An Introduction to Stepper Motors, DC Motors, and Motor Drivers

Introduction

Motors are electric devices that convert electrical energy to mechanical motion in the form of a rotor rotating around a stationary axis. These versatile devices are a driving force in a wide range of applications, including security cameras, smart locks, and 3D printers. For both engineers and hobbyists, it is vital to understand the differences between different motors, as each motor impacts not only the end application, but motor driver selection.

The article will introduce two types of common motors and their respective motor drivers: stepper motors and DC motors. It will also describe the similarities and differences between these motor types while introducing stepper motor drivers and DC motor drivers that can be utilized for seamless control and optimization.

Stepper Motors

A stepper motor converts electrical pulses into precise mechanical motion. As its name implies, stepper motors operate in discrete steps, where each step is a precise angle of rotation (typically about 1.8°). Stepper motors rotate a set number of times based on how many electrical pulses they have received. Because each rotation follows the exact angle of rotation, stepper motors are highly controllable.

The main components of a stepper motor are:

1. Rotor: The rotor (connected to the shaft) is the rotating component in a stepper motor. The rotor has teeth or magnetic poles that produce motion when they interact with the stator.
2. Stator: The stator is the stationary segment of the motor. The stator has coils of wire that can produce magnetic fields; these coils are organized into groups called phases.
3. Winding phases: Stepper motors can be either bipolar or unipolar, with bipolar stepper motors having two winding phases, and unipolar stepper motors having four winding phases. Each phase is associated with one winding on the stator.
4. Pulses and control: A sequence of electrical pulses must be sent to the winding phases to rotate the stepper motor, with the order and timing of these pulses being used to determine the direction and distance of each step.

Figure 1 shows a cross-section image of a stepper motor.

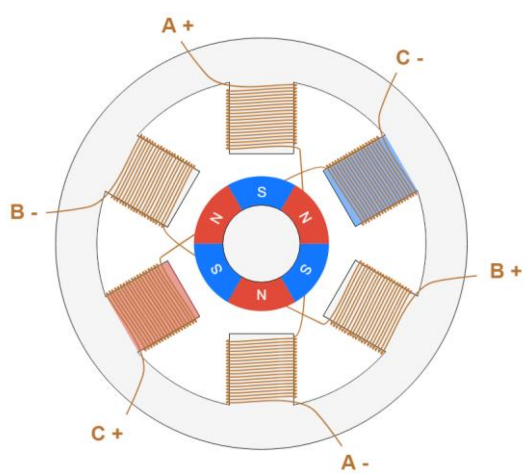

Figure 1: Stepper Motor

Stepper motors are highly precise because they move in discrete steps. In addition, they were designed to maximize their holding torque, which requires them to maintain a maximum current and makes them ideal for position-holding tasks, such as robotics and camera gimbals.

DC Motors: Brushed DC and Brushless DC Motors

A DC motor converts electrical energy to mechanical motion and operates based on electromagnetic induction. These motors generate a magnetic field between the rotating and stationary components; this magnetic field moves the rotor, which then rotates the motor. There are two main types of DC motors: brushed DC motors, and brushless DC (BLDC) motors.

Figure 2 shows a brushed DC motor, and the main components of a brushed DC motor are described below:

1. Rotor: The rotor (or armature) is a coil of wire wound around a core. Like a stepper motor's rotor, it is the rotating component of a brushed DC motor, and it is connected to the stator.
2. Stator: The stator is stationary and consists of one (or more) permanent magnets or electromagnets. The stator produces a magnetic field that interacts with the rotor's magnetic field, which creates torque while rotating the rotor.
3. Commutator: The commutator is a ring mounted on the rotor's shaft. The commutator is electrically connected to the windings on the rotor. The commutator can reverse the direction of current flow in the rotor's windings, which enables the motor to move.
4. Brushes: Brushes are stationary blocks made out of carbon or graphite that brush against the commutator. They conduct an electrical current that allows the motor to operate.

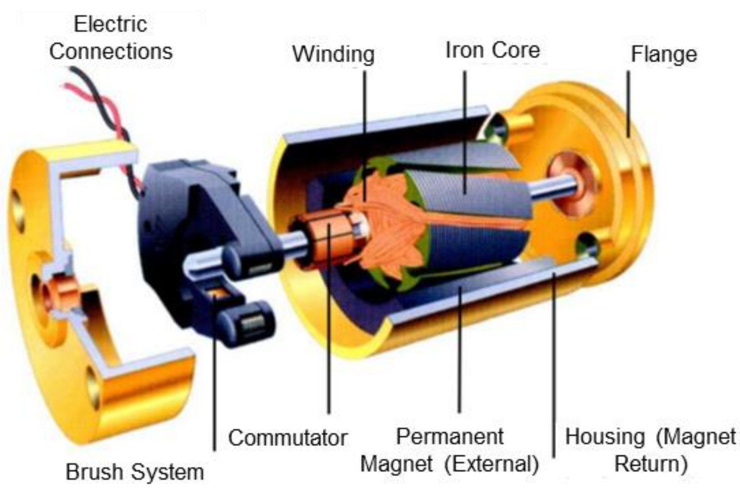

Figure 2: Brushed DC Motor

Figure 3 shows a BLDC motor. BLDC motors do not have brushes, which typically makes them more reliable and longer lasting due to less wear and tear. BLDC motors have a stator with multiple coils, and permanent magnets or electromagnets on the rotor. They use electronic commutation and utilize a controller to control the current in the stator windings.

