

## Some technical and maintenance issues regarding the IC-781 and IC-R9000

by Traian Belinas, YO9FZS

When Icom released their IC-781 HF transceiver and IC-R9000 receiver, these were the best radios available to the amateurs. Even now, more than 15 years later, the 781 and R9000 are considered as very capable radios which can still compete with the more modern ones, at least regarding some of their characteristics.

They were at the top of the wish list for such a long time for many of us contemplating the radio magazines, ads, brochures and catalogs. However, as for any such product, they are not perfect and some users are not aware of this.

I have owned, maintained and done some repairs on both the IC-781 and IC-R9000; here are some technical related observations and my experiences regarding them.

I don't like to mention this, but have to specify:

***Don't forget that what you are doing is at your own risk, and that injury or expensive damage may be caused by improper work, by accident or by the consequences of wrong information or misunderstandings, for which I am not responsible.***

***If required, please seek further assistance from a qualified/trained person.***

***Pay attention to the dangerous high voltages that may exist in some areas (especially in the REG and CRT Units)!***

### The CRT display module

The CRT module displays most of the information and it is the most important user interface.

It is actually a video monitor, accepting a standard  $1V_{p-p}$  composite video signal (CVBS) as its input signal. It is designed for the US and Japanese video/TV standard (NTSC) so the specified vertical sync frequency is 60 Hz, not 50 Hz as it is here in Europe.

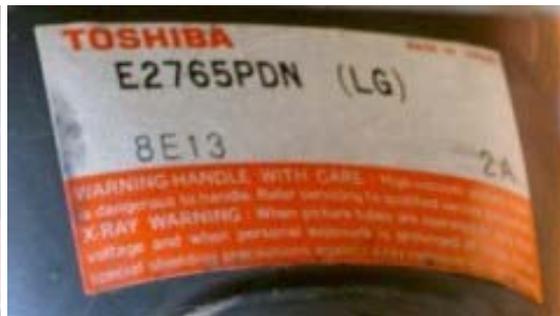
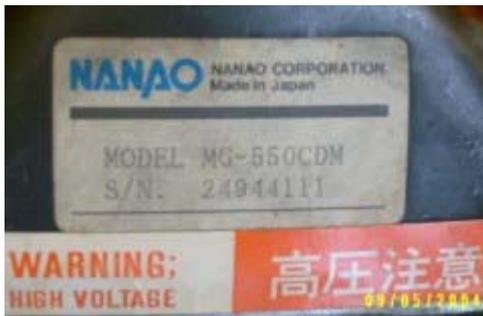
As it is used to display a reduced number of particular pictures or video patterns (which are selected by the F1 to F6 function keys), long-term continuous display of these images may affect the CRT and produce so-called CRT screen burns. This may happen and it is a common problem for any CRT used to display the same picture or pattern for a very long time. Even the expensive plasma TVs and displays may be affected by this. This is why it is a good practice to periodically change the patterns displayed on a CRT or plasma display; while this is simple for a computer display, it is inapplicable to the IC-781 or IC-R9000. Thus, after so many years of use, most of them are presenting this CRT screen burn problem.

It is as if the picture pattern has been "imprinted" on the CRT screen. For the affected areas, the picture brightness and CRT phosphor efficiency is lower.

**This is permanent damage and cannot be corrected or avoided, but fortunately this kind of problem is not really catastrophic – this type of CRT may still function for many years after the first visible appearance of the burns, even if it may be uncomfortable to some. If needed, an external video monitor accepting NTSC CVBS input may be also used (or NTSC TV).**

You may see below how these burns may look; this example is from an IC-R9000.

The CRT below had maybe 10 years of use, most at a government agency before I got it (so it may had intensive use), and even now after I have sold it, it is still functioning at the new owner's QTH without these burns causing much trouble. This is also because the CRT itself is a relatively good quality one made by Toshiba. The CRT module is made by Nanao.



