ROBOTICS

Position sensing

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YOU DON'T HAVE TO WORK WITH A robot arm for long to realize that position information is highly important. There are numerous ways of obtaining that sort of information; let's examine several.

Digital position sensing

Most digital approaches to position sensing involve optical devices. Recently in this column we discussed tactile sensing using IR emitters and detectors. Some of the same approaches can be used for position sensing.

For example, a device called an optical shaft encoder or an optical interrupter encodes the position of a shaft by means of opto-electronics. An infrared (IR) detector/emitter pair couples to the shaft of a motor or the pivot of a robot arm and provides a series of digital pulses. The encoder requires only a source of five-volt power. How does it work?

A disk like the one shown in Fig. 1 is used to interrupt a beam of infrared light passing from an LED to a photo-transistor. Overall the disk is transparent, but it has dark stripes that block the IR periodically as it spins. The LED and the transistor are integrated in a single package, as shown in Fig. 2. The encoder disk is attached to the end of a rotating shaft, and then it passes through the slot in the optical interrupter. As the shaft turns, the disk rotates, so the dark areas of the disk periodically prevent the LED light from reaching the photo-transistor. The output of the detector is a series of pulses that may be squared up and fed to digital control circuitry.

FIG. 1

The disk is manufactured so that the distance between each radial stripe is equal. So the number of pulses that are output indicate how far the shaft has turned. Industrial optical encoders may have several hundred, or a thousand or more divisions.

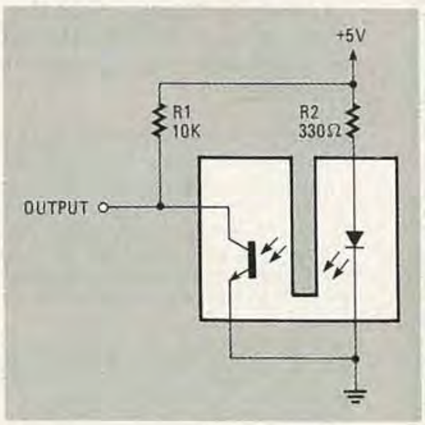

FIG. 2

Commerical encoder disks are usually expensive because they are manufactured under tight mechanical tolerances. In addition, they offer a minimum of 256 slits. For purposes of experimentation, sixteen slits are sufficient because hobbyist-grade motors cannot be positioned very accurately.

You could photocopy the disk in Fig. 1 on a piece of acrylic to provide position information for a Milton Bradley *Robotix* arm. The basic idea is shown in Fig. 3.

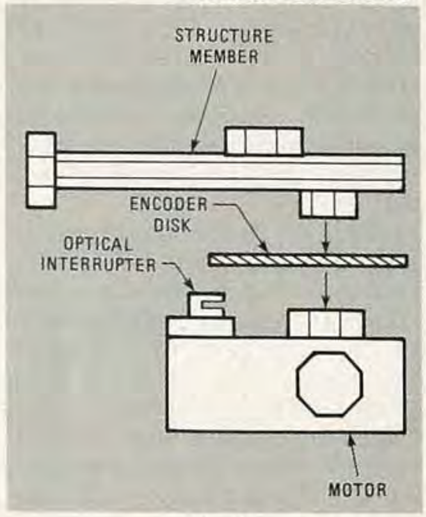

FIG. 3

The optical interrupter is readily available, but if you have trouble locating one, or if you would like to purchase some encoder disks, MJR Digital (Mason Road, Milford, NH 03055) has an experimental kit consisting of nine transmissive encoder disks, nine reflective encoder disks, five H22A1 optical interrupters, and an application note available for $19.95. We'll discuss use of the reflective encoder disks below.

Because two connections go to ground, only three wires must be brought to the encoder. In addition, several encoders may share the ground and five volt lines.

To use the encoder, the computer that controls the motor must monitor the output of the encoder. To begin a motion sequence, the arm must be "homed." In other words, the joint (or joints) in question must be brought to a limit—all the way up, down, left, right, etc.

