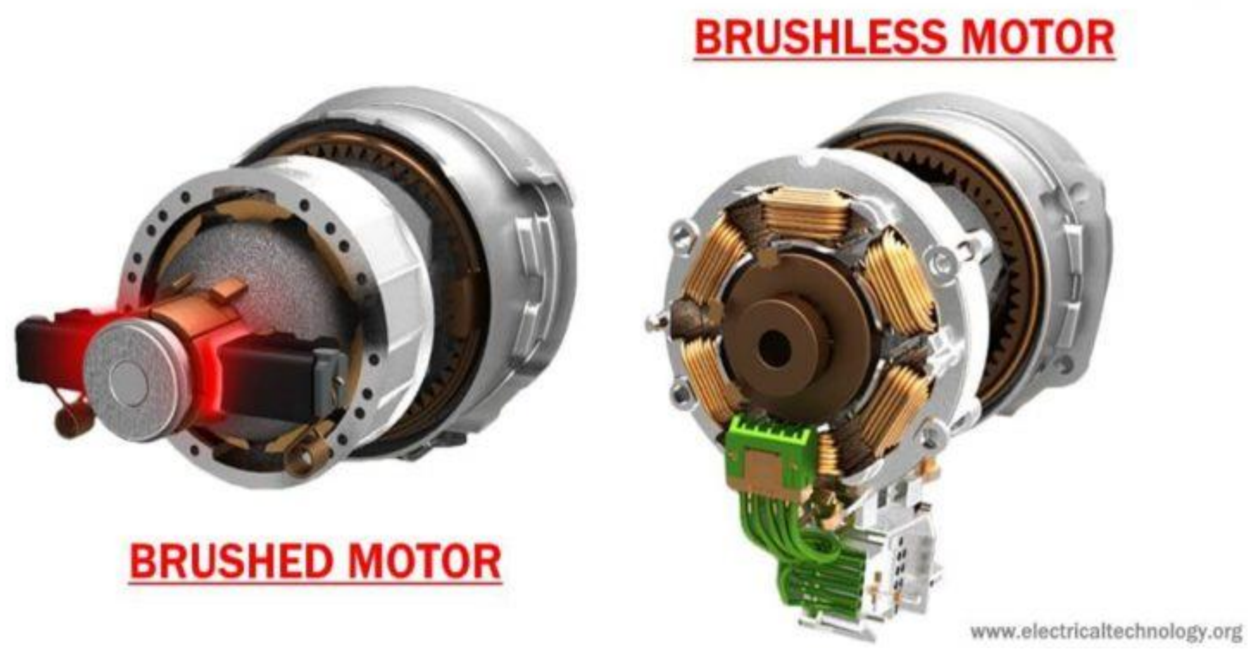
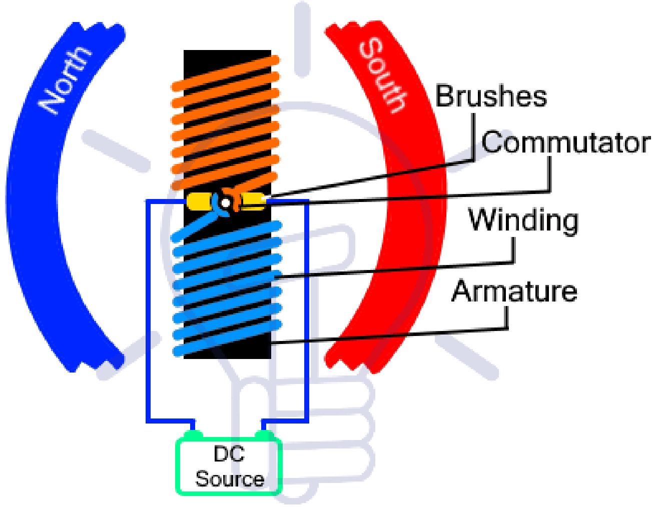
Brushless DC Motor

Difference Between Brushed & Brushless Motor





Brushed Motor

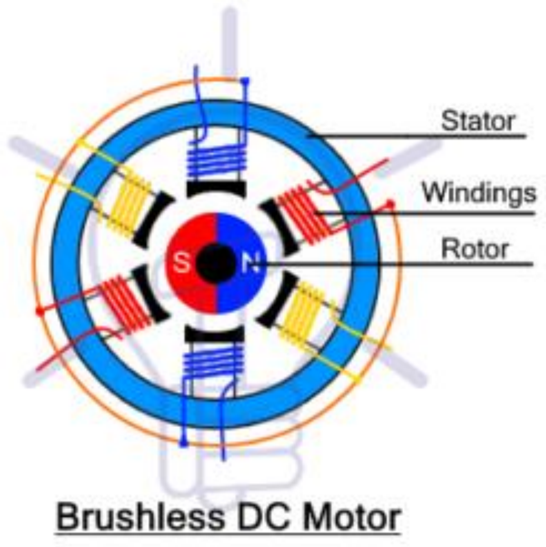
Brushed Motor

The brushed motors are the earliest motor in the history. It uses carbon brushes mechanism to supply power to the rotating part of the machine called rotor. While the stator which is made of permanent magnet surrounds the rotor.

