Icom IC-756 VFO Encoder Repair

Figure 1 - Icom IC-756

It seems like certain repair types run in groups. This is the third IC-756-series radio (Figure 1) that I have had on the bench in the past two months, and this one was another case of a failed VFO encoder. The symptoms that the owner reported to me were that there was no response on the display when she rotated the VFO knob in one direction, and a skipping response when rotating the VFO knob in the opposite direction. These are some of the typical indications of a failed encoder.

I have recently replaced the encoder in one radio, in which I was able to obtain an exact factory replacement part. In the second set that I worked on last week, I replaced the encoder with a standard off-the-shelf encoder, though that replacement encoder was not an exact-fit part. In that repair, I needed to install a JST-style four-pin plug to the wire leads on the encoder, and I had to install a shaft extender that I had made for this purpose.

Figure 2 - Encoder

Both of those repairs were discussed in separate repair case-history articles, so I will not go into great detail here about either of those repairs. However, because there is some commonality in the failure modes of these radios, some discussion is called for.

The VFO knob on this series of radios is all metal, without the usual rubber tire or grip that so many of these knobs have. As a result, static electricity on the body of the operator is sometimes passed through the knob and the shaft and directly into the encoder (Figure 2), where it plays havoc with the LM393 comparator IC that is on the encoder's circuit board. In many cases, the IC is damaged or destroyed, and in some cases, the damage is severe enough that the small PCB on the encoder body is damaged beyond use. In cases where the PCB is damaged, the encoder is usually not repairable and therefore must be replaced. However, when there is no damage to the board and the only problem is a failed comparator, it is generally possible to replace the comparator IC on the encoder and restore the encoder to useful service. That type of repair is what I ended up doing with this most recent failed IC-756.

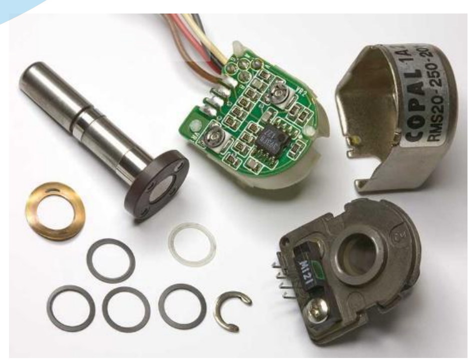

Figure 3 - Encoder fully disassembled

As far as cost to the customer is concerned, it is pretty much an even exchange, whether I repair the encoder or replace the encoder, as the cost of the encoder is approximately the same as the labor cost and the price of the IC when repairing the encoder rather than replacing it. There is, however, a slight advantage to be had in the replacement option, as there is a simple means of preventing a repeat of the static damage to the encoder. I will talk about that later on in this article.

For now, let's take a closer look at the encoder. This encoder, shown fully disassembled in Figure 3 and unlike many that are found in amateur radio applications, is magnetic rather than optical. Physically, there is a wheel that is mounted to the shaft and therefore rotates with the shaft. This wheel consists of a series of small magnets mounted into an epoxy structure. Mounted in close proximity to the rotating magnet set is a Hall-effect sensor unit that puts out two separate signals in response to the motion of the magnets. These signals are basically sinusoidal and are out of phase with each other by ninety degrees. The leading/lagging relationship can be used to determine direction of rotation. These signals are processed on the PCB that is mounted to the encoder body, converting them into a series of square-wave pulses of varying duty-cycle or pulse width. The width of the pulses produced is directly proportional to the rotation speed.

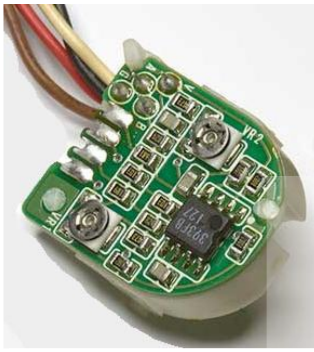

Figure 4 - Encoder PCB

The processing circuitry is comprised of an LM393 dual comparator IC, a pair of potentiometers, and several resistors and capacitors. While the LM393 is primarily responsible for the square or digital shaping of the pulse train, the pulse widths of the two separate pulse trains generated must be equal (or *balanced*) in order for the pulse trains to be meaningful and reliable. This balance between the independent spontaneous widths of the two pulse trains is adjusted via the twin potentiometers on the circuit board, with each potentiometer affecting one of the two pulse trains.

