Repairing an Icom PS-30 power supply

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I recently saw an advertisement on VKham for an Icom PS-30 switchmode power supply. After some searching the internet with Google to find out more about the PS-30 and to check for known problems and any reviews of the same (from the Eham site), I bought it.

Reading the manual and sorting the specs

The PS-30 power supply is circa 1980 and was intended to be used as the main power supply for an amateur radio station. It is rated at 13.8 V dc, 25 amps, and 10 minutes on/10 minutes off, 50% duty cycle. The dc output voltage tolerance is 10%, which may seem a bit high (I have a commercial 13.8 V dc supply that only drops 500 mV when 22 A is drawn from it), but is in keeping with the age of the design (I have checked the specifications for the dc input tolerance of some of the HF rigs from that era and they show a 15% tolerance of 13.8 V dc).

To this end the PS-30 has three two pin connectors across the back panel (each rated at 6 A) and the usual single 6 pin dc power connector common to HF radios of the era, fitted at the end of a short lead. Removal of the Icom nameplate on the rear panel will uncover two holes where banana sockets can be fitted if required.

The front panel has a power switch, power on indicator LED and an illuminated analogue meter, which indicates either the dc output voltage or the dc output current, this being selected by a rotary switch, also on the front panel. In the example I purchased, initial testing showed that the power on LED, the meter scale lamp and the current indication function of the front panel meter were not working. Otherwise the power supply worked.

In the course of surfing the 'net for information on the PS-30 I had downloaded the user manual and schematic, together with adjustment information for the power supply and regulator boards (authored by Adam Farson VA7OJ/AB4OJ). I also found an article on the repair of the power supply (authored by Ernesto Lastra Bohme DF1ELB) and downloaded it as well. I made sure that I was familiar with this information before I tackled the power supply faults.

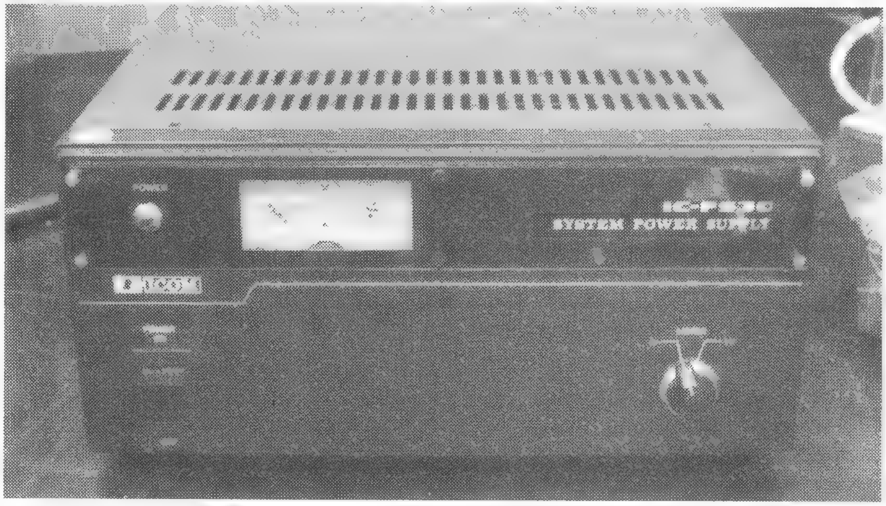

Photo 1: The front panel of the Icom PS-30 power supply.

Screwdriver time

Removing the six screws that held the power supply top cover revealed uninsulated mains wiring, which was common practice when the power supply was made (I have seen both Icom and Kenwood equipment wired this way), a cooling fan driven by an induction motor and a circuit board, mounted on standoffs to a black diecast box which was in turn attached to the bottom of the case.

This board is the supply board which has several functions: it converts the incoming ac mains to high voltage dc for the switchmode regulator, contains the circuitry that drives the current function of the front panel meter and also a small linear supply used for both the current indicator circuitry and as a bootstrap power supply to start the main switchmode regulator.

