DC BRUSHLESS MOTORS

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Brushless DC Motor (BLDC)

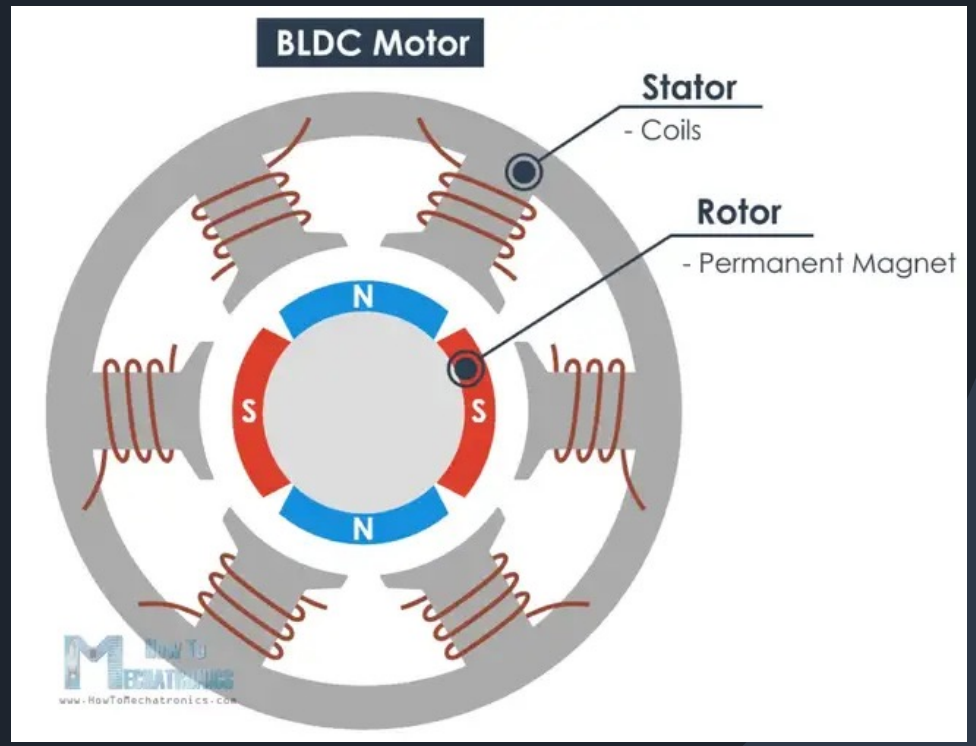


Figure 1: Brushless DC Motor

- Consists of a rotor, which is a permanent magnet, and a stator that has stationary coils.
- When a current is applied to the coils it creates a magnetic field, changing the magnitude and direction of the current allows you to control the rotation of the rotor.
- Uses hall sensors to detect the position of the coils

