Electronic Basics #18: DC & Brushless DC Motor + ESC

Introduction to DC Motors

A **DC (Direct Current) motor** is a type of electric motor that operates on the principle of **electromagnetic induction**, converting electrical energy into **rotational mechanical energy**. It consists of a stationary component called the **stator**, and a rotating component called the **armature (rotor)**. The motor operates by applying a **direct current (DC)** to generate motion. DC motors are widely used in applications requiring variable speed and torque control.

Structure of a DC Motor

A typical **DC motor** consists of the following main parts:

- **Stator**: This is the stationary part of the motor and is usually composed of **permanent magnets** or **electromagnets**.
- **Armature (Rotor)**: The rotating part of the motor, made of coils of wire. It rotates within the magnetic field of the stator.
- **Commutator**: A rotary switch that reverses the direction of current flow through the armature coils, ensuring continuous rotation.
- **Carbon Brushes**: These brushes provide electrical contact between the **commutator** and the external power supply, allowing current to flow through the armature windings.

Fig18.1: DC motor

Working Principle

1. When **current** flows through the armature winding, it creates a **magnetic field** around the armature.
2. The interaction between the armature's magnetic field and the **magnetic field of the stator** generates a **torque** that causes the armature to rotate.

3. The **commutator** switches the direction of current in the armature windings every half-turn, ensuring that the armature continues to rotate in the same direction.
4. **Carbon brushes** maintain the connection between the power source and the rotating commutator.

The rotation continues as long as **current** is supplied to the motor.

Brushless DC Motors (BLDC Motors)

A **Brushless DC motor (BLDC)** eliminates the need for **carbon brushes** and **commutators**. Instead of these mechanical components, BLDC motors use **electronic controllers** to regulate the current flow to the stator windings.

Structure of a Brushless DC Motor

- **Stator**: Similar to a conventional DC motor, the stator is a set of **permanent magnets** or electromagnets.
- **Rotor (Armature)**: In contrast to conventional motors, the armature in a brushless DC motor is located on the **stator** and contains the **electromagnets**.
- **Electronic Controller (ESC)**: This component controls the timing of current flow through the stator windings to create a rotating magnetic field that causes the rotor to rotate.

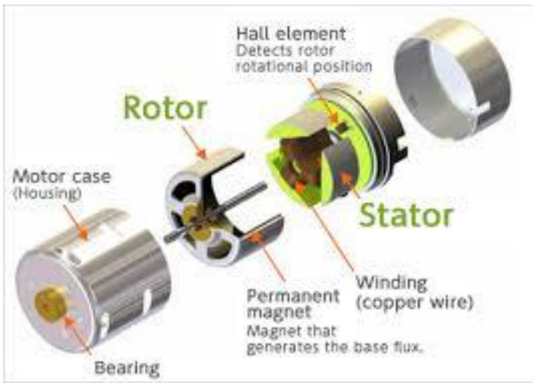

Fig18.2: Brushless DC Motor

How Brushless Motors Work

1. In a **brushless motor**, **permanent magnets** are placed on the rotor, while the **stator** has wound coils that generate a rotating magnetic field when energized.
2. The **electronic controller (ESC)** manages the switching of current through the stator coils.
3. As the rotating magnetic field interacts with the rotor's permanent magnets, it causes the rotor to **spin**.
4. **Hall sensors** or **position sensors** in the motor provide feedback to the ESC, allowing it to maintain proper timing of the current switching to sustain smooth rotation.

Unlike traditional DC motors, BLDC motors are more efficient and require less maintenance due to the absence of brushes and commutators.

Differences Between Brushless and Brushed Motors

- **Brushless Motors**:
  - No **commutator** or **brushes**, resulting in **less wear** and **higher efficiency**.
  - **Electronic controller (ESC)** regulates the current flow.
  - **Higher reliability** and **longer lifespan**.
  - **More complex electronics** for control.
- **Brushed Motors**:
  - Use **carbon brushes** and a **commutator** to switch current.
  - **Lower efficiency** due to friction and wear from brushes.
  - Easier to control with simpler circuits but require more maintenance.
  - **Shorter lifespan** due to wear on brushes.

Electronic Speed Controller (ESC)

The **ESC** is a critical component in **brushless motors**, as it controls the speed, direction, and power of the motor by regulating the current to the stator. It ensures that the **correct sequence of current pulses** is sent to the motor coils, creating a **rotating magnetic field**. The ESC is usually connected to a **microcontroller or receiver** in remote control systems.

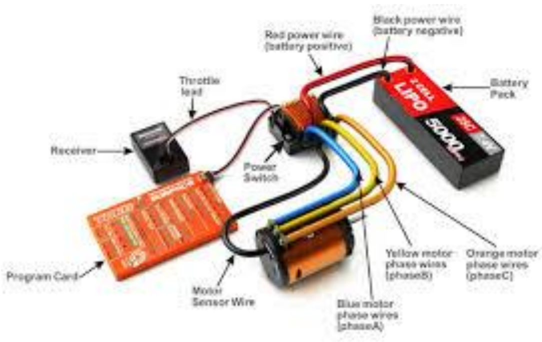

Fig18.3: Electronic Speed Controller

Key Functions of ESC:

- **Speed Control**: Adjusts the duty cycle of the current to change motor speed.
- **Direction Control**: Switches the current flow direction to change motor rotation.
- **Overcurrent Protection**: Ensures that the motor is not overloaded.
- **Brake Function**: Provides dynamic braking by reversing the current flow in the motor.

Current Drawn by the Motor and Relation with RPM

The **current** drawn by a DC motor is directly related to its **load** and **speed (RPM)**.

- In a **brushed DC motor**, when the load increases, the motor **draws more current** to maintain a constant speed.
- In a **brushless DC motor**, the current is proportional to the torque required by the load, and the **ESC adjusts the current** accordingly.

The **relationship between current and speed (RPM)** can be described as follows:

- In **brushed motors**, the speed is generally **linearly proportional** to the applied voltage and current.
- In **brushless motors**, speed is also influenced by the **timing of current switching** through the ESC, which is regulated to match the required RPM.

Frequency and RPM Relation in Motors

- **Frequency** refers to the **rate at which current is applied** to the stator coils of a motor. It is measured in **hertz (Hz)**.
- The **RPM (Revolutions Per Minute)** of a motor is related to the **frequency** of the AC current supplied to the motor windings, especially in **AC motors**. The relationship is given by:

$RPM=60\times f$

where:

- f= frequency in Hz
- P = number of poles in the motor

For a **brushless DC motor**, the **ESC** controls the frequency of the current switching to the stator, which directly affects the RPM of the motor.

Conclusion

- **DC motors** are simple, reliable, and widely used but require maintenance due to **brush and commutator wear**.
- **Brushless DC motors (BLDC)** offer **higher efficiency** and **longer lifespan** with electronic control.
- The **ESC** is a crucial component for controlling brushless motors, ensuring optimal performance.
- The **current drawn** by the motor is proportional to its load, and **RPM** is influenced by both current and frequency.

Would you like more details on any specific section or motor type?