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

To ensure electric vehicle safety, a Battery Management System must manage the electronics of a rechargeable battery pack. It safeguards the user and the battery by ensuring that the cell operates within its safe parameters. BMS State Of Health (SOH) of the battery, collects data, controls environmental factors that affect the cell, and balances them to ensure the same voltage across cells.      The term "smart battery pack" refers to a battery pack that has a BMS connected to a data bus or an external communication system. As well as providing information about the battery's power status, it may also include features and functions such as fuel gauge integration, smart bus communication protocols, General Purpose Input Output (GPIO) options, cell balancing, wireless charging, embedded battery chargers, and protection circuitry. This information can help the device conserve power intelligently. BMS will continuously monitor key parameters like voltage, current, internal resistance, and ambient temperature. The monitoring system in BMS will protect the device by generating an alarm and disconnecting the load/charger.BMS will be used for different purposes, so there is a variety. A BMS may protect its battery by preventing it from operating outside its safe operating area, such as preventing overcharging and over-discharging Over-current during charging Over-current during discharge Over-voltage during charging, especially significant for lead–acid, Li-ion, and LiFePO4 cells Under-voltage during discharging, especially relevant for Li-ion and LiFePO4 cells Over-temperature Charging while under low-temperature Over-pressure (NiMH batteries) Ground fault or leakage current detection (system monitoring that the high voltage battery is electrically disconnected from any conductive object touchable to use like vehicle body) The BMS may prevent operation outside the battery’s safe operating area by: Including an internal switch (such as a relay or MOSFET) which is opened if the battery is operated outside its safe operating area Requesting the devices to which the battery is connected to reduce or even stop using or charging the battery. Actively controlling the environment, such as through heaters, fans, air conditioning, or liquid cooling

Basic BMS can be divided into two categories.

1) Hardware BMS:-

A BMS must have at least all the functions of a hardware BMS. Mainly the functions are

Overvoltage cutoff

Under voltage cutoff

Continuous current

Over-current detection

Over temperature cutoff

The BMS will also control the recharging of the battery by redirecting the recovered energy (i.e., from regenerative braking) back into the battery pack (typically composed of several battery modules, each composed of several cells).

Battery thermal management systems can be either passive or active, and the cooling medium can either be air, liquid, or some form of phase change. Air cooling is advantageous in its simplicity. Such systems can be passive, relying only on the convection of the surrounding air, or active, utilizing fans for airflow. Commercially, the Honda Insight and Toyota Prius both use active air cooling for their battery systems.[2] The major disadvantage of air cooling is its inefficiency. Large amounts of power must be applied to operate the cooling mechanism, far more than active liquid cooling.[3] The additional components of the cooling mechanism also add weight to the BMS, reducing the efficiency of batteries used for transportation.

2)     Software BMS / smart BMS:-

It has all the features of hardware BMS. Besides that, they can control data, store data, and transmit data via CAN, and Bluetooth. A smart BMS offers benefits such as online monitoring for battery status regarding voltage, current, impedance, internal temperature, etc. 24/7 monitoring allows for timely response in case of potential battery accidents while reducing human maintenance costs.

Furthermore, real-time alarming and online balancing enables the system to analyze uploaded data and auto-judge. For example, you can custom set the alarm threshold, and if the uploaded information is abnormal, the system sends out an alarm to maintenance via its server.

A smart BMS can be called a BMS data center due to all the historical data collection, storage, and analysis. At the same time, you can get real-time battery information via a certain system.

Additionally, it is straightforward to set up and operate due to the friendly user interface design of the smart BMS. Due to its numerous benefits, the smart BMS is increasingly being used as an assistant in various industries. To summarize, there are mainly six application areas with a wide array of use at various levels. These include:

·        Data centers

·        Power utility like substations

·        Transportation such as railway transport

               Base transceiver station sites

·        Energy storage stations Financial institutions like banks.

The majority of battery monitoring suppliers provide common solutions for these industries. Therefore, DFUN provides a targeted solution for different industries that meet the needs of professional customers.

Types of battery management systems

Battery management systems range from simple to complex and can embrace a wide range of different technologies to achieve their prime directive to “take care of the battery.” However, these systems can be categorized based on their topology, which relates to how they are installed and operate upon the cells or modules across the battery pack.

