W09

Stepper and Brushless Motors

Stepper Motor

Definition

A Stepper Motor or a step motor is a brushless, synchronous motor which divides a full rotation into a number of steps

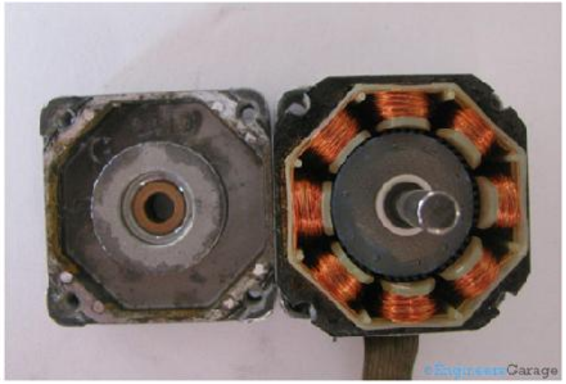
Stepper Motors are also electromechanical actuators that convert a pulsed digital input signal into a discrete (incremental) mechanical movement are used widely in industrial control applications.

As it name implies, the stepper motor does not rotate in a continuous fashion like a conventional DC motor but moves in discrete “Steps” or “Increments

The Stepper Motors therefore are manufactured with steps per revolution of 12, 24, 72, 144, 180, and 200, resulting in stepping angles of 30, 15, 5, 2.5, 2, and 1.8 degrees per step.

Structure

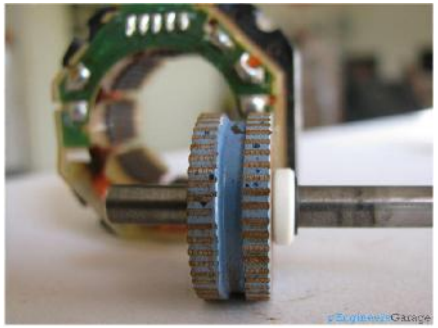
A stepper motor is a type of synchronous brushless motor in that it does not have an armature with a commutator and carbon brushes but has a rotor made up of many, some types have hundreds of permanent magnetic teeth and a stator with individual windings.



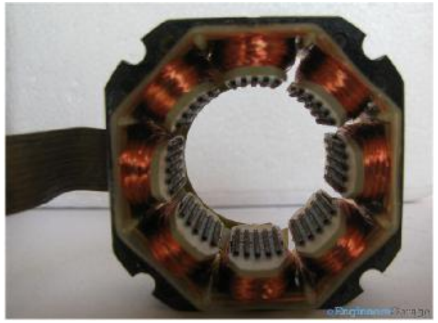
“Steps” or “Increments”, with the angle of each rotational movement or step dependent upon the number of stator poles and rotor teeth the stepper motor has.

Stepper Motor

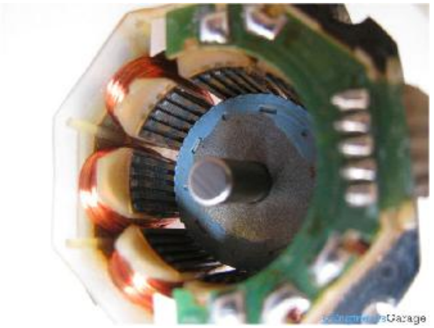
Structure



The rotor is made up of a permanent magnets core with two soft iron discs with teeth on the periphery. The number of teeth decides the step angle of the motor. The teeth on the front disk form the permanent magnetic south poles whereas the teeth on the rear disk form the permanent magnet north poles. The overall structure looks like a pair of gears stick to each other.



The stator also contains teeth which are electromagnetic in nature. Every tooth is surrounded by a coil. Depending on the polarity of the current supplied in the coil, the tooth can be made to behave like N or S poles. There are a total of eight teeth in the stator.