There are four wires attached to the PCB (Figure 4), as well as the four leads from the Hall-effect sensor body. The wires are as follows:

- RED – +5VDC;
- BRN – output “B”;
- WHT – output “A”; and
- BLK – GND.

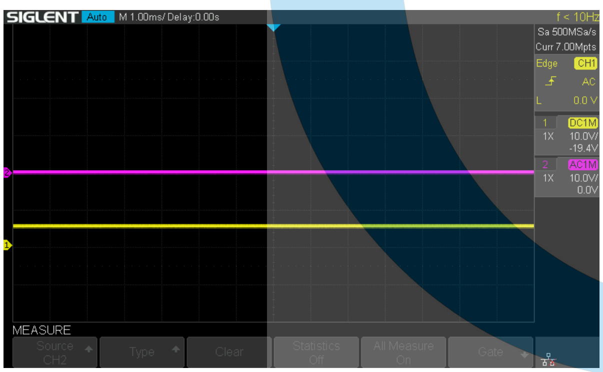

Figure 5 - No pulse train outputs

The reason that the “A” and “B” outputs are out of their logical or alphabetic order in the list above is because the wires are listed in the sequence in which they are inserted into the JST-4 plug that terminates the wire leads. In operation, the encoder is supplied with a +5VDC supply and a GND connection, and then the two outputs from the encoder are taken as control inputs into the CPU on the radio front panel.

Accessing the encoder PCB for adjustment and/or repair requires the removal of the steel shield that covers the encoder body. This is best done by gently prying the crimped spots along the edge of the shield out of the notches into which the edges of the shield have been crimped. There are three such locations – one along the single straight edge of the encoder body end, and one on either side just before the start of the arc that forms the opposite end of the body. Once these crimps are pried out far enough, the steel shield can easily be pulled off the body.

Testing of the encoder involves the connection of the encoder’s two output leads to the two inputs of a dual-trace oscilloscope, while providing the requisite +5VDC supply to the encoder. The encoder GND connection and both oscilloscope probe grounds are all connected together. Making these connections can be tricky unless you know how to do so.

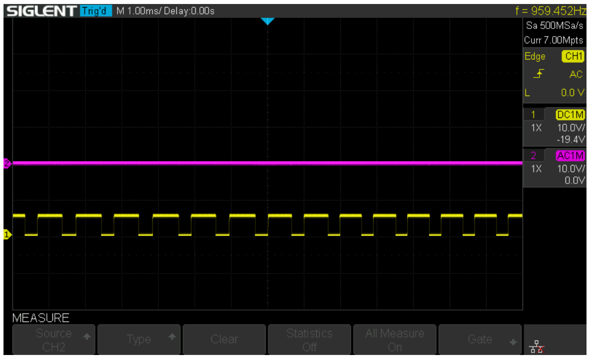

Figure 6 - Single pulse train

There are three methods that will allow easy connection of the encoder to the oscilloscope. The first involves removing the wires from the JST plug. This is done by gently lifting the latch tab over each wire just enough to allow the wire and terminal to be pulled from the plug body. Be sure to make photos or a diagram of the wire sequence and direction in the plug for later re-insertion of the wires. The second method requires the use of a mating JST connector to which a set of four wire leads has been attached, with each wire lead having a stripped and tinned opposite end for connection to the oscilloscope. The third method, and perhaps the most effective and easiest, is to simply make a short harness, about six inches long, out of individual lengths of 22AWG *solid* wire in the four colors used, RED, BRN, WHT, and BLK. At one end, strip a quarter-inch of insulation from each wire. At the opposite end, strip a half-inch of insulation from each wire. Use two or three zip ties to bundle the four wires together (Figure 7). To use this harness, simply insert the quarter-inch bare ends into the JST connector, matching up the colors. The half-inch bare ends are then ready for connection to the power supply and to the oscilloscope probe leads. The 22AWG solid wire will fit the JST terminals quite nicely.

Figure 7 - Encoder test harness

Once the oscilloscope and power supply are properly connected to the encoder, it is time to make the encoder turn. I find that the easiest means of doing this is to chuck the encoder shaft up into a portable electric drill and using the drill to turn the encoder. It is critically important that the drill, however, be of a variable-speed design, as it is inadvisable to turn the encoder at the full speed of the drill.

As the encoder turns, two square-wave pulse trains should appear on the oscilloscope. There are several outcomes possible, and the list below will help to identify the outcome indications with their most likely causes.