Visual inspection of the supply board showed that the magic smoke had definitely escaped from resistor R12. Consulting the schematic, I found that this resistor together with zener diode D6 and capacitor C17 form a shunt regulator, powered from the 13.8 V dc output, which feeds the power on LED and the meter scale illumination lamp. Further testing showed that the power on LED was OK but that the meter scale illumination lamp was open circuit.

The schematic of the power supply does not indicate the clamp voltage of zener diode D6. While I could get a replacement diode from Icom I felt that I could sort it out myself. After isolating the power supply from the mains and allowing the main filter capacitor bank to discharge, I removed the six screws holding the supply board to the black diecast box and removed the zener diode, which was shorted, and the remains of resistor R12.

Repair, replace, refurbish

I replaced the meter lamp with a 5 mm green LED, as I had some to hand and I have found that LEDs do very well as replacements for the meter lamps used in amateur equipment, and fitted it into the existing lamp grommet. After experimenting with powering the LED from a variable voltage test supply to find the voltage for best meter scale visibility in low light, I temporarily paralled the power on LED with the new meter scale LED and found its brightness acceptable, so the green LED was connected via the original lamp wiring in parallel with the power on LED wiring,

The connection was made at the rear of the Vo/Io meter function switch which includes a 1k ohm ¼ W resistor, mounted on the rear of the meter switch and wired in series with R12 on the supply board, which was replaced with a 22 ohm ¼ W resistor.

Zener diode D6 on the supply board was not replaced as I think the shunt regulator was there mainly for the dial lamp and is now not needed as the new meter scale lamp is a LED (and also because I did not know what zener voltage to use when replacing it).

I did note that the coil of relay RL1 on the supply board, which is powered from the 13.8 V dc output (and functions as a soft start circuit for the power supply) does not have a diode across it to clamp any spikes the relay coil will generate when the power supply is turned off. I soldered a 1N4007 diode directly across the relay coil, on the underside of the board, to fix this as the spike generated by the coils magnetic field collapsing would appear on the 13.8 V dc output. While I had access to the solder side of the supply board I resoldered all the joints as some of them looked decidedly unreliable.

With the meter scale illumination and power on indicator working, it was time to sort out the current indicator. The current sensor is on the regulator board and to access this board requires removing the diecast box (in which the regulator board is mounted) from the power supply bottom cover. Note that the screws securing the diecast box to the bottom cover are insulated from the power supply metalwork, as is the diecast box.

At this point in the proceedings I reinstalled the supply board on its standoffs and, to make working on the regulator board that much easier, decided to replace the power supply top cover which would hold the front and rear panels in the correct alignment as the power supply would have to be operated while it was upside down in order to test and adjust the regulator board.

After removing the six insulated screws holding the diecast box to the bottom cover, I removed the power supply bottom cover, which involves removing eight screws with lockwashers and the two screws that hold the dc output terminal strip to the bottom cover. I did not remove the mains terminal strip, which is also screwed to the bottom cover, as I found that with the power supply turned upside down the mains wiring has enough slack to allow the bottom cover to be 'hinged' out of the way and not have any of the mains wiring touch the metalwork. It did, however, present a possible shock hazard, so I was careful to exercise due caution.

Now that I had sorted out the basic access to the diecast box, I had a look at it and found that the bottom of the diecast box could be removed by unscrewing