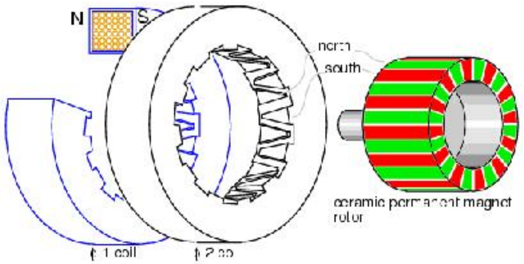


Assembled motor

There are three basic types of stepper motor, Variable Reluctance, Permanent Magnet and Hybrid (a sort of combination of both).

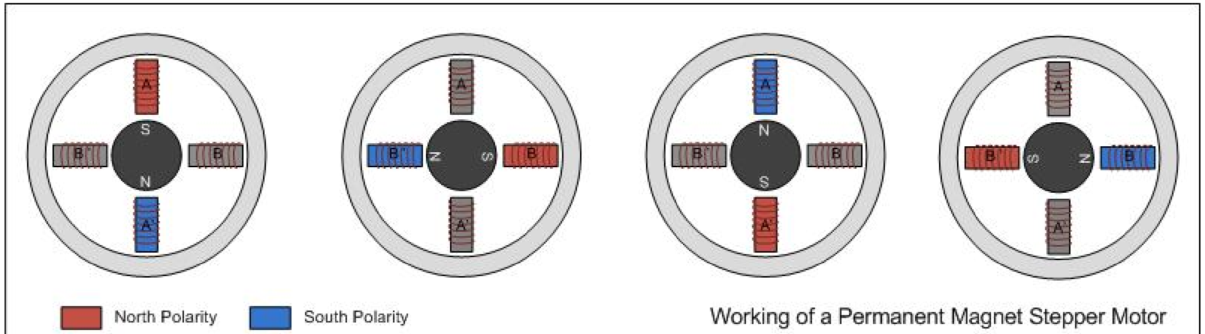
Stepper Motor

Types Permanent Magnet



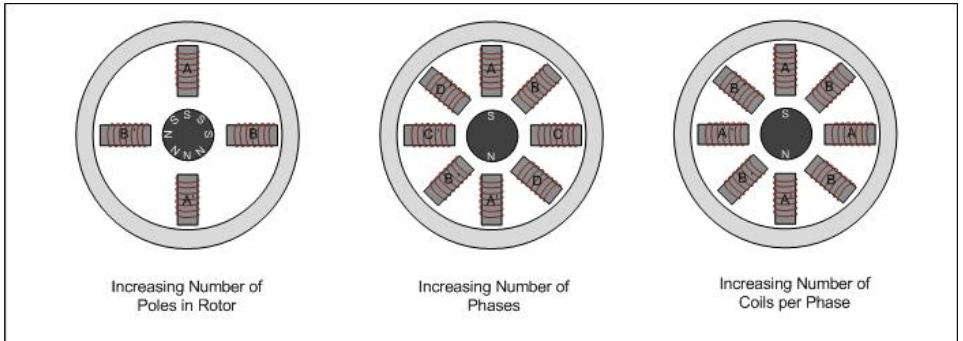
The rotor and stator poles of a permanent magnet stepper are not teethed. Instead the rotor have alternative north and south poles parallel to the axis of the rotor shaft.

When a stator is energized, it develops electromagnetic poles. The magnetic rotor aligns along the magnetic field of the stator. The other stator is then energized in the sequence so that the rotor moves and aligns itself to the new magnetic field. This way energizing the stators in a fixed sequence rotates the stepper motor by fixed angles.



Working of a Permanent Magnet Stepper Motor

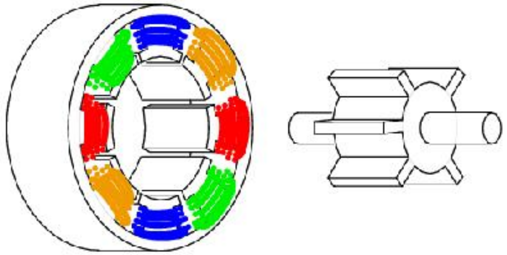
The resolution of a permanent magnet stepper can be increased by increasing number of poles in the rotor or increasing the number of phases