The computer must then read the status of the encoder. If the output is low, then any subsequent high indicates movement. Conversely, if the initial reading is low, then subsequent highs indicate an absence of movement. It's important to know whether you're starting with a high or a low; otherwise you may not be able to return the arm to the home position accurately.

To move the arm to a specified position, load a counter with the number of slits that must be counted. Then, after homing the arm, turn on its motor and monitor the encoder's output for a pulse. When a high or a low (as previously described) is detected, decrement the internal counter. Repeat that operation until the counter has a value of zero. At that point the arm should be in the desired position.

You could perform the counting in hardware (without a computer) if you like. Doing that is simply a matter of using a counter IC and a logic gate to shut the motor off when the counter reaches zero.

Reflectance decoder

In some situations, a *reflectance-type* encoder disk is more practical. Rather than a clear disk with dark stripes, a reflectance disk is basically reflective with dark stripes. It is used as shown in Fig. 4.

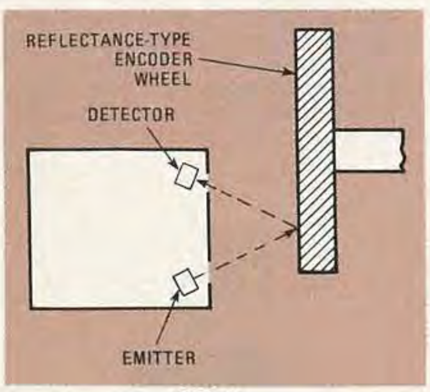

FIG. 4

A beam of infrared light is emitted from an IR emitter at an angle. An IR detector is mounted at a complementary angle. Light will be reflected from the reflective areas of the disk, and not from the striped areas. As the joint moves, the wheel turns, so the output of the detector is a series a highs and lows, like those produced by the transmissive disk. That data can be used to position the arm as previously described.

Analog sensing

Of course, there are other ways to sense the position of an arm. An analog approach might use a variable resistor, an A/D converter, and a little software. The shaft of a potentiometer is connected to the pivot point of a robot's arm, so the potentiometer's resistance should provide an accurate indication of the arm's position. The voltage across that resistor would be read by the A/D converter, and the control computer could then use that information to make an intelligent decision about what step should be done next.

The arm must start from a known position, so, on power up, the arm should be homed. That is best accomplished by rotating each pivot until a microswitch (used as a limit indicator) is activated. At that point motion must halt. Then the control computer should check the output of the A/D device. The voltage read there represents a reference point in relation to which other positions are known.

Some A/D converters require supply voltages of ±12 or even ±15 volts. However, there are several 5-volt A/D IC's on the market. For example, National Semiconductor's A/D0816 can digitize 16 channels of analog information. Each channel has eight bits, so any input between 0 and 5 volts will be converted to one of 256 digital values in steps of about 20 mV. Other A/D IC's provide 12 bits, for a total of 4096 discrete values.

There are several drawbacks to the analog approach. The first is that the potentiometer must be coupled physically to the arm's pivot, and that may be difficult. Also, the mechanical drag of the potentiometer may adversely affect the operation of the arm. And for the beginner, the most serious drawback may be creating the software required to operate the A/D converter.

Speed may also be a problem. Many A/D converters operate much slower than the digital systems controlling them. Often a computer must wait until the A/D converter is ready.

A typical computer-to-A/D dialog might go like this: The computer asks for the current reading, then the A/D works on the request. Some hundreds of microseconds later, the A/D signals the computer that the current reading is ready. Then the computer reads the value. If necessary, the process then repeats.

The speed problem can be alleviated by using a faster A/D converter. However, they're harder to find and more expensive than run-of-the-mill hobbyist-grade devices. And for experimental purposes, a slow A/D converter should prove to be quite sufficient.

As you can see, there are a number of ways of gaining position information about a robot arm. Some of those methods are more useful than others in different circumstances, but the digital approach is generally the simplest to implement as well as the most accurate. **R-E**