AVR Microcontroller

Microprocessor Course

Chapter 14

RELAY, OPTOISOLATOR, AND STEPPER MOTOR INTERFACING WITH AVR

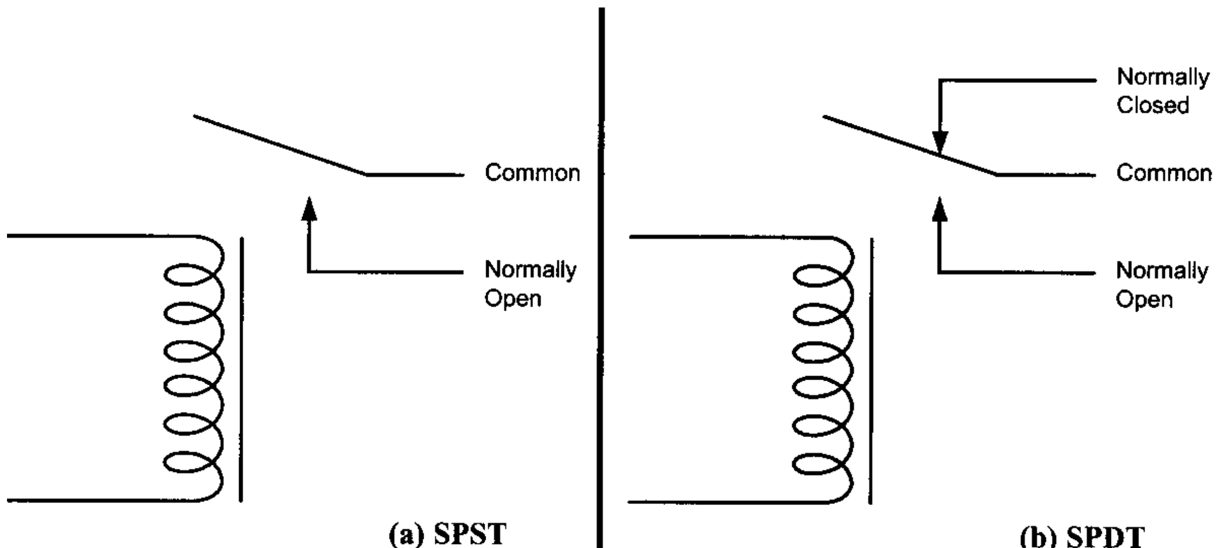
Day 1393

14.1 RELAY, OPTOISOLATOR

Electromechanical relays

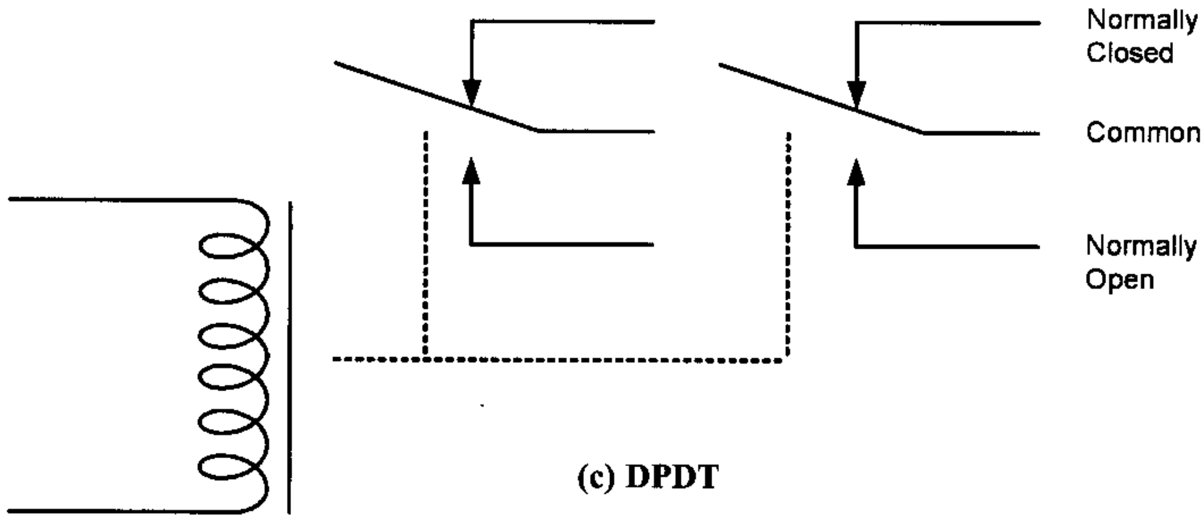
A relay is an electrically controllable switch widely used in industrial controls, automobiles, and appliances. It allows the isolation of two separate sections of a system with two different voltage sources.

