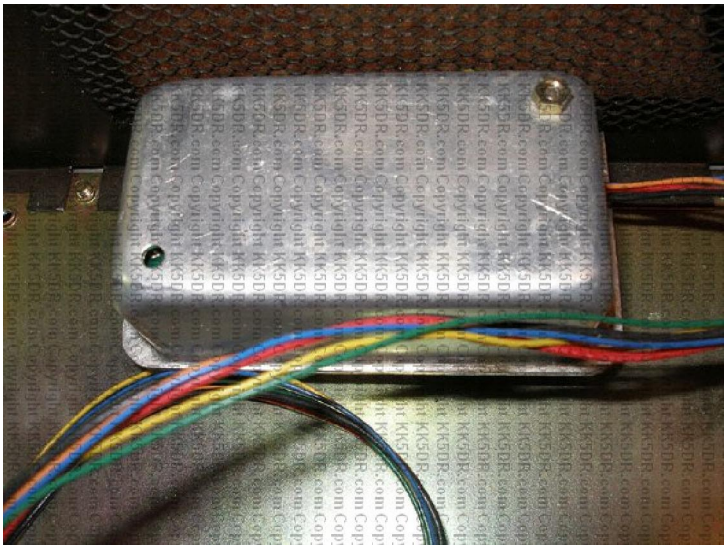


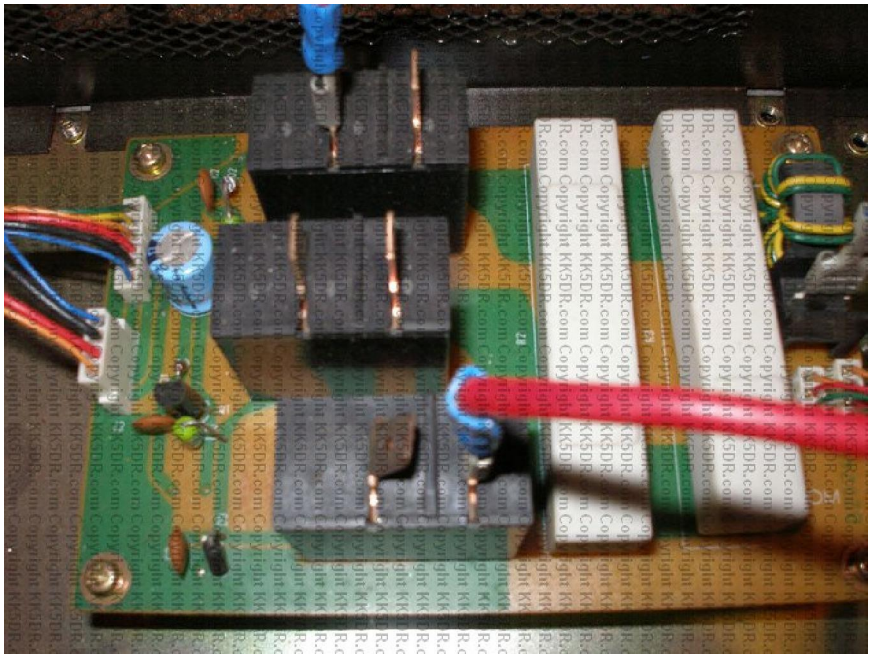
Each filter section is selected by the CPU based on band of operation, through relays. These coils are quite large, about 2" in diameter.

PSU:



The PSU is shown above. This is the OEM +40Vdc @ 60A. switched-mode power supply. No schematics exist for this unit (EP102), there would be virtually no way to fix it. There is a separate DC to DC converter unit that converts the +40Vdc provided by the main PSU (EP102) into + & -13.8Vdc which is converted to +/- 5Vdc by regulators on the main board. A photo of the converter is shown below. This converter is the same type as used in the IC-2KL and AT-500.