How it differs from a Brushed Motor

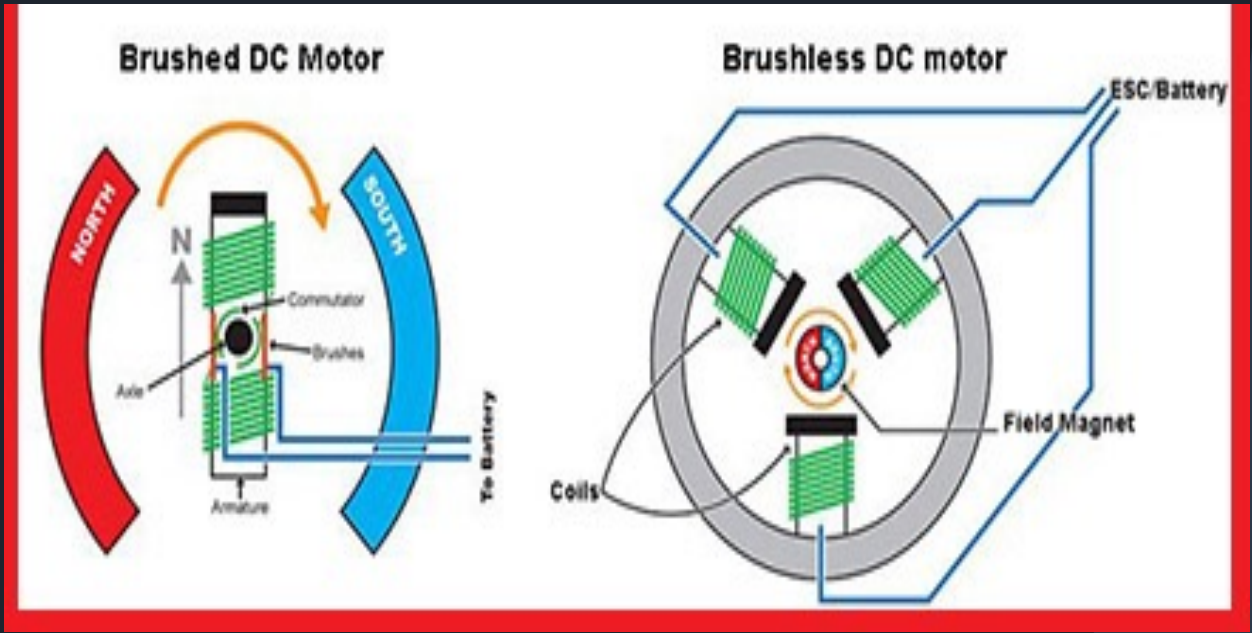


Figure 2: Brushed and Brushless Motor Comparison

- In a brushed motor, current is transferred through physical contact between a brush and the motor windings. There is a commutator in the middle that is constantly rotating, as it rotates it makes contact with the brushes and allows current to be transferred.
- In a brushless motor, there is no physical contact between the rotor and stator, current is applied to the coils which results in the permanent magnet rotating.
- A brushless motor is basically a brushed motor that has been flipped inside out, where the coils are on the stator instead of on the rotor.

Stator

- Made up of steel laminations and coils of wire called windings.
- Connected to a DC power supply
- Stationary

Rotor

- Permanent magnet
- Alternating North and South poles
- Rotates

How it operates

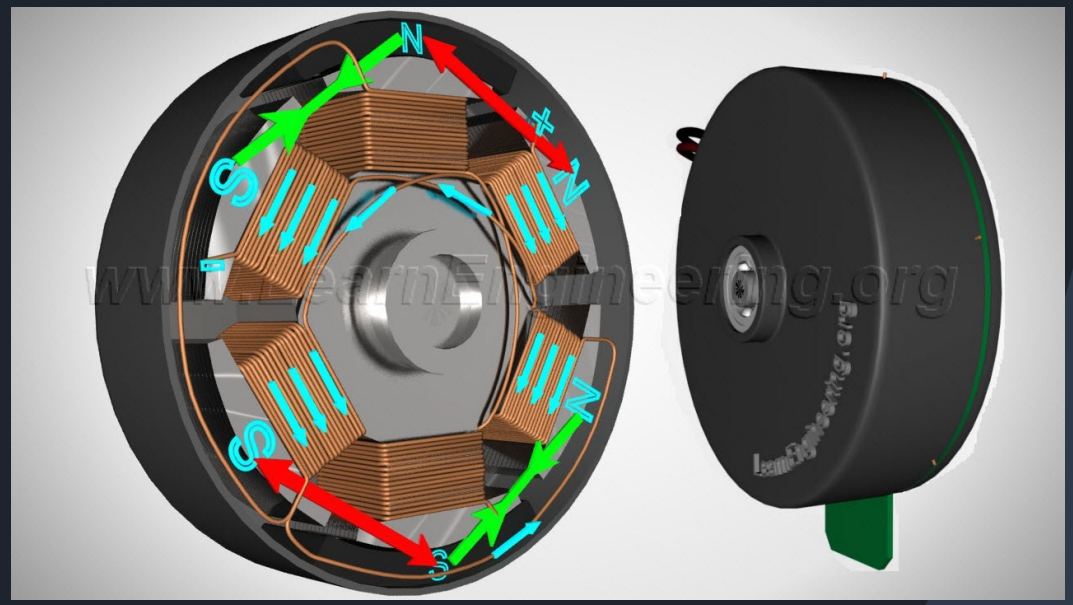


Figure 3: Brushless Motor Coil and Pole Representation

- The coils are energized at different times, the rotor is attracted to the current coil that is energized, then the next coil is energized. This process continuously rotates the rotor as it is pushed and pulled by the electromagnets.
- An electronic controller is used to properly distribute power throughout the motor. By using hall sensors to determine the position of the rotor, the controller will know which electromagnet to energize next

- At any given time, the current in one winding is positive, one is negative, and the other is zero. This control scheme is called trapezoidal.
- Coils are generally setup in a Y configuration, where two coils are energized at a given time, one pushing the rotor and the other pulling the rotor.
- The motor constantly cycles through these different phases which allows it to rotate.