For example, a +5 V system can be isolated from a 120 V system by placing a relay between them. One such relay is called an electromechanical (or electromagnetic) relay (EMR) as shown in Figure 14-1



14.1 RELAY, OPTOISOLATOR

The EMRs have three components: the coil, spring, and contacts. In Figure 14-1, a digital +5 V on the left side can control a 12V motor on the right side without any physical contact between them. When current flows through the coil, a magnetic field is created around the coil (the coil is energized), which causes the armature to be attracted to the coil. The armature's contact acts like a switch and closes or opens the circuit. When the coil is not energized, a spring pulls the armature to its normal state of open or closed. In the block diagram for electromechanical relays (EMR) we do not show the spring, but it does exist internally.



(c) DPDT

RELAY, OPTOISOLATOR AND STEPPER MOTOR …
14.1 RELAY, OPTOISOLATOR

In choosing a relay the following characteristics need to be considered:

1. The contacts can be normally open (NO) or normally closed (NC). In the NC type, the contacts are closed when the coil is not energized. In the NO type, the contacts are open when the coil is unenergized.
2. There can one or more contacts. For example, we can have SPST (single pole, single throw), SPDT (single pole, double throw), and DPDT (double pole, double throw) relays.
3. The voltage and current needed to energize the coil. The voltage can vary from a few volts to 50 volts, while the current can be from a few mA to 20 mA. The relay has a minimum voltage, below which the coil will not be energized. This minimum voltage is called the "pull-in" voltage.
4. The maximum DCIAC voltage and current that can be handled by the contacts. This is in the range of a few volts to hundreds of volts, while the current can be from a few amps to 40 A or more, depending on the relay.

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14.1 RELAY, OPTOISOLATOR

The fact that one can use such a small amount of voltage/current on one side to handle a large amount of voltage/current on the other side is what makes relays so widely used in industrial controls. Examine Table 14-1 for some relay characteristics.

Table 14-1: Selected DIP Relay Characteristics (www.Jameco.com)

Part No.	Contact Form	Coil Volts	Coil Ohms	Contact Volts-Current
106462CP	SPST-NO	5 VDC	500	100 VDC-0.5 A
138430CP	SPST-NO	5 VDC	500	100 VDC-0.5 A
106471CP	SPST-NO	12 VDC	1000	100 VDC-0.5 A
138448CP	SPST-NO	12 VDC	1000	100 VDC-0.5 A
129875CP	DPDT	5 VDC	62.5	30 VDC-1 A

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Driving a relay

Digital systems and microcontroller pins lack sufficient current to drive the relay. While the relay's coil needs around 10mA to be energized, the microcontroller's pin can provide a maximum of 1-2mA current. For this reason, we place a driver, such as the ULN2803, or a power transistor between the microcontroller and the relay as shown in Figure 14-2.