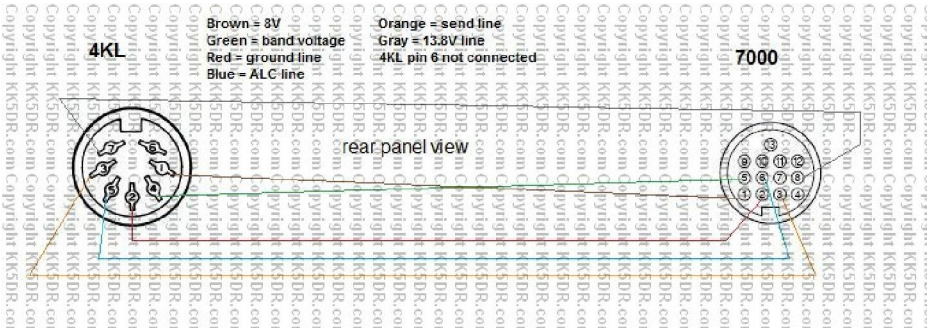




The photo above shows the REG unit which switches automatically from 120Vac to 240Vac. It also acts as a "step-start" module.

ICOM exciter interface:

I have drawn up simple DIN to DIN cable interface(s) for various ICOM exciters. The 13 pin IC-7000 is given as an example and should be the same for all ICOMs with 13pin DIN ACC plugs, such as the 718, 706 series, and 703. However verify the connection prior to using the cable.



The interface cable for all other ICOM radios with a 7 pin DIN ACC plug are the same as that of the 4KL, the pin/color key above can be used to construct your own cable.

It is important that you use only the 7 pin DIN (on the exciter) for this interface. The 8 pin DIN is not entirely wired properly, and the amp will not function properly, The correct configuration is 7 to 7, or 7 to 13 for all ICOM radios. **Do not** use the 8 pin DIN (on the exciter) to connect to the 4KL! There are only 7 pin DIN connectors on the amp.

Known common failures:

Some of the areas that have been well known for failures are; (1) PSU failure, (2) PA module failures (PA imbalance). A PSU failure is not an unrepairable problem. A replacement switching PSU of 40V @ 50A can be had, but are not inexpensive. As long as the replacement unit fits inside the PSU cabinet it should not be too difficult to repair (see the paragraphs below for more details). A PA module failure is also not a total loss, even though the 2SC2652 transistors are no longer made, a close replacement is the MRF-448. If a PA module needs repair, it must have a matched set of transistors to work properly. There have also been reports of intermittent problems, many of these can be traced to poor electrical connections or a result of connection oxidation and or corrosion. This item could be fixed by the use of De-Oxit® and or Pro-Gold® applied to all the cable junctions, most of all, the remote control cable connections.

Meter lamps are "grain-o'-wheat" type lamps that have a very short life span. The lamps can be replaced every few years, or can be replaced with high intensity LEDs and current limiting resistors. LEDs will last a lifetime. There may be more on this later in this article at some future date.

Maintenance;

All 4KLs are reaching an age where certain things need to be checked and or repaired from time to time. All checks that are not done annually, should be done at least every couple years or whenever unusual operation is noted.

(1) Check the REG unit for evidence component heating. Since this unit is "on all the time" whenever the AC mains are connected, and the breakers are <ON>, the heat dissipated by the board components can de-solder some of the PCB connections over time. The connections should be re-soldered. A better solution is to replace the parts that overheat with parts having a higher dissipation rating. A good interim procedure would be to place the breakers in the <OFF> position whenever the amp is not in use.

(2) Loosen and then re-tighten all the screws on all the PCBs. Pay extra attention to the PA module boards.

(3) Check the filter PCB for cracked or "cold" solder joints; if in doubt re-flow the solder connection.

(4) Remove and re-seat all the cable plugs. An extra measure of preventive maintenance would be to apply Pro-Gold® to each of the plug pins and re-seat them.

(5) Check the large high-voltage filter capacitors in the PSU for evidence of leakage (whitish crystalline deposits around the vent port in the rubber plug), and replace as needed. If the rubber plug in the end of the cap has blisters in it, replace the cap.

(6) Inspect each PCB for any unusual signs, such as cracks, burn marks, discoloration of the board or components, or anything else that doesn't seem right.