The CRTs are vacuum tubes, so they are actually “consumables”. This is true not only for the cathode system (regarding its electron emission capability) but also for the CRT’s screen surface phosphor. The burns are the result of the “consumable” phosphor. As the sum of these two characteristics, the CRT’s brightness, contrast and focus quality may get low after extended use. This is why the allowed CRT brightness and contrast will be reduced after extended use.

[**Note:** The use of the CRT depends not only on duration of usage, but also on the brightness and contrast of the displayed picture. The higher they are set, the faster the CRT will be used up. This is why the IC-781 User Manual specifies: “Great intensity will shorten the life of the CRT display.” (page 12)].

The low brightness of the old used CRT’s may be improved by using the internal adjustments of the CRT module. You have to open the CRT module top cover to gain access to them. To do this, you need to open the transceiver case, then to take out the six screws holding the CRT module top cover. The ATU preset pots PCB must also be removed. These adjustments are located on the CRT module PCB, close to its right side:



The pots have common-sense labels, from L to R:  
H-HOLD is the adjustment for the Horizontal Hold (H synchronization)

H-PHASE adjust the Horizontal Phase (the position of the picture in the H direction)

V-HOLD adjust the Vertical Hold (V synchronization)

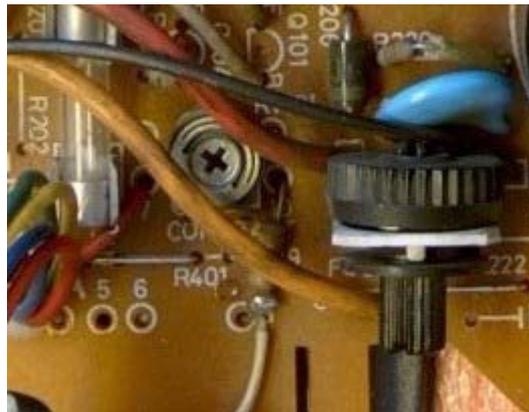
V-LINEAR adjust the linearity of the picture in the V direction

V-SIZE adjust the vertical size of the picture

**SUB-BRI and BRIGHT** are the ones adjusting the brightness of the picture; adjusting them CW will increase the brightness of the CRT displayed picture.

[Note: don't worry if the CRT PCB seems to have slightly different parts on it, I had taken the above pictures after completing the entire work which included preventive replacement of some capacitors as I wanted that the possible new owner to have no problem regarding it...].

There are another two but less obvious adjustments, one is the same type of small pot which adjusts the **Contrast (CONT)**, the other one is a larger pot including its shaft which adjusts the focus of the picture; they are located on the same PCB, just between the fuse and the CRT flyback transformer.



Contrast and Focus adjustments

**If the CRT picture is dim**, try to adjust the Contrast pot first, and then the Brightness pots. When adjusting them, do not exaggerate. Don't set so high that the background (normally black) becomes very bright/amber, because using it in this way for a long time will shorten the CRT life (as explained previously), and the very high contrast may tend to a faster appearance of the burns on the screen.

If the image does not have very good focus quality (not crisp, not sharp), you may need to adjust the focus.

But if the focus is fine so you can see (separate) the individual scanning lines and dots when looking very close to the CRT center image and if the image is not very foggy/unfocused at the CRT corners, then you may leave it as it is, as adjusting it while the module is still inside the radio is difficult. (There is a special dedicated hole for this adjustment, but it is located on the CRT module back panel, inaccessible while the module is still inside the radio).

If adjusting the internal contrast and brightness doesn't give results, then the CRT may be bad/"soft" because of long-term use and may need replacement. If to obtain a decent brightness and contrast you have to turn up these adjustments very much (near to max) and the focus is bad and impossible to improve, then you may also have to replace the CRT.

In the event of CRT replacement, will have to readjust all of the four pots of course.

For both of the radios I had (IC-781 and IC-R9000), the CRTs had burns and were dim, they are normal for these old devices, except for the few which have very low hours on them and/or were used at low brightness/contrast settings. The dim picture was easy to fix by adjusting the abovementioned pots. Do not worry much about the burns if they are not very bad and if the image is still ok. You may not need to replace the CRT immediately unless the need exists for a very bright and high contrast image. Replacement may be worthwhile if you intend to keep the radio for a long time, or if you wish to avoid unpleasant surprises in the future....