The carbon brushes when slides across the commutator, it breaks and makes the contact with the armature windings (inductive load) that results in generating electromagnetic noise in the system.

The brushed motors are very noisy. That is why the industries having very extreme environment where noise is not an issue often uses brushed motors due to its cheaper cost. It saves a great deal of equipment cost.

Brushless Motor

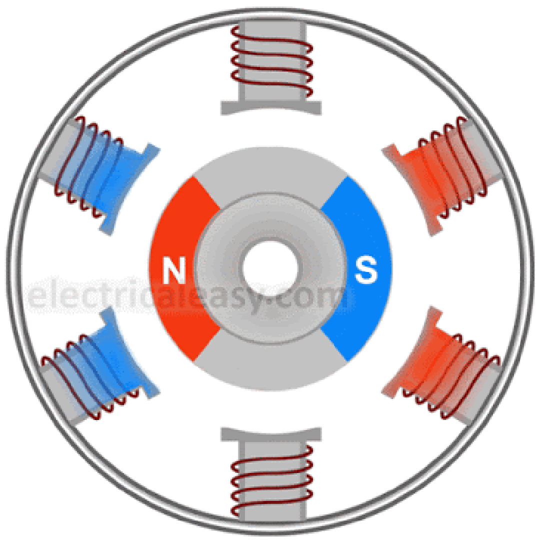


The brushless motor (also known as BLDC Motor) as its name suggests, does not have brushes and it does not require it to operate.
Since there are no brushes, the input power is supplied to the stator of the motor which in this case is made of multiple windings that surrounds the rotor. While the rotor is made of permanent magnet.

The input is switched between the stators winding to generate magnetic field that push and pull on the rotor's magnetic field causing it rotate in its direction. A hall effect sensor is used to detect the position of the rotor and switch the input to the correct stators winding respectively.
Since the DC input to the stator needs to be switched, such motors used electronic commutations instead of mechanical commutation using switching devices such as thyristors. These switches are controlled using microcontroller to precisely switch the input between the stators windings. It essentially switches the DC input into a 3-phase supply which generates a smooth rotating magnetic field.
The controller used for brushless motor is more sophisticated and very expensive. It does not operate without its controller which also offers the precise speed control and positioning of the rotor. But the cost of the controller is far more greater then the motor itself.
Since there are no brushes, there are no electrical or electromagnetic noises and the sparks generated in mechanical commutation. It helps in increasing the life span of the motor as well as the efficiency of the motor.

A type of motor that requires carbon brushed to supply the input power to the armature windings.	Such motors that do not require carbon brushes to supply the input power to the armature windings.
The input power is supplied to the rotor of the motor.	The input power is supplied to the stator of the motor.
The stator contains permanent magnet.	The stator contains armature windings that generates magnetic field upon input supply.
The rotor contains armature winding.	The rotor is made of permanent magnet.
The input is switched using mechanical commutations through slip ring commentators.	The input is switches using electronic commutations though semiconductor switches.
The brushes wear out due to friction which decreases its life span.	There are no sliding brushes, thus it has very long life span.
The brushes need frequent maintenance for continuous operation.	It does not require such scheduled maintenance.
The brush making and breaking contacts with the windings generates electromagnetic noise.	The input is continuously supplied to the stator winding thus there is no electromagnetic noise.
The continuous sliding of brushes with the commutator generates heat.	There is no overheating problem due to friction.
The brushed motor has a speed limitation because of the overheating at high speed due to friction.	There are no mechanical commutators thus there is no speed limitation.
It does not offer position control.	It provide precise positioning using its sophisticated controller.
Increasing the speed over certain range decrease the torque significantly.	It offer great deal of torque at various high ranges of speed.
Their efficiency is lower as compared to brushless motor due to the energy lost in mechanical commutation.	Its efficiency is comparatively higher due to absence of brushes.
They have comparatively larger size for the same ratings of motor.	They have relatively smaller size.
It has very simple design and construction including only a single winding.	The motor design is complex where the stator contains multiple separate windings.
The overall cost is cheaper than brushless motor.	Brushless motors are quite expensive.
The speed control equipment used in very simple and cheaper.	The controller used for speed control is very expensive.
For fixed speed applications, it does not require any controller.	It requires the controller to operate in any condition.
It requires very few or no external components.	It require very expensive and several external components to function properly.
They are best suited for extreme noisy environment such as in industries to compensate for cost investment.	They are best suited for smooth and noiseless application.