(7) The grease on the gears of the ATU will become hard over time, if during an inspection you notice that the grease is hard or the gears are now dry, a good quality silicone or Teflon based lube grease should be applied to the gears, but not in excess. A small amount will do. A drop of light machine oil should be applied to the bearing sleeves of the ATU drive motors as well at the time when the grease it applied to the gears.

(8) Annually, the cabinet should be vacuumed of any dust accumulations. To reduce the accumulation of dust and make it easy to clean, use plastic air-conditioner media inside the removable air intake grills on the front of the main unit. The media can be cut to size to fit nicely. This media can be washed annually and will replace the need to vacuum the interior of the unit. This media can be found at most hardware stores, such as, Lowe's, Home depot, Ace, etc.

(9) During an annual inspection, a quick check of some parameters should be performed; Check into a dummy load that the output is 1kW at about 40A DC, with about 50-60 watts drive level, with ALC at the upper ALC limit on the meter on 14MHz. Any variation should be investigated further for possible problems or a meter that is out of calibration.

(10) Check the blowers every other year for free movement and dust accumulations.

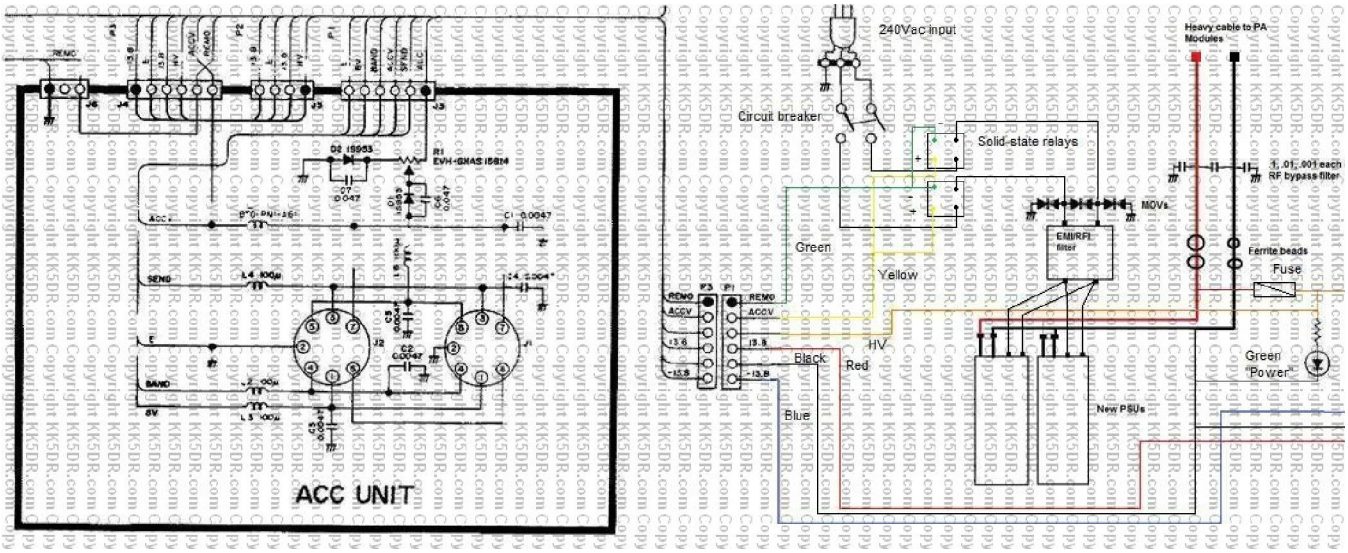
Dead PSU! Now what!?:

Unfortunately my 4KL main PSU died. I am not sure exactly when or why (it happened before I got it, I know that much). No 40Vdc output at all; there is 24Vdc output for the fan, but nothing else. Without 40Vdc the DC-to-DC converter will not make +/- 13.8Vdc which in turn will not produce +/-5Vdc for the controller system. This means the unit is dead. Repairing these units is virtually impossible. Firstly there is no existing schematic for this section (EP102 on the main schematic). Secondly, the defective devices that have likely failed are not available anymore. So, in other words the original PSU is now a scrap bin.

