**Brushed DC-motor**

A brushed DC motor is a type of electric motor that runs on direct current (DC) power and uses mechanical brushes to transfer electrical current to the rotating parts. It consists of two main components: a stator (the stationary part) and a rotor (the rotating part). The stator consists of permanent magnets, while the rotor, also known as the armature, is a coil of wire wound around an iron core.

When a voltage is applied to the motor's terminals, current flows through the brushes and into the armature. The current in the armature generates a magnetic field that interacts with the magnetic field produced by the stator's permanent magnets. This interaction creates a torque that causes the rotor to rotate. As the rotor turns, the brushes maintain contact with the commutator, a segmented ring attached to the rotor, allowing for continuous current flow and rotation.

Brushed DC motors are relatively simple in design, easy to control, and low-cost, making them popular for various applications like toys, power tools, and automotive systems. However, they have some disadvantages, such as limited lifespan due to brush wear, increased maintenance requirements, and lower efficiency compared to brushless DC motors.

**BMS**

A Battery Management System (BMS) is an electronic system designed to monitor, control, and protect the performance and safety of rechargeable battery packs, primarily those used in electric vehicles (EVs), energy storage systems, and portable electronics. The primary objective of a BMS is to extend the life, maintain optimal performance, and ensure the safe operation of a battery pack.

Key functions of a BMS include:

Monitoring: The BMS constantly measures crucial parameters like voltage, current, and temperature of individual battery cells or the entire pack. This data is used to assess the state of charge (SOC), state of health (SOH), and other performance indicators.

Balancing: Since battery cells may charge and discharge unevenly over time, the BMS actively balances the cells by redistributing charge, ensuring that all cells have similar charge levels. This process helps to maximize the battery pack's capacity and prolong its life.

Protection: To prevent hazardous situations, the BMS safeguards the battery pack from overcharging, over-discharging, overheating, and short-circuits. It does this by monitoring and controlling charging and discharging rates, as well as disconnecting the battery pack if necessary.

Communication: The BMS communicates vital information about the battery pack's performance and health to the user or other systems, such as the vehicle's main control unit, enabling informed decision-making and optimized energy management.

Thermal management: The BMS can control the cooling or heating of the battery pack to maintain optimal operating temperatures, ensuring maximum performance and safety.

In summary, a Battery Management System is an essential component in managing rechargeable battery packs, enabling optimal performance, extended life, and safe operation.

**MPU**

A Motion Processing Unit (MPU) is a microelectromechanical system (MEMS) that combines several sensors to measure and analyze motion-related data. The primary components of an MPU are accelerometers, gyroscopes, and occasionally magnetometers. These sensors collectively gather information on linear acceleration, angular velocity, and magnetic field intensity.

The MPU processes data from these sensors to calculate an object's movement, position, and orientation in three-dimensional space. By merging data from multiple sensors, the MPU can deliver more precise and dependable measurements than when using individual sensors separately. This proves particularly beneficial in applications where comprehending an object's motion and orientation is vital, such as robotics, drones, wearable technology, and mobile devices.

Gyroscope: A gyroscope is an instrument that measures angular velocity or the rate of rotation around an axis, which helps determine an object's orientation and stability during motion. This device is commonly used in equipment requiring precise control over their orientation, such as drones and smartphones with image stabilization features. The gyroscope's functionality is based on the Coriolis effect, which is used to calculate angular velocity.

When the gyroscope rotates around an axis, the Coriolis effect induces a vibration that leads to displacement or deformation of the capacitive position sensors. This deformation causes a change in capacitance, which is then transformed into a voltage signal and amplified. The voltage is converted into a digital signal using an integrated ADC (analog-to-digital converter) on the chip.

Accelerometer: An accelerometer is a type of MEMS (micro-electro-mechanical system) that operates based on the deformation of a spring. When the accelerometer is subjected to acceleration, such as gravity, the mass attached to the spring compresses it. This deformation causes a change in capacitance, which can be measured and translated into acceleration. The MPU-9250 contains three accelerometers that measure acceleration in the x, y, and z directions. As a sensor, an accelerometer measures linear acceleration, or changes in velocity over time along a straight path, and can detect movement, orientation relative to gravity, and vibrations. They have numerous applications, including determining a phone's orientation and counting steps in fitness trackers.