1. Centralized BMS Architecture

Has one central BMS in the battery pack assembly. Batteries are directly connected to the central BMS. The structure of a centralized BMS is shown in Figure 6. The centralized BMS has some advantages. It is more compact, and it tends to be the most economical since there is only one BMS. However, there are disadvantages to a centralized BMS. Since all the batteries are connected to the BMS directly, the BMS needs a lot of ports to connect with all the battery packages. This translates to lots of wires, cabling, connectors, etc. in large battery packs, which complicates both troubleshooting and maintenance.

1. Modular BMS Topology

Similar to a centralized implementation, the BMS is divided into several identical modules. Each module has a dedicated bundle of wires and connections to an adjacent assigned portion of a battery stack. See Figure 7. In some cases, these BMS submodules may reside under a primary BMS module oversight whose function is to monitor the status of the submodules and communicate with peripheral equipment. Thanks to the duplicated modularity, troubleshooting and maintenance are easier, and extension to larger battery packs is straightforward. The downside is overall costs are slightly higher, and there may be redundant functionality depending on the application.

1. Primary/Subordinate BMS

Conceptually similar to the modular topology, however, in this case, the slaves are more restricted to just relaying measurement information. The master is dedicated to computation and control, as well as external communication. Nonetheless, the costs of slaves may be lower than modular types, since their functionality tends to be simpler with less overhead and fewer unused features.

1. Distributed BMS Architecture

Considerably different from the other topologies, where the electronic hardware and software are encapsulated in modules that interface to the cells via bundles of attached wiring. A distributed BMS incorporates all the electronic hardware on a control board placed directly on the cell or module that is being monitored. This reduces the bulk of the cabling to a few sensor wires and communication wires between adjacent BMS modules. Consequently, each BMS is more self-contained and handles computations and communications as required. However, despite this apparent simplicity, this integrated form does make troubleshooting and maintenance potentially problematic, as it resides deep inside a shield module assembly. Costs also tend to be higher as there are more BMSs in the overall battery pack structure

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

There are 6 components of the 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 measures the voltage of battery systems. It is a high-speed system that offers a low overall cost for high-voltage measurements.

By monitoring the individual cell voltages in relation to the set voltage level, the battery pack's charge can be determined easily.

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. The remaining cells will be partially charged.

2.      Cutoff FETs

The FET driver is responsible for connecting the battery to the charger and isolating it from the load. 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 a 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 make the IC more sensitive to insinuated noise measurements, affecting its performance.

3.      Monitoring of Temperature

The batteries have been delivering currents at fixed voltages at a constant surge due to the increase in product demands. Continuous operation processes may result in a catastrophic event, such as a fire or explosion. We can identify whether battery charging or discharging is desirable using temperature measurements. For portable applications, temperature sensors monitor the energy storage system or cell grouping. The circuit temperature is monitored by the internal ADC voltage-powered thermistor. Employing the internal voltage reference helps reduce 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 proper running condition to ensure 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. Battery packs connected in parallel increase the overall drive current, while those connected in series increase 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 the battery management system is needed to collect, organize and assess the information from the sensing circuitry. Rennes’ 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 are prevented from synchronizing with a third-party battery pack through battery authentication. A voltage reference/regulator is used to provide peripheral power to the components of a battery management system.

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

The main goal of BMS is to keep the battery within the safe range in terms of voltage, current, and temperature. This is during the charge, the discharge, and in certain cases at an open circuit. When working with a BMS, you usually use a BMS IC. Depending on the BMS IC being used to control your BMS, you may need to connect it to an external microcontroller or another external IC.

These ICs need to be able to communicate with each other to send and/or receive information from one another. For example, you may have a BMS IC that doesn’t have the capability of measuring current. Therefore, you use an external IC that measures current. This current data then needs to be fed to the BMS IC. Or, another example, is you have a microcontroller connected to the BMS IC that reads the data from the IC to make decisions governing the BMS. So communication protocols are vital for a battery management system with multiple ICs to be able to communicate with each other.