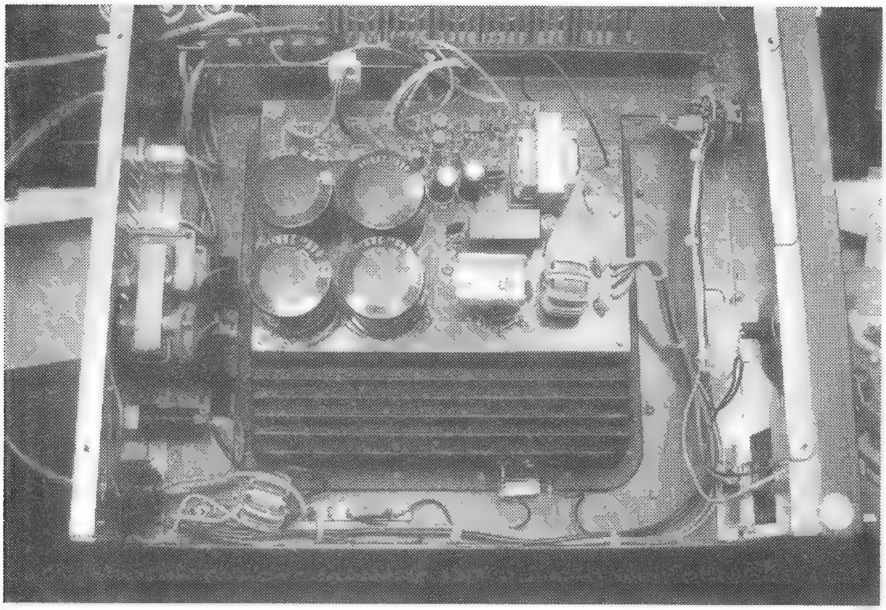

Photo 2: An overhead shot of the internals of the PS-30 power supply.

a mere eighteen self tapping screws. These are under a clear plastic cover that ensures the diecast box metalwork can not touch the power supply bottom cover. This plastic cover is glued to the bottom of the diecast box but it can be flexed enough to easily access the screws that hold the lid on.

All is revealed

With the lid unscrewed, I had a look at the regulator board.

To remove it involves unsoldering three high current connections to a smaller board mounted in one corner of the diecast box, removing four plastic screws holding down the four transistors soldered to the regulator board and unscrewing the seven screws that hold down the regulator board itself. The regulator board can then be carefully 'hinged' away from the diecast box as there is just enough play in the wiring that exits via each of two grommets in the side of the box to allow this.

Referencing DF1ELB's internet article that mentioned a specific fault, I checked the area of the regulator board mentioned in the article and found two resistors, virtually covered with a brown 'glue' used to hold down the capacitors on the regulator board. Multimeter testing (with the power supply unplugged from the mains) showed that one resistor read low and the other was open circuit.

These two resistors are wired across the two 33 uF capacitors that are wired in series across the high voltage dc fed from the supply board. There are another two resistors of the same value (68 kohm, ½ W, 5%) on the supply board, wired across the main capacitor bank. For the sake of easy confusion, both sets of resistors are designated in the schematic as R1 and R2.

Calculations with a plastic brain (calculator) showed that these resistors would dissipate around 400 mW which I felt was a bit close to their 500mW limit; and as two of them were faulty anyway, all four were replaced with 1 W metal film resistors of the same ohmic value. While I had the soldering iron to hand, I resoldered all the joints on the regulator board as some of them looked decidedly unreliable.

I then replaced the regulator board, checked I had properly reconnected everything I should and made sure that the cooling fan could spin without fouling anything. The dc output terminal block was insulated so that it could not touch the potential short circuit represented by the side of the case. I found that the assembly of the supply board and regulator board (in its diecast box) would rest easily on the four large capacitors on the supply board which would also keep the whole assembly isolated from the case metalwork.

The acid test— switch on (but stand well back)

With some trepidation and making sure I was well outside the blast radius, I turned the power supply on. It all worked as expected so I connected a current sink set for 4 A (which I had lying around, as you do).

Success! The current indicator function of the meter was now working, although it was off calibration.

Checking voltages around the regulator board with no dc load current and then again with approximately 22 A load current (doesn't everybody have eight paralleled 5 ohm 95 W ceramic resistors to hand?) I noted that the dc voltage across each of the two 33 uF capacitors (C4 and C5) dropped by about 10V at approximately 22 A load current with reference to the no dc load current state. These two capacitors are specifically mentioned in the article by DF1ELB as requiring replacement.

More replacement

This same internet article also mentioned replacing C18 to C21 (470 uF 16 V) and C22 (4700 uF 16 V) on the regulator board, together with C14 and C16 (470 uF 16 V) on the supply board, with 35 V rated equivalents.