Methods to increase resolution of a Permanent Magnet Stepper

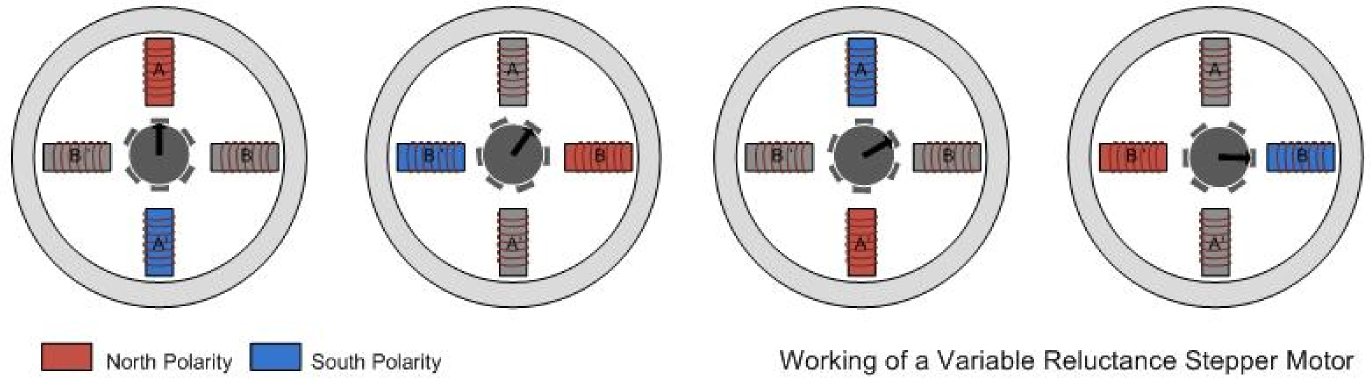
Stepper Motor

Types Variable Reluctance



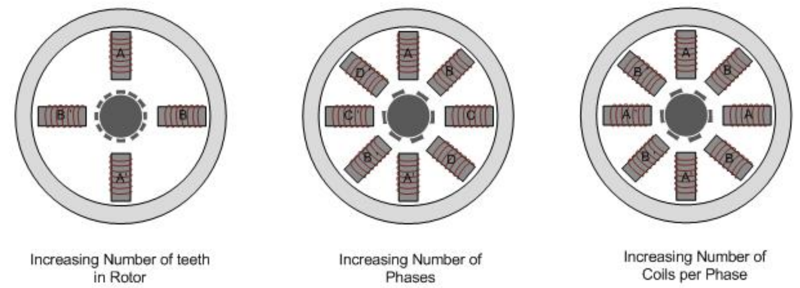
The variable reluctance stepper has a toothed non-magnetic soft iron rotor. When the stator coil is energized the rotor moves to have a minimum gap between the stator and its teeth

The teeth of the rotor are designed so that when they are aligned with one stator they get misaligned with the next stator. Now when the next stator is energized, the rotor moves to align its teeth with the next stator. This way energizing stators in a fixed sequence completes the rotation of the step motor.



Working of a Variable Reluctance Stepper Motor

The resolution of a variable reluctance stepper can be increased by increasing the number of teeth in the rotor and by increasing the number of phases.