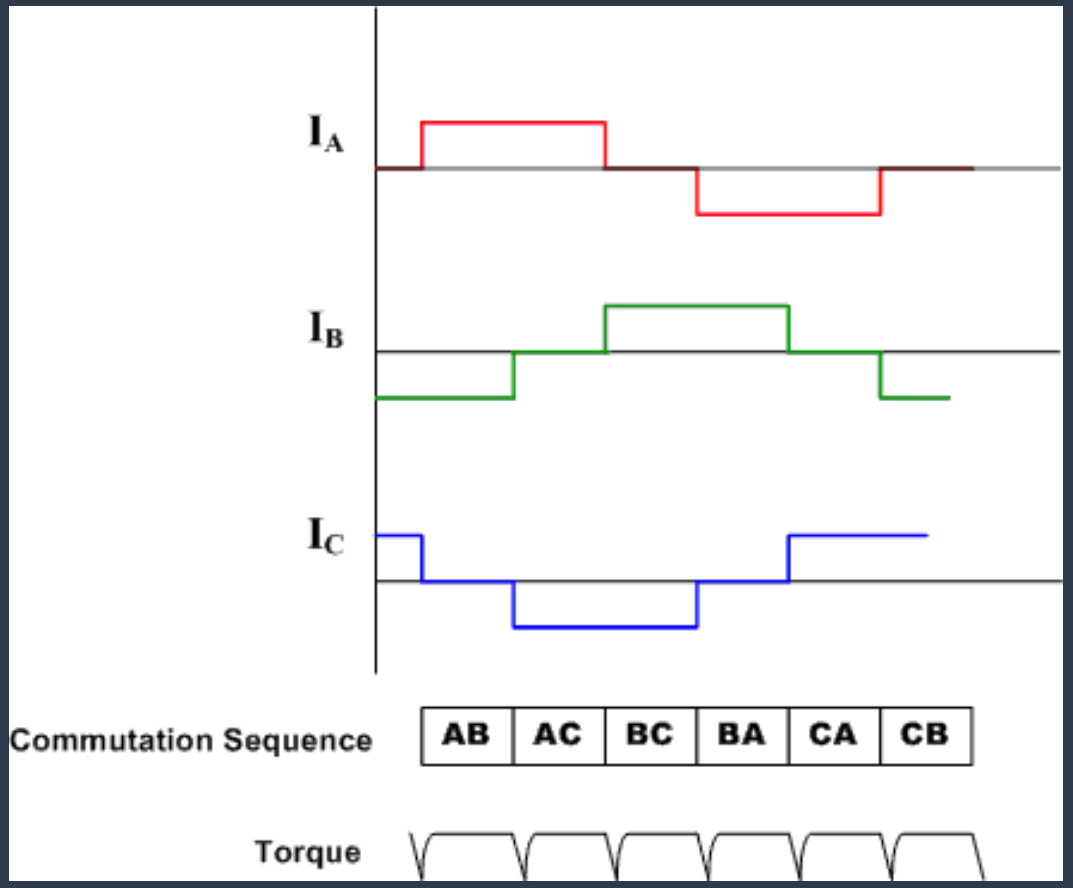
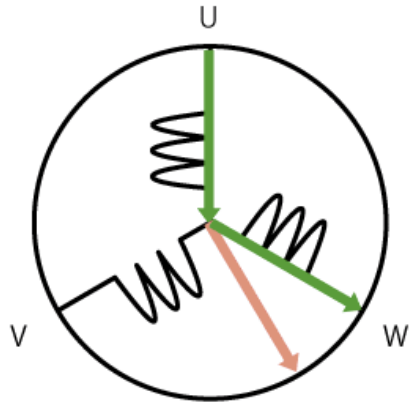


Figure 4: Trapezoidal Control Scheme



Energizing Mode	Energized Phase	Resultant Flux
1	U → W	
2	U → V	
3	W → V	
4	W → U	
5	V → U	
6	V → W	

Figure 5: Energized Coil Configurations

- With a three-phase BLDC motor, there is 6 configurations that the motor will go through to energize different phases at different times. This is called 120º conducting control.
- By following this sequence, the rotor magnet is constant being pulled which results in rotation.