However, all is not lost. Here I will replace the PSU and show you how it can be done. Keep in mind that this is no cheap fix; switching PSUs of this voltage and current are not cheap at all. I have priced a single unit rated at 48Vdc @ 60A, at over $2500! I have taken an alternate route in replacement units, I found a pair of current sharing 48V @ 32A. units that will fit inside the lower cabinet of the 4KL with some room to spare. There are slight modifications needed for proper cooling air-flow and interface into the system with the least amount of re-design.

The new PSU will operate on 90-264Vac, and will do this automatically; so the REG unit will no longer be needed, so I have removed it. The DC-DC converter is needed because the control boards need two separate voltages, +13.8V & -13.8V which are each converted to +5V and -5V by separate regulators on the main PCB.

Below is a basic schematic showing the interface of the new PSU. It is a mix of the original schematic and the new circuit integration I have designed.



The theory of operation of the new PSU is; ACCV/+13.8Vdc from the exciter is fed to the control circuit of each of a pair of 240Vac @ 25A solid-state relays (Opto-22 model 240D25), when the <Power> switch on the 4KL control head is pressed in, the circuit is grounded and activates the relays. This causes the PSUs to power up providing 40Vdc/HV to the DC to DC converter and to the PA modules. The 40V provided to the converter is converted to +/- 13.8Vdc which is provided to the main PCB where it is converted to +/- 5Vdc for the IC circuitry. During power-up, if the PSU is operating normally the Green "Power" LED will be lit. There are circuits in these PSU modules for external alarm indicator but I will not use them for now. These PSU modules are fully automated and protect themselves very well. The output of these PSUs can be remotely controlled by an external switch or relay contact connected to the proper pins of the unit. The input of the PSU is NOT controlled by this switch, so it will run as long as AC voltage is connected.

The new switching PSU I am using is the Mean Well® RPS-1500-48 which can current-share in a master/slave configuration. It is important that both units be adjusted to within 100mV of a volt of each other for current sharing. Voltage is externally adjustable from 70-100% of the full 48Vdc, or down to 38Vdc. I found that the built-in voltage trimmers can adjust down to 40V very easy. I set both units to 41.01Vdc each, to allow for voltage drop from the PSU to the PA terminals. The trimmers are a little hard to adjust with precision due to the small size, but should be set as close to each other as possible. An external trimmer would allow more precision and range to the adjustment, but are not needed for this application since these are "set and forget" adjustments.