Working Principle



Brushless dc motors are essentially permanent-magnet stepping motors equipped with position sensors (either Hall effect or optical) and enhanced control units. As in the stepper motor, power is applied to one stator winding at a time.

When the position sensor indicates that the rotor has approached alignment with the stator field, the controller electronically switches power to the next stator winding so that smooth motion continues. By varying the amplitude and duration of the pulses applied to the stator windings, speed can be readily controlled. The result is a motor that can operate from a dc source with characteristics similar to those of a conventional shunt dc motor.

Brushless DC motors (BLDC) are used for a wide variety of application requirements such as varying loads, constant loads and positioning applications in the fields of industrial control, automotive, aviation, automation systems, health care equipments, etc. Some specific applications of BLDC motors are :

- Computer hard drives and DVD/CD players
- Electric vehicles, hybrid vehicles, and electric bicycles
- Industrial robots, CNC machine tools, and simple belt driven systems
- Washing machines, compressors and dryers
- Fans, pumps and blowers.

Stepper Motor Basics

The basic operation of a stepper motor allows the shaft to move a precise number of degrees each time a pulse of electricity is sent to the motor. Since the shaft of the motor moves only the number of degrees that it was designed for when each pulse is delivered, you can control the pulses that are sent and control the positioning and speed.

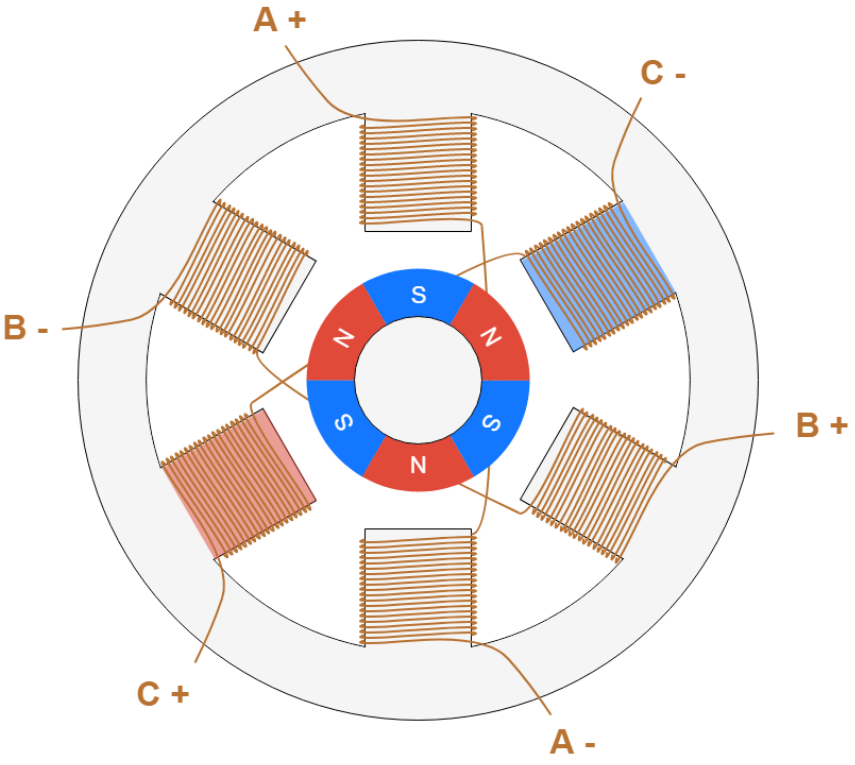
The stepper motor uses the theory of operation for magnets to make the motor shaft turn a precise distance when a pulse of electricity is provided.

Stepper motors have a stationary part (the stator) and a moving part (the rotor). On the stator, there are teeth on which coils are wired, while the rotor is either a permanent magnet or a variable reluctance iron core.

The rotor will require 24 pulses of electricity to move the 24 steps to make one complete revolution. Another way to say this is that the rotor will move precisely 15° for each pulse of electricity that the motor receives. The number of degrees the rotor will turn when a pulse of electricity is delivered to the motor can be calculated by dividing the number of degrees in one revolution of the shaft (360°) by the number of poles (north and south) in the rotor. In this stepper motor 360° is divided by 24 to get 15°.