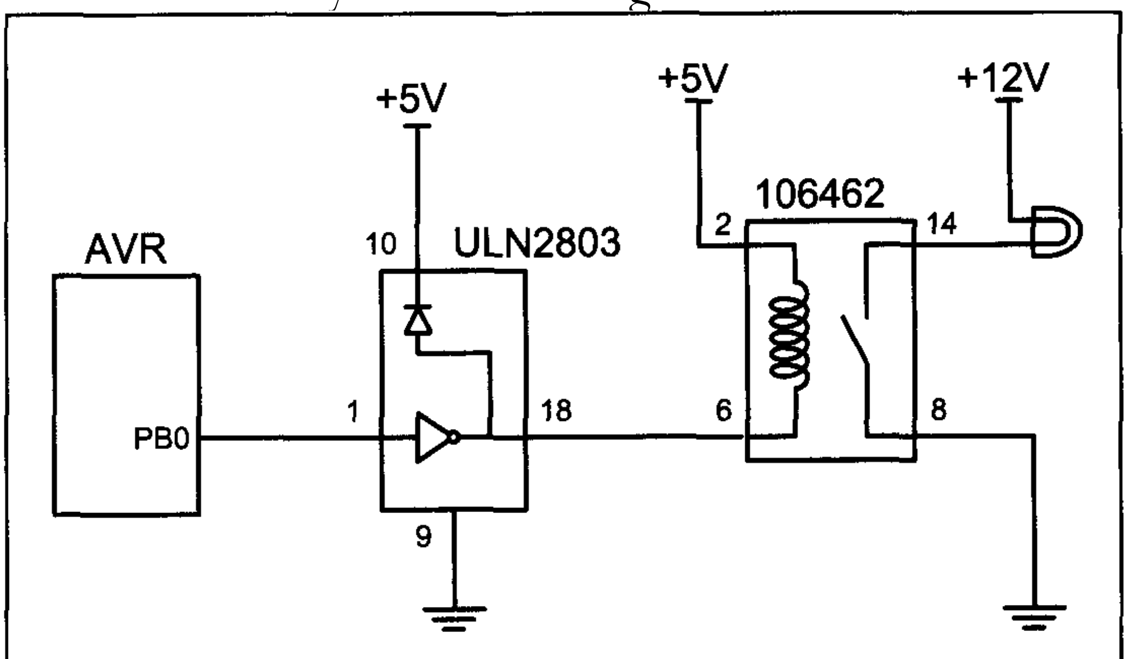

Figure 14-2. AVR Connection to Relay

14.1 RELAY, OPTOISOLATOR

Program 14-1 turns the lamp shown in Figure 14-2 on and off by energizing and de-energizing the relay every second.

```
;Program 14-1
.INCLUDE "M32DEF.INC"

      LDI   R16,HIGH(RAMEND) ;initialize stack pointer
      OUT   SPH,R16
      LDI   R16,LOW(RAMEND)
      OUT   SPL,R16

      SBI   DDRB,0           ;PB0 as an output
BEGIN:SBI   PORTB,0          ;PB0 = 1
      RCALL DELAY_1s
      CBI   PORTB,0          ;PB0 = 0
      RCALL DELAY_1s
      RJMP  BEGIN

DELAY_1s:
      ...   ;add the DELAY_1s function from Example 9-32
      RET
```

14.1 RELAY, OPTOISOLATOR

Solid-state relay

Another widely used relay is the solid-state relay. See Table 14-2. In this relay, there is no coil, spring, or mechanical contact switch. The entire relay is made out of semiconductor materials. Because no mechanical parts are involved in solid-state relays, their switching response time is much faster than that of electromechanical relays.

Table 14-2: Selected Solid-State Relay Characteristics (www.Jameco.com)

Part No.	Contact Style	Control Volts	Contact Volts	Contact Current
143058CP	SPST	4–32 VDC	240 VAC	3 A
139053CP	SPST	3–32 VDC	240 VAC	25 A
162341CP	SPST	3–32 VDC	240 VAC	10 A
172591CP	SPST	3–32 VDC	60 VDC	2 A
175222CP	SPST	3–32 VDC	60 VDC	4 A
176647CP	SPST	3–32 VDC	120 VDC	5 A

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Another advantage of the solid-state relay is its greater life expectancy. The life cycle for the electromechanical relay can vary from a few hundred thousand to a few million operations. Wear and tear on the contact points can cause the relay to malfunction after a while. Solid-state relays, however, have no such limitations. Extremely low input current and small packaging make solid state relays ideal for microcontroller and logic control switching. They are widely used in controlling pumps, solenoids, alarms, and other power applications. Some solid-state relays have a phase control option, which is ideal for motor-speed control and light-dimming applications.

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175222CP	SPST	3–32 VDC	60 VDC	4 A
176647CP	SPST	3–32 VDC	120 VDC	5 A

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14.1 RELAY, OPTOISOLATOR

Figure 14-3 shows control of a fan using a solid-state relay (SSR).