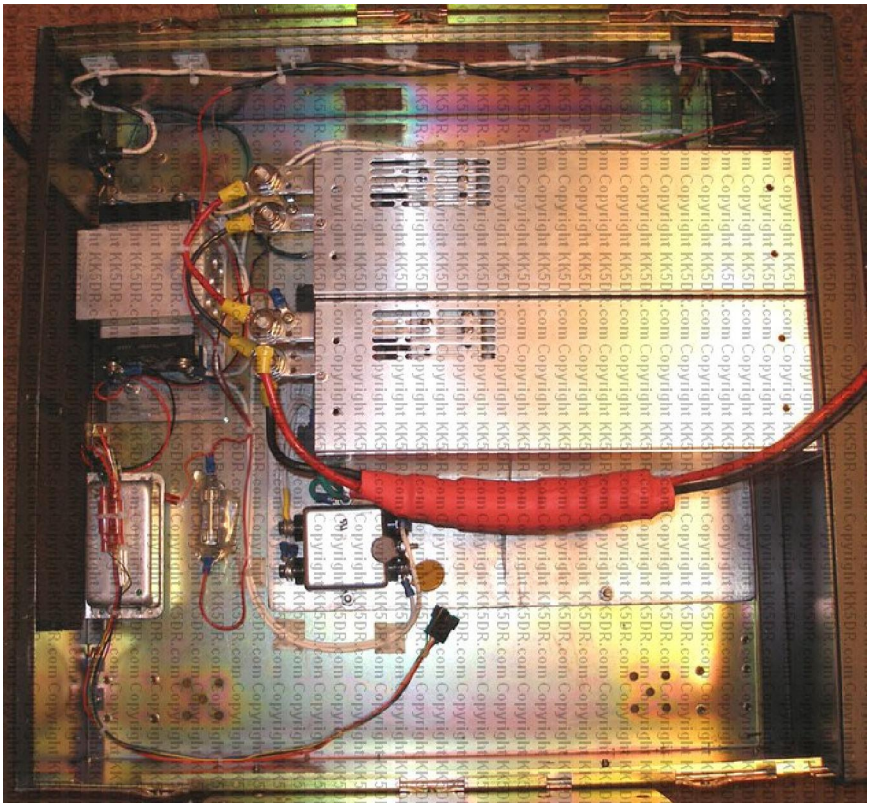
The photos above show the end views of the new PSUs, the photo on the left shows the AC input/DC output end of the PSU. The photo on the right shows the cooling fan (3" dia.). Cooling air is drawn in this end, and exhausted from the input/output control end. You will notice that there are a set of connector pin sockets on the control end of the PSU; the connectors for these are special 2mm pitch type. The PN for each from Mouser are; 855-M22-3020300 (2 req.), 855-M22-3020400 (4 req.), and the pin clips are 855-M22-3050042 (at least 20 are required.). All these cost about $5.50 plus shipping. Specific wiring details are shown on the data sheet for these units. Unfortunately the clips do not grasp the pins very well since the clips are made for square pins and the pins on these PSUs are round. So, I had the tedious task of carefully crimping the clips so that they will grasp the pins better, at best they are still rather delicate. I could not find a source for the round pin clips. Care should be exercised with this control wire harness, it is not retained very well, so it would be easy to knock loose, the harness should be tied down to help prevent this.

Solid-state relays and heat-sink:

Most AC solid-state relays have a voltage drop across them and therefore heat dissipation, so a heat-sink should be used if that level is over a few watts. The relays I am using have a 1.6V drop at 25A load, which is about 25 watts of heat. Since there are two units I have 50 watts of heat to get rid of. Below is a photo of the relays and the heat-sink I fabricated for the job.

The heat-sink is made from a solid block of aircraft aluminum, with through holes drilled to produce a "block-o'-cheese" type sink. The purpose for this design is for PSU fan blown air to flow through and remove the built up heat. The relays will be mounted to each side of the block, and the block will be mounted to the deck of the 4KL PSU bay. Thermal grease will help transfer the heat from the relays into the block.

A standard open-frame relay could be used for this circuit, but the coil current would be much higher. The Opto-22 relays have a control current of about 10mA at 12Vdc, so the total current will be about 20mA on the remote line through the <power> switch in the control head of the 4KL. A few of my reasons for using this type of relay are; (1) Ultra low control current draw. (2) Wide range of control voltage. (3) Zero-crossing start up, which controls "in-rush" current. (4) Totally silent operation. (5) I had them in my stock pile of parts. The primary drawback is that they have a voltage drop and heat output. I am willing to live with that.



The photo above shows the new PSU modules installed in the PSU bay of the 4KL. The mounting plate allows the use of the original PSU mounting holes through the bottom. The reason for the positioning of the modules is to have the cooling air intake align with the air intake filter of the 4KL PSU bay.

AC mains power enters the bay at the upper left of the photo, passes to the main two pole circuit breaker on the front panel, then is routed to the EMI/RFI filter module seen at the lower center of the photo. Separate line feeds go to both PSU modules from the EMI/RFI filter output. You will notice a set of three MOV voltage surge suppressors are mounted on the input side of the filter, these were salvaged from the original PSU. The yellow MOVs are 130Vac type from each line to chassis ground. The gray MOV is a 275Vac type across the AC main lines. I have designed this system to operate only on single phase 240Vac, 120Vac would not be an efficient way to operate this system because the AC line voltage drop would be too great. This would affect regulation and possibly cause the PSU to shut down due to low AC input voltage at full load (32A.), which switching PSUs really do not like.