1. No output traces at all:
    a. power supply inoperative;
    b. misconnected encoder;
    c. open circuit(s) on PCB; or
    d. failed comparator IC.
2. Two flat traces (no pulses) (Figure 5):
    a. failed Hall-effect sensor;
    b. badly imbalanced encoder; or
    c. failed comparator IC.
3. One flat trace and one pulse train (Figure 6):
    a. failed Hall-effect sensor;
    b. imbalanced encoder; or
    c. failed comparator IC.
4. Two pulse trains with one pulse train having a greater amplitude:
    a. imbalanced encoder.

5. Two pulse trains with unequal pulse widths (Figure 8):
    a. imbalanced encoder.
6. Two pulse trains of equal heights and widths (Figure 9):
    a. normal indication of a properly working encoder.

There is no relevance to the order in which the likely causes are listed above, meaning that there is no greater likelihood of one failure mode over another in the listings provided. However, in the overall scheme of things, the most likely failure would involve an imbalance, the next most likely would involve a failed comparator IC, and the least likely would be a failed Hall-effect sensor.

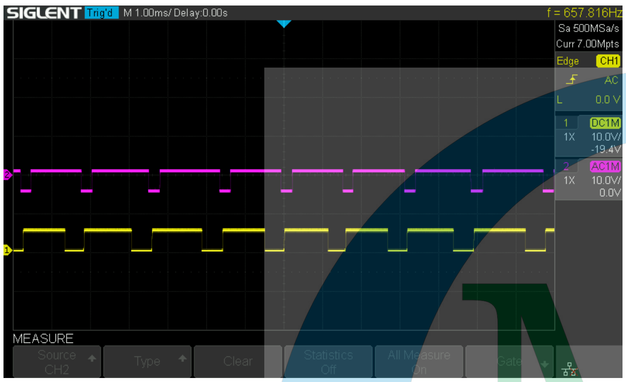

Figure 8 – Imbalanced pulse trains

If, while testing the encoder with the oscilloscope, any imbalance in the pulse trains or missing pulse trains are noted, attempt to adjust the potentiometers before condemning the comparator IC. Each potentiometer controls the pulse formation on one of the two outputs. When adjusting the potentiometers, adjust in very small increments, as it is easy to turn right through the active portion of the range. These potentiometers are full-rotation devices without limit stops in their design, so they can be adjusted continually in one direction and will eventually end up where they started. So… adjust a little bit at a time.

With a helper, it is possible to adjust the potentiometer(s) while the encoder is turning. Be sure to turn the encoder at a relatively slow rate, but fast enough to produce a consistent pulse train. If no pulse train at all can be developed, or if only a single pulse train can be produced, it is most likely time for a replacement of the comparator IC.

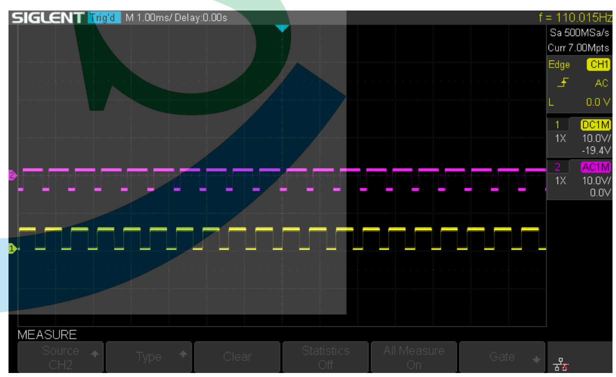

Figure 9 – "Normal" pulse trains

Unfortunately, there is another failure mode for these encoders. The circumstance can exist whereby the encoder produces a single pulse train in its "normal" condition, but if the shaft is held outward or away from the body of the encoder, it will produce both pulse trains. The user indication of this condition is the fact that when turned normally, the VFO seems to "skip" or jump in steps rather than varying smoothly. However, if the VFO knob is pulled outward while it is turned, the VFO adjustment seems to vary normally. I have seen this failure mode a few times, and the solution in every case is to replace the encoder *unless you have a source of proper shim washers*. I believe that in these cases, the cause is the disintegration of one or more shim washers that start out life on the shaft of the encoder, between the magnet wheel and the body of the encoder. In every case with this type of encoder failure, it has been accompanied by a fine black powder emanating from the encoder, coming out along the shaft. These shim washers can be seen in the photo of the disassembled encoder presented earlier.