I checked these capacitors and found they all had a temperature rating of 85 degrees centigrade which, for the regulator board capacitors, I felt was a bit low as the diecast box in which the regulator board is mounted has no internal air cooling (or indeed air flow at all, which is one of the characteristics of the space inside closed boxes), so I sourced replacements with a temperature rating of 105 degrees centigrade (except for C22, the 4700 uF 16 V dc output filter capacitor as I could not find a 35 V dc rated replacement that would physically fit).

After all the replacement capacitors were sourced, I removed the regulator board (again!) and replaced the capacitors one at a time to make it harder for me to put the right capacitor in the wrong place. Following the removal of each capacitor, the brown 'glue' on the board around where each capacitor had been was carefully removed with a sharp knife. Once all the capacitors were replaced they were glued down with Dow Corning 738 electrical sealant, which I had on hand.

The other important property this has, apart from being non-conductive is that it is NEUTRAL CURE. This means that as it cures it does not produce any acidic or acetic compounds. This is important, given that the (mildly) corrosive properties of the previous brown 'glue' caused some of the problems I had fixed.

With the regulator board reinstalled in the diecast box the power supply was tested after the sealant had cured and on checking the voltage drop across each of the two 33 uF capacitors on the regulator board I found the voltage drop was now 5 V with 22 A load current drawn, with reference to the no dc load current state, where it had been a 10 V drop with the original 33 uF capacitors.

The power supply was then set at 13.8 V dc no load with preset pot R5 and then the 22 A load was again applied. Previous testing showed an approximate 1 V drop from 13.8 V when a 22 A load was applied which is well within the 10% tolerance specified. The current limit was then set, with preset pot R10, in the following manner: with the 22 A load connected preset pot R10 is adjusted so that the output voltage starts to drop with a 22 A load applied and then is readjusted slowly until the output voltage just stops rising (if the output voltage continues to fall as you adjust the current limit preset then turn the preset the other way). With the 22 A load removed the dc output voltage should again be 13.8 V dc. In the instance of the PS-30 I was working on, at 22 A load the dc output was approximately 12.8 V. Both of the presets are on the regulator board.

DF1ELB's article also recommended changing C4 and C5 on the regulator board from 33 uF to 47 uF, the intent being to improve the regulation of the dc output. I have tried this, with very little improvement. Ernestos' article does not, however, make mention of the mains supply voltage he was using when he wrote the article, which would make a difference as the high voltage dc circuit on the supply board works as a voltage doubler when the mains input is set for 110 V ac and as a rectifier when the mains input is set for 230 V ac.

Power off —recalibrate — covers on

I then turned the power supply off and replaced the insulated lid on the diecast box and replaced the eighteen screws that hold the lid on and reinstalled the diecast box on the bottom cover of the power supply with the six insulated screws. Just for fun I checked that the diecast box was indeed open circuit to the power supply chassis, as it should be, before doing anything else.

Since I had the power supply top cover off anyway when reinstalling the diecast box, I recalibrated the meter dc output current scale. This is done by switching the meter switch to Io (output current) and then adjusting the current meter scale to zero with preset R15 while there is no dc current drawn from the power supply. A 10 A load is then connected, so that the meter needle will be approximately mid scale when correctly calibrated, mid scale being the most accurate part of the scale for a moving coil meter, and then preset R14 is used to adjust the current meter calibration with the 10 A load connected. Both R14 and R15 are on the supply board.

Voltmeter

The voltmeter is calibrated by switching the meter switch to Vo (output voltage) and then adjusting preset R4, which is on the back of the meter switch, to show the correct output voltage while there is no dc load connected.