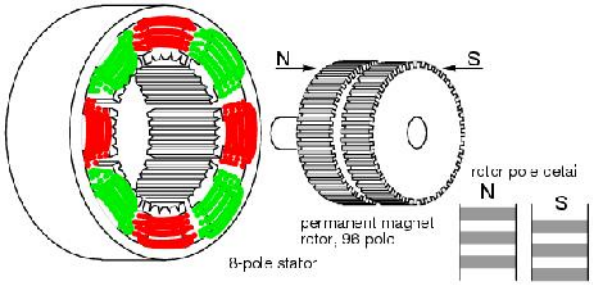


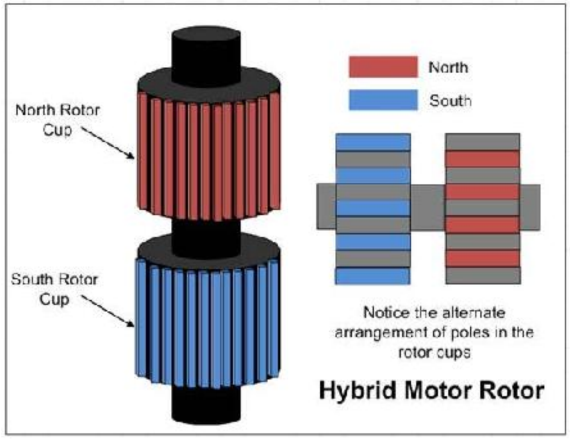
Methods to increase resolution of a Variable Reluctance Stepper

Stepper Motor

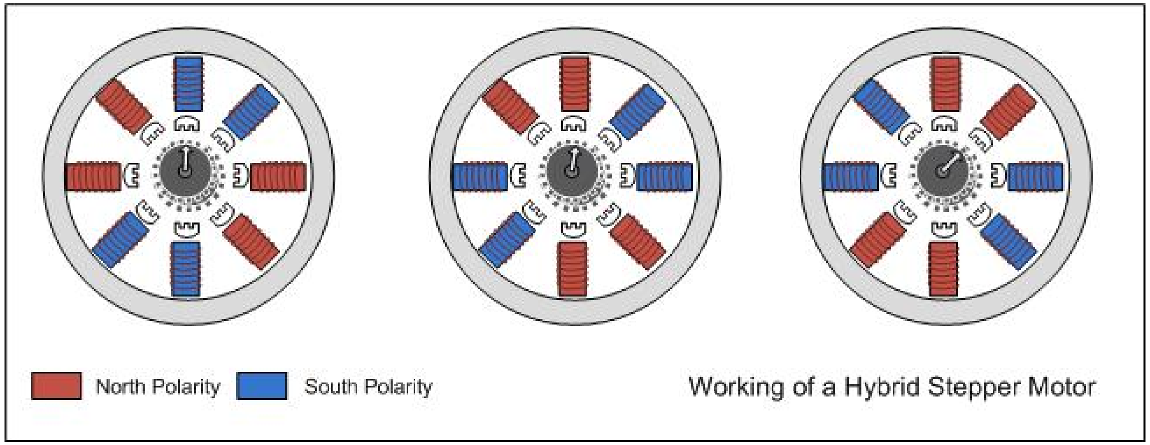
Types Hybrid

The hybrid stepper motor combines features of both the variable reluctance stepper and the permanent magnet stepper to produce a smaller step angle. The rotor is a cylindrical permanent magnet, magnetized along the axis with radial soft iron teeth. It has a magnetic teethed rotor which better guides magnetic flux to preferred location in the air gap.





