Stepper Motor

A stepper motor is an electromechanical device which converts electrical pulses into discrete mechanical movements. The shaft or spindle of a stepper motor rotates in discrete step increments when electrical command pulses are applied to it in the proper sequence. The motors rotation has several direct relationships to these applied input pulses. The sequence of the applied pulses is directly related to the direction of motor shafts rotation. The speed of the motor shafts rotation is directly related to the frequency of the input pulses and the length of rotation is directly related to the number of input pulses applied.

Stepper Motor Advantages and Disadvantages

Advantages

1. The rotation angle of the motor is proportional to the input pulse.

2. The motor has full torque at standstill (if the windings are energized)

3. Precise positioning and repeatability of movement since good stepper motors have an accuracy of 3 – 5% of a step and this error is non-cumulative from one step to the next.

4. Excellent response to starting/ stopping/reversing.

5. Very reliable since there are no contact brushes in the motor. Therefore the life of the motor is simply dependent on the life of the bearing.

6. The motors response to digital input pulses provides open-loop control, making the motor simpler and less costly to control.

7. It is possible to achieve very low speed synchronous rotation with a load that is directly coupled to the shaft.

8. A wide range of rotational speeds can be realized as the speed is proportional to the frequency of the input pulses.

Disadvantages

1. Resonances can occur if not properly controlled.

2. Not easy to operate at extremely high speeds.

Types of stepper motor

There are three basic stepper motor types. They are:

• Variable-reluctance

• Permanent-magnet

• Hybrid

Variable-reluctance (VR)

This type of motor consists of a soft iron multi-toothed rotor and a wound stator. When the stator windings are energized with DC current the poles become magnetized. Rotation occurs when the rotor teeth are attracted to the energized stator poles.

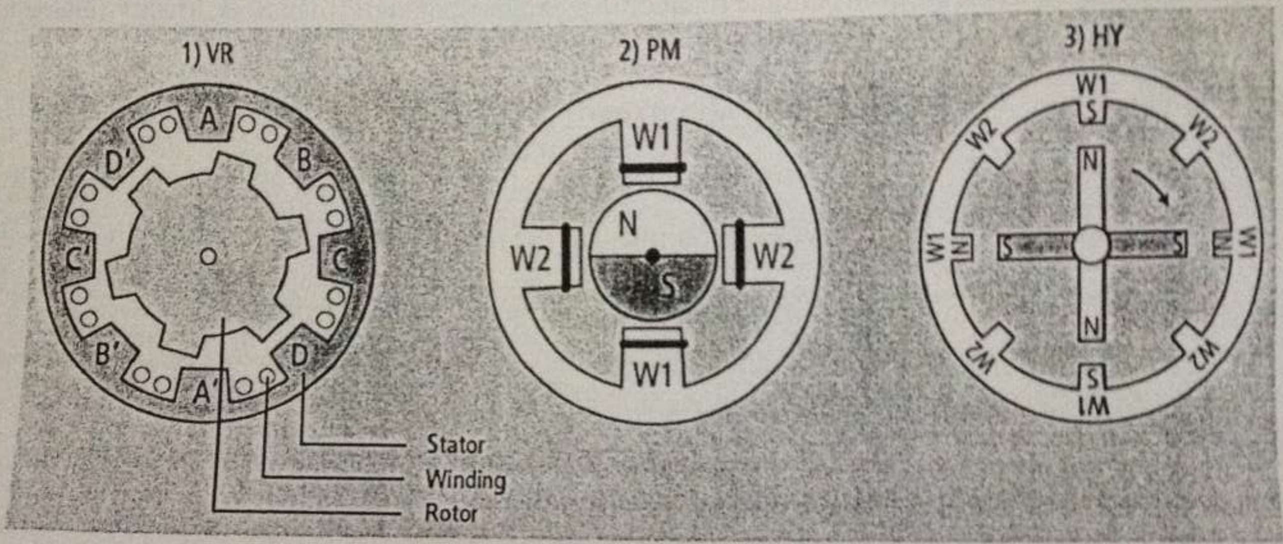


Fig. 1 **Basic stepper motor types: reluctance stepper motor, permanent magnet stepper motor, and hybrid stepper motor**

Permanent Magnet (PM)

Often referred to as a "tin can" or "canstock" motor the permanent magnet step motor is a low cost and low resolution type motor with typical step angles of 7.5° to 15°. (48 – 24 steps/revolution) PM motors as the name implies have permanent magnets added to the motor structure. The rotor no longer has teeth as with the VR motor. Instead the rotor is magnetized with alternating north and south poles situated in a straight line parallel to the rotor shaft. These magnetized rotor poles provide an increased magnetic flux intensity and because of this the PM motor exhibits improved torque characteristics when compared with the VR type.

