**Q1. What is a BMS? Types of BMS and differentiate the types of BMS.**

ANS: A Battery Management System (BMS), which controls the electronics of a rechargeable battery, whether a cell or perhaps a battery pack, becomes a critical component in ensuring the safety of electric vehicles. It helps protect both the user and the battery by maintaining the cell within its safe operating parameters. The battery management system (BMS) monitors the battery's state of health (SOH), collects data, controls environmental factors that affect the cell, and balances them to ensure the same voltage across cells. A smart battery pack is one that contains a BMS and is linked to an external communication data transfer system or a data bus. A smart battery pack can manage its own charging, produce error reports, detect and alert the device to any low-charge condition, and estimate how long the battery will last or how much run-time it has left. It also reports the cell's current, voltage, and temperature and constantly self-corrects any errors to retain prediction accuracy. Battery management systems keep the battery safe and reliable while enhancing senility without causing harm. To maintain the state of the battery, voltage, current, and ambient temperature, different monitoring techniques are used. To monitor and control the charging of the battery pack, the BMS communicates with the onboard charger. It also adds to the vehicle's range by maximizing the use of the energy stored in it. It is a critical element in electric vehicles that ensures batteries are not overcharged or over discharged, preventing battery damage and occupant harm.

The BMS is responsible for critical operations and functionalities such as:

* Voltage, Current and Temperature control and measurement
* SOC and SOH assessment
* Detection of faults
* Passive cell balancing
* Data storage

Normally the BMS can be classified into 2:

1. Hardware BMS
2. Software BMS

Hardware BMS is an inevitable component of an EV. The functionality of the BMS is related to the cost of an EV, but a BMS consists of these basic functions.

* Over voltage cutoff
* Under voltage cutoff
* Continues current
* Over current detection
* Over temperature cutoff

Software BMS All of the features, such as hardware BMS, are included. Its main feature is data manipulation. They can control data and send data via CAN and Bluetooth. A smart BMS provides advantages such as online monitoring of battery status such as voltage, current, impedance, internal temperature, and so on. 24/7 monitoring enables timely response in the event of a potential battery accident while lowering human maintenance costs. Real-time alarming and online balancing allow the system to analyze and auto-judge uploaded data.

 You can, for instance, create a custom the alarm threshold, and if the uploaded data is abnormal, the system sends an alarm to maintenance via its server. Because of all the historical data collection, storage, and analysis, a smart BMS can be referred to as a BMS data centre. At the same time, a specific system can provide real-time battery information. Furthermore, the friendly user interface design of the smart BMS makes it simple to set up and operate. The smart BMS is used as an assistant in a variety of industries due to its numerous benefits.

Types of battery management systems

1.Centralized BMS Architecture

The battery pack assembly has a single central BMS. All of the battery packages are directly linked to the central BMS. Figure 6 depicts the structure of a centralized BMS. There are some advantages to using a centralized BMS. It is more compact, and because there is only one BMS, it is usually the most cost-effective. However, there are some drawbacks to a centralized BMS. Because all of the batteries are directly connected to the BMS, the BMS requires a large number of ports to communicate with all of the battery packages. This translates to a large number of wires, cabling, connectors, and so on in large battery packs, complicating both troubleshooting and maintenance.

2.Modular BMS Topology

The BMS is divided into several duplicated modules, each with a dedicated bundle of wires and connections to an adjacent assigned portion of a battery stack, similar to a centralized implementation. Figure 7 depicts this. In some cases, these BMS submodules may be overseen by a primary BMS module whose function is to monitor the submodules' status and communicate with peripheral equipment. Because of the duplicated modularity, troubleshooting and maintenance are simplified, and expansion to larger battery packs is simple. The disadvantage is that overall costs are slightly higher, and depending on the application, there may be duplicated unused functionality.

3.Primary/Subordinate BMS

Similar to the modular topology, the slaves in this case are more restricted to just relaying measurement information, while the master is dedicated to computation, control, and external communication. As a result, while the costs may be lower than for modular types, the functionality of slaves is likely to be simpler, with less overhead and fewer unused features.

4.Distributed BMS Architecture

Unlike the other topologies, where electronic hardware and software are encapsulated in modules that connect to cells via bundles of attached wiring. A distributed BMS houses all of the electronic hardware on a control board that is installed directly on the cell or module being monitored. This reduces the majority of the cabling to a few sensor wires and communication wires between BMS modules. As a result, each BMS is more self-contained, handling computations and communications as needed. Despite its apparent simplicity, this integrated form makes troubleshooting and maintenance potentially difficult because it is located deep within a shield module assembly. Costs rise as the number of BMSs in the overall battery pack structure increases.

