

All Motors are Stepping Motors

In 1938, General Electric began production of a two phase synchronous induction motor which, at 60 Hz, ran at 75 RPM. The low speed resulted from there being a different number of rotor to stator poles or teeth which made the motor a good bi-directional control motor. This motor was used by Superior Electric Company of Bristol, CT for running power driven autotransformers used to dim lights in auditoriums and similar applications. General Electric ceased production on this motor in the mid 1950's because sales were not high enough to support production.

Superior Electric engineers redesigned the motor to run at 72 RPM on 60 Hz and began to consider using a four step DC voltage sequence to have the motor move in increments of 1.8 degrees per step or 200 steps per revolution. Microswitches, magnetic reed switches and relays were used to demonstrate the basic operation at engineering conferences and seminars. In the early 1960's transistors made operating the stepping motor practical and applications quickly developed. The hybrid stepping motor came alive.

The principle of the stepping motor

If you create two magnetic fields of opposite polarities, they will attract each other – creating motion. If one of the magnetic fields is fixed on a shaft, you have rotary motion of some angle. Now, to continue this rotary motion, you have to create a new magnetic field at a different position.

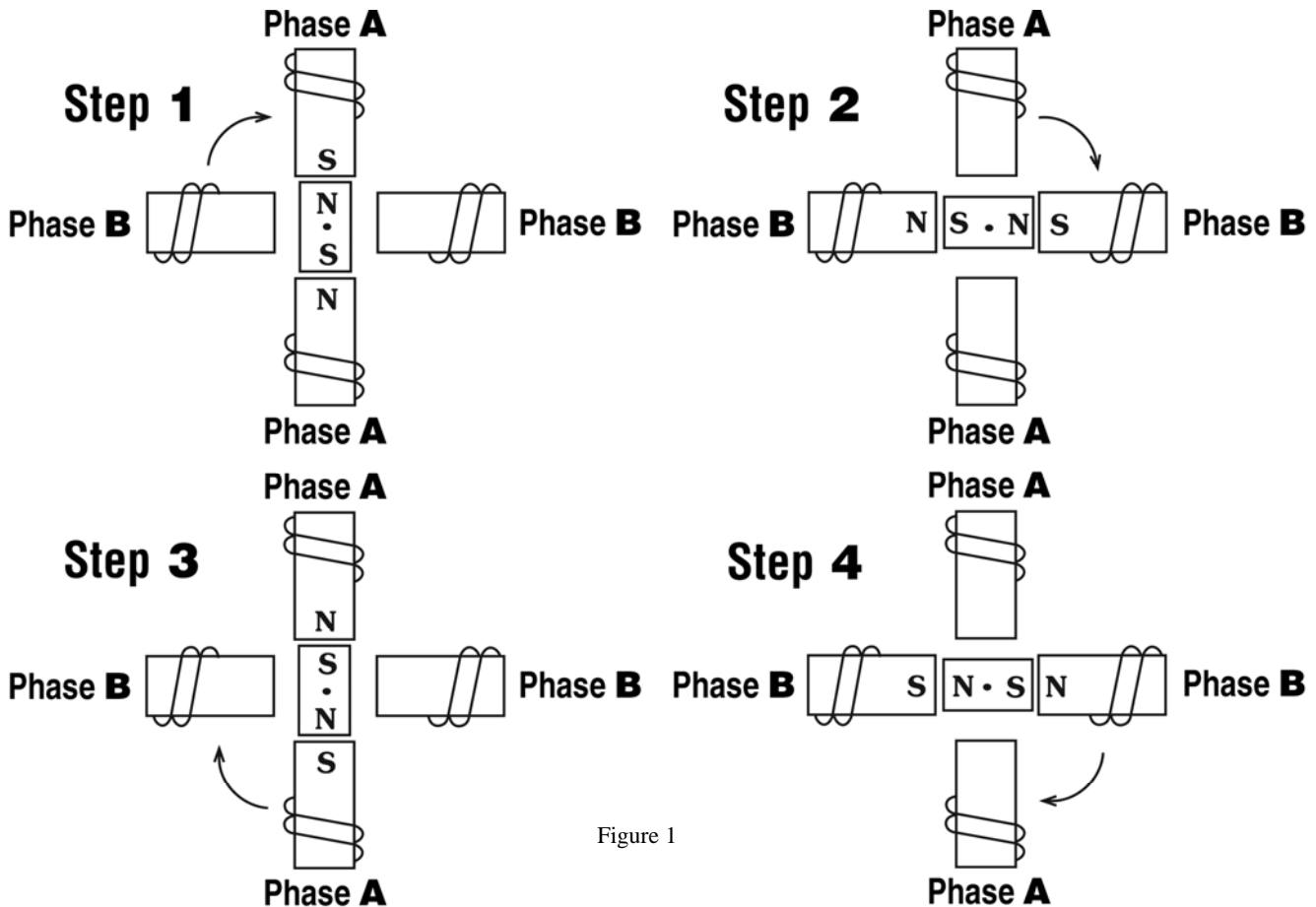


Figure 1

Figure 1 illustrates a typical step sequence for a two phase motor. In Step 1 phase A of a two phase stator is energized. This magnetically locks the rotor in the position shown, since unlike poles attract. In step 2, phase A is turned off and phase B is turned on. The rotor rotates 90° clockwise. In Step 3, phase B is turned off and phase A is turned on but with the polarity reversed from Step 1. This causes another 90° rotation. In Step 4, phase A is turned off and phase B is turned on, with polarity reversed from Step 2. Repeating this sequence causes the rotor to rotate clockwise in 90° steps. See Figure 2 for an electrical representation of the current flow in the two phases.

