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

A Battery Management System (BMS), which manages the electronics of a rechargeable battery, whether a cell or a battery pack, thus becomes a crucial factor in ensuring electric vehicle safety. It safeguards both the user and the battery by ensuring that the cell operates within its safe operating parameters. BMS monitors the 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.A battery pack with a BMS connected to an external communication data transfer system or a data bus is referred to as a smart battery pack. It may include additional 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, all aimed at providing information about the battery's power status. This information can help the device conserve power intelligently.

A smart battery pack can manage its own charging, generate error reports, detect and notify the device of any low-charge condition, and predict how long the battery will last or its remaining run -time. It also provides information about the current, voltage, and temperature of the cell and continuously self-corrects any errors to maintain its prediction accuracy. Smart battery packs are usually designed for use in portable devices such as laptops and have embedded electronics that improve the battery's reliability, safety, lifespan, and functionality. These features enable the development of end products that are user-friendly and more reliable. For instance, with embedded chargers, batteries can have longer life cycles as the chargers charge the batteries to optimal, ideal specifications within the temperature limits. Accurate fuel gauges allow users to confidently discharge batteries to their limits and not worry about damaging the cell. GPIO, which stands for General Purpose Input/Output (GPIO), is an interface used to connect electronic devices and microcontrollers such as diodes, sensors, displays, and so on.

Also, in larger systems such as car batteries, the additional components needed for air-based systems such as filters can increase the weight of the car, further affecting the battery's efficiency.

Liquid-cooled systems have a higher cooling potential than air because they are more thermally conductive. The batteries are submerged in coolant, or the coolant can freely flow into the BMS without affecting the battery. However, this indirect form of thermal cooling can create large temperature differences across the BMS due to the length of the cooling channels. But they can be reduced by pumping the coolant faster, so a tradeoff is created between the pumping speed and thermal consistency.

Making key calculations

A BMS calculates various battery values based on parameters such as maximum charge and discharge current to determine the cell's charge and the discharge current limits. These include:

The energy in kilowatt-hour(s) (kWh) delivered since the last charge cycle

The internal impedance of a battery to measure the cell's open-circuit voltage

Charge in Ampere per hour (Ah) delivered or contained in a cell (called the Coulomb counter), to determine the cell's efficiency

Total energy delivered and operating time since the battery started being used

Total number of charging-discharging cycles the battery has gone through

Facilitating internal and external communication

A BMS has controllers that communicate internally with the hardware at a cellular level and externally with connected devices. These external communications differ in complexity, depending on the connected device.

Optimal Energy Utilization

Battery management systems keep the battery safe, reliable, and increase the senility without entering a damaging state. Different monitoring techniques are used to maintain the state of the battery, voltage, current, and ambient temperature. The BMS communicates with the onboard charger to monitor and control the charging of the battery pack. It also helps maximize the range of the vehicle by optimally using the amount of energy stored in it. It is a crucial component in electric vehicles to ensure that batteries do not get overcharged or over discharged, thus avoiding damage to the battery and harm to occupants.

The battery is a fundamental component of the electric vehicle, which represents a step forward toward sustainable mobility. The battery management system is a critical component of electric and hybrid electric vehicles. Its chief purpose is to ensure safe and reliable battery operation. As an engineering services provider, Cyient works closely with industry experts through our focus areas of megatrends—Sustainable Energy Solutions and Electrification.

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 upon 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. All the battery packages are connected to the central BMS directly. 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 of 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.

2.Modular BMS Topology

Similar to a centralized implementation, 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. 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 is easier, and extension to larger battery packs is straightforward. The downside is overall costs are slightly higher, and there may be duplicated unused functionality depending on the application.

3.Primary/Subordinate BMS

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

4.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 alleviates 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?

Mainly, there are 6 components of 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?

The main goal of BMS is to keep the battery within the safety operation region in terms of voltage, current, and temperature during the charge, the discharge, and in certain cases at 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 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 used communication protocol used in battery management systems.UART is a form of serial communication, which means bits are sent one after another sequentially instead of multiple bits sent at once which is what occurs with parallel communication.The 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, which 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 the 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 goes 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. This way the transmitting data of one device goes to the receiving end of the other device, thus, 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, while all other 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 the serial clock (SCL) and serial data (SDA) lines. Both SDA and SCL lines must be connected to VCC through a pull-up resistor.Being that the SDA line is bidirectional, it functions to transmit data or 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 tmeperature or pressure sensors, control devices such as ADC, DAC, digital POTs, and audio codec, and other devices such as touch screen devices, LCD devcies, 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 there can only be transmission or receiving of data that can occur at a given time but not both 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 most widely used communication protocol in the automotive industry. CAN communication are used frequently in automotive applications because it removes all signal noises such as electromagnetic noises. 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 simple to extremely complex applications.They are used in both gasoline and electric vehicles.The CAN protocol is used with a chip that allows for CAN communication. Texas Instruments is one manufacturer which makes CAN chips that allow for 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 connects to the outside devices.The CAN chip has TXD and RXD pins, which allow it to communicate with the micrcontroller. The TXD pin is for the transmission of data and the RXD pin is for the receiving of data.So these are the most common and most used communication protocols for battery management systems.

Submitted by Navya K