Types of Stepper motor

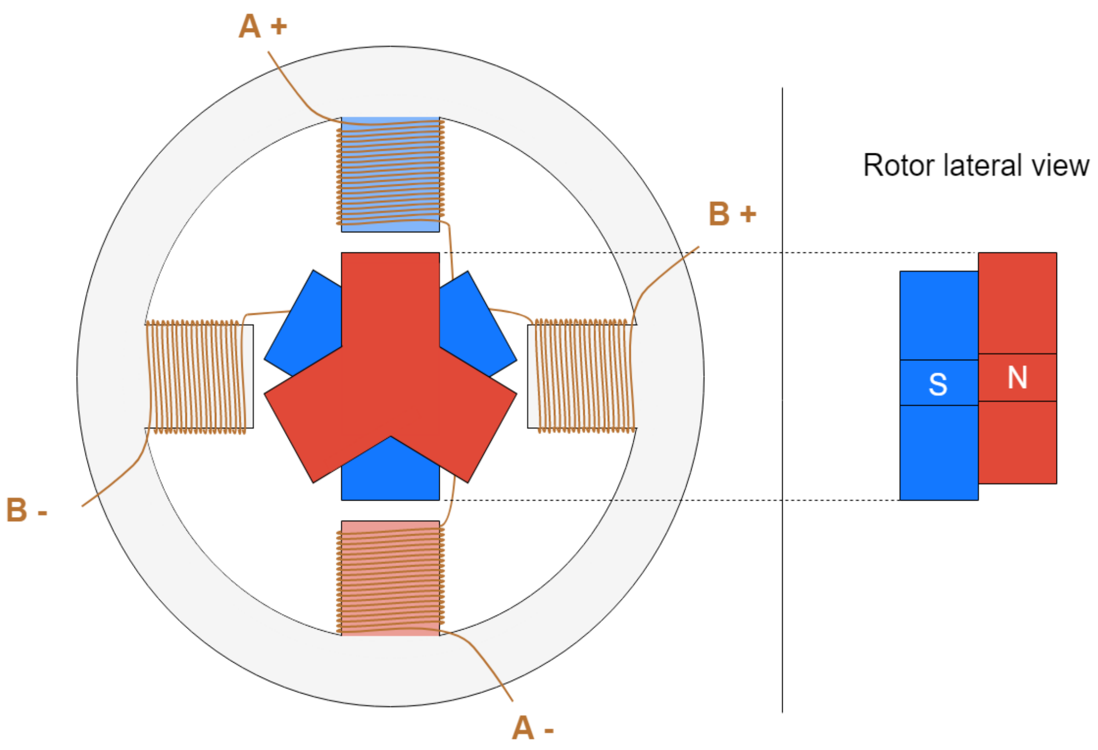
One feature of stepper motors that differentiates them from other motor types is that they exhibit holding torque. This means that when the windings are energized but the rotor is stationary, the motor can hold the load in place. But a stepper motor can also hold a load in place when there is no current applied to the windings (for example, in a power-off condition). This is commonly known as the detent torque or residual torque.



Of the three types of stepper motors — variable reluctance, permanent magnet, and hybrid — only variable reluctance motors do not exhibit detent torque. This is due to the difference in construction between variable reluctance motors versus permanent magnet and hybrid designs. Both permanent magnet and hybrid stepper motors use a permanent magnet rotor, which is attracted to the poles of the stator even when there is no power to the stator windings. Variable reluctance motors, on the other hand, use a passive (non-magnetized) rotor made of soft iron; therefore, there is no attraction between the rotor and the stator when the stator windings are not energized.

The drawbacks of the permanent magnet SM is that it has a lower speed and a lower resolution compared to the other types. **Figure** shows a representation of a section of a permanent magnet stepper motor.

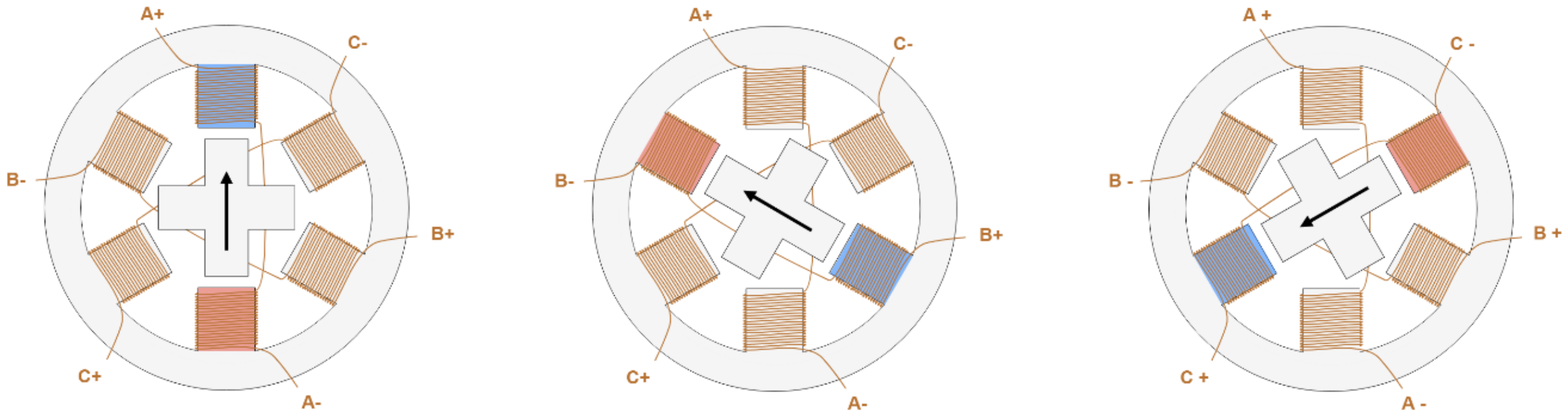
This kind of rotor has a specific construction, and is a hybrid between permanent magnet and variable reluctance versions. The rotor has two caps with alternating teeth, and is magnetized axially. This configuration allows the motor to have the advantages of both the permanent magnet and variable reluctance versions, specifically high resolution, speed, and torque. This higher performance requires a more complex construction, and therefore a higher cost. **Figure** shows a simplified example of the structure of this motor.