**Q2. What are the technical parameters to keep in mind while procuring a BMS for assembling a battery pack?**

ANS:

Mainly, there are 6 components for a battery management system.

1. Battery cell monitor

2. Cutoff FETs

3. Monitoring of Temperature

4. Cell voltage balance

5. BMS Algorithms

6. Real-Time Clock (RTC)

1. Battery cell monitor

A battery cell monitor primarily monitors the voltages for battery systems. It is a high-speed system that offers a low overall cost for high voltage measurements.

The easiest way to determine the battery pack’s charge is to monitor individual cell voltage with reference to the set voltage level.

When the voltage of the first cell reaches the voltage limit, the charging automatically trips. It indicates that the battery charging limit has been reached.

If the battery pack has a lesser charge than the average cell, then the least charged cell will reach the limit first, and the rest of the cells will be left partially charged.

2. Cutoff FETs

FET driver is accountable for connection and isolation between load and charger of the battery pack. The behavior prediction is done through voltage, current measurements, and real-time detection circuitry.

They can be connected to a battery pack’s low or high side.

NMOS FETs activation is needed for enabling high-side connection and requires a charge pump driver. A reference for the solid ground is set using a high-side driver for the rest of the circuitry.

We use a low-side FET driver to reduce costs in integrated solutions since a charge pump is not needed. High voltage devices are not required in such cases.

The ground connection of the battery pack floats using low-side cut-off FETs. This can affect the IC performance, making it more sensitive to insinuated noise measurement.

3. Monitoring of Temperature

With the increase in product requirements, the batteries have been on a constant surge in delivering currents at fixed voltages. The continuous operation processes may cause a catastrophic event such as fire or explosion.

We can identify whether battery charging or discharging is desirable using temperature measurements.

Temperature sensors monitor the energy storage system or cell grouping for compact portable applications.

The circuit temperature is monitored by the internal ADC voltage-powered thermistor. Employing the internal voltage reference helps reduce the temperature inaccuracies and improves the overall measurement system.

4. Cell voltage balance

It is crucial to determine the health of the battery pack. That is why cell voltage monitoring is done to ensure that the cells are in a proper running condition for attaining a long battery life.

The operating voltage ranges from 2.5V to 4.2V in a lithium-ion battery.

The battery life is significantly affected while performing battery operations beyond the voltage range. This reduces the life of a cell, which may even make it unfit for use.

Connecting the battery pack in parallel increases the overall drive current, whereas series connection adds the overall voltage.

5. BMS Algorithms

To make quick and effective decisions in real-time based on the information received. For this purpose, a microcontroller for battery management system is needed to collect, organize and assess the information from the sensing circuitry.

Renesas’ ISL94203 is the most famous example of employing a battery management system algorithm. It is a standalone digital solution embedded in a single chip with programmable capabilities.

The memory space and microcontroller for battery management system clock cycles can be cleared using these standalone solutions.

6. Real-Time Clock

Allowing the user to know the battery pack’s behavior before any alarming event, the real-time clock acts as a black box system for time-stamping and memory storage.

The BMS electronics is kept away from synchronizing with a third-party battery pack through battery authentication.

The peripheral power circuitry is used around the components of battery management system through voltage reference/regulator.

**Q3. What is the purpose of BMS with communication? What are the various protocols of communication used in a BMS?**

ANS: The primary goal of a BMS is to keep the battery within the safe operating range in terms of voltage, current, and temperature during charge, discharge, and in some cases open circuit. A BMS IC is typically used when working with a BMS. You may need to connect to an external microcontroller or another external IC depending on the BMS IC used to control your BMS. These ICs must be able to communicate with one another in order to send and/or receive information. For example, you may have a BMS IC that is incapable of measuring current. As a result, you employ an external integrated circuit (IC) that measures current. This current data must then be fed into the BMS IC. Another example is having a microcontroller connected to the BMS IC that reads data from the IC to make BMS decisions. As a result, communication protocols are essential for a battery management system with multiple ICs to communicate with one another.