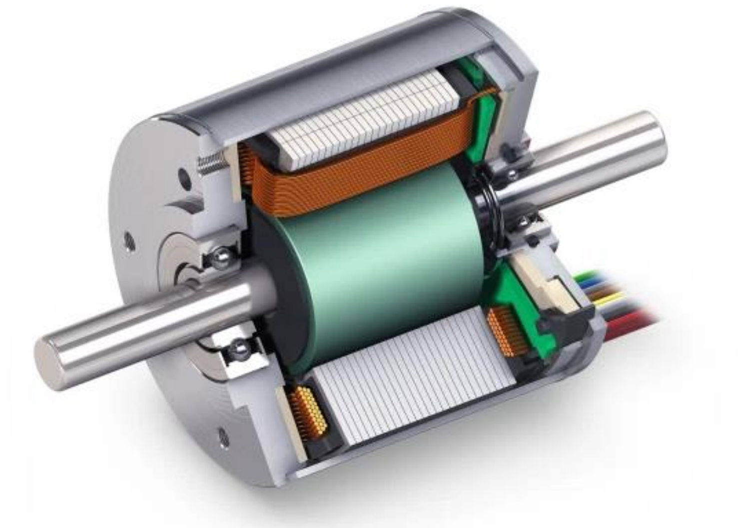

Figure 3: BLDC Motor

For DC motors, the applied current generates torque. DC motors are recommended for applications such as computer hard drives, toys, and solar tracking systems.

Comparing Stepper Motor Drivers and DC Motors

Stepper motors, brushed DC motors, and BLDC motors are distinct types of electric motors with advantages and disadvantages that make each well-suited for certain applications. A few of these key differences are described below.

Operation/Controllability

Stepper motors can operate within an open-loop system, which means that the motor's precise position is determined by the exact number of steps or pulses sent to the motor. Because they operate in discrete, easily quantified steps, stepper motors do not need position control. However, stepper motors do require an external device, such as a microcontroller (MCU), to adjust the motor's speed and direction.

Brushed DC motors are powered by a DC power supply that is connected to the rotor via carbon brushes. Simple brushed DC motors can be controlled via an open-loop system, but more advanced motors may require feedback mechanisms. Typically, these motors do not require external controllers, and they can be easily adjusted. For example, adjusting the motor's voltage changes its speed.

BLDC motors must operate in closed-loop systems, which provide high precision but require additional control circuitry for smooth operation.

Lifecycle

Due to their simplicity, stepper motors are highly reliable and can be used for upwards of 4 to 5 years, or for about 10,000 hours.

DC motors are also relatively reliable, but brushed DC motors require continuous maintenance to prevent failure from the brushes, with a general lifespan of a few thousand hours before needing maintenance.

Brushless DC motors have a longer lifespan than brushed DC motors since they do not experience the same mechanical wear and tear from the brushes, and they can operate for over 10,000 hours.

Efficiency and Noise

Stepper motors tend to be less efficient because they lose energy through heat dissipation; in addition, stepper motors operate at their maximum current at all times, which means they demand high amounts of energy. DC motors are more efficient, with brushless DC motors being the most efficient because they do not lose as much energy through friction from the brushes.

In terms of noise generation, stepper motors produce the most noise because of their discrete steps, which results in a whirring or ratcheting sound when the motor is rotating at a continuous speed. Brushed DC motors are less noisy, but when the brushes brush over the commutator, this still generates noise; as expected, BLDC motors produce the least amount of noise.

Summary

Table 1 shows a summary of the advantages, disadvantages, and common applications for both stepper motors and DC motors.