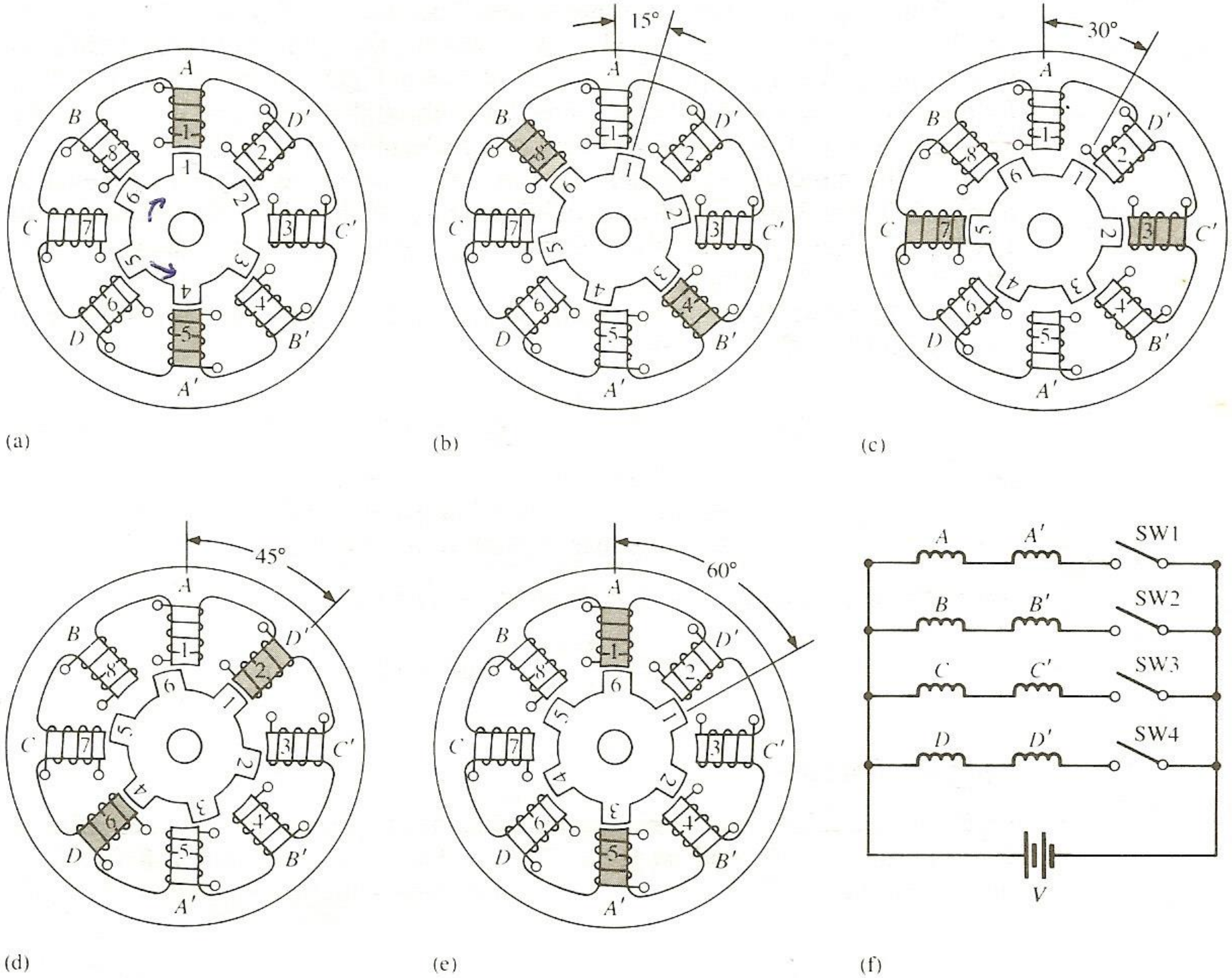


Hybrid stepper motors incorporate teeth on the surface of the rotor, so they are able to better manage the magnetic flux between the stator and rotor, which gives them higher holding, dynamic, and detent torque values than permanent magnet steppers.