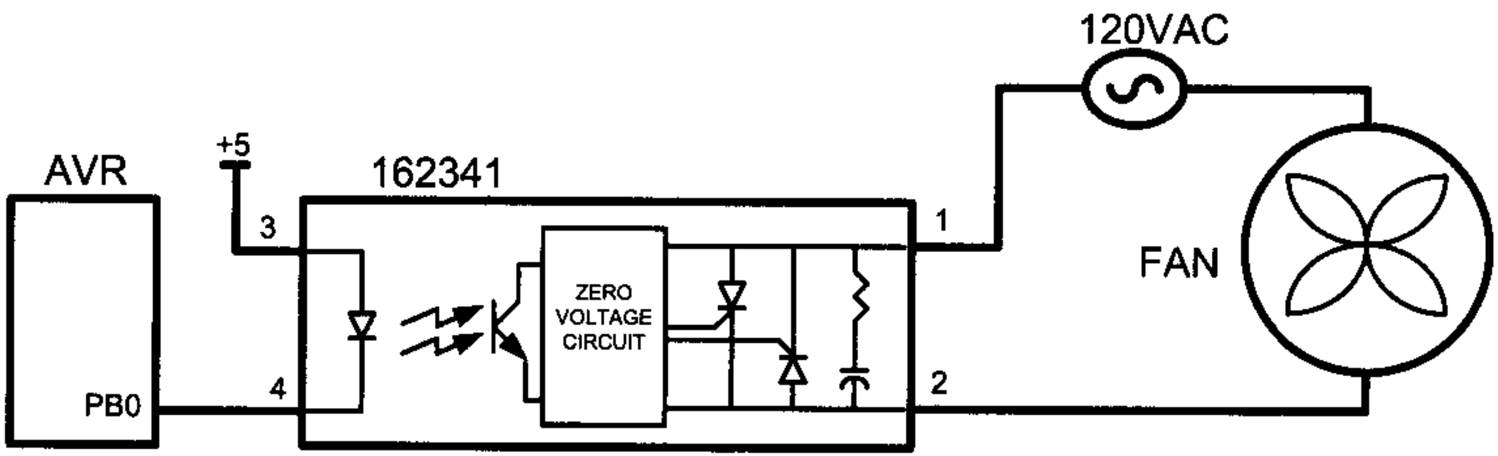


Figure 14-3. AVR Connection to a Solid-State Relay

14.1 RELAY, OPTOISOLATOR

Reed switch

Another popular switch is the reed switch. When the reed switch is placed in a magnetic field, the contact is closed. When the magnetic field is removed, the contact is forced open by its spring. See Figure 14-4. The reed switch is ideal for moist and marine environments where it can be submerged in fuel or water. Reed switches are also widely used in dirty and dusty atmospheres because they are tightly sealed

