

Build Your Own Optical Encoder

The theory and construction of an inexpensive optical encoder.

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Not being very satisfied with commercially available mechanical encoders, I decided to build an electro-optical encoder. I used this encoder in an RF generator and in a receiver, but it can have many more applications. And because there are no mechanical contacts, it is very reliable.

Encoder and Circuit Discussion

An electro-opto-mechanical encoder converts the angular position of its shaft into a digital signal by producing pulses from the shaft rotation. As shown in Figure 1, the encoder basically consists of a disk, usually plastic, attached to a rotating shaft, and divided into transparent and dark areas. There is also a pair of

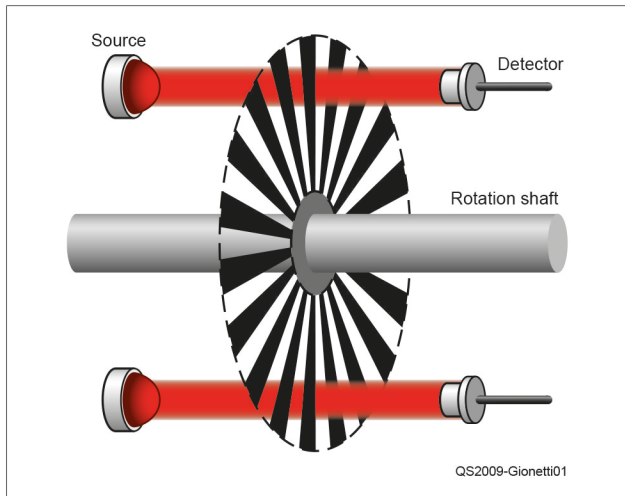


Figure 1 — The rotary encoder working principle.

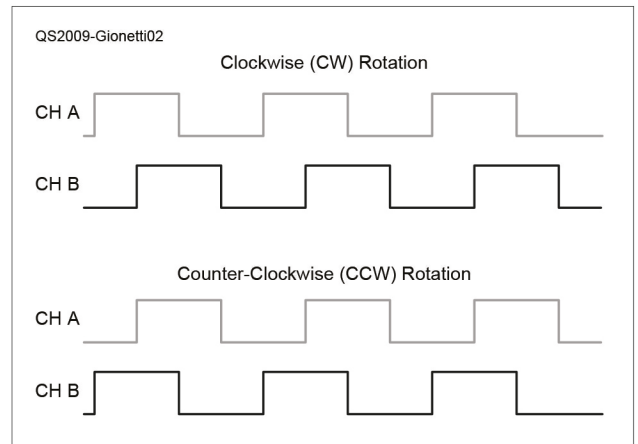


Figure 2 — The clockwise and counterclockwise rotation.