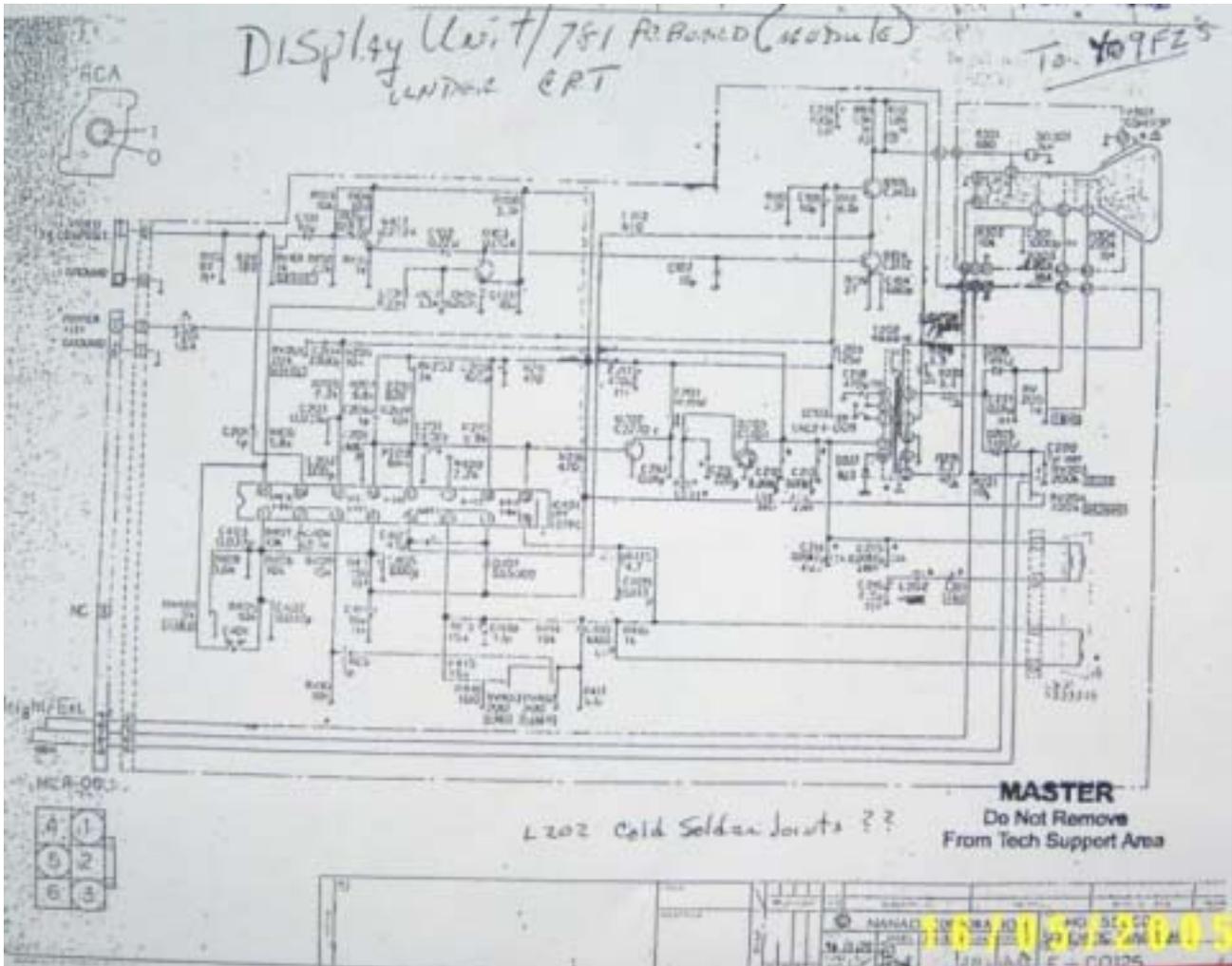
[I do not recommend the crude method of "rejuvenating" the CRT cathode emission by applying a higher CRT filament voltage; it may not last for a long time...]