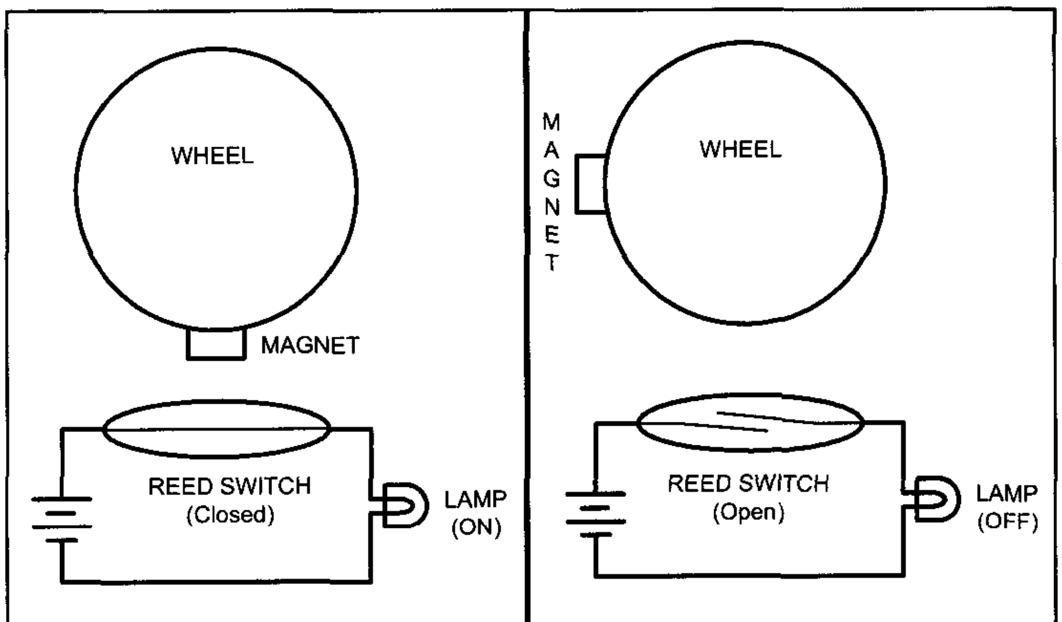
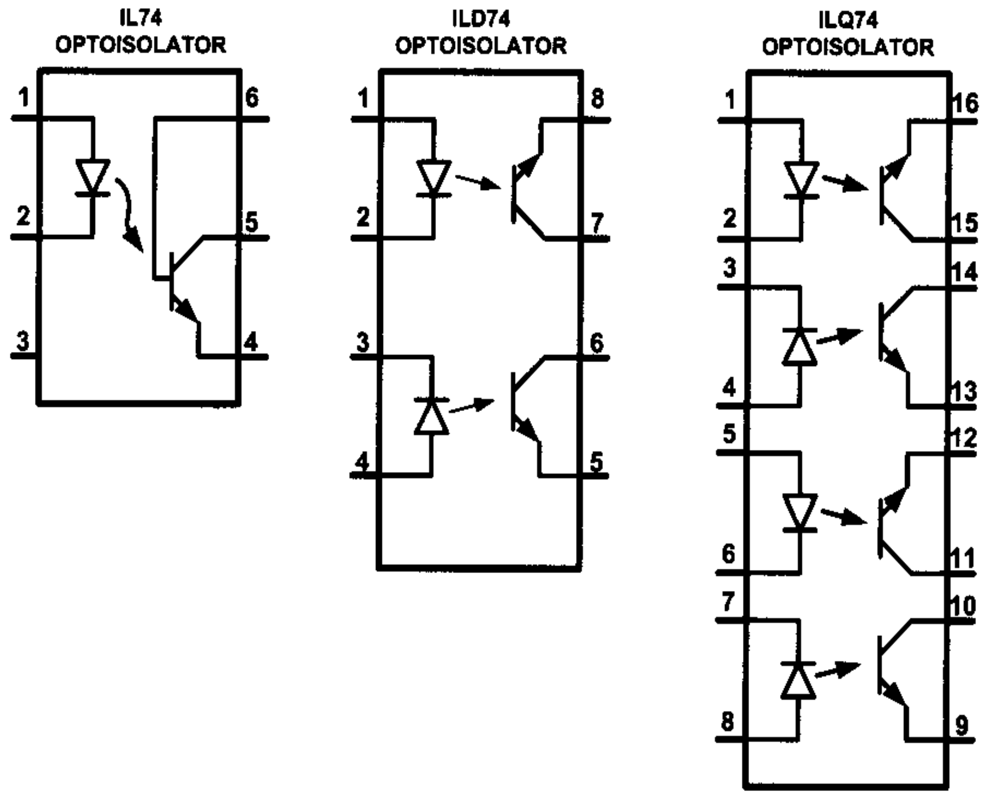


Figure 14-4. Reed Switch and Magnet Combination

14.1 RELAY, OPTOISOLATOR

Optoisolator

In some applications we use an optoisolator (also called *optocoupler) to* isolate two parts of a system. An example is driving a motor. Motors can produce what is called *back EMF, a high-voltage spike produced by a sudden change of* current as indicated in the formula V=Ldi/dt. In situations such as printed circuit board design, we can reduce the effect of this unwanted voltage spike (called *ground bounce) by using decoupling capacitors.*



14.1 RELAY, OPTOISOLATOR

In systems that have inductors (coil winding), such as motors, a decoupling capacitor or a diode will not do the job. In such cases we use optoisolators. An optoisolator has an LED (light-emitting diode) transmitter and a photosensor receiver, separated from each other by a gap. When current flows through the diode, it transmits a signal light across the gap and the receiver produces the same signal with the same phase but a different current and amplitude.

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Interfacing an optoisolator

The optoisolator comes in a small IC package with four or more pins. There are also packages that contain more than one optoisolator. When placing an optoisolator between two circuits, we must use two separate voltage sources, one for each side, as shown in Figure 14-6. Unlike relays, no drivers need to be placed between the microcontroller/digital output and the optoisolators.