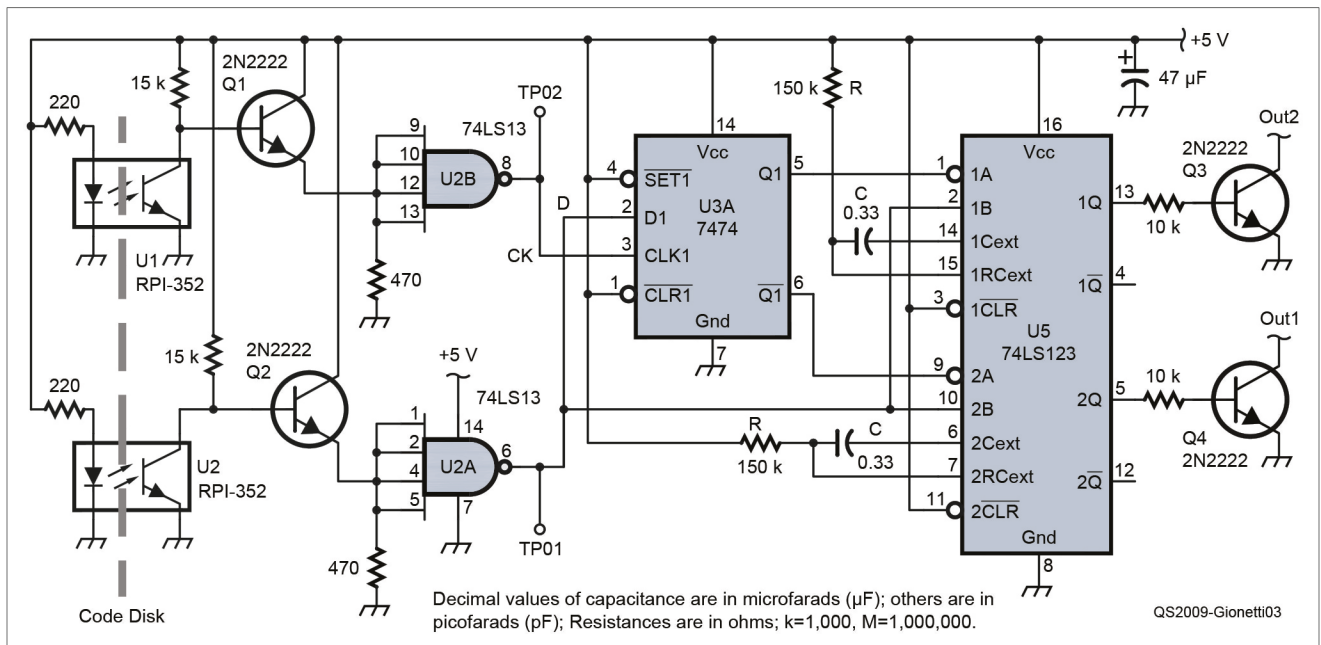


Figure 3 — The schematic diagram.

photo emitters/detectors, which generate the light that passes through the transparent areas of the disk, and it receives the light signal and converts it into voltage pulses. The two photo emitters/detectors are positioned to cause a 90-degree phase difference between the clocks. This phase relationship determines the direction of rotation. Figure 2 shows the output sequences at TP01 (channel A) and TP02 (channel B) in Figure 3. For clockwise rotation, A leads B by 90 degrees. For counterclockwise rotation, A lags B by 90 degrees.

Figure 3 shows how the photo detector outputs connect to a digital board. A Schmitt trigger removes the small linear region between the on and off states of the detectors. By applying channel A to input D, and channel B to the input clock of a 74LS74 D flip-flop, we can determine the sense of encoder rotation. When A leads B, output Q is low. Q becomes high when A lags B (see Figure 4). To have duration pulses independent of the rotation speed of the encoder shaft, the Q and \bar{Q} outputs of the D flip-flop are connected to gates 1A and 2A (Pins 1 and 9) of a 74LS123 dual-monostable multi-vibrator, while the channel B connects to gates 1B and 2B (Pins 2 and 10) of the 74LS123. With this configuration, clockwise rotation activates monostable A, while counterclockwise rotation activates monostable B. The duration of the pulses is determined by the RC time constant (about 15 ms with the values shown). The period depends on the shaft rotation speed.

The Q or \bar{Q} outputs of the monostables are connected to the device to be controlled by open collector transis-

tors. Pull-up resistors (not shown) provide high-state voltage when Q is off, or low-state voltage when Q is on. The open collectors allow interfacing to TTL, TTL LS, CMOS, and HCMOS. Figure 5 shows the CW and the CCW pulses at the open collector outputs.

Assembly

Figure 6 shows the necessary mechanical and electrical parts. The threaded collar and brass shaft are from

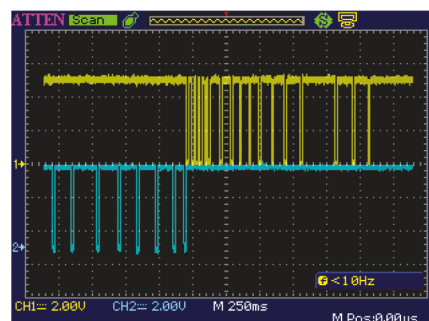


Figure 5 — A view of the CW and CCW pulses at the open collector outputs.

