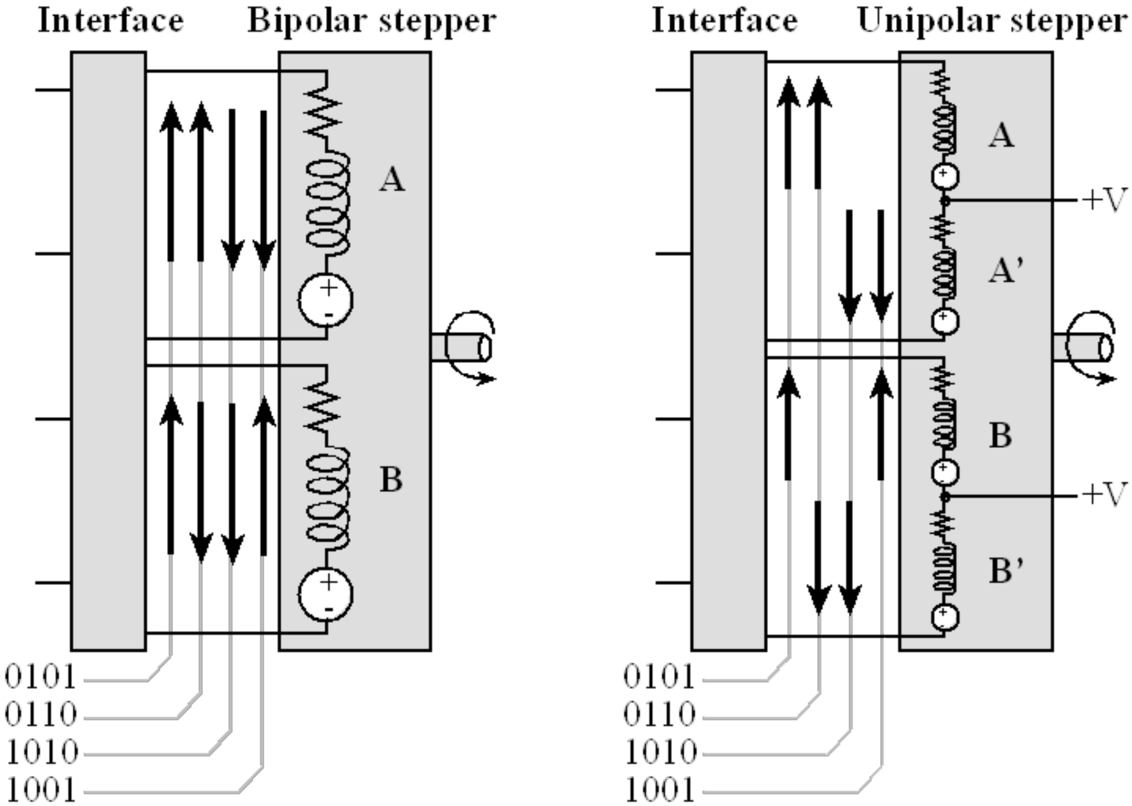
Larger motors provide more torque, but require more current. It is easy for a computer to control both the position and velocity of a stepper motor in an open-loop fashion. Although the cost of a stepper motor is typically higher than an equivalent DC permanent magnetic field motor, the overall system cost is reduced because stepper motors may not require feedback sensors. They are used in printers to move paper and print heads, tapes/disks to position read/write heads, and high-precision robots.

A bipolar stepper motor has two coils on the stator (the frame of the motor), labeled **A** and **B** in Figure 10.10. Typically, there is always current flowing through both coils. When current flows through both coils, the motor does not spin (it remains locked at that shaft angle). Stepper motors are rated in their holding torque, which is their ability to hold stationary against a rotational force (torque) when current is constantly flowing through both coils. To move a bipolar stepper, we reverse the direction of current through one (not both) of the coils, see Figure 10.10. To move it again we reverse the direction of current in the other coil. Remember, current is always flowing through both coils. Let the direction of the current be signified by up and down arrows in Figure 10.10. To make the current go up, the microcontroller outputs a binary 01 to the interface. To make the current go down, it outputs a binary 10. Since there are 2 coils, four outputs will be required (e.g., 0101_2 means up/up). To spin the motor, we output the sequence 0101_2, 0110_2, 1010_2, 1001_2… over and over. Each output causes the motor to rotate a fixed angle. To rotate the other direction, we reverse the sequence (0101_2, 1001_2, 1010_2, 0110_2…).