Magnetometer: A magnetometer is a sensor that measures the strength and direction of magnetic fields, such as Earth's magnetic field. It can help determine an object's orientation relative to Earth's magnetic poles, providing additional information for calculating the object's position and heading. Magnetometers are commonly found in smartphones and other devices with GPS and compass functionality.

**Current Sensor**  
  
A current sensor that uses the Hall effect to measure current is a type of device that detects the magnetic field generated by the flow of electrical current in a conductor. The Hall effect is a phenomenon in which a voltage is induced across an electrical conductor when it is placed in a magnetic field perpendicular to the direction of current flow.

Current flow: When an electrical current flows through a conductor, it generates a magnetic field around it. The strength of this magnetic field is proportional to the magnitude of the current.

Hall effect sensor: A Hall effect sensor is a small, thin piece of semiconductor material (usually made of silicon or gallium arsenide) that is sensitive to magnetic fields. When placed near the conductor carrying current, the sensor experiences the magnetic field generated by the current.

Hall voltage: As the Hall effect sensor is exposed to the magnetic field, a voltage (known as the Hall voltage) is induced across the sensor perpendicular to both the magnetic field and the current flow direction. The magnitude of the Hall voltage is proportional to the strength of the magnetic field and, by extension, the current flowing through the conductor.

Signal conditioning: The Hall voltage is usually very small, typically in the microvolt to millivolt range. To make this signal usable, it is amplified and conditioned using additional circuitry. This may involve filtering, temperature compensation, and other adjustments to improve the accuracy and stability of the output signal.

Output signal: The conditioned Hall voltage is typically converted into a proportional analog or digital output signal, which can be read and processed by a microcontroller or other data acquisition system to determine the magnitude and direction of the current being measured.

Hall effect current sensors are widely used in various applications due to their non-invasive nature, isolation between the measured current and the sensing circuit, and their ability to measure both AC and DC currents. They are commonly found in power supplies, motor control systems, battery management systems, and other applications requiring precise current monitoring.

**Absolut and incremental encoder**

Absolute and incremental encoders are devices used for measuring position, rotation, or movement in various applications such as robotics, automation, and manufacturing. They convert the position or rotation of an object into a digital or analog signal that can be read by a control system.

**Absolute Encoder:**

An absolute encoder provides a unique code (output) for each position or angle it measures. This means that even after a power loss or system restart, the encoder can determine its exact position without the need for a reference (home) position. Absolute encoders are typically more complex and expensive than incremental encoders but offer more reliable position information.

**Incremental Encoder:**

An incremental encoder, on the other hand, generates output signals (pulses) relative to the movement from its previous position. It does not store or provide absolute position information. To obtain position information, the control system must count the number of pulses and keep track of the direction of movement. Incremental encoders are generally simpler and less expensive than absolute encoders, but they require a reference (home) position after a power loss or system restart to reestablish their position.

The main difference between absolute and incremental encoders lies in the way they provide position information. Absolute encoders give unique codes for each position, allowing them to remember their exact position even after a power loss. Incremental encoders provide relative position information and require a reference position to determine their exact location.

**Magnet encoder AS5600**

A magnetic encoder like the AS5600 operates by detecting the rotation of an object through the use of magnetic fields. First, a permanent magnet is affixed to the rotating object, such as a motor shaft. Next, a magnetic sensor called a Hall element is positioned nearby the rotating magnet and mounted in a fixed location, such as on a circuit board. As the object rotates, the magnetic field produced by the magnet also rotates. The Hall element senses the changes in the direction and strength of the magnetic field as the magnet rotates. Finally, the sensor converts these changes into electrical signals that represent the object's rotational position and speed. In essence, the AS5600 magnetic encoder employs a magnet and a sensor to detect rotation by monitoring variations in a magnetic field and then transforming this information into electrical signals to indicate the object's position and speed.

**Voltage regulator (Step converter, LM2596S)**

A DC-DC step-down converter, or buck converter, is an electronic device that efficiently lowers the output voltage while simultaneously increasing the current. It maintains a constant power supply to the load, making it more energy-efficient than other methods, such as linear regulators. The buck converter achieves this by quickly switching the current flow on and off, which adjusts the voltage and current levels as needed.