Hybrid Motor Rotor

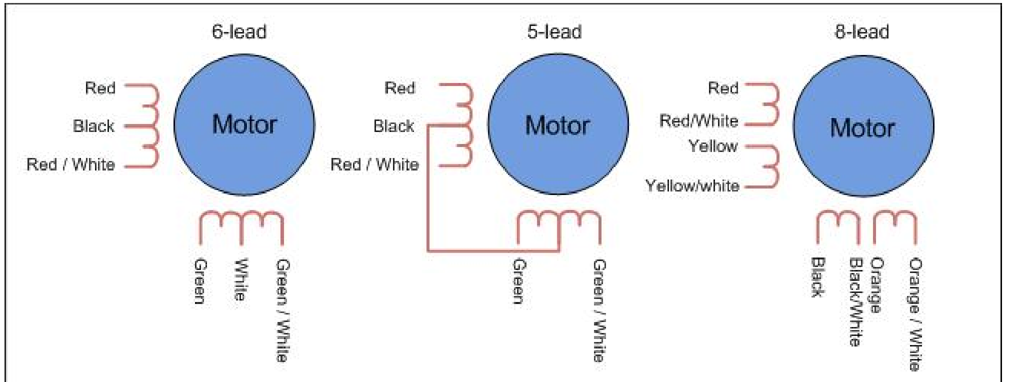


Working of a Hybrid Stepper Motor

Stepper Motor

Structure Windings

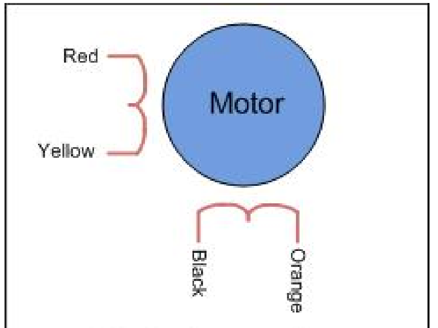
The step motors are mostly two phase motors. These can be unipolar or bipolar. In unipolar step motor there are two winding per phase.



Unipolar Stepper Motor

The unipolar motor simplifies the operation because in operating them there is no need to reverse the current in the driving circuit

In bipolar stepper there is single winding per pole. The direction of current need to be changed by the driving circuit so the driving circuit of the bipolar stepper becomes complex



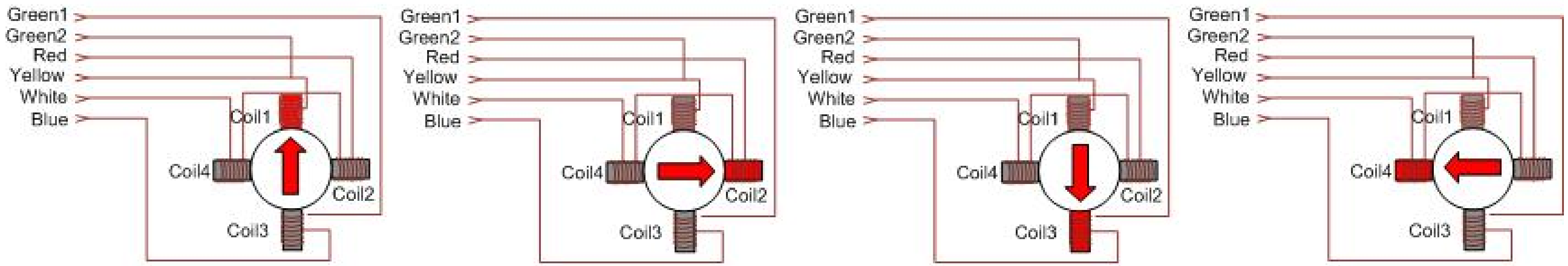
Bipolar Stepper Motor

Stepper Motor

Control

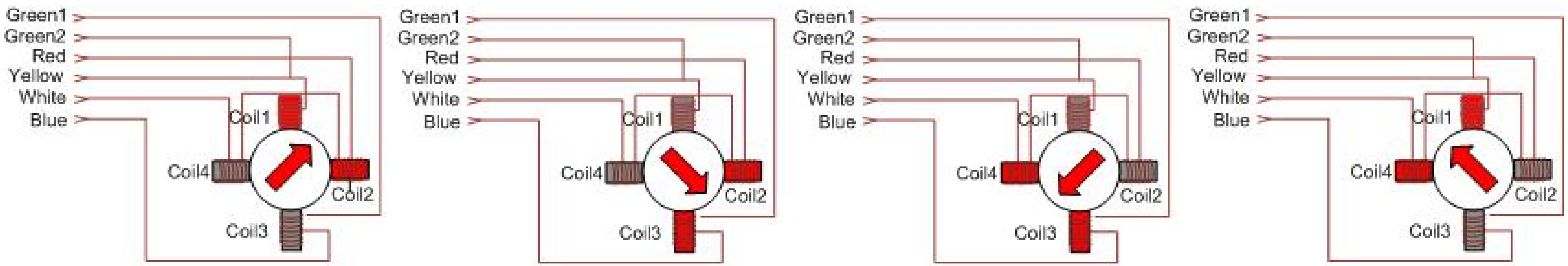
There are three stepping modes of a stepper motor. The stepping mode refers to the pattern of sequence in which stator coils are energized.

Wave Drive In wave drive stepping mode only one phase is energized at a time.



Full Drive :

In full drive, two phases are energized at a time.