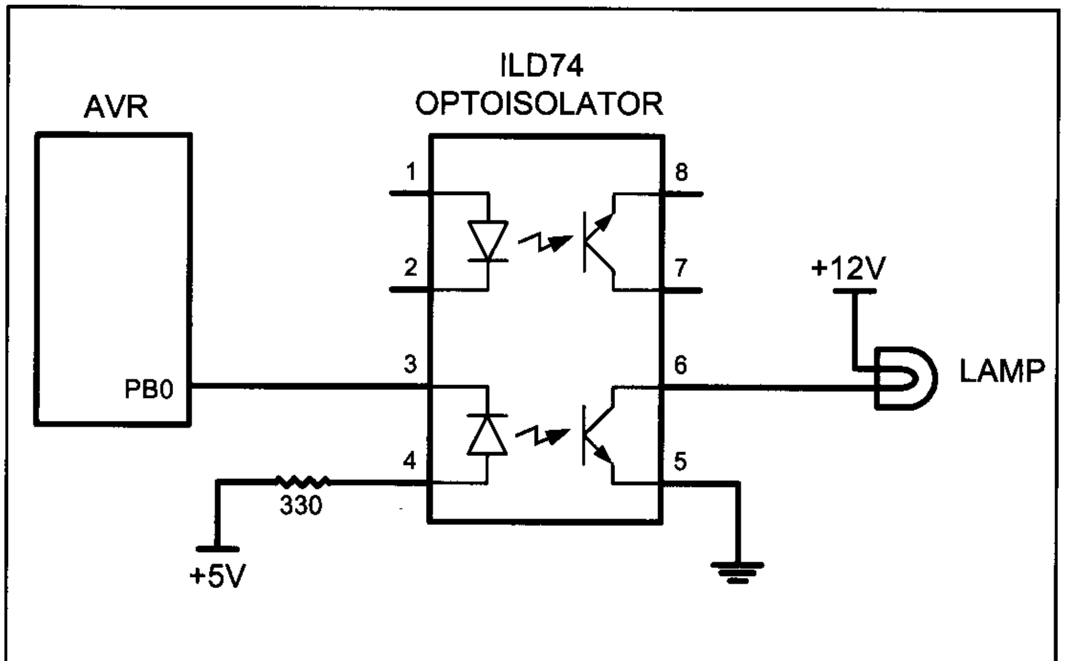

Figure 14-6. Controlling a Lamp via an Optoisolator

14.2 STEPPER MOTOR INTERFACING

Stepper motors

A *stepper motor is a* widely used device that translates electrical pulses into mechanical movement. In applications such as disk drives, dot matrix printers, and robotics, the stepper motor is used for position control. Stepper motors commonly have a permanent magnet *rotor (also called the shaft) surrounded by a stator* (see Figure *14-7*).