A DC-DC step-down converter, also known as a buck converter, is a type of power supply circuit that takes an input direct current (DC) voltage and converts it into a lower output DC voltage, while increasing the current to maintain a constant power supply. This process makes it more energy-efficient compared to linear regulators, which dissipate excess energy as heat.

The primary components of a buck converter include an input capacitor, an inductor, a diode, an output capacitor, and a switch (usually a transistor). These components work together to control the flow of current and regulate the output voltage.

The basic operation of the buck converter consists of two stages: the ON state and the OFF state.

ON state: When the switch is closed (turned on), the input voltage is applied across the inductor, causing the current to flow through the inductor and charging it with magnetic energy. Simultaneously, the diode is reverse-biased, preventing current flow through it. The output capacitor supplies power to the load during this stage.

OFF state: When the switch is opened (turned off), the inductor's magnetic energy is released, maintaining the current flow through the diode to the output capacitor and the load. The output voltage is determined by the ratio of the ON state and OFF state durations.

By rapidly switching between the ON and OFF states, the buck converter can adjust the voltage and current levels to deliver the desired output voltage, while maintaining a constant power supply to the load. This fast-switching action also minimizes power losses and increases the energy efficiency of the converter.

DC-DC step-down converter or buck converter is an electronic device that efficiently reduces the output voltage while increasing the current, using a switching mechanism to maintain a constant power supply to the load. This method provides a more energy-efficient solution compared to linear regulators, which dissipate excess energy as heat.

**Communication protocol**

**CAN-Bus**

The CAN bus, or Controller Area Network, is a communication system developed in the 1980s, mainly used in the automotive industry due to its noise resistance. It allows multiple devices (nodes) to connect and share information on a single data line without a host computer. One advantage of CAN bus over alternatives like Ethernet is its ability to prioritize signals, ensuring critical signals like braking in a car are delivered promptly.

CAN bus enables communication between microcontrollers and other devices using two signals: CAN-high and CAN-low. These wires are twisted together to reduce noise interference. A 120-ohm termination resistor is placed at each end of the bus to further minimize noise. CAN bus communication is asynchronous, meaning it doesn't rely on clock signals for synchronization. CAN bus does not use a clock signal for synchronization. Instead, it relies on bit-timing, where nodes synchronize to the edges of the transmitted bits, making it an asynchronous communication method.

**I2C/SPI**

I2C and SPI are two communication protocols used to transfer data between a controller (master) and a device (slave). These protocols are used for data transfer within a circuit, unlike CAN-bus which is used for longer distances.

I2C, short for Inter-Integrated Circuit, is often called a two-wire interface because it only requires two wires for data transfer: SDA (data line) and SCL (clock line). The data is transferred serially on the SDA line, meaning a sequence of 0s and 1s is sent one after the other. The SCL line is the clock signal used to synchronize the processes between the controller and the device. A drawback of I2C is that it is half-duplex, meaning it cannot send and receive data simultaneously due to having only one data transfer line.

SPI, on the other hand, is often called a "four-wire interface" because it uses four wires for data transfer. These include MISO (master in slave out), MOSI (master out slave in), SCLK/SCK (clock signal), and CS (chip select). SPI has two data transmission lines, making it full-duplex, which allows simultaneous sending and receiving of data, resulting in faster data transfer than I2C. The downside is that SPI requires two additional cables compared to I2C. The clock signal (SCLK/SCK) functions similarly to the clock signal in I2C. The CS line, found on the device/slave, enables communication with the controller when it is high.

**Serial (USB, UART)**

Serial communication with UART (Universal Asynchronous Receiver/Transmitter) is a method used for transferring data between two devices, one bit at a time, over a communication channel. It's called "serial" because the data is sent sequentially (in a series), and "asynchronous" because the transmitter and receiver use their own separate clocks, without relying on a shared clock signal.

The data that is to be transmitted is held in a data register within the UART. The UART adds a start bit and stop bit to the data, which helps the receiver identify the beginning and end of each data packet. This process is called "framing" the data. The framed data is then sent sequentially over the communication channel, one bit at a time, at a predefined speed known as the "baud rate."

On the receiving end, the UART detects the start bit, samples the data bits, and removes the stop bit. The received data is placed in a data register and made available for further processing.

For accurate communication, both the transmitting and receiving devices must agree on the baud rate and the number of data bits, stop bits, and parity bits (if used). Errors can occur if there is a mismatch in these settings or if there is noise on the communication channel.