Other Control Schemes

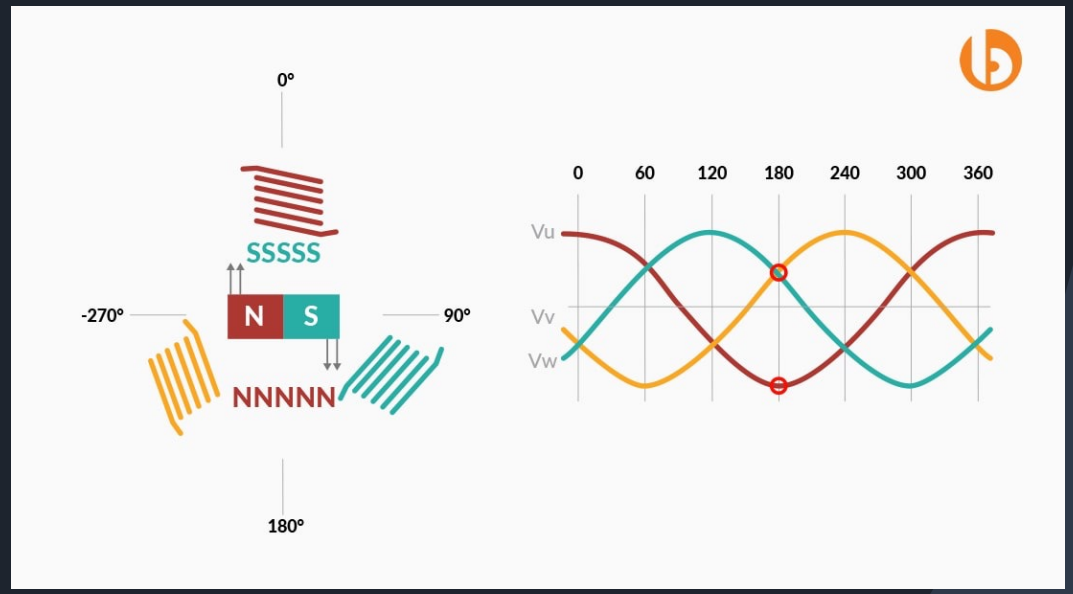


Figure 6: Brushless Sinusoidal Waveform

- With trapezoidal, two windings are energized with opposite polarities, and the other is off. Can be noisy and cause vibrations and is not very smooth.
- Sinusoidal control makes use of pulse width modulation (pwm). All three coils are constantly energized but the duty cycle is changed so that there is varying current delivered to each coil at a given time. This results in a smoother rotation as the current is constantly adjusted.

Circuit

- For a three-phase BLDC motor, 3 pairs of MOSFETs are arranged in a bridge like structure
- Based on the position of the rotor, two MOSFETs are switched which controls the voltage flow
- Hall-effect sensors are connected to the switches, when ones of the sensors gets triggered by the rotor which creates a voltage pulse that equates to a logic high or low. The feedback from the sensors allows the controller to know which MOSFET configuration to do next.

