White Paper

Implementing Inter-Module Communications in EV Battery Systems

How Electric Vehicle Battery Systems Work

High voltage battery packs for electric vehicle (EV) drivetrain applications typically comprise a number of discrete cells, which are configured or “stacked” into blocks of cells to form the battery. These blocks are connected to each other in various series and parallel combinations to achieve the required terminal voltage and energy rating. Each individual block of cells in the stack is managed by a battery control module, which incorporates a battery management IC to handle cell control, monitoring and balancing functionality.

The modules are connected or “daisy chained” to each other and back to the vehicle control system using interconnecting communications cables (see Figure 1). These cables carry the communications required between the modules for optimal and safe battery operation; however, they can be susceptible to general electrical switching transients. This includes, but is not limited to, inverter and battery charger switching noise, externally generated EMC/EMI and other electrical disturbances. Similarly, in a centralized battery management system (BMS), where all control electronics are incorporated onto a single PCB, communication occurs between individual ICs using copper tracks. Being fixed in position, copper PCB tracks can potentially be more easily controlled and communications distances kept to a minimum, but the PCB still requires careful design, track routing, and component placement and selection.

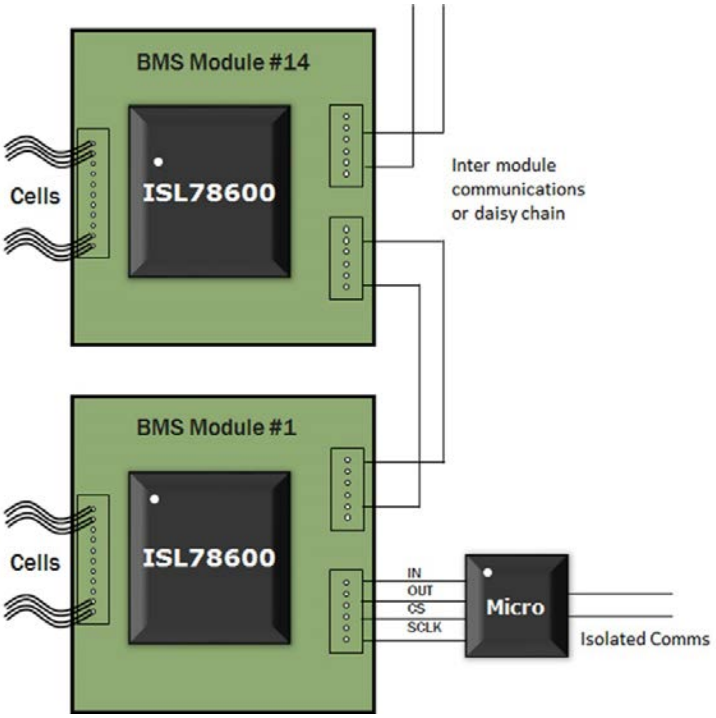


Figure 1. Multiple BMS modules can be daisy chained to each other and back to the vehicle control system

Inter-Module Communications

The inter-module communications, or daisy chaining, can be implemented using a range of automotive standard topologies and protocols, for example SPI or CAN. Irrespective of the topology employed, all require some form of electrical DC isolation between the “hot,” high voltage domain, and the “cold,” low voltage or vehicle chassis voltage domain. This isolation can be realized using digital techniques; however, digital isolators require a complementary power supply and can be relatively expensive. Cost effective alternatives, specifically designed for EV’s, are offered by a number of vendors using proprietary communication protocols and are implemented in a variety of ways. DC isolation is achieved using capacitors, transformers or a mixture of both.

A significant advantage of proprietary protocols over standard auto protocols for communication between battery management modules is that they are specifically designed to meet the stringent safety, regulatory and communication integrity standards required by the automotive industry. They are generally lower power than standard interfaces such as CAN. The under-the-hood environment under which these modules must operate is extremely hostile, as they are being exposed to temperature extremes and particularly from an electrical transient and EMI/EMC perspective. Even at the battery assembly and testing stage there are significant transients and stresses to be considered that can disrupt communications or even cause damage to parts on PCB’s that are not optimized or protected properly. Assembly and test transients are typically caused by “hot plugging,” the point at which the cell strings or communications lines are connected to the battery management module or the inter-module communication cables are plugged together. Significant energy levels can be present at this stage and cell connection sequencing can be random and highly unpredictable. As a result, the circuit being connected must be able to handle this and the system design should incorporate suitable external protection components.