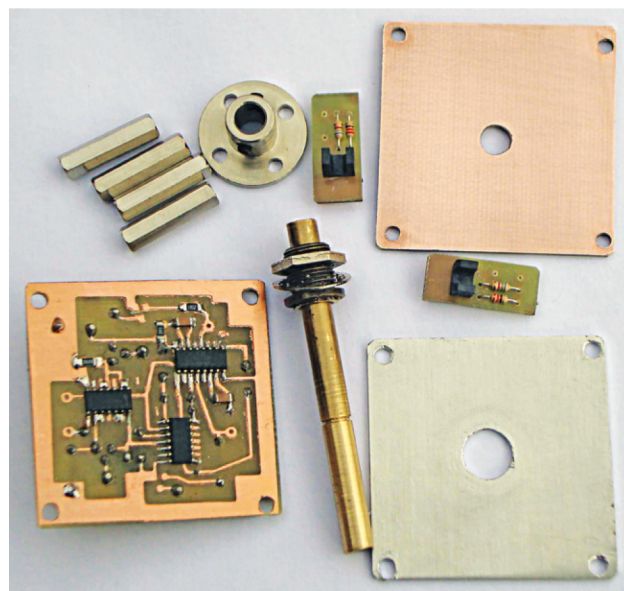


Figure 6 — The encoder's main parts.

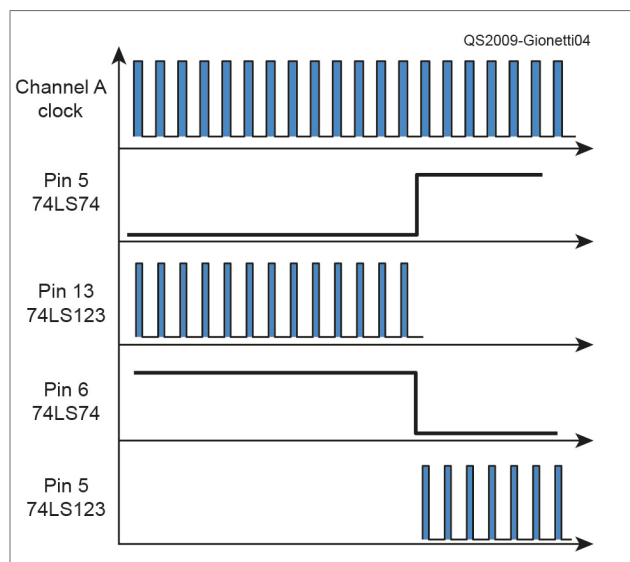


Figure 4 — The encoder output in CW and CCW rotation.

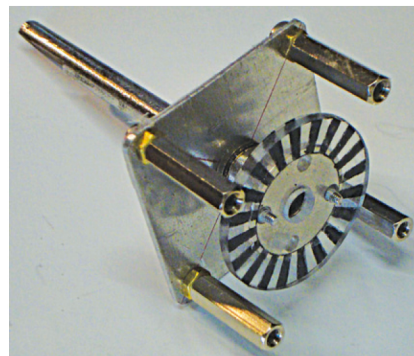


Figure 7 — The code wheel mounted on the shaft.

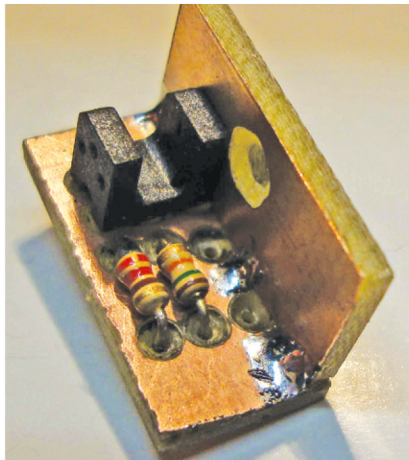


Figure 8 — The photo interrupter mini-board.