Table 1: Stepper Motors vs. Brushed DC Motors

Motor	Advantages	Disadvantages	Applications
Stepper Motor	• High accuracy • High precision • Easy to control • Long lifespan (10,000 hours)	• Less efficient • Requires external control (microcontroller) • Noisy	• 3D printers • Telescope • Disk drives • Robotics
Brushed DC Motor	• Moderate efficiency • Faster response time • Can detect overload conditions	• Shorter lifespan; require maintenance to ensure reliability • Complex control	• Electric tools/appliances • Automotive (e.g. windshield wipers) • Toys • Fans
BLDC Motor	• High efficiency • Requires little maintenance • Quiet • Very long lifespan (10,000+ hours)	• Complex control • Susceptible to extreme temperatures	• Electric vehicles • Household appliances • Medical devices (e.g. infusion pumps, imaging)

Motor Driver ICs

All motors require a motor driver IC, also just called a motor driver, which controls and manages how the motor operates. Motor drivers are used to regulate a motor's speed, direction, and sometimes other parameters that ensure reliable and efficient operation. Motor drivers have a few different functions, such as amplifying electrical signals to power and control the motor, enabling precise speed control, and feature robust protections, such as over-current protection (OCP) and over-temperature protection (OTP).

MPS provides both stepper motor drivers and brushed DC or BLDC motor drivers that can be used with these three motor types. A few of MPS's motor driver ICs are discussed below.

Stepper Motor Drivers from MPS

The MP6605 family consists of the MP6605C, MP6605D, and MP6605E. These parts offer the same main features, and varying control interfaces. They are 4-channel low-side driver ICs with integrated low-side MOSFETs (LS-FETs) and high-side (HS) clamp diodes for unipolar stepper motors. Figure 4 shows the typical application circuit for the MP6605C.

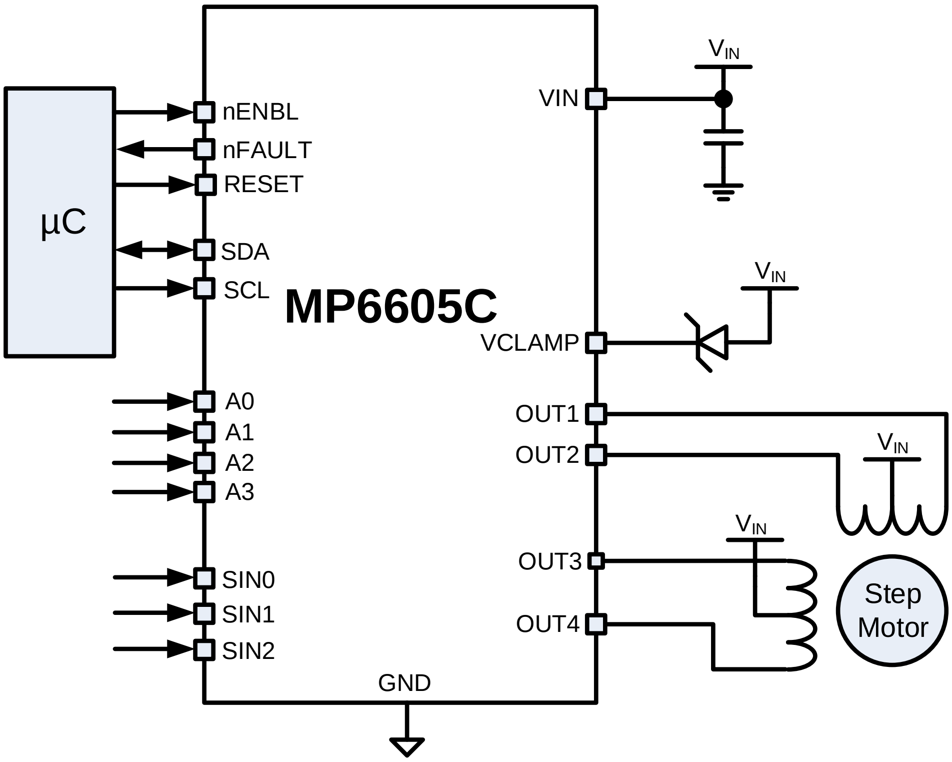

Figure 4: The MP6605C

All three parts operate from a 4.5V to 60V input voltage (V_{IN}) range and are available in tiny QFN-24 (4mmx4mm) packages. In addition, they can deliver up to 1.5A of output current (I_{OUT}) and feature protections such as OCP, OTP, and under-voltage lockout (UVLO) to ensure that the device does not attempt to operate when there is insufficient input voltage (V_{IN}).

The difference between these parts is their control interface. The MP6605C is controlled via an I^2C interface. The MP6605D is controlled via a parallel interface, which means that individual input pins control each output. Lastly, the MP6605E is controlled via a serial (SPI) interface that sends data to the MP6605E's outputs while reading the state of the three sensors' inputs.

Brushed DC Motor Drivers from MPS: The MP6612 Family

The MP6612 is an H-bridge motor driver that was designed to drive reversible loads. The outputs are controlled via the IN1 and IN2 pins for additional flexibility, and the device can drive one DC motor, one stepper motor winding, and other loads. This brushed DC motor has a low quiescent current (I_Q) when the device is disabled in brake mode, which reduces power consumption when the device does not need to be active.