Bad solder joints on the module board or at the CRT socket board may cause intermittent display problems. Check especially for the soldering on the terminals of the big coils.

If the power transistor fails, don't hesitate to replace it with a newer and slightly better part. I have used the 2SC4106 with great success; it runs relatively cool and is problem-free.

The most and only difficult part to obtain in case of a problem is the fly back transformer.

If you need to repair the module outside the radio, you may use a separate 12V supply and an external CVBS video signal (I have successfully used an old computer having CVBS output for this).



The CRT module diagram is not included in the service manual, but the above is a low-resolution copy which may be of some help (many thanks to K2SB).

[Some interesting and inexpensive small LCD modules accepting a CVBS input signal exist on the market; some are used for surveillance systems. They may worth a try for these radios, but they need to be adapted]

### **The IC-781 REG (power supply) unit**

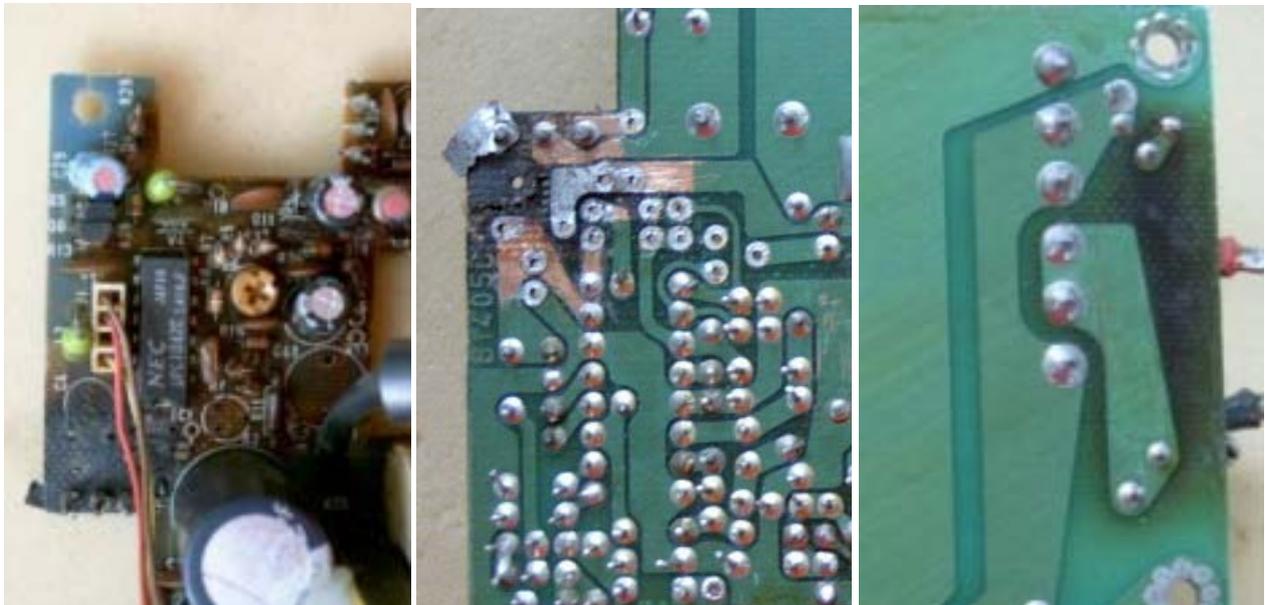
The REG board and especially its linear voltage regulators are dissipating a significant amount of heat. While they are mounted on a big heatsink, the entire REG PCB is sealed; it is like being placed inside a hot oven... The designers allowed for an air passage between the PA's blower air exhaust and the REG compartment, but as the air can not go out of it (unlike the PA, it has no holes on the back cover like the PA does) it is obvious that the air will not move much across the REG PCB. The only cooling is by conduction from the surrounding metallic walls and by the local air

turbulence produced by the blower. It is like trying to cool a 3CX800 while covering and sealing its anode/chimney exhaust air outlet...