Hybrid (HB)

The hybrid stepper motor is more expensive than the PM stepper motor but provides better performance with respect to step resolution, torque and speed. Typical step angles for the HB stepper motor range from 3.6° to 0.9° (100 – 400 steps per revolution). The hybrid stepper motor combines the best features of both the PM and VR type stepper motors. The rotor is multi-toothed like the VR motor and contains an axially magnetized concentric magnet around its shaft. The teeth on the rotor provide an even better path which helps guide the magnetic flux to preferred locations in the airgap. This further increases the detent, holding and dynamic torque characteristics of the motor when compared with both the VR and PM types.

The two most commonly used types of stepper motors are the permanent magnet and the hybrid types. If a designer is not sure which type will best fit his applications requirements he should first evaluate the PM type as it is normally several times less expensive. If not then the hybrid motor may be the right choice.

When to Use a Stepper Motor

A stepper motor can be a good choice whenever controlled movement is required. They can be used to advantage in applications where you need to control rotation angle, speed, position and synchronism. Because of the inherent advantages listed previously, stepper motors have found their place in many different applications. Some of these include printers, plotters, 3-D printer, CNC machines, high end office equipment, hard disk drives, medical equipment, fax machines, automotive and many more.

Permanent magnet step motor Operation

The principle of step motor can be understood from the basic schematic arrangement of a small permanent magnet step motor is shown in Fig.1. This type of motor is called a *two-phase two pole* permanent magnet step motor; the number of windings being two *(phase 1 and phase 2) each split* into two identical halves; the rotor is a permanent magnet with two poles. *So winding A is split* into two halves A1 and A2. They are excited by constant d.c. voltage V and the direction of current through A1 and A2 can be set by switching of four switches Q1, Q2, Q3 and Q4 as shown in Fig.2(a). For example, if Q1 and Q2 are closed, the current flows from A1 to A2, while closing of the switches Q3 and Q4 sets the direction of current from A2 to A1. Similar is the case for the halves B1 and B2 where four switches Q5-Q8 are used to control the direction of current as shown in Fig. 2(b). The directions of the currents and the corresponding polarities of the induced magnets are shown in Fig. 1.

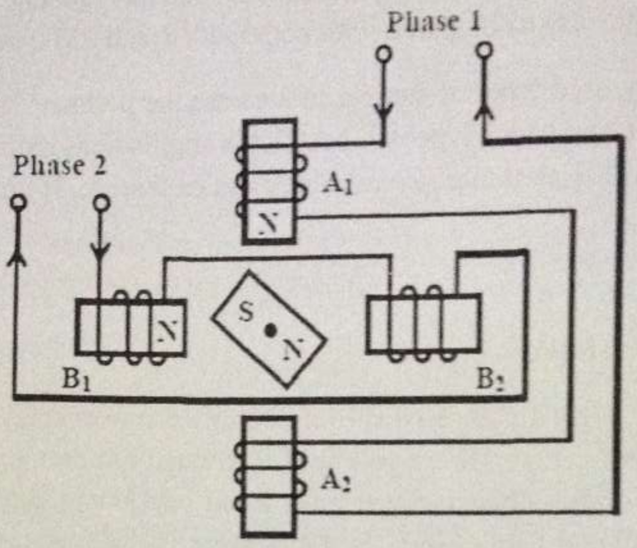


Fig. 1 Schematic diagram of a two-phase two-pole permanent magnet stepper motor.

