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Understanding battery management systems: Key components and functions

Here's what you need to know about fuses, sensors, controllers and all the other building blocks of the BMS.

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Batteries store more than just electricity. In a world desperate to transition to renewable energy, batteries store the promise of a greener future. And to fulfill that promise, they need the help of a battery management system, or BMS.

"Any place where there are batteries, there has to be a battery management system," Mohammad Mohiuddin, field applications engineer at Eaton, told engineering.com.

Mohiuddin and his team help engineers design and build battery management systems that can handle the unique requirements of their applications. While there are some off-the-shelf BMSs, most of the time these crucial systems need a designer's touch. Here's what you need to know about how they work and why they're so important for the energy transition.

What is a battery management system?

Today's battery-powered applications are significantly more complex than a pair of classic AAs. Electric vehicles (EVs), for instance, involve massive lithium-ion battery packs with multiple cells connected in series and parallel. It's essential to ensure that these cells charge and discharge at a equal rate, which enables the system as a whole to perform at its best for the longest possible lifetime. Even more importantly, it's crucial to ensure that these batteries work safely within their operating limits, as thermal runaway is a real hazard in lithium-ion battery systems.

And EVs are easy compared to today's energy storage systems. These are room-sized banks of batteries that store energy from renewable sources, such as solar and wind, and distribute it as needed. As with EVs, all the cells of an energy storage system must be put to optimal use and protected from adverse conditions. But while EV batteries have a capacity measured in tens of kilowatt-hours, energy storage systems can reach into the gigawatt-hour range, with significantly higher power outputs.

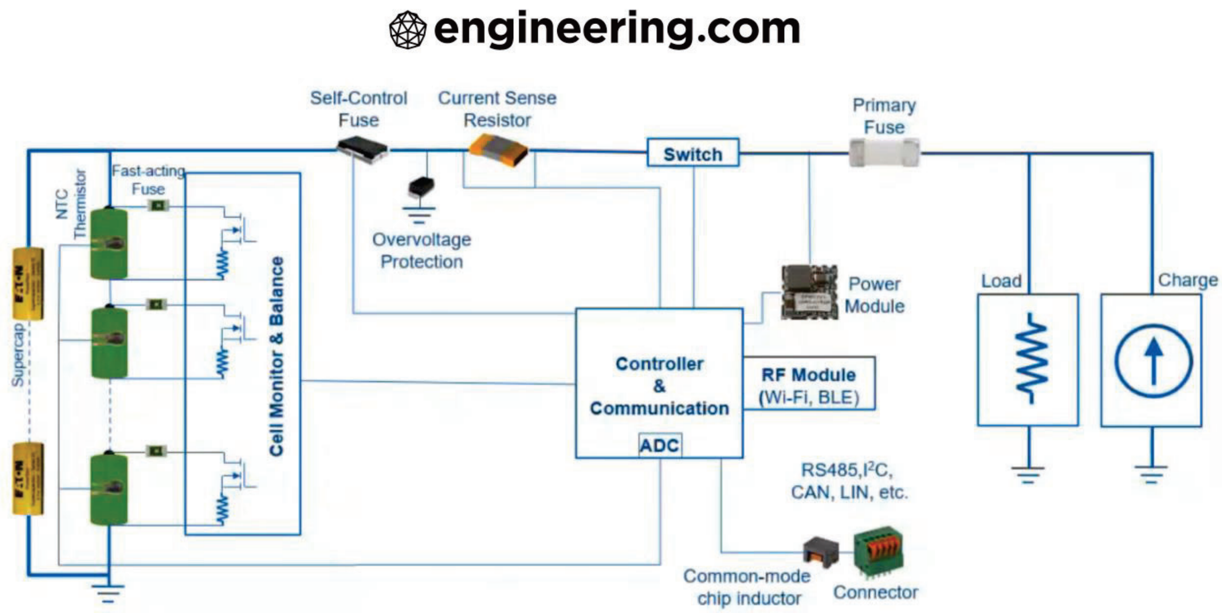
Complicating the matter even further is the addition of supercapacitors into the mix, an increasingly common technique for large-scale energy storage. While batteries have been a well-understood technology for many years, supercapacitors are on the frontier of energy storage. Combining the two technologies is a challenge for many of Mohiuddin's clients. "They want to know the conditions that a supercapacitor has to be operated along with the batteries so that the two can go together," he said.