The LM393 comparator IC used in this encoder is in the SOIC-8 package, a surface-mount type measuring a mere 4mm x 6mm body size. It is best removed using some solder wick to pull most of the solder out, and then using a dental pick and the soldering iron to heat and gently lift the chip at the same time, one side at a time. Be careful not to overheat the PCB or to pull traces off the board, because at that point, the encoder must be replaced. Work slowly and carefully, using limited heat, and you should be successful.

Once the IC has been removed, clean the pads with the solder wick, and then clean the PCB with some 99.9% IPA. Lightly tin the pads, and then apply an abundance of liquid flux to the area. Place the new IC onto the pads and heat its leads enough to bond them to the tinned pads. Touch up the soldering of the leads as necessary. Clean up the excess flux with some 99.9% IPA, and then you are ready to adjust the pulse train balance.

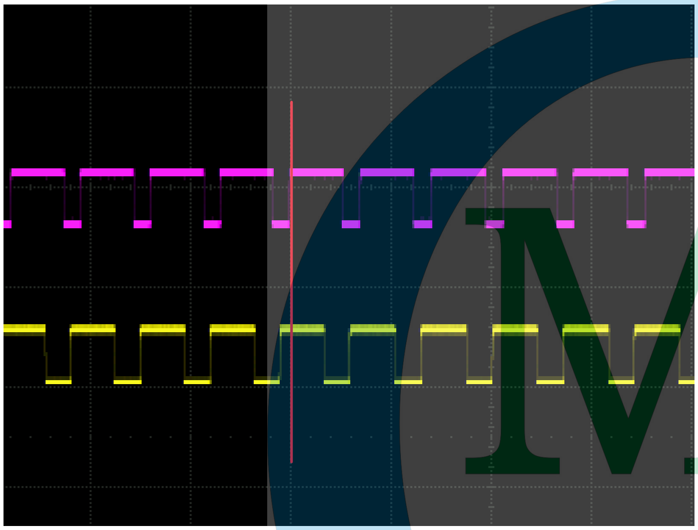
Figure 10 - Phasing indicated by red line on photo

Set up the encoder in the test configuration again, and then adjust the potentiometers for a pair of balanced pulse trains. When properly adjusted, the pulse trains will have equal amplitudes and the pulse widths will be equal between the pulse trains. Note however that the pulses will be out of phase with each other, as illustrated in Figure 10. If you reverse the rotation direction, the phase difference should reverse, swapping the leading and lagging status between the pulse trains.

Assuming that you achieve a balanced adjustment of the pulse trains, it is time to put the encoder back together and back into the radio. If removed for the test procedure, re-insert the four lead wires into the JST plug, being sure to insert them in the proper sequence and direction as they were in the beginning. Install the steel cover shield back onto the encoder body and crimp the edges into the notches where they were crimped before.

Install the encoder back into the radio following the reverse of the procedure used during disassembly. If all goes well, the encoder's operation should now be back to normal, making for a successful repair.

It was mentioned earlier that there was a slight advantage to replacing the encoder with the standard and readily available part as opposed to the factory part. What this is about is the fact that the readily-available replacement encoder, while an exact fit electrically, is not an exact fit physically. Icom had a custom version of this encoder produced for their use, with the differences being the inclusion of the JST plug on the end of the wire leads, and the fact that the encoder shaft is about 16mm longer than that of the standard encoder. Installation of the JST plug is no problem, as these plugs and their associated terminals are stocked items at my shop. However, the shaft length difference called for a little bit of ingenuity to resolve. I started out by having some aluminum shaft extenders turned. These extenders, while solving the problem of the shaft length, also perpetuated the problem of the transfer of static electricity into the encoder. As a result, I further experimented with 3-D printed plastic shaft extenders. This is possible because there is really no torsional load on the shaft even with the knob brake fully tightened. The encoder turns freely, so a plastic extender can easily handle the job. In addition, it also breaks the static path into the encoder, thus affording that extra advantage that I talked about.

The bottom line is that repair or replace, the choice is yours. Using the information provided in this article, it should be possible for anyone who is reasonably competent with tools to make the required repairs or adjustments to the magnetic encoder used in these (and other) Icom units. Remember that there is an oscilloscope on the test and repair bench at the GCARC Clubhouse that can readily be used for this job, as well as suitable power supplies and test leads for the job. With the addition of the solder station and the lighted magnifier, replacement of the comparator IC should be a breeze as well. Don't be afraid to take this on – the worst that can happen is that you end up replacing the encoder that you already expected to replace.