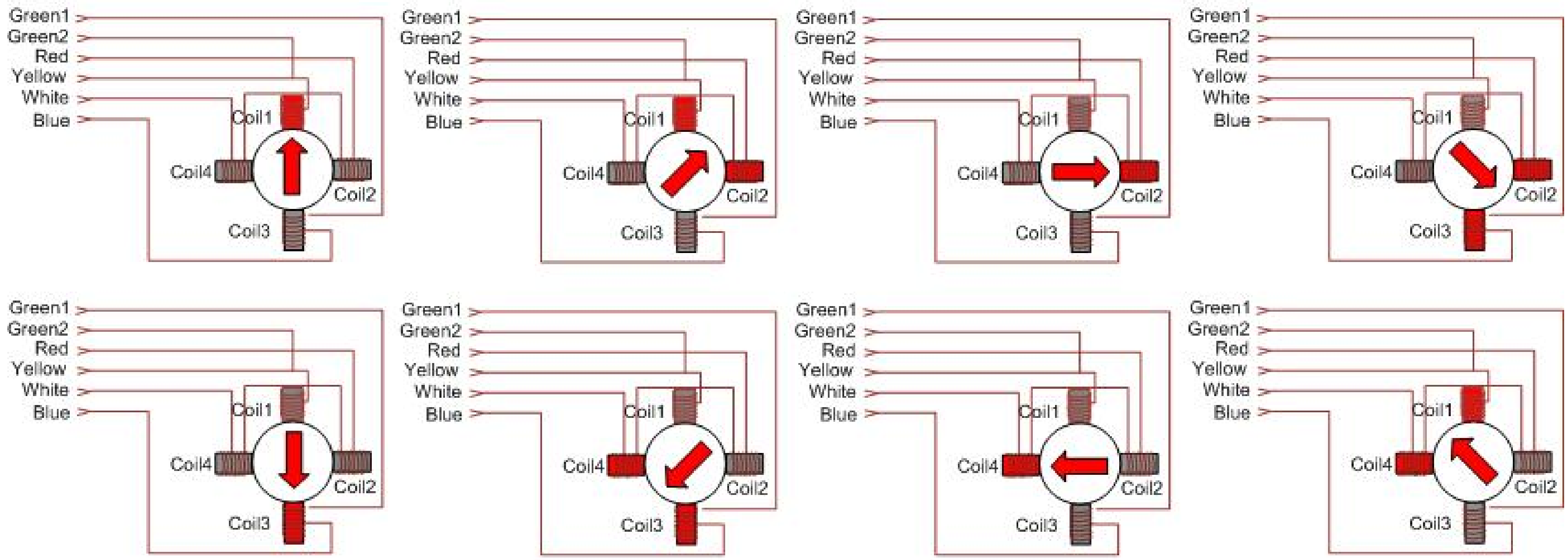


Stepper Motor

Control

Half Drive :

In half drive, alternately one and two phases are energized. This increases the resolution of the motor



Stepper Motor

Application

Pitch of lead screw

number of turns your leadscrew must travel to move a millimeter

Steps per Revolution

how many steps your stepper motor requires to move one full revolution

Resolution of movement

Effect of Frequency

Brushless DC Motor

BLDC motors have many similarities to AC induction motors and brushed DC motors in terms of construction and working principles respectively. Like all other motors, BLDC motors also have a rotor and a stator.

Stator

Similar to an Induction AC motor, the BLDC motor stator is made out of laminated steel stacked up to carry the windings.

Windings in a stator can be arranged in two patterns; i.e. a star pattern (Y) or delta pattern (Δ).

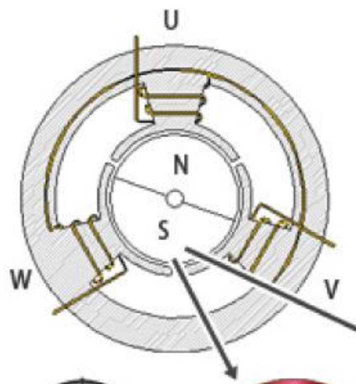
The major difference between the two patterns is that the Y pattern gives high torque at low RPM and the Δ pattern gives low torque at low RPM.