Switching Sequence

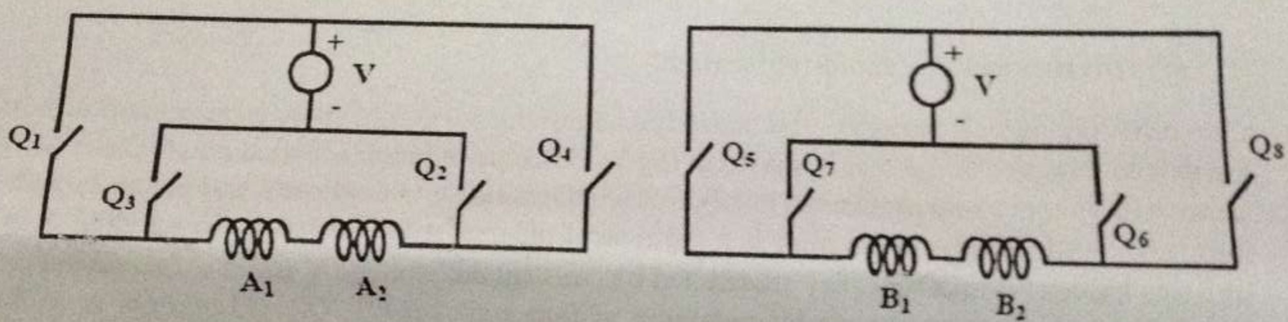


Fig. 2 Switching sequence for Fig. 1.

Now consider Fig. 3. Let Winding A be energized and the induced magnetic poles are as shown in Fig. 3(a) (we will denote the switching condition as S_1=1). The other winding B is not energized. As a result the moving permanent magnet will align itself along the axis of the stator poles as shown in Fig. 3(a). In the next step, both the windings A and B are excited simultaneously, and the polarities of the stator poles are as shown in Fig. 3(b). We shall denote S_2=1, for this switching arrangement for winding B. The rotor magnet will now rotate by an angle of 45° and align itself with the resultant magnetic field produced. In the next step, if we now make S_1=0 (thereby de-energizing winding A), the rotor will rotate further clockwise by 45° and align itself along winding B, as shown in Fig. 3(c). In this way if we keep on changing the switching sequence, the rotor will keep on rotating by 45° in each step in the clockwise direction. The switching sequences for the switches Q_1 to Q_8 for first four steps are tabulated in Table 1.