UART

UART, which stands for Universal Asynchronous Receiver/Transmitter, is the most widely adopted communication protocol for in battery management systems. UART is a form of serial communication. This means bits are sent one after another sequentially instead of multiple bits sent at once. This is what parallel communication involves. UART communication is widely used for communication between a microcontroller and the BMS IC in a BMS. It is also used for communication between the microcontroller and the GSM, Bluetooth, or WIFI modules. It is also used extensively for debugging purposes when developing the firmware of a BMS to check particular sections or lines of code; using UART, the output of code can be printed and displayed on a screen. In UART communication, two UARTs communicate directly with each other UARTs transmit data asynchronously. This means there is no clock signal to synchronize the output of bits from the transmitting UART to the sampling of bits by the receiving UART.UARTs do not operate on clock signals but with baud rates. The baud rate is the speed of data transfer expressed in the number of bits per second that communication occurs in. The baud rates must be set equally on the transmitting and receiving ends in order for communication to work. The baud rates can only vary by about 10% before the timing of the bits becomes too far off. Only 2 wires are needed to transmit data between 2 UART devices. For example, if we have 2 devices, device 1 and device 2, each device has 2 connections, Rx and Tx. The Tx of each device connects to the Rx of the other device. So, the transmitting data of one device reaches the receiving end of the other device, establishing communication.

I2C

I2C, Inter-Integrated Circuits communication, is a protocol used for IC to IC communication.I2C is intended primarily for short-distance communication between 2 ICs (Integrated Circuits) on the same printed circuit board (PCB).I2C allows Multi-Master – Multi Slave topology. The I2C is a standard bidirectional interface that uses a controller known as the master to communicate with slave devices. Examples of slave devices include things such as an RTC clock, an EEPROM, flash memory, or SD card memory. The device that generates the clock is the master device. All devices are slave devices Each device on the I2C bus has a specific device address to differentiate between other devices that are on the same I2C bus. A device can have one or multiple registers where data is stored, written, or read. The physical I2C interface consists of serial clock (SCL) and serial data (SDA) lines. Both SDA and SCL lines must be connected to VCC through a pull-up resistor. Since the SDA line is bidirectional, it can send and receive data.

SPI

SPI, Serial Peripheral Interface, is a master-slave type protocol that provides a simple and low cost interface between a microcontroller and its peripherals. The SPI protocol uses a dedicated clock signal that is created by the master device to synchronize the transmitter and receiver or Master and Slave.One device is considered the Master of the bus (usually a microcontroller) and all the other devices (peripheral ICs or even other microcontrollers) are considered as slave devices. The microcontroller can communicate with the BMS IC via SPI communication, along with other peripheral devices that can communicate with SPI communication. These applications omc; ide memory devices such as SD cards, MMC, EEPROM, or Flash, sensors such as temperature or pressure sensors, control devices such as ADC, DAC, digital POTs, and audio codec, and other devices such as touch screen devices, LCD devices, RTC, or video game controllers. SPI communication uses 4 lines for each device. There is an input data line (receiving data), and output data line (transmitting data), a clock line, and a chip select line to identify which slave device the master is trying to communicate with. If there are multiple SPI slave devices connected to the master, then the chip select line functions to select the specific slave device either to transmit data to it or receive data from it. Specifically, the pins of a SPI bus 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 how the master device transmit data to the slave and the MISO is how the master device reads information from a slave device. SPI communication is a full-duplex communication that occurs with very high speeds. By full duplex, it is meant that the transmission and receiving of data can occur simultaneously. This is advantageous over UART or I2C communication, in which data can only be transmitted or received at a given time but not simultaneously. The disadvantage of SPI is that 4 wires are required instead of 2 for UART and I2C.

CAN

CAN, Controller Area Network, is the automotive industry's most widely used communication protocol. CAN communication is commonly used in automotive applications because it removes all signal noise, such as electromagnetic interference. It also removes a host of wire harnesses from a system. It is one of the most robust and reliable communication protocols. CAN applications can be used in both simple and complex applications. They are found in both gasoline and electric vehicles. The CAN protocol is used with a chip that allows CAN communication. Texas Instruments is one manufacturer that makes CAN chips that allow CAN communication between devices. One example of this is the TCAN1042-Q1 Automotive Fault Protected CAN Transceiver with CAN FD.

The microcontroller connects to the CAN chip, which then connect to outside devices. The CAN chip has TXD and RXD pins, which allow it to communicate with the microcontroller. The TXD pin is for transmission of data and the RXD pin is for receiving data. So these are the most common and most used communication protocols for battery management systems.