Help



Help

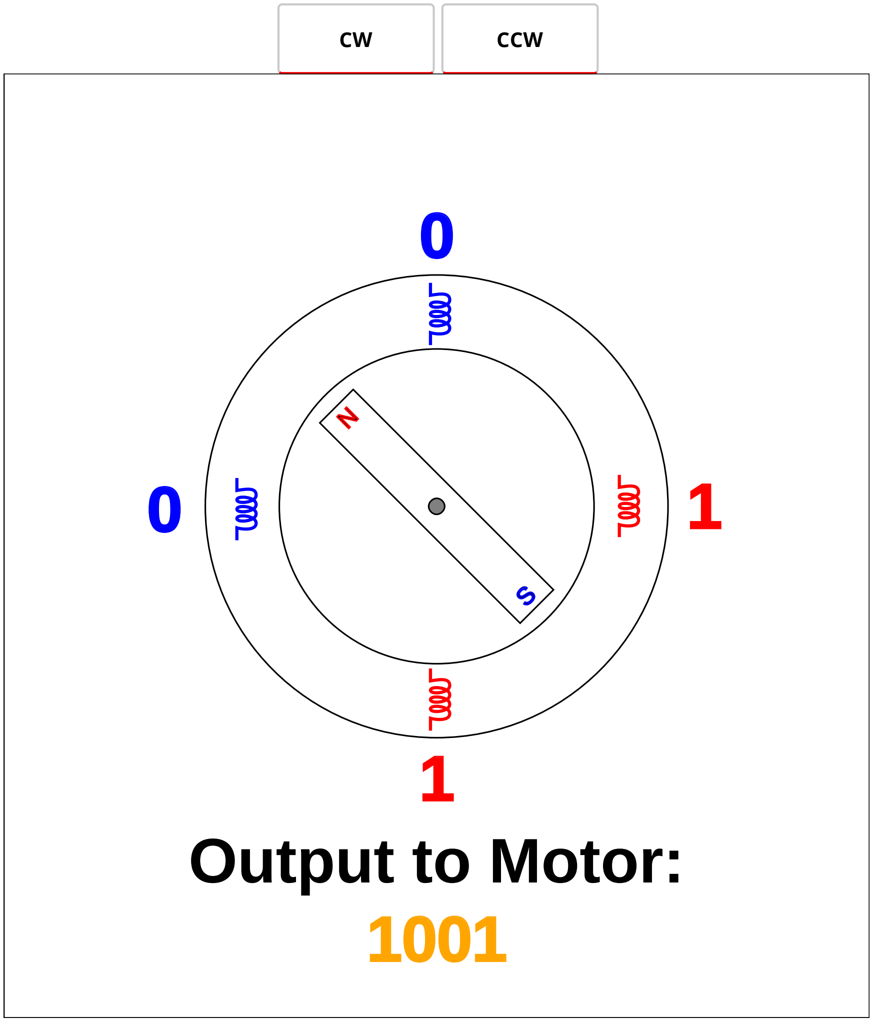
Figure 10.10. A bipolar stepper has 2 coils, but a unipolar stepper divides those two coils into four parts.

There is a North and a South permanent magnet on the rotor (the part that spins). The amount of rotation caused by each current reversal is a fixed angle depending on the number of teeth on the permanent magnets. For example, the rotor in Figure 10.11 is drawn with one North tooth and one South tooth. If there are *n* teeth on the South magnet (also *n* teeth on the North magnet), then the stepper will move at *90/n* degrees. This means there will be *4n* steps per rotation. Because moving the motor involves accelerating a mass (rotational inertia) against a load friction, after we output a value, we must wait an amount of time before we can output again. If we output too fast, the motor does not have time to respond. The speed of the motor is related to the number of steps per rotation and the time in between outputs. For information on stepper motors see the data sheets
http://users.ece.utexas.edu/~valvano/Datasheets/StepperBasic.pdf
http://users.ece.utexas.edu/~valvano/Datasheets/StepperDriveBasic.pdf
http://users.ece.utexas.edu/~valvano/Datasheets/StepperSelection.pdf
http://users.ece.utexas.edu/~valvano/Datasheets/Stepper.pdf
http://users.ece.utexas.edu/~valvano/Datasheets/Stepper_ST.pdf

Click 'CW' or 'CCW' to step the motor clockwise and counterclockwise, respectively.

Observe how different microcontroller outputs to the motor coils produce different responses from the motor.

Assume that an output value of '1' to a motor coil will cause current to flow in that motor, resulting in a 'N' oriented magnetic field at that coil.