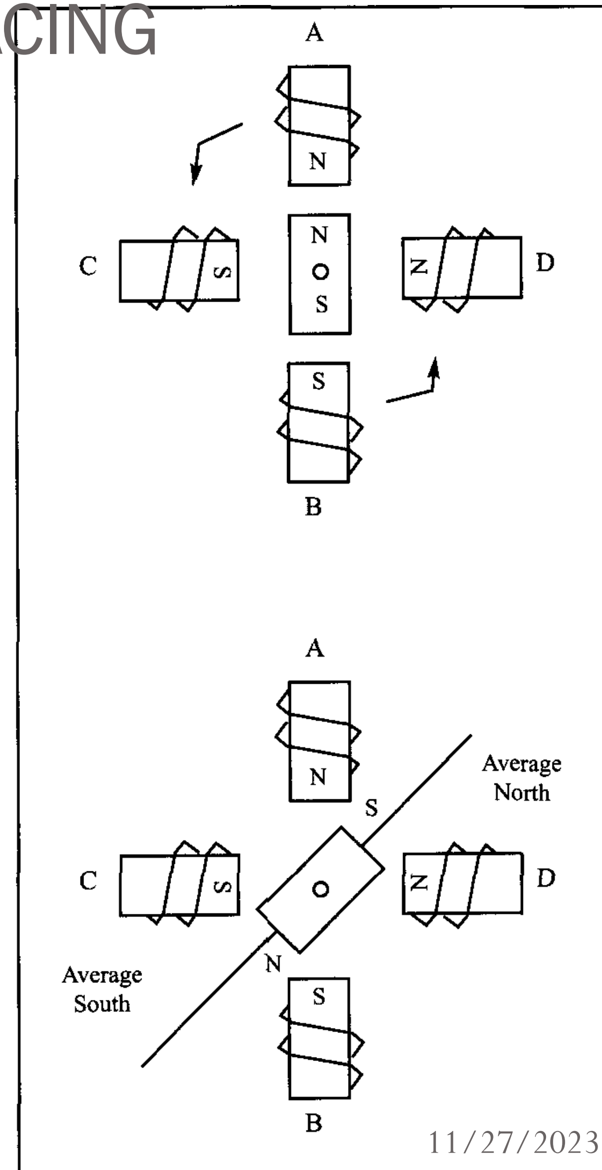

Figure 14-7. Rotor Alignment

14.2 STEPPER MOTOR INTERFACING

There are also steppers called variable reluctance *stepper motors that* do not have a permanent magnet rotor. The most common stepper motors have four stator windings that are paired with a center-tapped common as shown in Figure 14-8. This type of stepper motor is commonly referred to as a *fourphase* or *unipolar* stepper motor.

The center tap allows a change of current direction in each of two coils when a winding is grounded, thereby resulting in a polarity change of the stator.

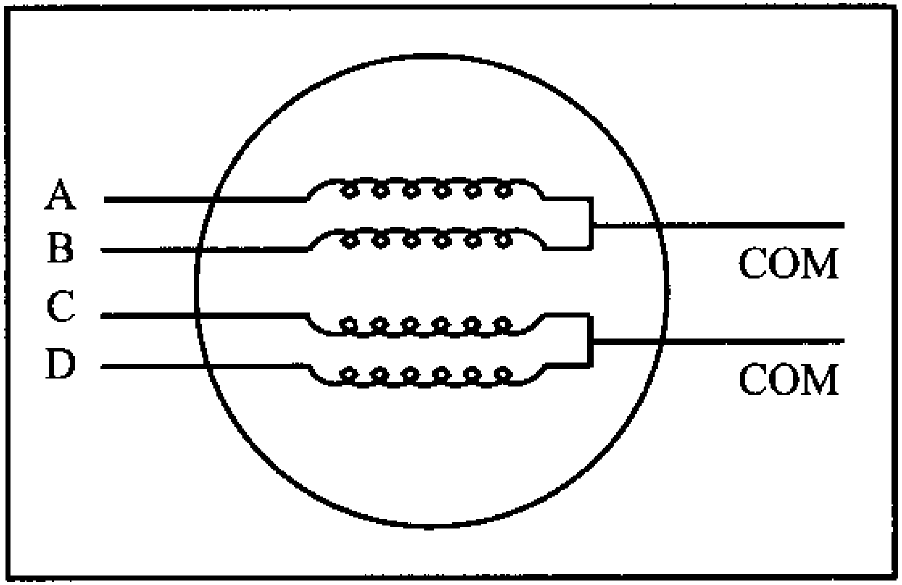

Figure 14-8. Stator Winding Configuration

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Notice that while a conventional motor shaft runs freely, the stepper motor shaft moves in a fixed repeatable increment, which allows it to move to a precise position. This repeatable fixed movement is possible as a result of basic magnetic theory where poles of the same polarity repel and opposite poles attract. The direction of the rotation is dictated by the stator poles. The stator poles are determined by the current sent through the wire coils. As the direction of the current is changed, the polarity is also changed causing the reverse motion of the rotor. The stepper motor discussed here has a total of six leads: four leads representing the four stator windings and two commons for the center-tapped leads.

As the sequence of power is applied to each stator winding, the rotor will rotate.

14.2 STEPPER MOTOR INTERFACING

There are several widely used sequences, each of which has a different degree of precision. Table 14-3 shows a two-phase, four-step stepping sequence.

Note that although we can start with any of the sequences in Table 14-3, once we start we must continue in the proper order. For example, if we start with step 3 (0110), we must continue in the sequence of steps 4, 1,2, and so on.

Table 14-3: Normal Four-Step Sequence

Clockwise	Step #	Winding A	Winding B	Winding C	Winding D	Counter-clockwise
↓	1	1	0	0	1	↑
	2	1	1	0	0	
	3	0	1	1	0	
	4	0	0	1	1	

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Step angle

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