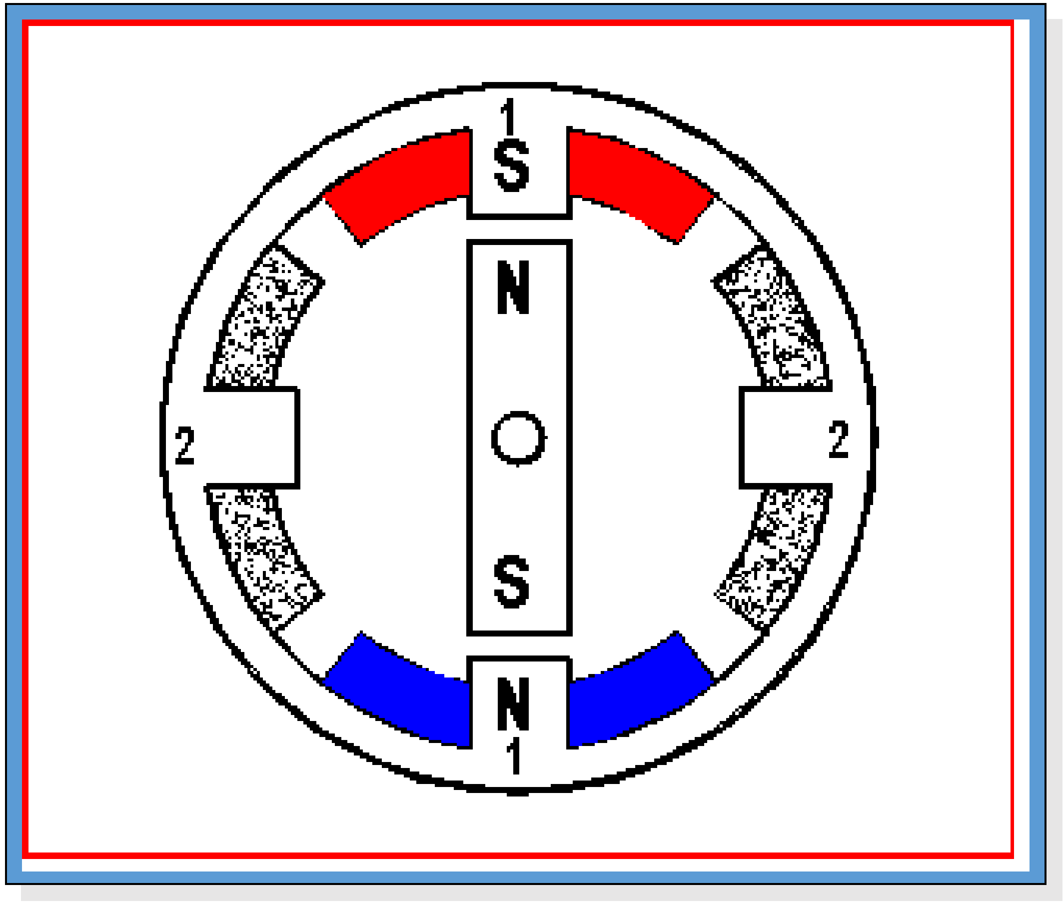
When coil A is energized, a tooth of the N-magnetized cap aligns with the S-magnetized tooth of the stator. At the same time, due to the rotor structure, the S-magnetized tooth aligns with the N-magnetized tooth of the stator. Real motors have a more complex structure, with a higher number of teeth than the one shown in the picture, though the working principle of the stepper motor is the same. The high number of teeth allows the motor to achieve a small step size, down to 0.9°.

The basic working principle of the stepper motor is the following: By energizing one or more of the stator phases, a magnetic field is generated by the current flowing in the coil and the rotor aligns with this field. By supplying different phases in sequence, the rotor can be rotated by a specific amount to reach the desired final position. **Figure 2** shows a representation of the working principle. At the beginning, coil A is energized and the rotor is aligned with the magnetic field it produces. When coil B is energized, the rotor rotates clockwise by 60° to align with the new magnetic field. The same happens when coil C is energized. In the pictures, the colors of the stator teeth indicate the direction of the magnetic field generated by the stator winding.