This is why overheating may damage the REG PCB, and the PCB itself may present burned areas and/or burned PCB traces, especially in the area close to R32 and Q7. Power resistor R32 can dissipate its rated power at 25°C, but not at 70°C... This overheating may also affect the electrolytic capacitors and even other small parts close to them. Special attention needs to be paid to potentiometer R2, which is included in the switching supply feedback loop. If R2 goes open or is damaged, it may cause output overvoltage, with possibly harmful consequences.



The REG PCB with most of the original parts on it;  
A few of the overheated parts near R32 area were already removed.



Burned PCB and copper traces near the R32, Q7 and R26; some parts are missing here.

In the event that the power supply gets burned and if the TR unit seems ok, then:

- Restore the PCB's circuit connections as needed, using the terminals of the newly installed parts if required;
- Check and if needed replace Q7, R32, D5, R2;
- Replace the small electrolytics with new high-quality parts; these must be rated for 105°C;
- If any sign of damage is visible at the C8, C9, C13, C15, C16, C20 to C23 (electrolytics), these may be replaced if spares are available - use the highest quality parts obtainable. Remember that the power supply must deliver 500W DC output and the caps must also be of 105°C type.

- Check the soldering around R22. If the transceiver had unstable output power before, this may be due to poor soldering of R22, which may cause abnormal and intermittent PA current limiting;
- Check feedback resistors R2 and R12, which adjust the output voltage, and also R6 which adjusts the short-circuit/high current limit; if any doubt, replace R2, R6 and R12.
- Check the protective “snubber” R/C circuits (R26/C28, R25/C27, R24/C17) and all the semiconductor devices;
- Secure L4,L5, L6, L7, C7 and the other large parts on the board using hot melt glue, and check the soldering on the back of the board for cracks or other problems.

Don't hesitate to make use of better and more trustworthy spare parts, it is not necessary to look for the 20-year-old “authentic originals”. I have found Q7 shorted and R32 interrupted and overheated. The 2SD1406 used for Q7 has 20W dissipation and maximum collector current 3A. I have used a 70W 8A TIP132 Darlington and insulating mica foil instead of the 2SD1906. [Don't use much higher current/power bipolar transistors as they usually have very low amplification (beta) and D5 may not withstand the higher base current required]. Don't forget to use thermal compound, insulating washers and mica foil where needed (D2, D3, Q2, Q3). Before assembling the PCB you may check the uPC1042 IC (it has to start oscillating) and verify the +9V and +5V regulator functionality after connecting an external current-limited 15V PS at C13 (observe polarity). Re-install the PCB inside its compartment only if all of these are OK. As a precaution, you may insert a 3.15A fuse in the 280V line (you may also leave it in circuit).

The power supply cannot be verified by simply applying the rectified/filtered 280V DC power; it needs a “start” voltage (STAR) from the transceiver. When applied, this voltage is only momentarily delivered to IC1 by the Q6 circuitry with R27/R28/C29 as the timing network. Once IC1 has started, it will continue power itself from the +15V output via D1. If you want to repair or verify the entire REG module on the table or without the outputs connected to the radio, then you have to supply the needed starting voltage from an external source. In this case you should also use some light loads for the +5V and +33V rails, and a 230V 100W lightbulb (or two in series) as the current limiting device in the 280V line.



[The repaired and re-installed board; there is an added 3.15 amp fuse in the 280V input line; R2 was replaced with a high quality sealed multi-turn pot mounted on one of the 33V line electrolytics].

After finishing the work, if everything checks out, then proceed to the REG adjustments as described in the Service Manual (page 6-40, OUTPUT VOLTAGE and CURRENT PROTECTOR); include a check of the APC circuit and PA current limiting (APC SET, page 6-26) and finally check for all the output voltages (page 6-1).

