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Design Approach for Battery Management Systems for Automotive and Industrial Applications

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Introduction

Designers and manufacturers of Battery Management Systems (BMS) often describe the complex features of their products. They tout flexibility and configurability with little focus on core functionality and reliability. The marketing literature for these systems frequently overlooks one of the most well known realities of current battery management technology, which is that the most likely cause of pack failure is due to the BMS itself.

With the state of the industry at present, automotive and industrial customers who are serious about building reliable and safe products know that transparent operation is more important than a prolific feature set. An electric vehicle, in particular, needs to work mile after mile, year after year. Toyota's model for the Corolla and Camry focused on delivering a basic yet reliable core feature set with extremely high reliability. This model resulted in two of the best selling cars on the planet, and did so without a high profile feature set.

The goal of a battery management system for automotive and industrial markets should be to provide maximum reliability and safety for the battery pack through minimum complexity. Success is being able to guarantee operation of the entire pack without faults for 3, 5, even 10 years.

A true automotive grade, highly reliable, safe, and cost effective BMS is designed uncompromisingly around the core criteria described in the following pages of this application note.

Less is More

Adding features beyond the clearly defined core set described below may seem like a good idea. However, the true cost of these features is reduced reliability through increased complexity and added failure modes. Industrial and automotive customers do not trade features at the expense of reliability or safety. Highly complex, feature rich designs are typically not appropriate for safety critical environments.

Occam Power Solutions' BMS11203 delivers the core functionality required of an automotive grade battery management system without features that necessarily reduce safety and reliability.

Low Quiescent current (does not kill low SOC packs)

Because it is impossible to take measurements without drawing some energy, the cell monitoring subsystem draws a small amount of current. In addition, the main BMS electronics require energy to operate. When the BMS is in sleep mode this current draw is called *quiescent current*. If these two subsystems are not carefully designed with the goal of near quiescent current during sleep, they can easily deplete a resting pack, especially one that is at a low State of Charge (SOC).

For instance, a normal BMS design may draw 1mA of current in its lowest power mode (sleep). This corresponds to an energy usage of 100mAH over a period of 4 days and 720mAH over a period of 1 month. Even with a high capacity pack in the 50-100AH range, this is ~1-2 percent parasitic discharge per month. If the pack is discharged and stored without charging for a period of one to two months, it could be depleted below the safe limit of the cells, causing permanent damage the pack.

In contrast, the BMS11203 design uses no more than 50μA in sleep. This corresponds to an energy usage of 5mAH over a period of 4 days and 36mAH over a period of 1 month. This single design change extends the safe storage time of a depleted pack by a factor of 20. In other words, it extends the safe storage time from a period of 1 month with a normal BMS design to a period of over 2 years with a BMS11203. This difference highlights the importance of attention to detail in the design of the entire BMS.

It is unacceptable for a BMS to cause pack failures. In contrast to most off-the-shelf BMS designs the BMS11203 is optimized for near zero quiescent current. The BMS11203 *does not kill packs*.

Personnel Safety

The high voltage and large amount of stored energy in a typical automotive pack is instantly lethal if handled improperly. This is not limited only to dangerous voltages at the pack output connections, but also includes the risk of fire during a faulty contactor latch condition if the system lacks a fail-safe High Voltage Interlock (HVIL). The BMS11203 includes an HVIL with three redundant failsafes and is designed so that all of these failsafes would have to fail simultaneously for a dangerous condition to exist. The failsafes are as follows:

- Failsafe 1: A logic level output for the HVIL signal is provided by the system itself and is both de-glitched and held in a disabled state (logic LO) by default. The Main Microprocessor has to configure this signal as output followed by setting the output line HI for a minimum time interval (glitch free) in order to enable the HVIL circuit. If these conditions are not met, the HVIL system (and pack) remain disabled. This mechanism ensures that if the BMS has not received an ENABLE signal (analog) or message (digital comms link), the HVIL logic level output is kept LO and the system is safe.
- Failsafe 2: An analog HVIL input signal which has no digital circuitry (it is intrinsically simple and robust) is used to enable the three contactor drive circuits. The HVIL signal must be held in an enabled state (logic HI) in order to enable contactor drive. In the event that the HVIL input signal line is damaged or destroyed, the input circuit is pulled to logic LO by design, immediately opening the contactors and disabling the pack. In the extremely unlikely case that this system malfunctions, there is an additional safety circuit protecting the pack.
- Failsafe 3: In the event that all of the HVIL circuitry mentioned above fails or is rendered inoperable, a final failsafe is built into the system via a switched contactor power supply. In the event that the analog (HVIL) and digital (Contactor Drive) signals to the contactor control circuit are permanently latched on during a fault condition, the power supply to the contactor drive can be disabled by the Main Microprocessor. This provides a final “signal override" method of disabling the pack in the event of a catastrophic failure.