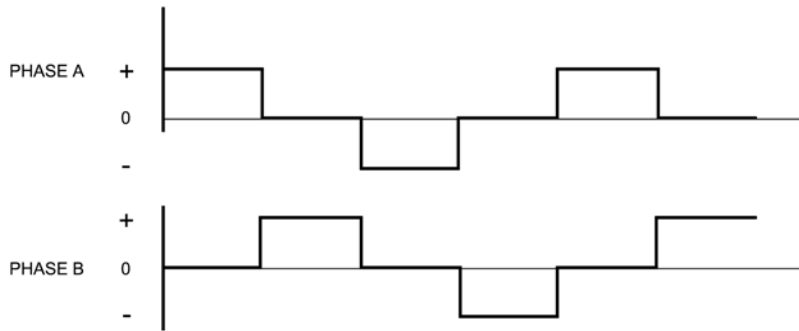


FIGURE 2

There is an electronic drive that sends the electrical pulses to the two phases at the appropriate time to create rotation. In this example, the rotation is 90 degrees per pulse or step.

In practice, the motors have more poles to create smaller step angles such as 15 degrees, 7.5 degrees or 1.8 degrees per step. The term “stepping motor” traditionally refers to a motor that runs from pulses from an electronic drive. By sending the motor a specific number of pulses, you would know the rotor position at any time. The movement created by each pulse is precise and repeatable, which is why stepper motors are so effective for positioning applications. However, all motors are really “stepping motors”. The only difference is the size of the step angle and how the switching of the pulses is created. Many AC motors can be run as “stepping motors”. The two phase alternating current 90 electrical degrees apart, creates a four step sequence

just like the electronic drive except that it is a sine wave instead of a square wave.

(See Figure 3)

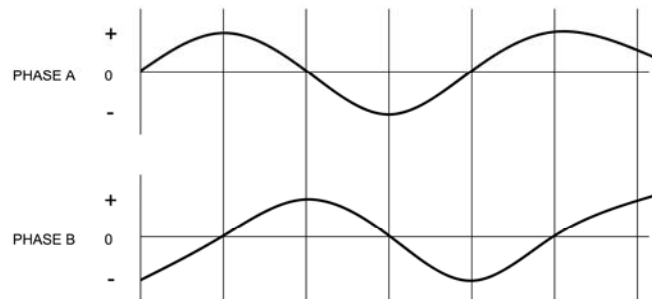


FIGURE 3

The limitation is that you are limited to only one speed, the 60 hertz of the incoming power. In this case, since the motor runs synchronously with the incoming frequency, it is now called a synchronous motor – not a stepping motor. However, it is the same motor. Nothing has changed. The motor can also be made to run on a single phase AC current. A phase shifting circuit is used to split the single phase into two phases.

Variable Reluctance Motors

A variable reluctance motor is a stepping motor that does not use a permanent magnet. A step is achieved by the principle that the rotor will rotate to minimize the reluctance path of a magnetic circuit. (See Figure 4)