To avoid future overheating problems, you may wish to install the Sherwood cooling improvement fan kit, or a homemade equivalent. <http://www.sherweng.com/IC781Fan.htm>

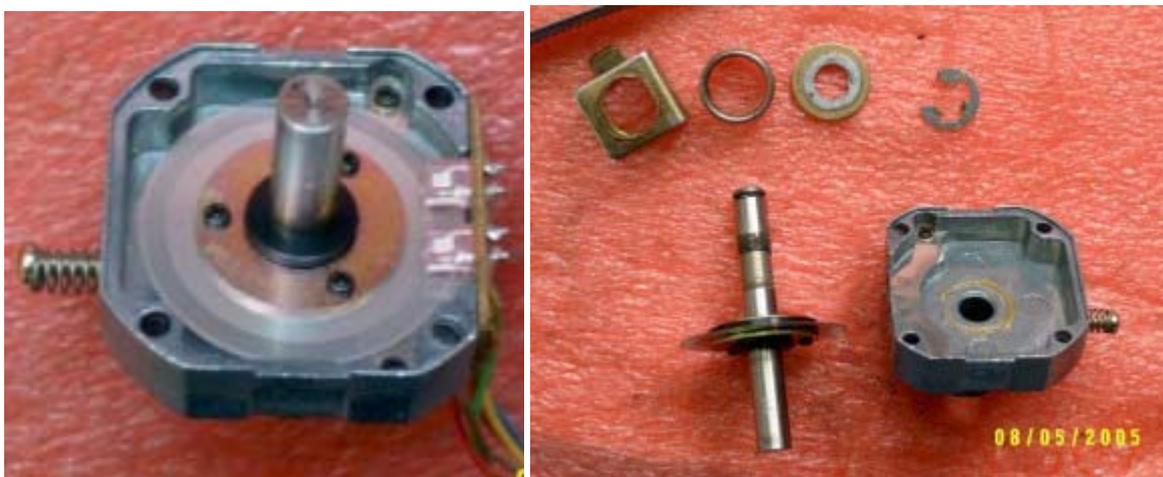
[From Adam, VA7OJ/AB4OJ, with thanks: the 781 was intended for 100V/200V mains; reducing the mains voltage when using the 110/220V mains will tend to lower the power dissipated by the linear regulator Q7 and will lower the generated heat also. Please see <http://www.qsl.net/icom/>] Actually the manual specifies the power supply requirements as being 100-120V and 200-240V, so a specific design problem is involved anyway. The problem seems to be the R32 and Q7 coming defective because of poor cooling.

***Once more, caution: High voltages are involved, so please be careful!  
The TR module, Q1/Q3 heatsink and other parts are at a high potential with respect to chassis.***

### **The main VFO optical encoders**

For both radios the VFO encoder knob had been rotating with some difficulty, even when its adjustable brake was released. This was caused by the old grease used in the shaft bearing. This grease has solidified because of age. It is inadvisable to use the radio with a stiff encoder shaft for any length of time, as this will cause a rapidly increasing backlash.

The encoders must be removed and disassembled. To do this, remove the VFO knob, unplug the encoder's connectors and then unscrew the screws holding the encoder to the front panel. This will allow removal of the encoder. Take care while opening the encoder unit, as it is a precision device involving small parts. Take special care in handling the thin slotted disk. Be careful when disassembling the more complex IC-R9000 encoder, which also includes the switch stepping mechanism.



Clean the dirty shaft and the sleeve bearing remove the existing grease using isopropyl alcohol and then re-lubricate shaft and bearing. To reduce any backlash, lubricate with grease rather than oil. Don't use much grease; a small quantity will suffice. Avoid getting lubricant on the optical parts;

clean them if needed. Also lubricate the small Teflon and metallic washers and take care when reassembling the encoder. The lubricated encoder will rotate easily and will feel like a new one.

## **The CRTC (CRT Controller) Unit**

The IC-781 and IC-R9000 both use the same CRT module, similar DDS modules and the same CRT Controller.

Over time, the image may become distorted, with the vertical lines bent and the picture shifted to the right side for some areas, especially for the larger bright areas of the picture. This occurred in both radios I had; it seems that the R9000 was presenting this behavior for a long time before acquired it, as the distorted image became permanent because of the CRT burns. Just look below for burns on the CRT's bottom edge; see how the upper parts of the highlighted menu labels were shifted to the right side, and the normal rectangular menu labels became similar to a flag, as if caused by a horizontal sync problem...