The carefully implemented and industry proven interlocking methodology used in the BMS11203 keeps people, property, and the battery pack safe, even under extreme conditions and multiple failure modes.

Voltage/Current Measurement Accuracy

Precise and accurate voltage and temperature measurement of the cells is important when judging the safety margin for over-charge, over-discharge, and extreme temperature conditions, which can result in physical damage to the cells. Additionally, high precision current measurement with high noise immunity is necessary in order to provide accurate monitoring of charge and discharge conditions as well as to provide extremely accurate gas gauging (coulomb counting). Incorrect implementation and characterization of both the analog and digital circuitry (e.g. improper filtering of a signal in hardware of firmware) can create a false sense of security, as the BMS will be providing information that indicates good pack health while the real pack conditions are no longer within safe limits. Getting accurate measurements while maintaining good transient response and system bandwidth requires an understanding of the operating environment as well as proper application of analog design principles.

In the development our analog measurement circuitry, Occam Power Solutions utilized real-world test platforms, including road going vehicles, in order to gain an understanding and appreciation of the automotive electric vehicle environment. This environment is full of transient fields, various noise sources, a myriad of noise coupling mechanisms, and wide temperature swings, all of which are not found in lab environments and are difficult to accurately simulate. Using actual vehicles in real-world driving conditions for development and testing allowed us to fine tune our component selection, filter designs, and board layout specifically for the automotive environment. We continue to utilize these test platforms on a daily basis for ongoing development and long term reliability testing of our system architecture.

The BMS11203 has a highly customized analog measurement subsystem that works as specified in the electric vehicle environment. It provides reliable, high precision, high accuracy, low latency measurements under the most challenging conditions.

Reliable Communications

In an automotive application, electrical noise is present everywhere. Like trying to carry on a conversation in a noisy restaurant or during a loud concert, this electrical noise can drown out communication signals both within the BMS itself as well as between the vehicle controller and the pack. Many BMS designs lose a substantial portion of their data due to this noise and are only able to communicate intermittently. Just like carrying on a conversation in a noisy environment, these BMS designs have difficulty piecing together this intermittant data into a meaningful understanding of what is happening within the pack. Un-reliable communication creates both safety and reliability issues for a battery pack as it results in windows of time where the BMS is unaware of the actual pack state as well as windows of time where the vehicle controller is unaware of the pack state. These lapses in communication can lead to pack over discharge, thermal runaway, and other conditions that result in catastrophic modes of failure.

In contrast to many BMS designs, which lose a significant portion of their messages under adverse conditions, the BMS11203 design loses less than 0.01% (100 ppm) of messages on internal and external communications channels under such conditions.

Simplicity Implies Reliability

The most successful BMSs to date in terms of reliability and volume are found in the Tesla Model S and Nissan Leaf battery packs. These designs have extremely low failure rates and sufficient performance for monitoring and balancing a pack reliably without introducing BMS related failures. They are the benchmark for EV designs because they are simple, rudimentary, and perform core pack management tasks extremely reliably.

In addition to implementing a similarly simple and reliable architecture, the BMS11203 uses automotive grade IP67 rated connectors and is fully potted in a one-piece enclosure, providing the highest degree of environmental protection possible while remaining extremely cost effective.

The BMS11203 improves on the excellent performance and reliability of the Model S and Leaf BMS designs, doing so with greater scalability, improved environmental protection, and decreased cost.

Conclusion

The BMS11203 delivers high reliability, low quiescent current, uncompromising safety, high precision measurement with excellent accuracy, and low complexity and cost. It provides battery manufacturers with the BMS platform they need in order to become a premier battery pack supplier to automotive and other industrial markets.

For more information about Occam Power Solutions and our world class systems, visit www.OccamPower.com or email info@OccamPower.com.