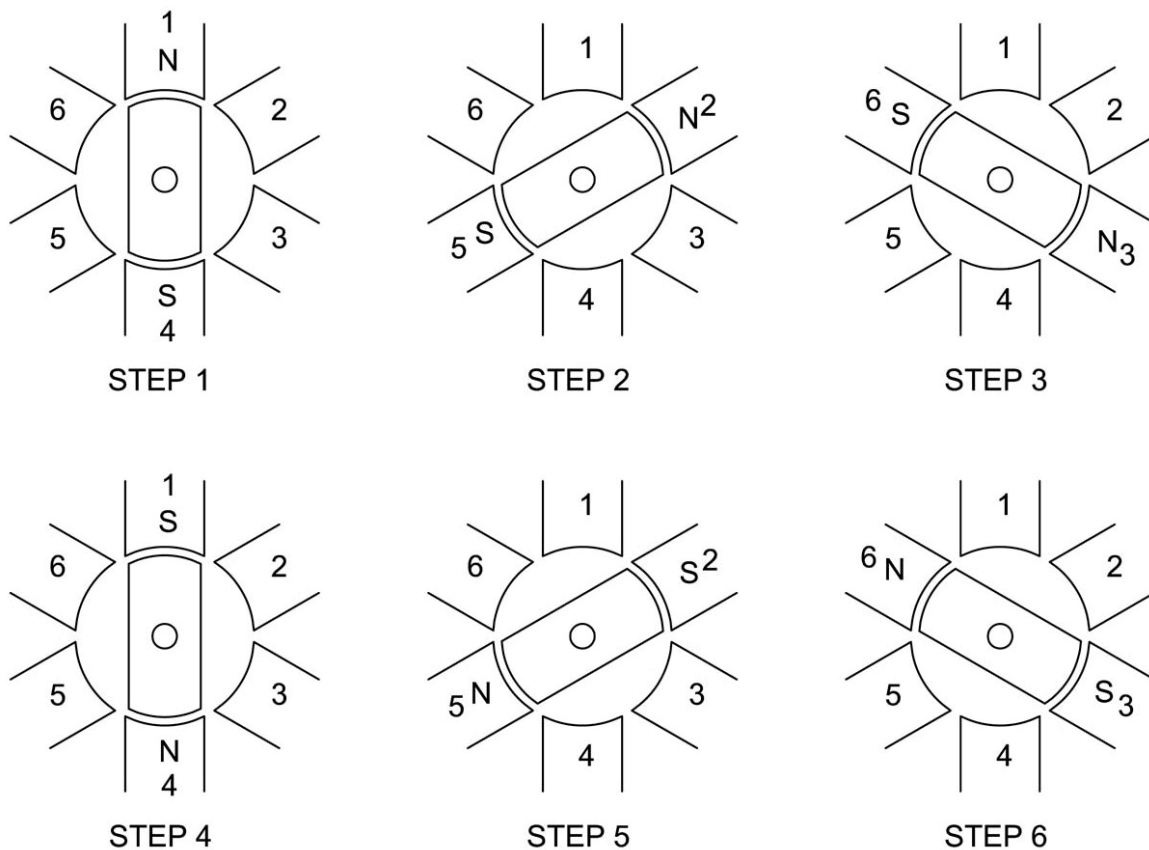


Figure 4

In the first step, pole 1 is magnetized north and pole 4 is magnetized south. In step 2, poles 2 and 5 are energized and poles 1 and 4 are turned off. The rotor rotates 60 degrees. In step 3, poles 3 and 6 are energized and so on....

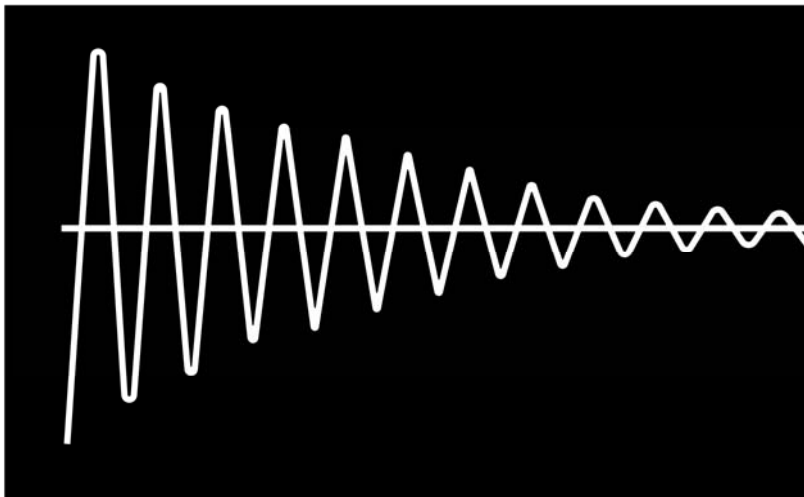


Figure 5

One of the disadvantages of a stepping motor is the ringing of the rotor when you take a single step. (See Figure 5) The rotor does not stop instantly but oscillates about its final position for several milliseconds. If a second step is introduced while the rotor is moving in a negative direction, you have a conflict and a loss of torque. In extreme cases, you can cause a resonance and the rotor will vibrate or stop.

There are ways to dampen this oscillation but this increases the price. In a brush type or brushless motor, the switching is done at exactly the right time and this problem is minimized.