The cause of the problem was C11, a 100uF electrolytic on the CRTC module. C11 had to be replaced.

As the CRTC module is hard to remove from the Digital board, I had to cut/extract the body of C11 while leaving its terminals still attached to the PCB. Then carefully free its terminals from the PCB by heating them with a soldering iron from the component side. I have used a small 100uF cap (a slightly larger value one will do also) which was installed horizontally over the passive components near IC2, with its terminals bent down and soldered at the original C11 holes from the more accessible component side of the PCB. This avoided the need for removing the entire CRTC module, a difficult and time-consuming exercise. Don't forget - use a good quality capacitor and you may not have any further problems in this area.



The opened CRTC module;  
C11 is the blue cap, to the right of the CRTC module.

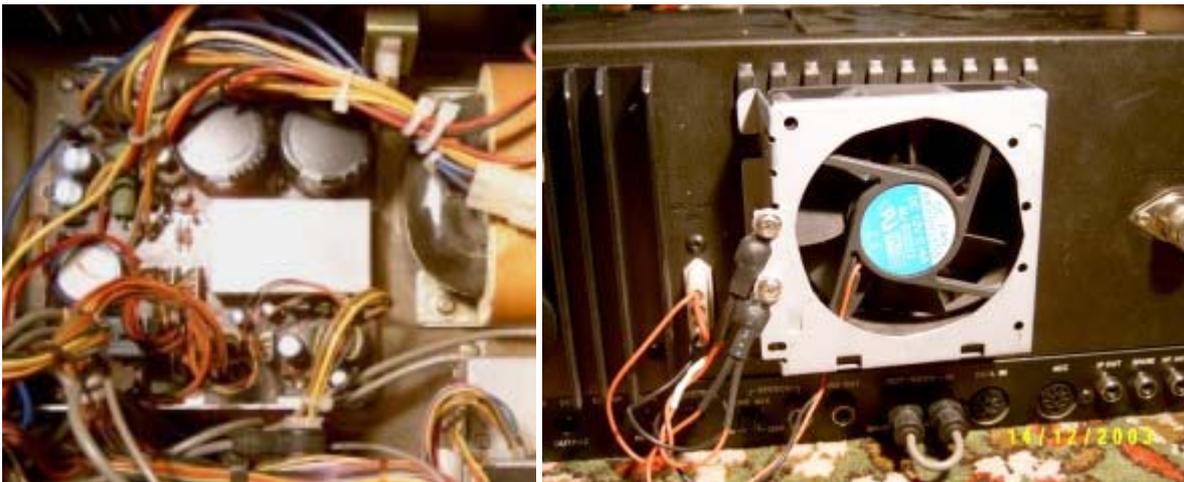
## **The IC-R9000 power supply (REG Unit) heat and DC to DC converter problem**

The IC-R9000 power supply (REG Unit) also generates a large amount of heat.

Because of this, and also because of their low quality, the electrolytic capacitors used in the DC-DC converter on the REG PCB board may fail. The usual symptom is no reception along with an abnormal S meter indication. It is caused by an incorrect value of the negative output voltage. C26, C29, C33 and possibly the other caps on the DC-DC converter in the REG Unit may be affected. They have to be replaced. If possible replace all of the converter's electrolytics. Use high quality 105 C ones.

The DC-DC converter is shielded, located on the REG PCB near the big filter capacitors and mains transformer, under the RF/TV Units module, so this one has to be removed as well.

After replacing the capacitors you may add a cooling fan so as to avoid any future problems. I have installed a temperature controlled 3" fan (using two 82 ohm NTC thermistors in series) and its mounting device from an old computer case. The mounting I have found fitted exactly under the back panel fins near the REG Unit. There was not need to run wires inside the radio, nor even to open it; it can use the voltage available at the DC output connector on the back panel. While the airflow is not very high, it is adequate. The cooling improvement is still significant. The interior of the power supply is no longer hot, and the noise is very low as the fan speed is limited by the two NTC's. The fan can be removed in a few seconds if required (e.g. for shipping).