Despite their differences, EVs and energy storage systems both solve these challenges in the same way: the battery management system. The BMS is the brain of any battery system. It's responsible for monitoring the condition of every cell in the battery pack and distributing the load accordingly, keeping track of important parameters including state-of-charge (SoC) and state-of-health (SoH). The BMS is also responsible for optimizing the life of the battery system by performing charging and discharging in a safe and sustainable way. If something should go wrong, it's the BMS's job to safely bring the battery under control or shut it down if necessary.

Primary functions of a BMS. (Image: Eaton.)

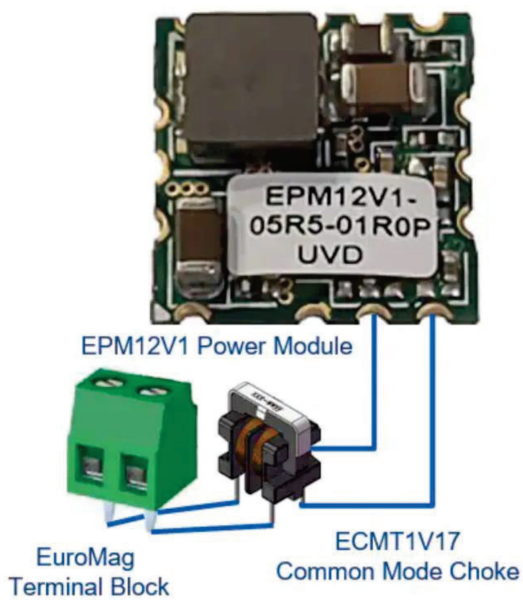
Key components of a battery management system

Any complex battery-powered application requires a BMS customized for its requirements. But while the details will be different, there are several components common to every BMS. The below diagram shows these BMS building blocks.



The building blocks of a BMS. (Image: Eaton.)

If the BMS is the brain of the battery, the controller is the brain of the BMS. This chip coordinates the functions of the BMS, monitoring the state of each cell and balancing the load amongst them. The controller also maintains communication with other systems, such as an EV's main computer. This communication can be either wired or wireless. If wired, the signal will be filtered through a common-mode chip inductor before passing through to the connector. If wireless, the controller will be connected to an RF module, typically for Wi-Fi or Bluetooth Low Energy (BLE). A power module brings down the high voltages at the BMS input to smaller values suitable for the electronics in the controller.



Closeup of the Eaton EPM12V1 power module, a non-isolated DC-DC converter suitable for battery management systems, connected to an Eaton common-mode choke and terminal block. (Image: Eaton.)

One of the most important components in the BMS is the primary fuse, which provides overcurrent protection to the whole battery pack. The BMS also includes a self-control fuse further down the circuit, attached to the BMS controller, that provides an additional layer of protection. "If an anomaly occurs, if the current is flowing and it is not being controlled for some reason, the controller can actually blow the self-control fuse open," Mohiuddin said. Finally, there are additional fuses on each cell that can act quickly to shut down problematic cells without having to shut down the entire battery pack.

Another fundamental BMS component is the current sense resistor, which monitors the current coming in and out of the battery pack and feeds that data to the BMS controller. This is no ordinary resistor. It must have both an extremely small resistance, on the order of a few milliohms, as well as an extremely tight tolerance, on the order of 1% or less. It must also be able to handle high levels of power, as much as 20 watts, without breaking down. To meet these requirements, Mohiuddin explained that Eaton's current sense resistors are designed with specialized materials.

There's more. "These resistors are available not only in two terminals, but four terminals," Mohiuddin said, describing a measurement scheme called the Kelvin, or 4-wire, method. "The two additional connection points allow precise monitoring of the current going through it and the voltage drop across it."

Finally, the BMS monitors the temperature of the batteries using negative temperature coefficient (NTC) thermistors. If the temperature gets too high, the controller can adjust the current to prevent dangerous overheating.

Sourcing the right components for your BMS

With the BMS serving such an important role in today's advanced battery-powered applications, it's crucial for engineers to design these systems to the highest possible standards. While the specific components necessary for each BMS will differ, look for components that have been designed and tested for battery management applications. These will provide the temperature, power and durability requirements that are so often necessary in BMS design.

Eaton offers battery management system components in each of the building block categories described above. For example, Eaton's Bussmann series CC06FA fuses are designed for automotive BMS applications, and so are Eaton's Bussman series CSKA current sense resistors, which use the 4-wire Kelvin method for increased measurement accuracy. If you need help designing your BMS, Eaton application engineers like Mohiuddin can share their expertise.

"We advise customers on what is needed and what is going on with harvested energy from different sources," he said.

To learn more about components for battery management systems, visit Eaton at TTI.