Questions:

What is the output sequence that produces one complete counterclockwise rotation in the motor?

What is the output sequence that results in one complete clockwise rotation in the motor?

Identify two sets of output values in the sequence that will never occur one after the other.

How can you implement a stepper motor with a finite state machine? Draw the complete state graph with all transition arrows.

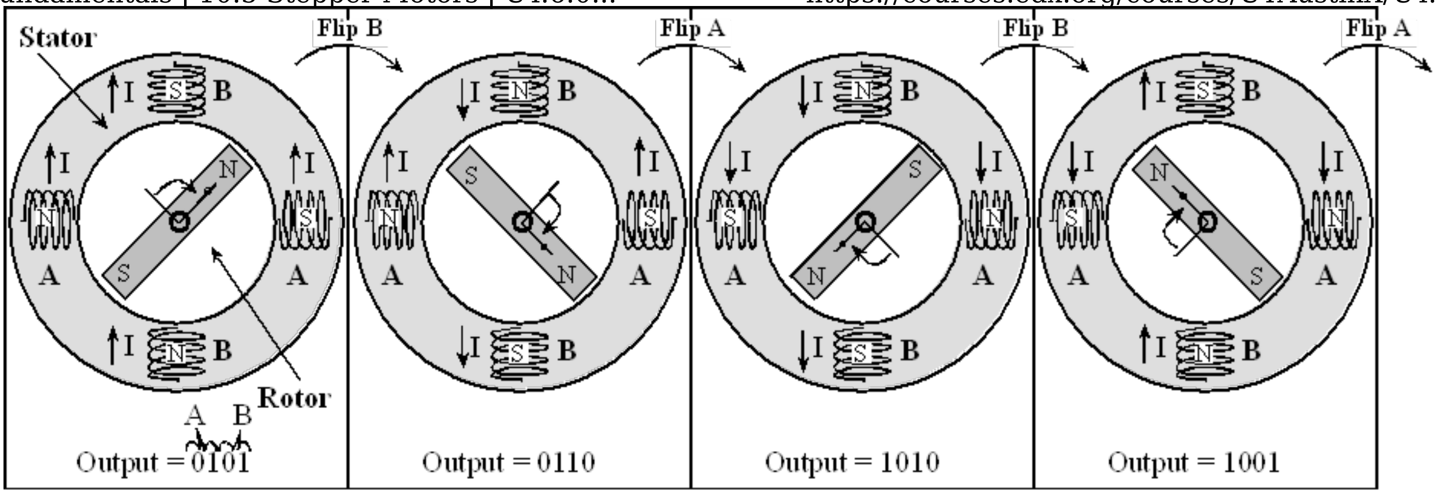


Figure 10.11. To rotate this stepper by 18°, the interface flips the direction of one of the currents.

The unipolar stepper motor provides for bi-directional currents by using a center tap, dividing each coil into two parts. In particular, coil **A** is split into coil **A** and **A'**, and coil **B** is split into coil **B** and **B'**. The center tap is connected to the +V power source and the four ends of the coils can be controlled with open collector drivers. Because only half of the electro-magnets are energized at one time, a unipolar stepper has less torque than an equivalent-sized bipolar stepper. However, unipolar steppers are easier to interface. For more information on interfacing stepper motors see Volume 2, Embedded Systems: Real-Time Interfacing to ARM® Cortex™-M Microcontrollers.

Figure 10.12 shows a circular linked graph containing the output commands to control a stepper motor. This simple FSM has no inputs, four output bits and four states. There is one state for each output pattern in the usual stepper sequence 5,6,10,9... The circular FSM is used to spin the motor is a clockwise direction.

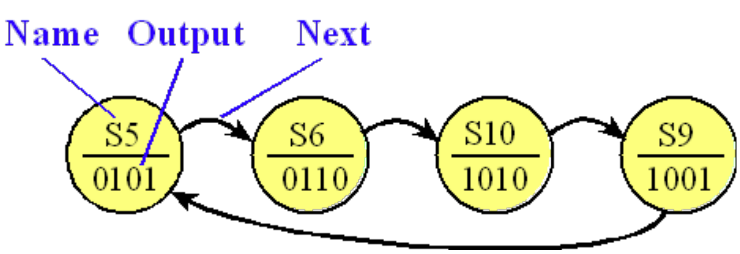


Figure 10.12. This stepper motor FSM has four states. The 4-bit outputs are given in binary.