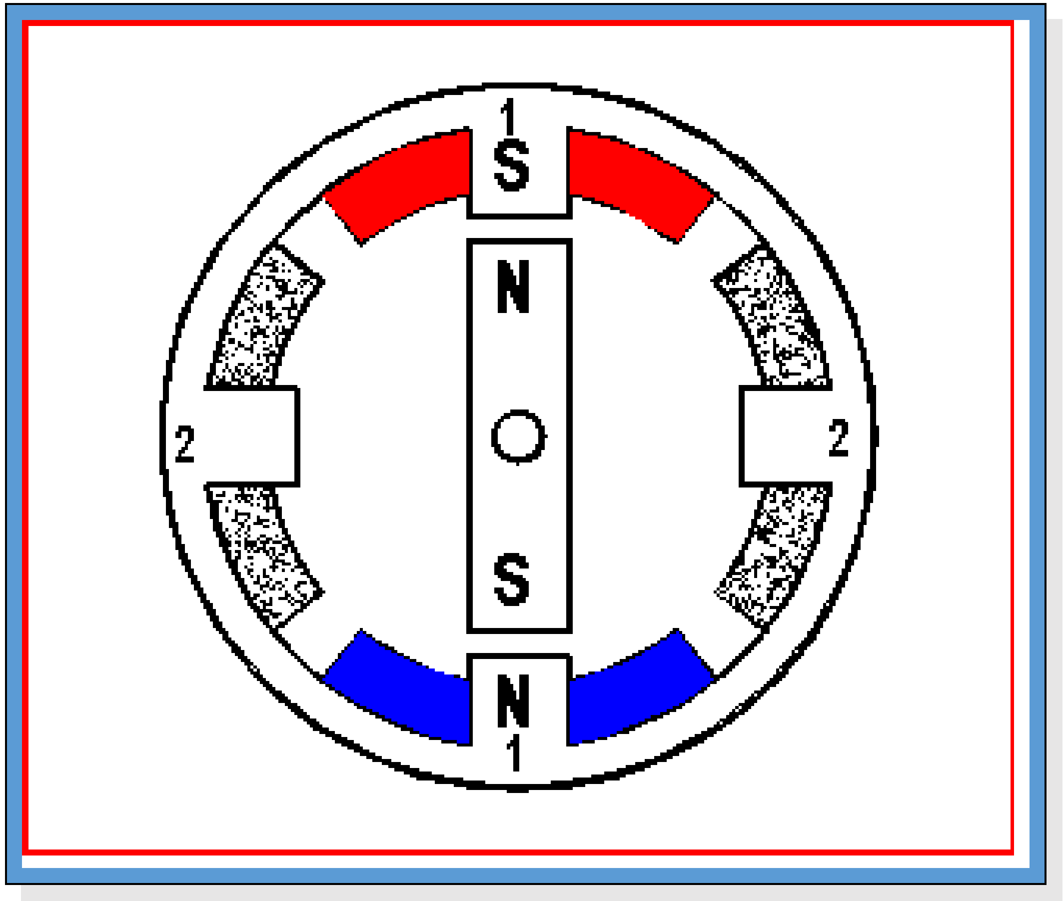

A
A′
B
B′
C
C′
D
D′
15°
30°
45°
60°
SW1
SW2
SW3
SW4
V
(a)
(b)
(c)
(d)
(e)
(f)