Rotor

The rotor of a typical BLDC motor is made out of permanent magnets.

Depending upon the application requirements, the number of poles in the rotor may vary. Increasing the number of poles does give better torque but at the cost of reducing the maximum possible speed.

Another rotor parameter that impacts the maximum torque is the material used for the construction of permanent magnet; the higher the flux density of the material, the higher the torque.



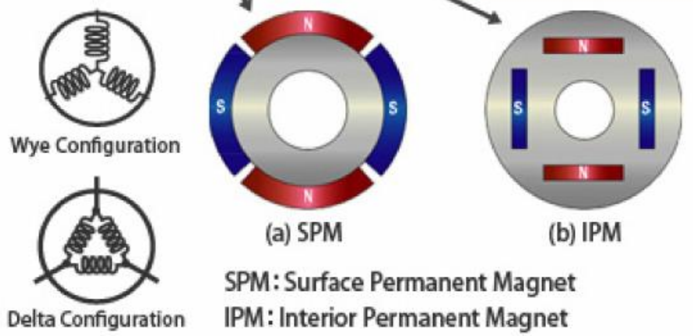
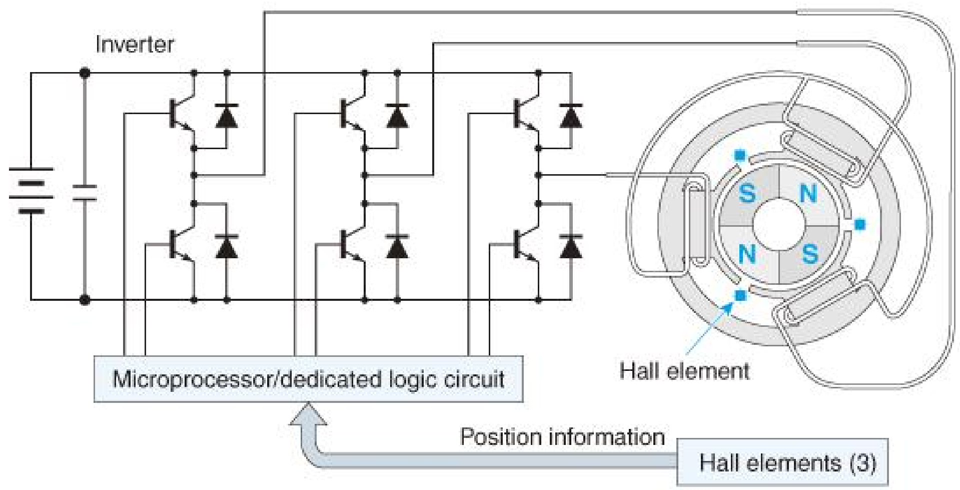