1. UART

 The most widely used communication protocol in battery management systems is UART, which stands for Universal Asynchronous Receiver/Transmitter. UART is a type of serial communication, which means bits are sent one after the other sequentially rather than multiple bits sent at once as in parallel communication. UART communication is widely used in BMSs to communicate between a microcontroller and the BMS IC. It also serves as a means of communication between the microcontroller and the GSM, Bluetooth, or WIFI modules. It is also extensively used for debugging purposes when developing the firmware of a BMS to check specific sections or lines of code; the output of code can be printed and displayed on a screen using UART. Two UARTs communicate directly with each other in UART communication. UARTs transmit data asynchronously, which means there is no clock signal to synchronize the transmitting UART's output of bits with the receiving UART's sampling of bits.

UARTs use baud rates rather than clock signals. The baud rate is the rate at which data is transferred, expressed in bits per second. In order for communication to work, the baud rates must be set equally on the transmitting and receiving ends. The baud rates can only vary by about 10% before the bit timing becomes unreliable. To transmit data between two UART devices, only two wires are required. For instance, if we have two devices, device 1 and device 2, each has two connections, Rx and Tx. Each device's Tx communicates with the other device's Rx. This way, data from one device is sent to the receiving end of another device, establishing communication.

2. I2C

I2C, or Inter-Integrated Circuits communication, is an IC-to-IC communication protocol. I2C is primarily intended for short-range communication between two ICs (Integrated Circuits) on the same printed circuit board (PCB). I2C supports a multi-master-multi-slave topology. The I2C is a bidirectional standard interface that communicates with slave devices via a controller known as the master. An RTC clock, an EEPROM, flash memory, or SD card memory are examples of slave devices. The device that generates the clock is referred to as the master device, while all other devices are referred to as slave devices. Each device on the I2C bus has a unique device address that allows it to be distinguished from other devices on the same I2C bus. A device may have one or more registers in which data can be stored, written, or read.The serial clock (SCL) and serial data (SDA) lines make up the physical I2C interface. A pull-up resistor must be used to connect the SDA and SCL lines to VCC. Because the SDA line is bidirectional, it can either transmit or receive data.

3. SPI

Serial Peripheral Interface (SPI) is a master-slave protocol that provides a simple and low-cost interface between a microcontroller and its peripherals. To synchronize the transmitter and receiver, or Master and Slave, the SPI protocol employs a dedicated clock signal generated by the master device. One device is designated as the bus's Master (typically a microcontroller), and all other devices (peripheral ICs or even other microcontrollers) are designated as slave devices. The microcontroller, along with other peripheral devices that support SPI communication, can communicate with the BMS IC via SPI communication. Memory devices such as SD cards, MMC, EEPROM, or Flash are used in these applications, as are sensors such as temperature or pressure sensors, control devices such as ADC, DAC, digital POTs, and audio codecs, and other devices such as touch screen devices, LCD devices, RTCs, or video game controllers. Each device in SPI communication uses four lines. To identify which slave device the master is attempting to communicate with, there is an input data line (receiving data), an output data line (transmitting data), a clock line, and a chip select line.

If the master is connected to multiple SPI slave devices, the chip select line functions to select the specific slave device to either transmit or receive data from. A SPI bus's pins are MOSI (Master Out, Slave In), MISO (Master In, Slave Out), SCLK (Serial clock), and CS or SS (Chip Select or Slave Select). The MOSI is used by the master device to send data to the slave, and the MISO is used by the master device to read data from a slave device. SPI communication is a full-duplex communication protocol that operates at extremely high speeds. Full duplex means that data transmission and reception can happen at the same time. This is preferable to UART or I2C communication, which only allow for data transmission or reception at a given time but not both at the same time. The disadvantage of SPI is that it requires four wires rather than two for UART and I2C.

4. CAN

The most widely used communication protocol in the automotive industry is CAN, or Controller Area Network. CAN communication is widely used in automotive applications because it eliminates all signal noises, including electromagnetic noises. It also gets rid of a lot of wire harnesses from a system. It is one of the most dependable and robust communication protocols. CAN applications can be used in applications ranging from simple to extremely complex. They're found in both gas and electric vehicles. The CAN protocol is used in conjunction with a chip that enables CAN communication. Texas Instruments is one company that produces CAN chips that enable CAN communication between devices. The TCAN1042-Q1 Automotive Fault Protected CAN Transceiver with CAN FD is one example.] The microcontroller links to the CAN chip, which interacts with the external devices. TXD and RXD pins on the CAN chip allow it to communicate with the microcontroller. The TXD pin is used for data transmission, while the RXD pin is used for data reception. As a result, these are the most popular and widely used communication protocols for battery management systems.