## **IC-781 fan/blower maintenance**

The IC-781 uses a radial fan (squirrel cage blower) for cooling the big PA and REG heatsink.

It is located under the RF/Filter Units module at the rear left side of the radio, and is attached to the big heatsink with screws. This fan may need lubrication. Its motor may have ball bearings (not requiring lubrication) - but the other end of the squirrel cage, at the right side looking from the front, it uses a sleeve bearing. The RF/Filter module has to be removed to gain access to the fan. Putting the radio on its left side may help to apply a small drop of oil to the sleeve bearing using a syringe.

If the fan and especially its squirrel cage (rotor) are very dirty and dusty, then the fan should be completely removed and dismantled and the rotor cleaned. Clean the heatsink fins as well.

The fan will not get much quieter (it is really noisy!), but at least it will work better and last longer.



IC-781; heatsink and fan removed;

The fan is sitting on its motor side, and the sleeve bearing is at the top part of the fan's case

### **The backup battery**

Each radio uses two batteries: one for the RAM memory and one for the clock.

If the batteries are dead, you may replace them with the more common CR2032 type if you also install the required sockets. This will facilitate their future replacement without the need for soldering.



### **IC-781 ALC problem**

This one is described on the [www.mods.dk](http://www.mods.dk) webpage, so there is no need for detailing it here.

Please visit [www.mods.dk](http://www.mods.dk)

You will also find on this site another of my article on the TS950 ATU mod as well as much other great information. I would like to take this opportunity to thank to all the contributors to [www.mods.dk](http://www.mods.dk)

## **Other observations**

After removing the IC-781 RF/Filter Unit module and before putting it back, check for these 3 items:

1. The coaxial plugs on the cables to the RF unit may slip out from their mating jacks, so you may have to reconnect them. You may secure them using small cable ties.
2. Take care that the wires near the blower are not so close to its squirrel cage rotor as to risk blocking it. Also ensure that wires are not pinched and damaged by the larger parts.
3. **[Most important]** Ensure that the small coaxial cable from the PA output to the Filter Unit input is secure! If it gets disconnected or loose, the MRF422 finals may be destroyed at the first transmission. The reason is simple. The IC-781 includes PA protection for high forward and reflected power, high SWR and high collector current. Note that the VSWR bridge is located on the Filter Unit, and in the event that the small coaxial cable is disconnected from its jack, then the protection will not be in line, and so will not act. The PA will see infinite impedance at its output which may result in destruction of the power devices

### **General rules for less experienced operators:**

Pay attention to the usual safety, ESD conditions, etc, and use the correct tools.

Always check for possible mistakes such as cables pinched between large or metallic parts, disconnected jacks/connectors, and so on.

Work seriously and cleanly, restore everything precisely as it was before you started the work, tighten the cables and wire harness using wire ties, etc. Keep an eye on the aesthetic part of the job. Don't try to do too many things/repairs/mods at once. Do them one at a time only, and check after each of the completed jobs for correct operation; carefully note errors or malfunctions. By doing so, you may avoid a lot of trouble.

Try to use good-quality parts from trustworthy sources. Don't forget that low quality or counterfeit parts may exist while the seller may not even know what he is offering for sale...

Don't be afraid to ask for some help from a knowledgeable ham when things get tough; if he is a real ham, he will be glad to help you (as you are in such cases).

*Now the final recommendation: if you can't assume the risk, then don't do it.*

The IC-781 User and Service Manuals can be found and downloaded from the <http://www.mods.dk> or from <http://www.marcucci.it/english/download/index.htm> websites; thanks again to the respective OMs. You may also want looking at <http://www.qsl.net/ab4oj/icom/icom.html>, it contains useful information on Icom radios (thanks to Adam Farson, VA7OJ/AB4OJ, also for his help on this article).

There is a lot of work and effort involved in this project, but in my opinion it is best that the information be shared among radio amateurs.

I hope this will be of help to those interested in servicing these fine radios.

Good luck and enjoy your hobby.

All the best & 73,  
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Bucharest, May 2005

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