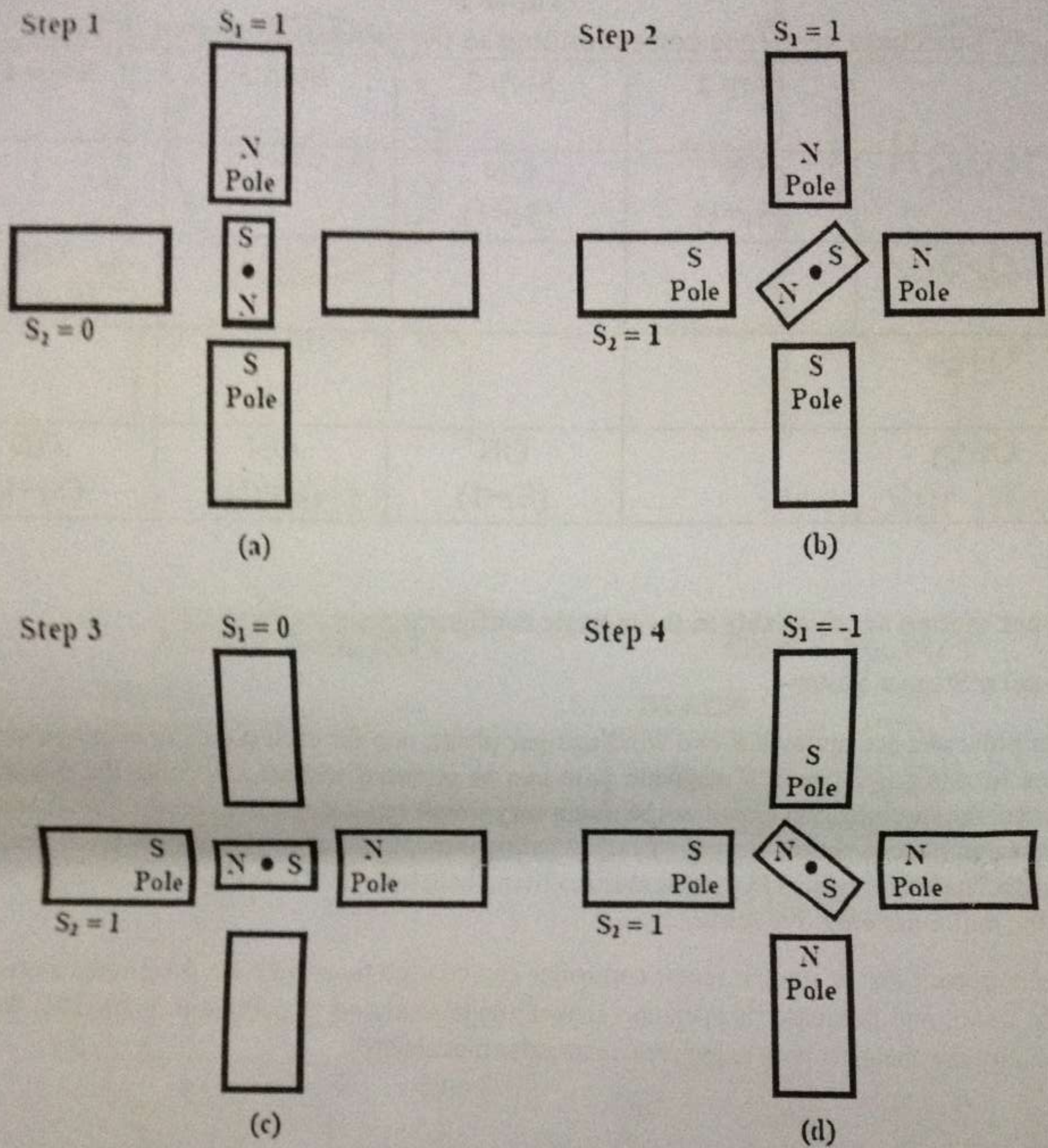


Fig. 3 Stepping sequence (half-stepping) for a two-phase two-pole PM step motor for clockwise rotation.

Table 1

Switching sequence corresponding to the movement shown in Fig.3

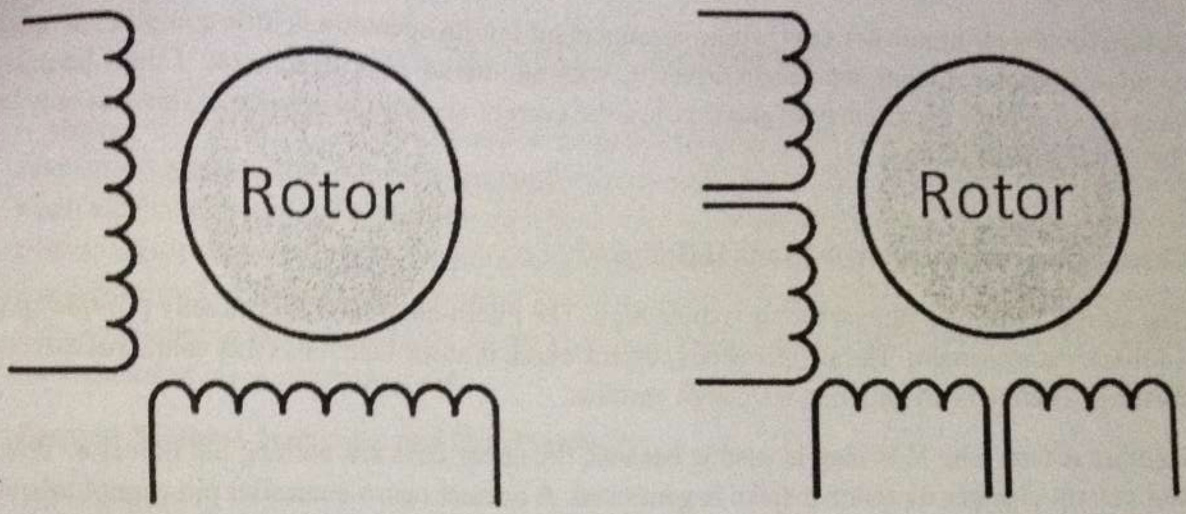
	Step 1	Step 2	Step 3	Step 4
Q_1-Q_2	ON (S_1=1)	ON (S_1=1)		
Q_3-Q_4				ON (S_1= -1)
Q_5-Q_6				
Q_7-Q_8		ON (S_2=1)	ON (S_2=1)	ON (S_2=1)

Stepper motors are available in three basic configurations:

- Uni-polar Stepper Motor-

A unipolar stepper motor has two windings per phase, one for each direction of magnetic field. Since in this arrangement a magnetic pole can be reversed without switching the direction of current, the commutation circuit can be made very simple (eg. a single transistor) for each winding. Typically, given a phase, one end of each winding is made common: giving three leads per phase and six leads for a typical two phase motor. Often, these two phase commons are internally joined, so the motor has only five leads.