Brush type DC motors have several coils wound on a rotor or armature. These coils are connected to a commutator. The commutator consists of copper segments. (See Figure 6) In this example shown, there are twelve coils so one step is $\frac{360}{12}$ or 30 degrees. The switching is done mechanically instead of electronically by means of a commutator with 24 copper segments. The coils are connected to the copper segments. Two brushes, 180 degrees apart connect to the appropriate coil which rotates the rotor 30 degrees. (See Figure 7)

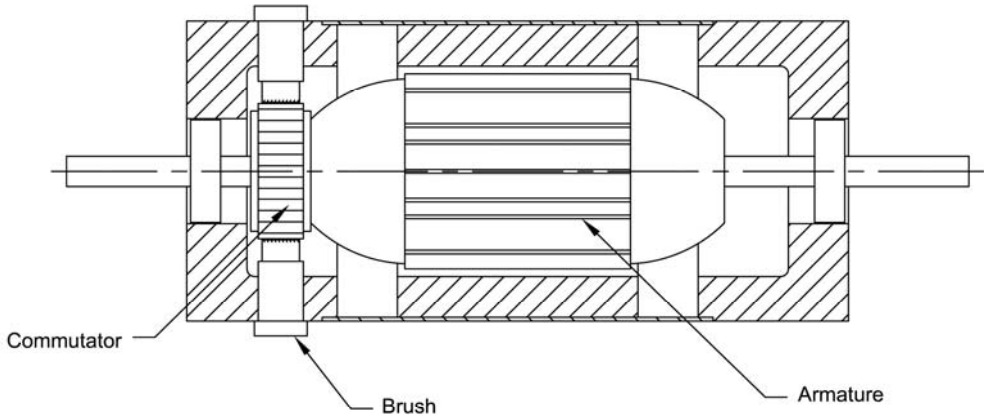


Figure 6

This rotation causes the brushes to connect to the next coil which causes another 30 degree rotation. This in effect, causes continuous rotation. This motor is called a brush type DC motor. The field can be either permanent magnets or a wound field. If it is a wound field, it is called a universal motor because it can run on alternating current or direct current.



Figure 7

Another version of this motor replaces the commutator and brushes with hall cells and a magnetic ring magnetized with many poles. (See Figure 8) The hall cell is a magnetic switch which switches on in the presence of a south magnetic field. This energizes the proper coil to take the next step.

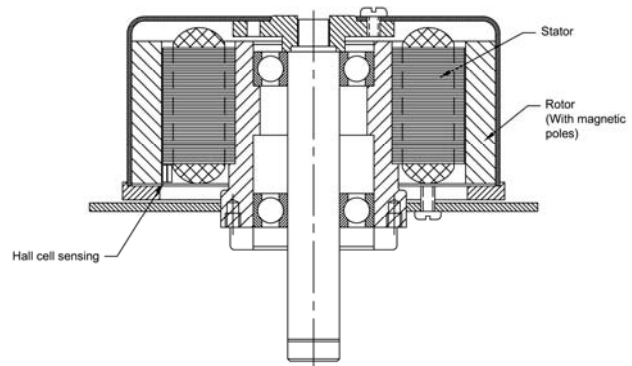


Figure 8

This is called a brushless DC motor. A photo of a brushless DC motors is shown in Figure 9 .

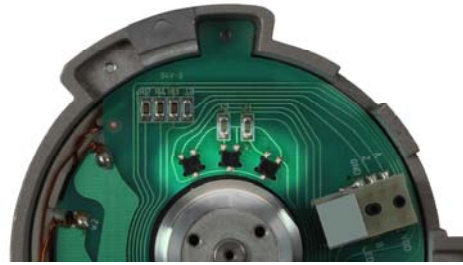


Figure 9

Induction and Squirrel Cage Motors

Induction and squirrel cage motors have but a single turn electrical conductor in the rotor. They generally use copper bars or cast aluminum. The electric current is induced into the rotor from the stator field. These are AC motors and stepping is derived from the line frequency. There are many other specialized motors. However, the end result is still the same; to obtain rotary motion, you have to create a rotating magnetic field.

Every once in a while you hear that this motor is better than another motor. There is no such thing as the “best” motor. If this were true, there would only be one motor on the market. When you have an application, you have to determine which is the best motor for that application. You would have to consider such things as cost, dependability, life and many other factors.

In summary, there are four ways to obtain steps for motors; electronic commutation, mechanical, magnetic and electrical. Hybrid, permanent magnet and variable reluctance stepping motors receive their steps from an electronic drive. The brush type DC motor receives its steps by a mechanical commutator and brushes. This assembly converts direct current into steps. The brushless DC motor uses magnetic hall cells and magnets to convert direct current into steps. AC motors such as the induction motor, squirrel cage motor, hysteresis synchronous motor and many other motors use the line frequency of 60 hertz for their steps. Each alternation of the sine wave is a step.

In the 1930's and 1940's, Haydon manufacturing Company was making clock motors and timing motors. During World War II, they were making DC motors used in aircraft, tanks, submarines and a variety of portable military equipment. In the 1960's Haydon began to make stepping motors. Today, Haydon Kerk Motion Solutions, Inc. is a recognized worldwide leader in permanent magnet and hybrid stepping motors and linear actuators. They have several patents related to stepping motors.