For protection, the MP6612 provides OCP, OVP, and OTP. There is also fault indication for these protections so that designers can be notified in the event of a failure. In addition, the MP6612 provides UVLO. It is available in a TSSOP-20 package with an exposed thermal pad for additional thermal efficiency (see Figure 5).

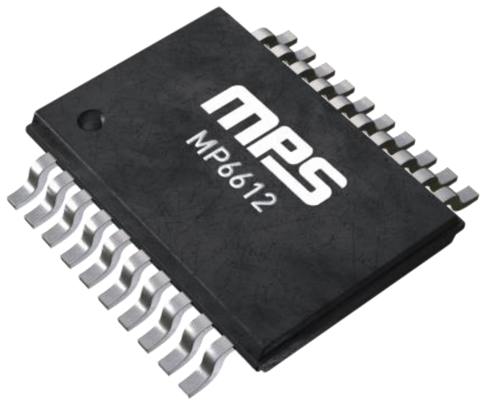

Figure 5: 3D Image of the MP6612

The MP6612 is part of a large family of similar parts that can meet many application needs. For example, the MP6612D is a similar part that provides a current-sense circuit, which is able to provide an output voltage (V_{OUT}) that is proportional to the load current.

Meanwhile, the MPQ6612A-AEC1 is an automotive-grade part that is similar to the MP6612 and MP6612D, but because it is rated for AEC-Q100 Grade 1, it can be used in automotive applications such as door handles and electronic locks.

BLDC Motor Drivers from MPS

The MP6546 is a 3-phase BLDC motor driver with an I^2C interface that provides configurable parameters such as protections, operation modes, and angles. This device used field-oriented control (FOC) logic and angle calculations for precise monitoring. The MP6546 provides fault indication for OCP, OVP, UVLO, and short-circuit protection (SCP), which protects the device from over-current conditions.

The device supports multi-slave mode and three-axis gimbals connected to a single I^2C interface bus, and each slave unit can calculate its own angle and controls the motor via the I^2C interface.

The MP6546 can operate in both magnetic angle sensor input mode and in linear Hall-sensor input mode, which means it can support both position feedback methods (see Figure 6). In magnetic angle sensor input mode, the MP6546 can work with MPS's MagAlpha magnetic angle sensor family. In linear Hall sensor input mode, the device sends its HA and HB signal to an analog-to-digital converter (ADC) so that the digital core can calculate the angle.

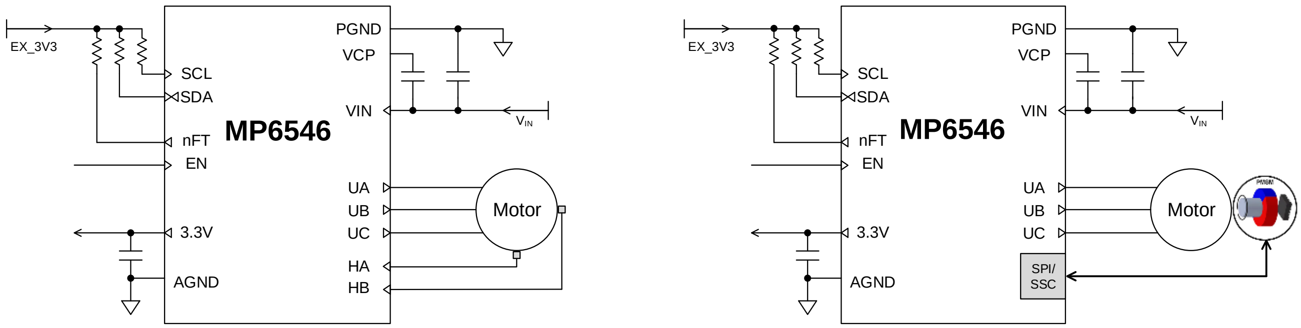

Figure 6: Input Mode (Left: Hall Sensor, Right: Magnetic Angle Sensor)

The MP6546 is a highly versatile BLDC motor driver, and its configurability means it can be implemented across different systems with minimal additional work or testing.

Conclusion

This article introduced and discussed various motor types and motor driver ICs to support them. Stepper motors are highly precise motors that operate in discrete, highly reliable steps, and DC motors are flexibly controlled by voltage and current, and convert electrical energy into mechanical motion. While stepper motors are highly accurate, they are not as efficient as DC motors.

Motors require motor driver ICs that can protect and control the motor by determining the motor's speed and direction. MPS provides a number of stepper motor drivers, though this article focused on the MP6605 family, including the MP6605C. In addition, MPS provides brushed DC motors such as the MP6612 and its variants, as well as BLDC motor drivers such as the MP6546. Explore MPS's full portfolio of motor drivers, designed for a number of applications for industrial and automotive markets.