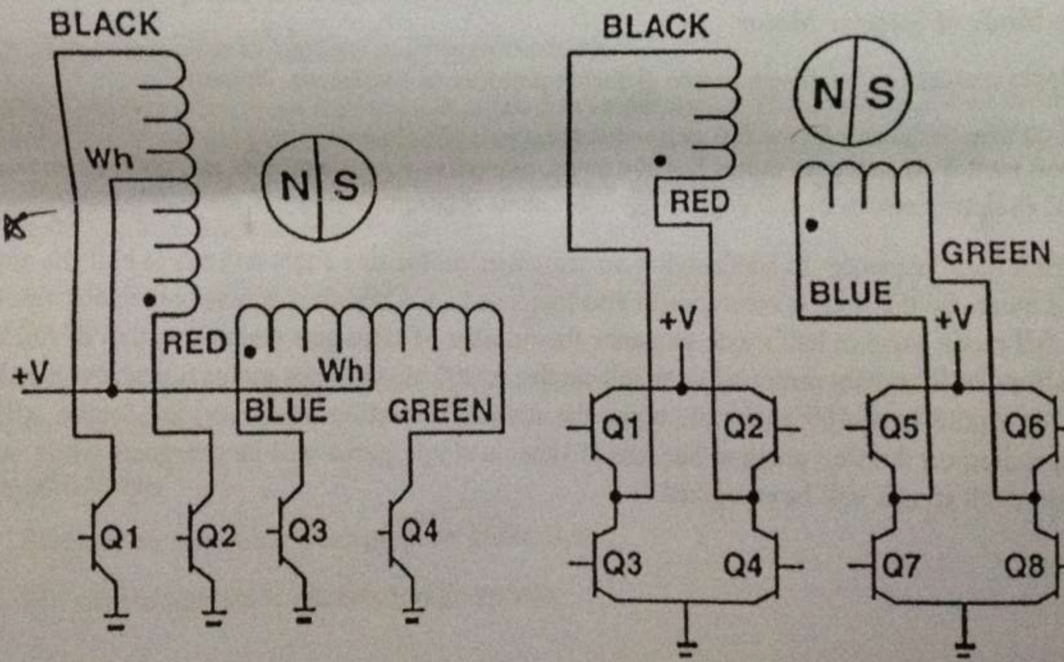
A microcontroller or stepper motor controller can be used to activate the drive transistors in the right order, and this ease of operation makes unipolar motors popular with hobbyists; they are probably the cheapest way to get precise angular movements.



Bipolar

Unipolar (8 wire)

UNIPOLAR **BIPOLAR**



Bipolar stepper Motor-

A bipolar stepper motor has one winding per stator phase. A two phase bipolar stepper motor will have 4 leads. In a bipolar stepper we don't have a common lead like in a uni-polar stepper motor. Hence, there is no natural reversal of current direction through the winding.

A bipolar stepper motor has easy wiring arrangement but its operation is little complex. In order to drive a bipolar stepper, we need a driver IC with an internal H bridge circuit. This is because, in order to reverse the polarity of stator poles, the current needs to be reversed. This can only be done through a H bridge.

There are two other reasons to use an H Bridge IC

The current draw of a stepper motor is quite high. The micro-controller pin can only provide up to 15-40 mA at maximum. The stepper needs current which is around ten times this value. An external driver IC is capable of handling such high currents.

Another reason why H Bridge is used is because the stator coils are nothing but inductor. When coil current changes direction a spike is generated. A normal micro-controller pin cannot tolerate such high spikes without damaging itself. Hence to protect micro-controller pins, H Bridge is necessary.

The most common H Bridge IC used in most Bipolar stepper interfacing projects is L293D.

Step Mode of Stepper Motor

Stepper motors can be driven in two different patterns or sequences. Namely,

- Full Step Sequence: In the full step sequence, two coils are energized at the same time and motor shaft rotates. If a stepper motor has 200 steps, one pulse equals one step. So, 200 pulses from the NC computer results in 360 degrees of motor shaft rotation.

- Half Step Sequence: In Half mode step sequence, motor step angle reduces to half the angle in full mode. So the angular resolution is also increased i.e. it becomes double the angular resolution in full mode. Also in half mode sequence the number of steps gets doubled as that of full mode. Half mode is usually preferred over full mode. A 200 step stepper motor operating in half step mode would have 400 positions, twice the normal resolution. However, the torque will vary depending on the step position because at times a single phase will be energizes while at other times both phases will be energized.