One of the interesting things I found while testing the power supply was the presence of a 390 V, approximately, peak sawtooth waveform superimposed on both the high voltage dc supply and the 13.8 V dc output. The fun part is that this waveform disappears if the negative side of the 13.8 V dc output is grounded, that is, tied to mains ground. I only found this as I was checking for switching noise on the 13.8 V dc output with the power supply under load; in one of the tests I was using an oscilloscope with the probe floating and in the next test I connected the oscilloscope's probe ground to the 13.8 V dc negative line (and as the probe's ground is tied to mains ground this tied the power supply dc negative to mains ground).

As an aside, trying to use the junction of the 33 uF capacitors on the regulator board as a ground reference for the oscilloscope while looking at switching waveforms on the high voltage dc supply does not work, as this point in the circuit is sitting at approximately 160 V dc and the workbench RCD (which we all have wired in, don't we!) will trip out as it detects you trying to do something stupid like trying to raise the mains ground by 160 V dc. This also results in a smack across the back of the head, courtesy of a person who will remain nameless, from the office next door to the workbench, who has also noticed that the RCD has tripped.

Back to the manual and a ground-making thought

With all this in mind I had a closer look at the schematic for the PS-30 and found an anomaly, the symbol used to represent the mains earth to the chassis connection and the symbol used for the power supply dc negative are the same (that is, power supply negative is tied to mains ground), yet a resistance check with a multimeter shows that this is not the case. Measuring ac volts between the

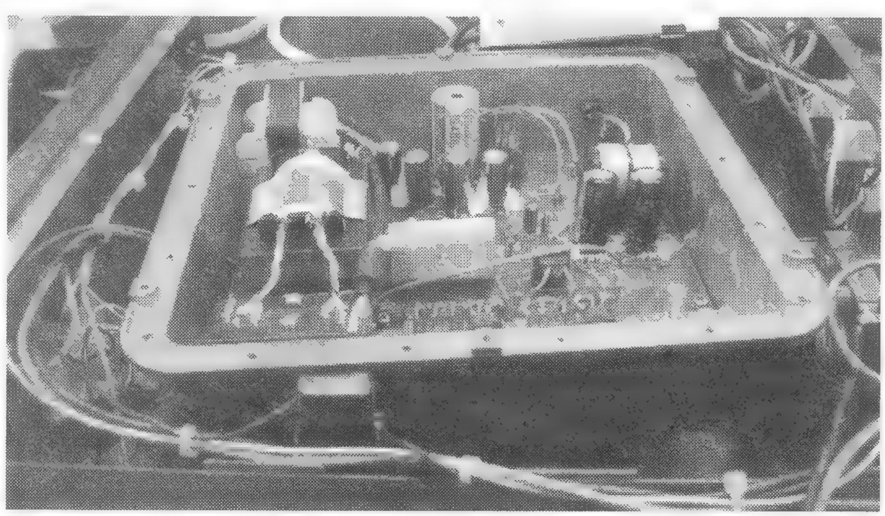

Photo 3: The regulator board of the PS-30 power supply.

power supply dc negative and the PS-30 chassis shows a substantial voltage is present, yet trying to measure the ac amperage and then the ac milli-amperage between the power supply chassis and the dc negative showed zero current flow in both cases.

After some further thought I have come up with a theory, based on how the PS-30 was intended to be used, namely to run an IC-271/471/720/730/740/745/751 transceiver (these models are specifically mentioned in the PS-30 user manual) together with a smaller vhf/uhf transceiver or transceivers.

This theory is based on the following observations: All of the transceivers mentioned and all the other 100 W rated HF transceivers I have seen have a large threaded stud with a wing-nut mounted solidly to the transceiver chassis. This is also tied to the transceiver dc supply negative. This point is intended to tie the transceiver (and yes I know the IC-271 and IC-471 are not HF transceivers) to a common ground point in the shack.

The PS-30 also has one of these threaded studs with a wing nut, located on the rear panel. It is meant to be grounded as well via this stud but since the stud is mounted on the PS-30 metal chassis it is also tied to mains ground. Both the threaded stud on the transceiver of choice and the threaded stud on the PS-30 would be tied together as both would be going to a ground point in the shack, nominally the RF ground. Tying all of our RF generation equipment to the same single ground point is something we all do, don't we?

