Technical Article
HEV/EV Battery Management Systems Explained Simply

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As shown in Figure 1, a very basic transmission system for an electric vehicle (EV) comprises three system blocks.

- The battery pack is an array of cells (typically lithium-ion [Li-ion] cells in full automotive EVs) that generates voltages up to hundreds of volts. The system needs of the EV will define the voltage.
- The next part of the system is the inverter. EVs use AC traction motors because they provide affective acceleration from a complete stop and are also very reliable. Voltage from the battery pack is in the form of DC; this is converted into AC (typically three phase) through the inverter. Like the voltage, the number of phases depends on the needs of the system and the type of motor used, but there are typically three phases.
- The electric motor is usually an induction motor, which requires an AC voltage. These types of motors are common in EVs because they are easily driven, reliable and cost-effective. The motor comprises three coils wound around an outer part called the stator. The inner portion is typically a cage made up of copper or aluminum rods called the rotor.

Figure 1. Simple Flow of an EV Transmission Chain – BMS Goes to Inverter Then to 3 Phase AC Motor

In this blog, I will talk about considerations related to the battery pack and managing state of charge. Because the battery pack is made up of multiple cells connected in series, its effective usability is based on the weakest battery cell. The cell charges differ because of different chemical imbalances that occur during manufacturing, position in the pack (where heating varies), and changes related to usage or longevity.

The difference between cell voltages indicates an unbalanced cell at the system level. The reasons for the differences are still being studied even now. Understanding this well is an important goal, because it affects how long the battery pack will last in terms of power output, as well as the usable life of each individual cell and the lifetime of the battery pack.

One of the most important parameters to consider is state of charge. This is the different amount of charges contained in the individual cells. The amount of imbalance between the cells is measured in percentage. So if one cell has a 94% state of charge and another has 88% state of charge, there is an imbalance of 6%. Each cell will also have a different voltage called the open circuit voltage (OCV), which is the chemical state of charge.

The challenge for a battery pack is that when drawing current, not every cell will lose charge at the same rate. So discharge rates happen at different rates, even though the cells are connected in series. Because some cells sink lower than others, their ability to recycle and absorb the amount of charge will change over time. This cycle is accelerated by other conditions, including temperature. As I mentioned earlier, some cells might be hotter in the pack simply by their position or location near cooling elements.

The main cause of cell failure is having the cell collapse completely, which will affect the battery voltage because the cell is essentially just a resistance lowering the voltage. One way to prevent this is through cell balancing, which is the process of managing how to bring each cell up to a full charge. There are several techniques that can accomplish cell balancing; the simplest is to put a resistor and a metal-oxide semiconductor field-effect transistor (MOSFET) in parallel with each cell, monitoring the voltage across the cells via a comparator that watches the voltage and using simple algorithms to turn on the MOSFET to bypass the cell. The disadvantage of this approach is that the bypassing wastes energy.

Another technique is known as charge shuffling, which doesn't use resistors and only a capacitor is connected between the cells. This technique does not waste energy in the bypassing, but it is more complex, because you need to connect over wider distances between the cells, rather than bypassing each cell individually.

The technique used in EVs is generally inductive charging, where a transformer connects between cells that are imbalanced because it is a higher power system. The circuit design tends to be quite large, which requires larger area within the design to accommodate the amount of circuitry required to implement the solution.

All of this balancing is based on extensive research into individual cell characteristics and chemistry, represented by spreadsheets and mathematical formulas that use tools like MATLAB to run them. A microprocessor plays an important part in the system by making sure that all balancing executes correctly. To power the microprocessor, the system supplies power from a DC/DC converter, which connects directly to the battery pack and provides either a 48V or 12V output based on the system design. Texas Instruments has two devices that can power the microprocessor; both have the ability to withstand tough conditions in terms of transient performance, along with wide voltage ranges.

The LM5165-Q1 is a 3V to 65V, ultra-low Iq synchronous buck converter with high efficiency over a wide input voltage and load current ranges. With integrated high- and low-side power MOSFETs, this device can deliver up to 150mA of output current at fixed output voltages of 3.3V or 5V, or an adjustable output. The converter is designed to simplify implementation while providing options to optimize the performance of applications like battery-management systems. Working up to 150°C Tj, the device can withstand the high operating temperature ranges found in EVs.

The LM46000-Q1 SIMPLE SWITCHER® regulator is a synchronous step-down DC/DC converter capable of driving up to 500mA of load current from an input voltage range of 3.5V to 60V. The LM46000-Q1 provides exceptional efficiency, output accuracy and dropout voltage in a very small solution size when you need a high input voltage or more current from the system.

There are many ways to manage balancing of Li-ion cells in a pack but how the design looks can depend on many factors, like cost, size, heat and needed accuracy. It is important to consider all these factors in the design strategy before implementation. Get more information about TI's products which meet strict automotive and system requirements, and view a system block diagram for a HEV high cell count battery pack.