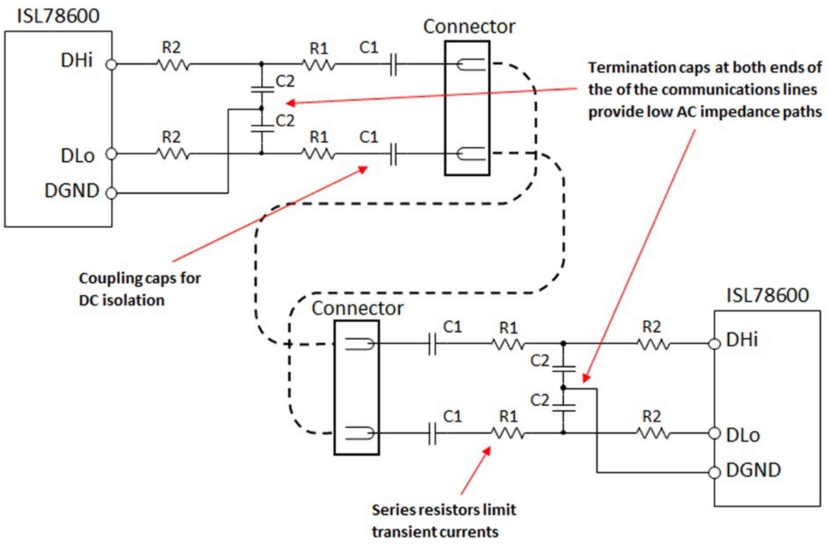
There are two basic techniques used to implement proprietary communication schemes: voltage mode and current mode. Voltage mode utilizes a low impedance transmitter and high impedance receiver, which has good transient immunity, but is susceptible to EMI/EMC. Current mode, on the other hand, uses a high impedance transmitter and low impedance receiver. It is less capable than voltage mode schemes at handling transients, but has good EMI/EMC immunity.

Intersil’s ISL78600 battery management IC incorporates a proprietary communication protocol, which consists of a symmetrical, two wire, bi-directional, asynchronous daisy chain (see Figure 2). By using capacitive source and load characteristics, the ISL78600 combines the best of voltage- and current-mode schemes, giving optimal high speed, high energy transient immunity and best-in-class EMI/EMC immunity.

Capacitive coupling for lowest cost provides isolation, and in distributed systems the connecting wiring between modules can be a simple, cost-competitive unshielded twisted pair (UTP), and minimal external components. Up to 14 battery management modules can be daisy chained together to realize battery systems of up to 168 cells, more than adequate for the majority of EV powertrain applications.

It is suitable for use where the highest levels of communications integrity stipulated by the ASIL standards committee is required and optimizes the systems designers’ opportunity to meet targeted ISO 26262 functional safety requirements. The proven ISL78600 meets and exceeds the most difficult hot plug and EMI requirements, including the stringent EMC evaluation stipulated by automotive OEMs. The EMC standard evaluation focuses on CAN transceivers and the extended hardware requirements for LIN, CAN and FlexRay interfaces in automotive applications.

This standard requires inducing a transformer coupled disturbance directly into the daisy chain cabling with a signal in the frequency range of 200MHz to 1000MHz, at an amplitude of 400V/m, both as a free field and using Bulk Current Injection (BCI). It also comprises a Direct Power Injection (DPI) test which is favored by European auto OEMs. This is where the power is injected directly into the device pins, generating power levels of up to 8W in the 1MHz to 1000MHz frequency range.



