Replacing the IC-7800 Reference Oscillator

<u>Reference Failure</u>

An IC-7800 indicated a 20 to 50 Hz frequency error when transmitting and receiving. A heterodyne was audible while receiving WWV at an indicated 10.000 MHz, and when the internal reference oscillator was directed to the BNC connector on the rear panel so that it could be measured with an external frequency counter, the error was measurable. At a cold start, the reference frequency was low, and it required more than an hour to stabilize at roughly 20 Hz below its calibration frequency. Supplying the reference from an external source via the BNC connector corrected the error.

When the oven-stabilized crystal oscillator (OCXO) was removed from the radio and tested independently, two facts emerged: The startup current and idle current were identical, indicating that the internal oven was not operating. Also, warming the oscillator with a lamp caused it to drift upward in frequency regardless of how much time it had been given to stabilize.

Photo 1. The oscillator frequency was measured using a frequency counter. The master clock in an HP 8647A signal generator was used as a reference.

<u>Finding a Replacement Oscillator</u>

The radio clearly needed a new oscillator, but we encountered several problems in finding a replacement. An exact replacement is no longer available from Icom, probably because the failure rate of the original part was found to be high. The size of the new part is different and its pin spacing and designations have changed. And Icom now recommends that the entire oscillator printed wiring board be replaced when the oscillator fails. Finally, the cost of the new PWB exceeds a staggering $800 USD, and although the OCXO without PWB is available from Icom, it is sold at over $500 USD.

The requirements for a replacement are not difficult to meet: The 10.0000 MHz oscillator and oven must operate at 12 Volts DC, preferably drawing less than 300 mA at startup and roughly 40 mA after the internal temperature has stabilized. The original also had an internal voltage reference and a control voltage pin. These allow the operator to "trim" the reference frequency using the "Ref Adjust" function in the front panel menu. (See "Frequency calibration" in the Instruction Manual.) The module should also be roughly the same size as the original so that it can be mounted on the oscillator PWB. Fortunately, 10 MHz, voltage-controlled, oven-stabilized oscillators often appear at swapfests and at online sites such as Ebay.

Installing the Replacement

We obtained a Raltron OX0437A-FZ-10-10-GL, which meets all but two of the requirements. K4HJU confirmed in his lab that the stability of this oscillator exceeds 1 part in 10^{-7}, which approximates that of the original part. It lacked an internal voltage reference, and it was slightly taller than the original oscillator. The new oscillator would require cutting clearance hole in the top of the module enclosure, and since the footprint was slightly smaller than that of the original, there would also be room to mount an external voltage reference circuit.

Four 1/16 inch diameter holes were drilled in the oscillator PWB to accommodate the pins of the new part. Drilling a fifth hole was not necessary, because one pin was placed in a hole used by the original oscillator. The new part was fixed in place using several daubs of RTV sealant. The voltage reference circuit was assembled using point-to-point wiring on a small terminal strip next to the oscillator.

The Icom technical support staff recommended against drilling holes in the PWB, because this was likely a multi-layer board. I chose to drill the holes and then counter-sink them to half the board thickness on the top and bottom sides. When I examined each of them under a microscope, I found that this is a two-layer board and that precautions were unnecessary. See Photos 2 and 3.

In the original circuit, the reference voltage developed in the OCXO is varied by a digitally-controlled potentiometer—IC91 in the schematic—before it is applied to the control (Vc) pin. Since an external voltage reference would be used in this case, the top and wiper terminals of the potentiometer (connections "A" and "W" on the schematic) were connected to the new regulator.

The station "junkbox" contained several Analog Devices REF-02 precision regulators, and one of these was used to develop the control voltage for the oscillator. The REF-02 is powered by the oscillator's dedicated 12 Volt supply, and the temperature stability of its 5 Volt output is claimed to be 8.5ppm/°C. This would not ordinarily allow the Raltron oscillator to meet its stability specification. In this case, stability is adequate because the regulator is mounted inside the enclosure, next to the OCXO. As a result, when the operating temperature has stabilized, the regulator voltage does so as well. The mounting arrangement is shown in Photo 4.