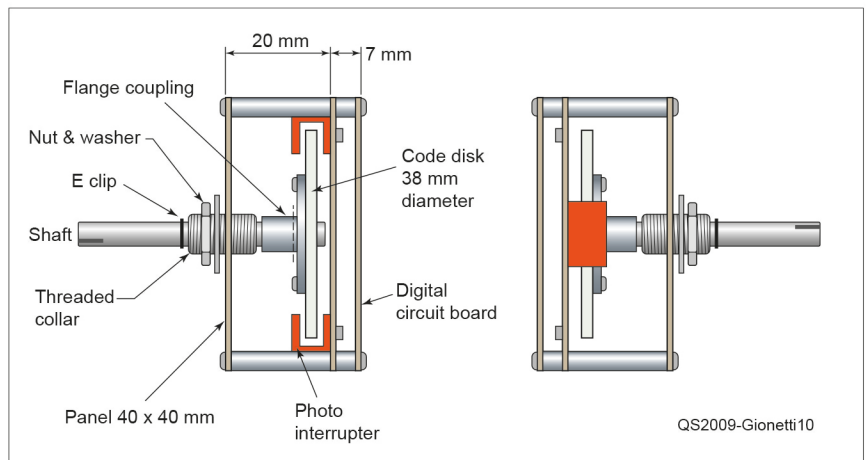


Figure 10 — The mechanical assembly.

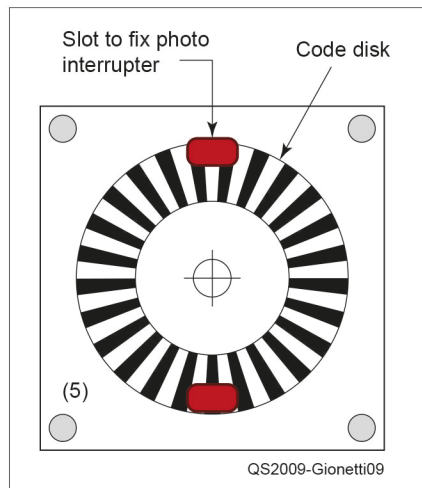


Figure 9 — The code disk.

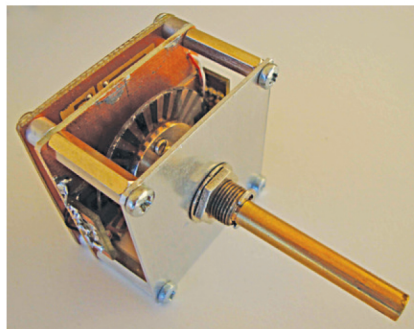


Figure 11 — The assembled encoder.

their mechanical positioning. Additional assembly detail is shown in Figure 10, and the completed unit is shown in Figure 11.

After mounting the digital card, connect the photo interrupter outputs to the A and B inputs on the digital board. Using a dual-channel oscilloscope, verify that pulses are present at the monostable outputs, as shown in Figure 5. There will be pulses from both monostables, so slightly move either photo inter-

rupter in its slot on the board until you have impulses from only one output when the rotation is in one direction. Reversing the rotation should show pulses on the other output. Now fix the photo interrupter in place with its screw. Your encoder is now ready to use.

an old potentiometer. A groove cut in the brass shaft is for a clip to prevent the shaft from coming out of the collar. The flange to which the code disk is attached was purchased on eBay.

The plexiglass encoder disk has a thickness of 1.5 millimeters and a diameter of 38 millimeters. Attached to this disk is a transparent adhesive sheet with the code wheel printed by a laser or inkjet printer. The code wheel has 50 cells, which provides 25 pulses per revolution. The code wheel generator software is available at <https://www.softpedia.com/get/Others/Miscellaneous/Codewheel-Generator.shtml>. Figure 7 shows the assembled 4 × 4 × 3 centimeter encoder. The photo interrupters are soldered on two mini boards (see Figure 8), and are then mounted on a board (see Figure 9) on which two slots provide for

All photos by the author.

Licensed since 1974, Riccardo Gionetti, IØFDH, attended the University of Rome "La Sapienza" at G. Marconi Institute and received a degree in Physics with specialization in cybernetics and electronics. He also took technical master courses in radar technology, microwave measurements, EMC, IR sensors, and electronic warfare. Now retired, Riccardo worked for 10 years in telecommunications, and 30 years for the main Italian defense industry. For the last 10 years, he was responsible for applied research and technology for radio frequency sensors. Riccardo has published over 50 technical articles and papers in professional and amateur radio fields, is coauthor of the handbook on *HF Power Linear Amplifier Design*, and he authored a course on "Tactical Radio Communications." You can contact Riccardo at rgionetti@virgilio.it.

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