Figure 3: 4 pole and 8 pole – Permanent magnet rotor

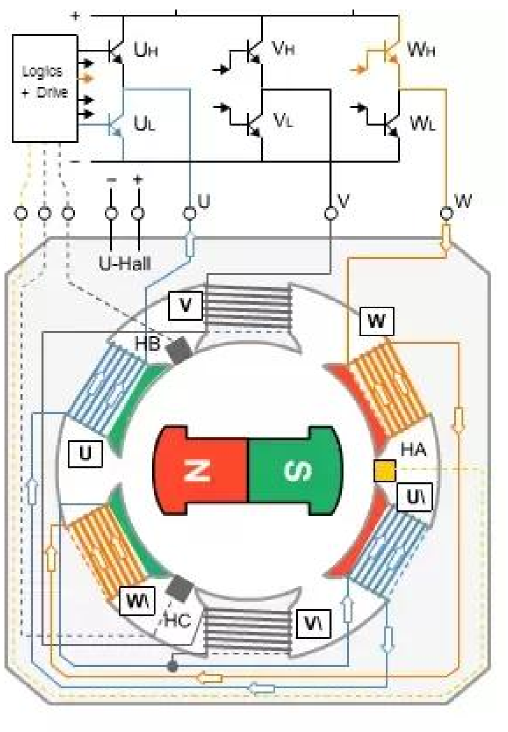
Brushless DC Motor

Structure and operating principle of a brushless DC motor.
Stationary electromagnets are built into the stator, while the rotor contains surface permanent magnets.
Current must be fed to the coils of the electromagnets in the correct directional sequence and timing in order to properly energize them to produce shaft rotation.
An inverter is necessary to change supplied DC power or 50/60-cycle AC into AC power with the requisite voltage and frequency.
To run a brushless DC motor, the AC current from an inverter flows to the electromagnets in the stator. That current generates a rotating magnetic field in the stationary electromagnets that interacts with the permanent magnets in the rotor, causing the rotor to turn.

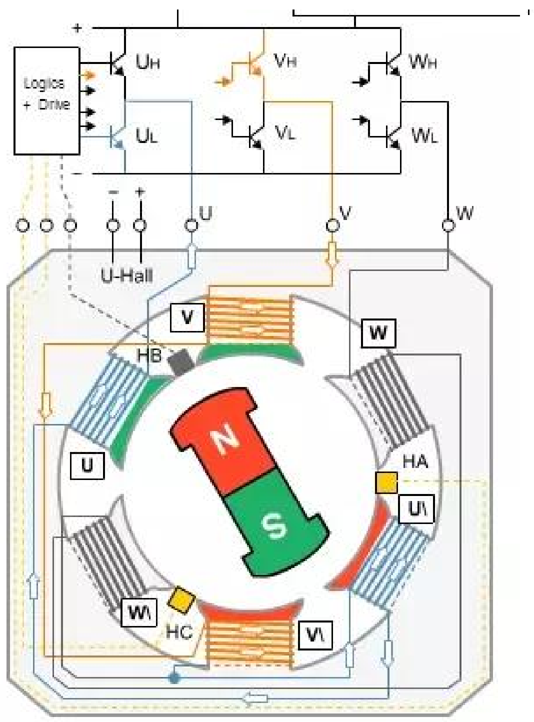
The underlying principles for the working of a BLDC motor are the same as for a brushed DC motor; i.e., internal shaft position feedback.
In case of a brushed DC motor, feedback is implemented using a mechanical commutator and brushes.
With a in BLDC motor, it is achieved using multiple feedback sensors. The most commonly used sensors are hall sensors and optical encoders.



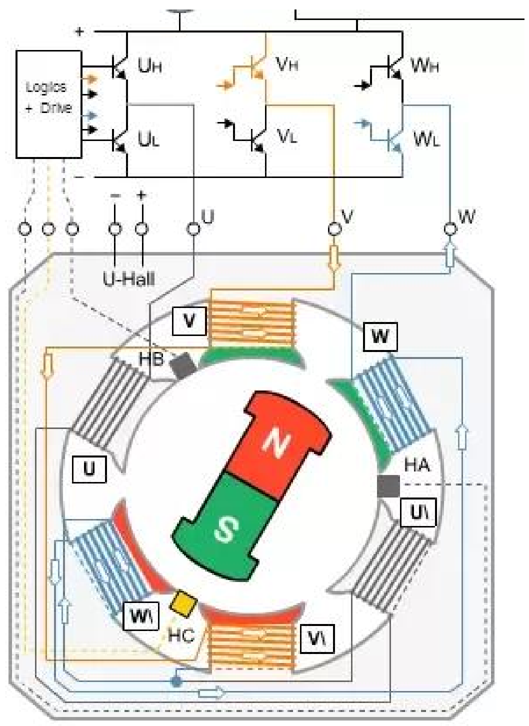
Brushless DC Motor



Assume rotor position as in above image. Since the North(Red) of the rotor and south(Green) of the stator (also vice versa) interacts it will attract and stay in this position



when the south of the stator is rotated the magnet north pole is aligned along with stator south.



Repeating the process of rotating stator pole, we can make the rotor to rotate.

https://en.nanotec.com/support/tutorials/stepper-motor-and-bldc-motors-animation/