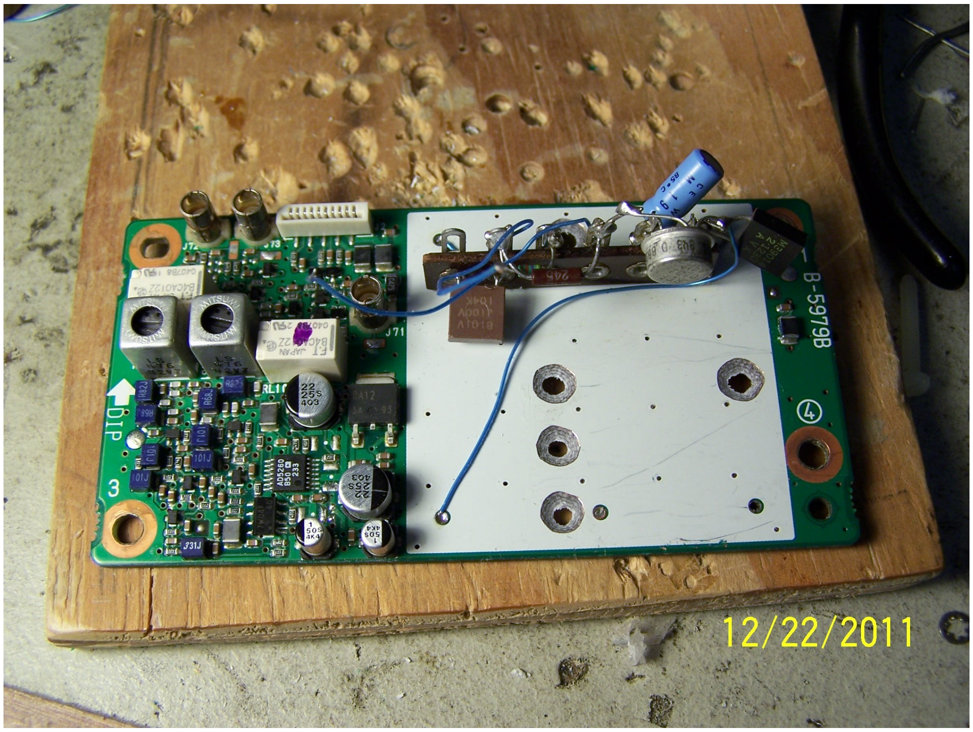

Photo 2. Holes were drilled to accommodate the new oscillator pins.
A countersink drill was then used to separate copper layers. Close
examination showed that this is not a multi-layer PWB. (See Photo 3.)

The 0.3% maximum tolerance of the regulator output voltage is unimportant, because the voltage applied to the control pin of the oscillator is adjusted by the digital pot. Since the oscillator frequency is correct when roughly 3.5 Volts is applied to the control pin, the 5 Volt output was “scaled” using a resistive divider. The divider values were chosen to produce 10.000 MHz output when the on-screen calibration graphic is close to 50 on its 0 to 100 scale. The circuit is shown in Figure 1. Photos 4 and 5 show the modified PWB and enclosure.

<u>Removing and Reinstalling the Oscillator Module</u>

A few comments about removing and re-installing the oscillator module are in order. The module is located on the top of the chassis, directly behind the upper right corner of the front panel. After removing the top cover of the radio, you may remove the two screws which secure the module to the chassis. This will allow you to lift and rotate the module so that the cover screws can be removed. At this point, you will want to mark each of the three coaxial cables so that they can be installed in the proper connectors during reassembly.

Use extreme care in removing the ribbon cable from its socket. The thickness of the contact area at each end of the cable is increased by a blue plastic shim, which is attached to the side opposite the contacts. I prefer to extract this kind of cable by grasping it and the blue shim with small, duckbill pliers. As these flexible cables age, the blue shim can detach itself and fall off as the cable is removed. Holding both the ribbon and the shim with flat-end pliers as it's extracted can reduce the chance that this will happen. Use the pliers when you re-install the cable too.

Photo 3. Checking the PWB structure using a microscope. If this had been a multi-layer board, it would have been necessary to make sure each exposed layer of copper was cleanly cut and to passivate the exposed layers with lacquer or epoxy.