Full Step Operation

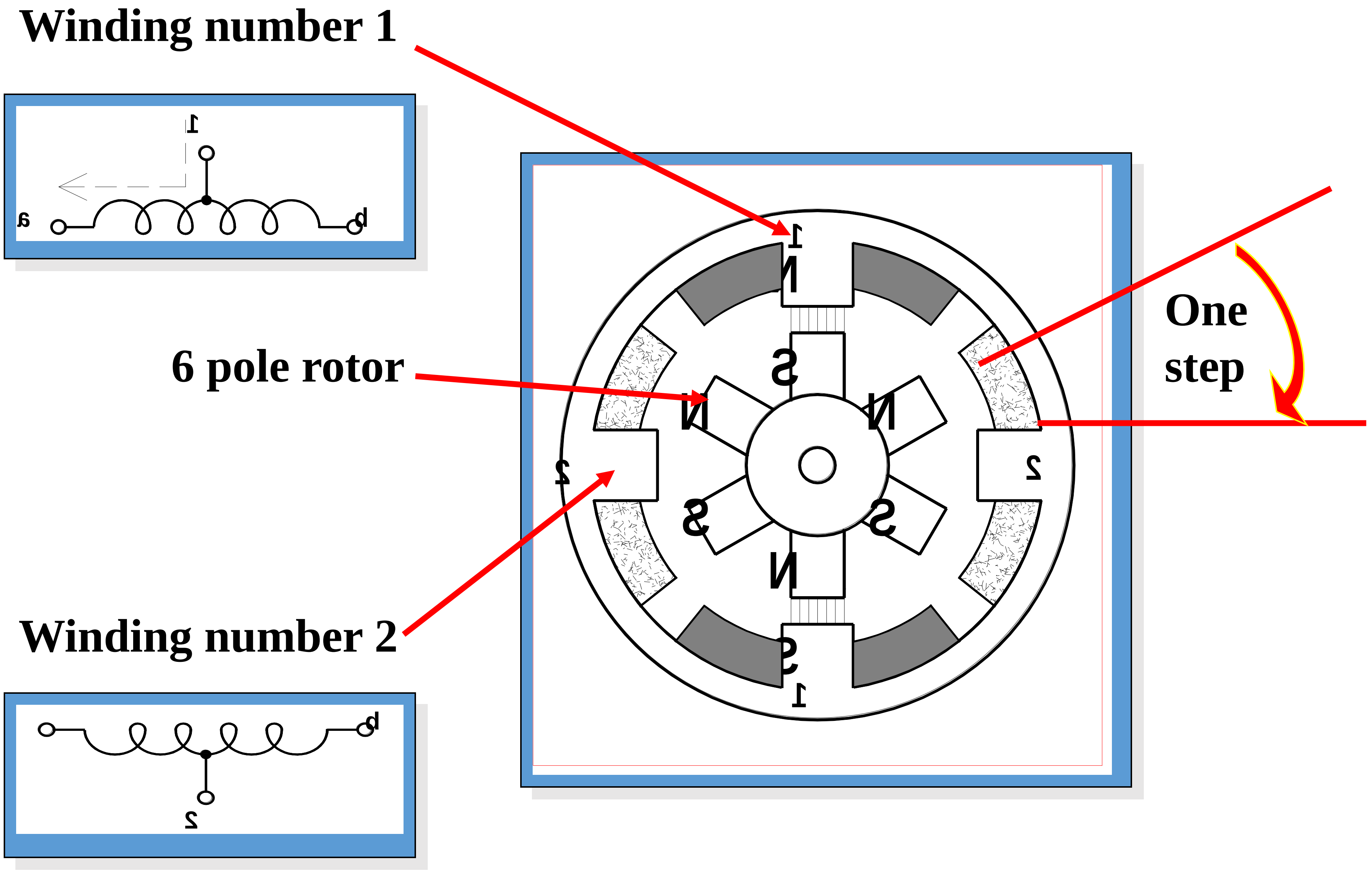


Four Steps per revolution i.e. 90 deg. steps.

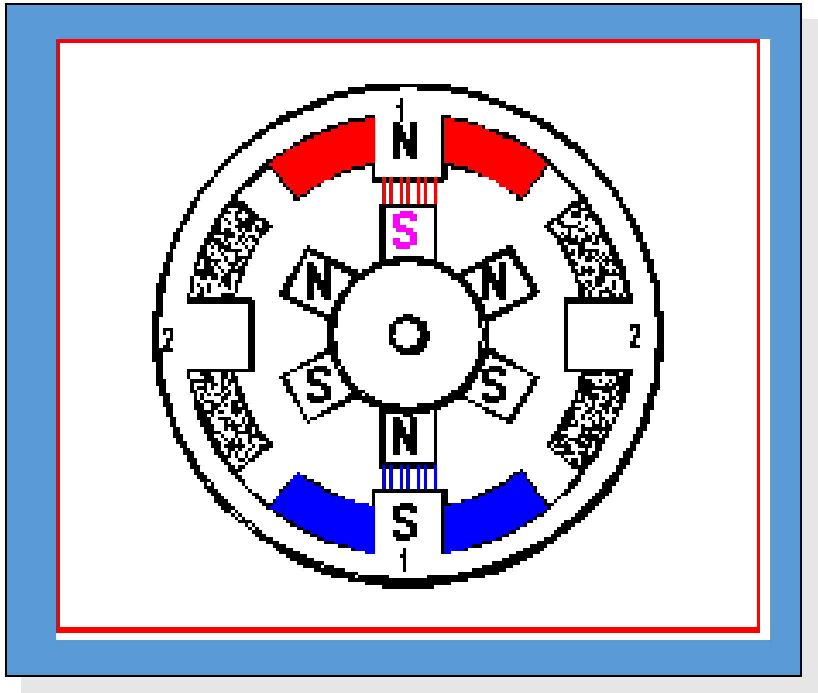
Half Step Operation



Eight steps per. revolution i.e. 45 deg. steps.


Winding number 1
6 pole rotor
Winding number 2
One step

Six pole rotor, two electro magnets.



How many steps are required for one complete revolution?

Applications:

Printers: Printheads, Paper Feed, Scan Bar

DSLR Cameras: Aperture/Focus Regulation

3D Printers: XY Table Drive, Media Drive

Video Cameras: Pan, Tilt, Zoom, Focus

Robots: Arms, End Effectors

Engraving Machines: XY Table Motion

ATM Machines: Bill Movement, Tray Elevators