A quick test of the DC output with an oscilloscope showed that the DC output is smooth and very clean. I found no switching transients or spikes. The ripple was very low - actually below spec. This means that the Mean Well switching PSU is very advanced technology when compared to older switching PSU designs. Usually a clean trace such

as this would only come from a linear PSU. How far the switching design has come over the years.

I must warn you that the fan noise is much noisier than the OEM fan. The level of noise is about equal to a typical Henry console amp. Since the amp/PSU cabinet is remote from the operating position, the noise should not be too objectionable. For those who can not tolerate any noise in your radio room, this replacement might not be for you; then again the 4KL in its original form might no be either.

Does it work?

Yes! It works nicely!

You will notice two things from the photo above: First you will notice that there is a large red heat-shrink sleeve on the main DC power cables. Originally there were two black-mix ferrite sleeves on the cables, I added nine more of gray, red and yellow mixes, to cover all frequencies and eliminate the possibility of any RF making it back to the PSU DC outputs, then I placed heat-shrink tubing over them to prevent movement and protect them from damage. Next, you will notice the fuse holder just to the left of the EMI/RFI filter which I added for protection of the DC-to-DC converter unit. Should there be too much current drawn from this unit for any reason, the fuse will protect it from serious damage. The fuse installed is a 1.5A. fast blow type, which seems high enough.

The <Power> LED on the front panel of the main unit lights when DC power is available. The LED is on the output side of the fuse, so if the LED goes dark, but the PSU fans still run, the operator will know that the fuse is open. The <Overload> LED is not connected at this time, but is present in the front panel.

When I first attempted to get the unit on the air it did not want to band-switch. It was stuck on 10MHz. I checked many things and it soon started working properly. I think I had a poor connection somewhere and my fiddling with them disturbed it enough to cause this poor connection to clear and make good a connection again.

The 4KL now puts out a full kW with about 50-60 watts RF drive, and draws about 40A DC. However, I think the DC current meter might be a little off calibration. I'll check and re-set that later. The DC voltage drop at full load is less than 1V.

I spent 2.5 hours doing on-air testing. Analysis showed that the unit is operating normally with a clean RF output. The efficiency is about 60% @ 14MHz.

The air-flow from the PA section was warm, and the air-flow from the PSU section was cool at full RF power out. The PSU modules seem to be loafing at 2kW input to the PA.

RFI/hash:

The new PSU operates at two switching frequencies, 70kHz and 100kHz. I did a noise search using my IC-7800 as the receiver. Without the 4KL powered up, I first did a sweep of the HF spectrum to find any noise sources and note that they could not be from the 4KL PSU. Next, I swept the HF spectrum with the 4KL powered up to locate any noise sources that could be attributed to the 4KL PSU. I paid particular attention to the 70 & 100kHz areas. I found no noise at all that could be traced to 4KL PSU. I scanned all the way up to 50MHz. I could not find any RF hash either. I can say that the Mean Well PSUs are totally clean and suitable for use in an RF environment provided that proper filtering and bypassing are included in the installation.

Update; It has been a while now, and the "rebuilt" 4KL is operating perfectly, and there is no reason that it will not continue to do so for the foreseeable future. I have taken what might have been a bad buyers experience and have turned it into a learning and teaching experience. I hope that this article is helpful to my fellow 4KL owners. I think that I'll have this 4KL for a long time. It is simple and I can work on it and repair it.

Another option that was not available at the time I did my repairs is the new model from Meanwell RSP-3000-48, a single unit 3kW, 48Vdc @ 62.5A. PSU, that is a little easier to install than the current sharing RSP-1500-48 pair. Go to this link to read about the new PSU and find out where to purchase one, RSP-3000-48. The interface is much the same as the PSU pair with the 4KL. It is not a cheap replacement, but is a reliable PSU and will last a lifetime.