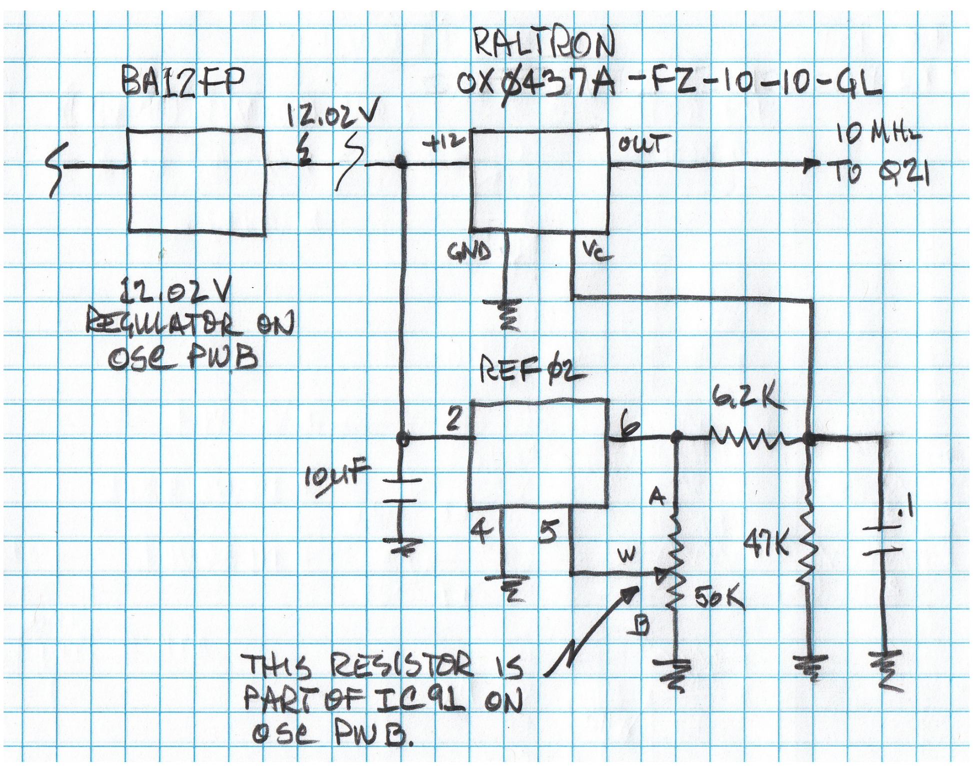

Figure 1. Regulator schematic. Fixed resistors are high-quality, 1% parts.

Photo 4. The modified oscillator PWB installed in the module enclosure.

Photo 5. The oscillator module with modified cover installed. The original oscillator is visible next to the module. Coax and ribbon cable connections are made through the smaller opening in the cover.

It was necessary to make a rectangular hole in the module cover because the Raltron oscillator is taller than the original. The finished hole, with oscillator installed, is shown in Photo 5. Because the space between the antenna matching unit toward the rear of the chassis and the panel on which the DC-DC supply is mounted toward the front of the chassis is limited, the module mounting holes were filed to make them slots. This allowed centering the module in the available space. (The slotted holes are not shown in the photo.)

Calibrating the New Reference Oscillator

The calibration procedure presented in the owner's manual will suffice if a precision reference is not available. We chose to use the 10.000 MHz reference oscillator in the station HP 8647A signal generator and a dual-channel oscilloscope to calibrate the new oscillator. The IC-7800 reference (taken from the BNC connector on the back of the radio) and the HP 8647A reference were applied to the “A” and “B” channels of the oscilloscope, which was set to trigger on the HP 8647A signal. The sweep speed was adjusted make the phase difference between the two signals visible.

After allowing the generator and the radio to warm up for several hours, the IC-7800 on-screen calibration display was used to synchronize the two oscillators. The oscilloscope indicated the two signals change phase by one-half cycle in approximately 15 minutes. This is equivalent to saying the two oscillators drift apart at a rate of 5.5 parts in 10^{-11}. The HP 8647A reference is only specified to 3 parts in 10^{-6}, so it's difficult to say what this number means. If you insist on knowing precisely how good your replacement oscillator is, then you will have to find a more stable and more accurate reference and compare the oscillator you install with it. The original oscillator may have been better than the Raltron we installed in this IC-7800, but on-air tests could not fault the Raltron.

A rough verification can be made by entering a useable WWV frequency, say 10.000 MHz, on the front panel keyboard, while the radio is in USB or LSB mode. Then, switching from one sideband to the other and to AM mode should cause no noticeable change in the pitch of the background tone.

Conclusions

This conversion is not difficult to implement, but it requires some skill in modifying a PWB, doing point-to-point wiring, and working sheet metal. It would certainly void the original equipment warranty, but this was not a consideration in the case of this radio, which is more than six years old.

If the owner were to sell the radio, it would be appropriate to inform a potential buyer that it had been modified. This could affect a decision to buy. On the other hand, this reliable modification supersedes a very expensive factory repair, which could be needed for any early-vintage IC-7800.

Brad Rehm, KV5V
Salado, Texas
January, 2012

* * *