When the transceiver of choice is plugged into the PS-30, the PS-30 dc negative would be tied to mains ground via the path: transceiver dc negative connection to transceiver chassis – transceiver chassis to ground point via its threaded stud – ground point to mains ground via the threaded stud on the PS-30.

With all this in mind and allowing for some paranoia on my part I tied the PS-30 13.8 V dc negative to mains ground (PS-30 chassis) via a one ohm ¼ W metal film resistor. The intention being that, if there is a large current flow from the power supply dc negative to mains ground, (which there should not be because previously I could not measure any current flow between these points), the resistor will get hot and go open circuit, the smoke and the smell from doing this being an indication of a fault condition.

Power up — again

Switching the power supply on, again making sure I was outside the blast radius, had no effect on the resistor.

There was no dc or ac voltage measurable across it. Checking the dc output with a floating oscilloscope probe showed no ac at all on either the high voltage dc or the 13.8 V dc output, which is what I wanted. Further testing showed the PS-30 working as expected.

Where did this ac waveform come from? Well each of the diodes in the bridge rectifier on the supply board has a 2.2 nF capacitor across it (C3 to C6) to keep rf out of the diodes. This is very nice but if you draw this circuit out you find that from each side of the ac mains there is a capacitive path to the dc output.

I hear you say, the ac voltage would not get that high because of the forward voltage drop of the diodes in the bridge rectifier! True enough, but only for the two conducting diodes of the four diodes in the bridge rectifier and only for one half cycle. You see, in a four diode bridge rectifier, as used in the PS-30 and numerous other power supplies, only two of the four diodes conduct at one time, leaving a nice high ac voltage across the two non-conducting diodes.

Grounding and dc negative

So how does grounding the supply dc negative get rid of the superimposed ac?

On the rectifier board each side of the floating high voltage dc has a capacitor directly connecting it to the dc output negative (C2 and C3) and on the regulator board the high voltage dc is indirectly connected to the dc output negative (via C4 and C5 through C6).

So if I tie the dc supply negative to mains ground, or in my case to mains ground via a 1 ohm resistor because I am paranoid, any RF that might appear on the dc side of the supply is provided with a low impedance path to ground, instead of a path to dc negative and possibly ground if both the power supply chassis and the chassis of the transceiver connected to the power supply have been tied to the same ground point.

This leads me to another point, the encapsulated bridge rectifier used (a GBPC 806) has a peak inverse voltage rating of 600 V (that is, the maximum voltage that can appear across a non-conducting diode in the bridge is 600 V) and for a nominal 240 V ac mains input.

I feel this is a bit low given the high voltage dc is a nominal 320 V and any mains borne spikes could easily reach 600 V for long enough to damage the bridge rectifier (yes I know there are some capacitor/inductor filters between the mains input and the bridge but they may not stop a fast, narrow spike that could damage the bridge rectifier) so I replaced the bridge with one from the same series, in this case a GBPC 810 which conveniently is the same mechanically, but with a PIV rating of 1000 V,\ (incidentally the 1000 PIV bridge is roughly 30% cheaper than the 600 PIV bridge, and no, I do not know why either!).

After some repair work and a steep learning curve, I can now retire the old shack power supply and replace it with one not that much larger but of at least twice the capacity.

If I total what it cost me in terms of the hip pocket, I would have to agree with some of my usual brians trust members who have told me that there are cheaper alternatives, but at least this way I have learned something!

Acknowledgements:

A lot of the approaches I have taken while testing and repairing the PS-30 were prompted by discussions with some of my usual suspects from the drive time net on the Melbourne 438.075 MHz repeater and their suggestions are gratefully acknowledged.

The internet articles by Adam Farson VA7OJ/AB4OJ, on adjusting the PS-30, and Ernesto Lastra Bohme DF1ELB, on fixing a problem he had found with his PS-30 are also gratefully acknowledged.

I would also like to acknowledge the suggestions of my boss, Ralph. The coffee has also helped!

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