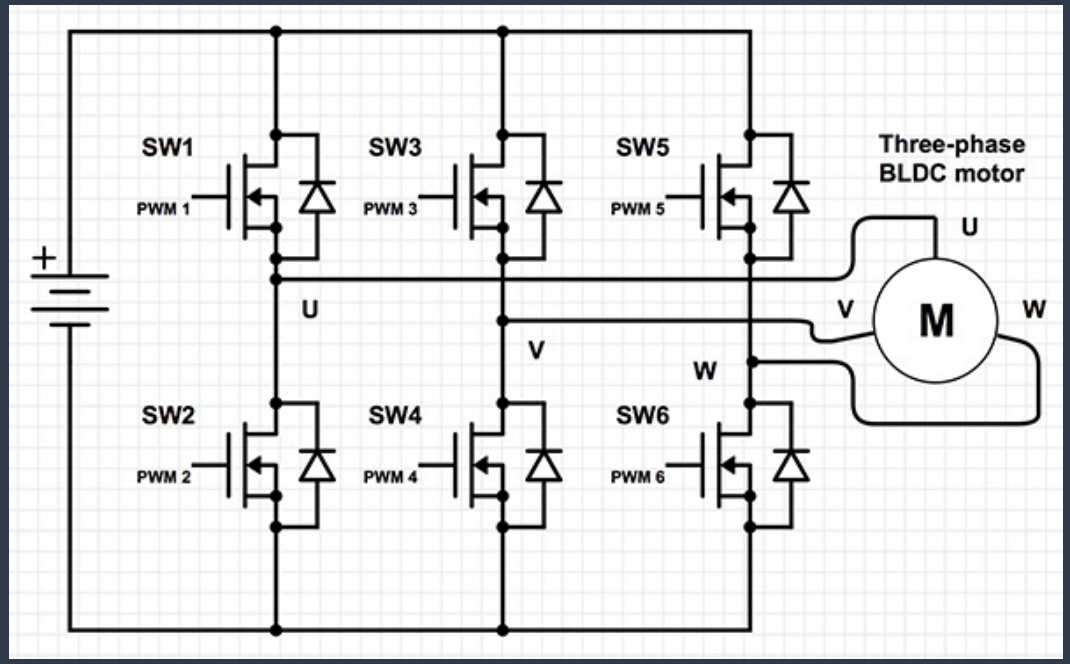


Figure 7: Brushless Motor Circuit

Positional Sensing

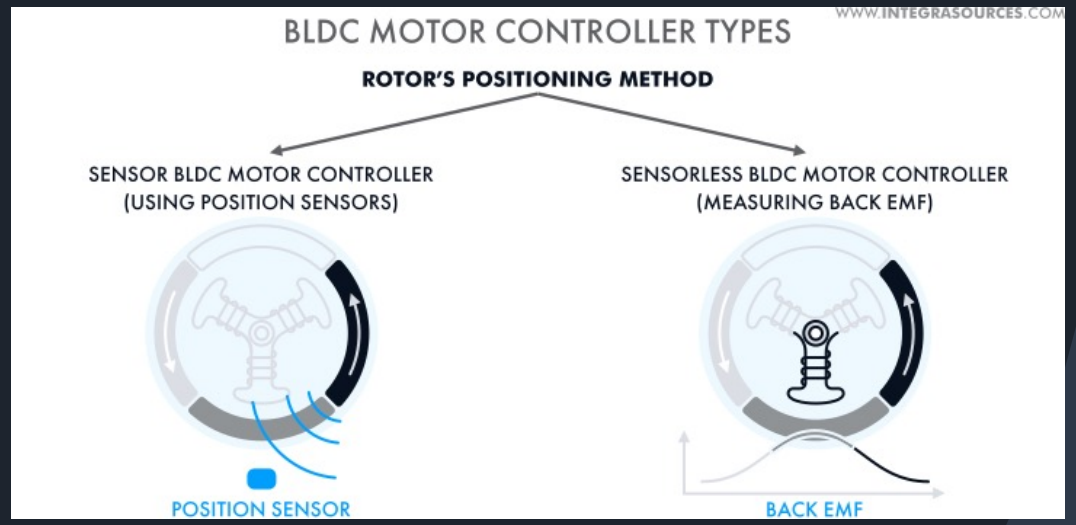


Figure 8: Rotor Sensor Types

- Multiple ways in which BLDC motors can sense where the rotor is positioned.
- Hall-effect sensors are positioned with a spacing of 60º, as they sense the change in magnetic field they activate and send this information to the electronic controller.
- The other way that the rotor position can be determined is through the back EMF. Instead of using sensors, the controller senses the voltage drops that occur in the coils because of current being fed through them, the controller then uses this to calculate the next interval.

Controlling Motor Speed

- The speed of the motor is determined by the magnitude of the voltage that is applied.
- The voltage is manipulated through PWM, as the pulses width is changed, the applied voltage also changes.

Why is the Brushless Motor Useful?

- More efficient
- Wears down slower due to no brushes and physical contact
- Lower chance of sparking and much quieter due to less physical contact
- Easier to control

Disadvantages

- The only disadvantage to using a brushless motor over a brushed motor is that they cost a lot more. This is due to the more complex circuitry and extra components such as sensors that need to be added.

Applications

- Brushless motors are best used in devices that run for prolonged periods of time. They are found in common household appliances such as washers and dryers and are often used in fans. They are also used in many vehicles and power tools along with many other things. They provide lower power consumption and a longer lifespan

References

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- [2] Cythinay, Rick, Ahmed, W. Vieira, and Dejan, “How Brushless DC Motor Works? BLDC and ESC explained,” How To Mechatronics, https://howtomechatronics.com/how-it-works/how-brushless-motor-and-esc-work/ (accessed Mar. 21, 2024).
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