Termination caps at both ends of the of the communications lines provide low AC impedance paths

Coupling caps for DC isolation

Series resistors limit transient currents

Figure 2. The ISL78600 provides optimal transient and EMI/EMC immunity

Layout Considerations

In addition to transients that occur during normal vehicle use, they are also induced during the battery system and vehicle construction. Shrinking process geometries and increasing complexities of parts reduce the immunity of modern ICs to certain types of Electrostatic Discharge (ESD) and increase the need for careful layout consideration and external component selection. Careful routing of tracks reduces the opportunity for circulating currents to cross the PCB and placing sensitive parts like the battery manager IC well away from the potential paths of transients, all serve to reduce their possible effects. Intersil recommends the use of high quality multilayer PCBs with at least one of the layers being dedicated to being a continuous ground plane. Keeping battery interface connectors close to each other and making track routing short maximizes the opportunities for circulating current caused by hot plug events to be contained within the battery connector's immediate locale.

Additionally, Intersil strongly recommends the use of Zener diode protection devices particularly across the communications interface. These can be simple, cost effective and extremely efficient at clamping both +Ve and –Ve transients induced in the communication interface cabling. These should be placed close to the cables termination point on the PCB.

In order to aid with optimal design and implementation of transient protection, auto industry specific ESD standards have been developed to test for robustness and levels of protection. These include the Human Body Model (HBM), Machine Model (MM) and Charged Device Model (CDM); however, there are more common hot plug events with subtle fast transients that can instigate a system failure.

Consideration should be given to leading edge analysis techniques that can map current flow across PCBs when subjected to transients. Being able to "visualize" current flow can be very revealing and an invaluable debug tool when optimizing a PCB construction and layout.

Hot plug transients can be a significant issue if not considered when designing a battery management system. To mitigate their possible effects it's recommended that careful consideration be given to PCB board layout, its construction and critical part positioning, and that suitable protection is incorporated (see Figure 3). Battery management ICs are precision parts, and using standard precision handling and assembly techniques for their use serves to eliminate many potential issues. These include keeping the signal and power paths as short as possible with high levels of isolation between the two, incorporating a ground plane and using highest quality protection components.

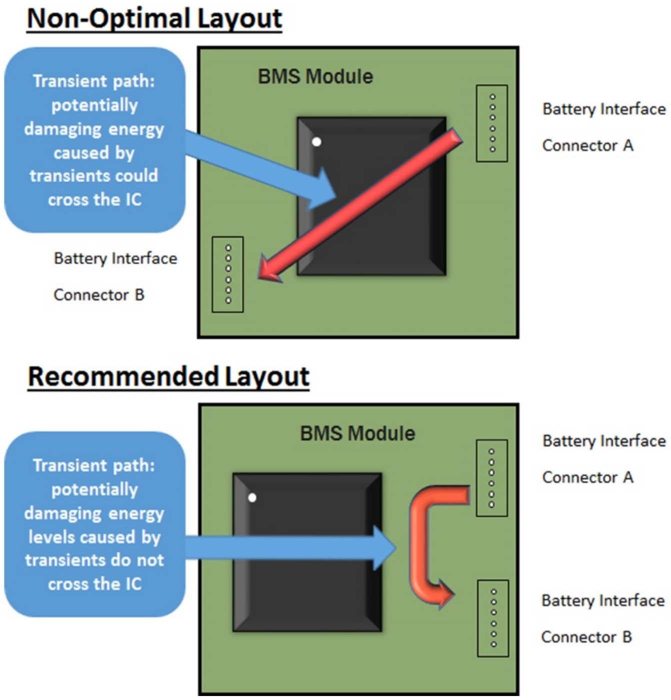


Figure 3. Careful PCB board layout will mitigate hot plug transients

Summary

Careful consideration must be given to the selection of a suitable battery management IC that is optimized for the rigors of automotive applications. Proprietary communication protocols and careful PCB layout can resolve a number of the issues introduced by the harsh environment of the EV battery and improve the performance of the system.

Next Steps

- Learn more about the ISL78600 multi-cell Li-ion battery manager
- Find out more about Renesas' automotive solutions
- Search for power management parts using our parametric search

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