

ISOLATION TRANSFORMERS FOR BATTERY MANAGEMENT SYSTEMS

Introduction

Unlike internal combustion engine (ICE) vehicles, simply powered by fossil fuel stored in a tank, electric vehicles (EV) depend on a more complex energy storage that requires rigorous instrumentation and control to accomplish an efficient and safe performance.

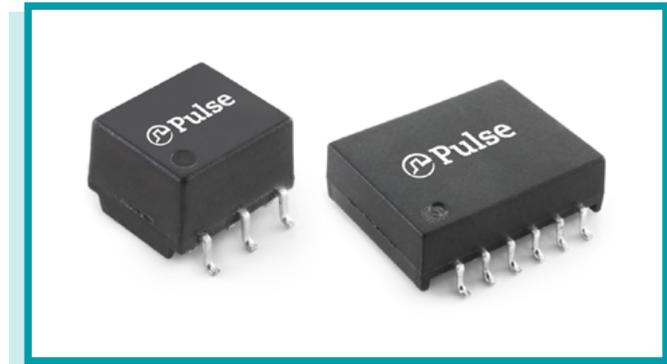
Battery management systems (BMS) are electronic regulators that monitor the behavior of the electrochemical reaction of each battery cell and control their charging and discharging procedures. In addition, BMS monitor battery temperature and battery health status, bypassing any defective battery cells, and notify the central processor unit (CPU) on the condition of each cell.

BMS may be as simple as electronics that measure voltage and stop charging when the desired value has been reached, however their ultimate goals are achieving reliability, performance and longevity of the installed battery packs. For that, electronics in the BMS needs to transmit its data to the central processor.

For high voltage applications, typical for electric vehicle drivetrains, modular packs are distributed throughout the vehicle to pursue optimal weight distribution and maximum use of available space. Yet the biggest challenge is ensuring that each battery pack communicates flawlessly with the central processor so the multiple packs can operate as a single unit.

Unfortunately, due to inverters, actuators, semiconductor switches, relays and other electromagnetic interference (EMI) sources within vehicles, BMS are immersed in an electrically noisy environment that requires data communication links to have isolation and EMI suppression that can provide sufficient noise rejection.

This paper will focus in discussing the use of [transformers and chokes](#) for safety isolation and EMI suppression in battery management systems.



Pulse Electronics HM2102NL and HM2103NL Isolation Transformers

The isoSPI Interface

To benefit from the advantages of a modular design, BMS communication datalinks require isolation capable of withstanding the harsh electromagnetic environment in vehicles. CANbus, the automotive standard, can be combined with isolation strategies to provide adequate noise rejection, however its implementation is a complex and expensive solution.

To address this challenge of the battery modularity trend, Linear Technology developed isoSPI, which transmits a differential signal via a twisted pair and an isolation transformer; translating a full-duplex signal at up to 1 Mbps.

The primary advantage of this interface relies on its ability to operate over extensive point to point and daisy chained configurations. This unleashes BMS design from its constraining centralized architecture or expensive isolation of the CANbus link for its interconnection.

How isoSPI Works

Through differential signaling on a balanced twisted pair of ungrounded wires, the result of common-mode noise, inflicted upon them by external EMI sources is almost identical to both conductors, resulting in an unaffected transmission of information.

A small transformer in the isoSPI interface magnetically couples and electrically isolates the signal between devices; replicating the same technique used in the proven Ethernet twisted pair standards. Simply the highest operating voltage determines the DC stand-off voltage required for the transformer to provide the necessary galvanic barrier. Additionally, this galvanic isolation permits the modules to be interconnected despite large DC voltage differences between them. The addition of a common mode choke (CMC) in to the data line further enhances the signal and the design of the chokes needs to be specific to the isoSPI interface.

Sourcing Isolation Transformers for BMS

In large battery pack applications with daisy chain connections, the high number of cells connected in series can generate greater voltage potential differences, which demand a higher level of component-to-component isolation. In these applications, serial communication links between boards need to be isolated by transformer coupling circuits instead of capacitor coupling.

Using the potential difference between ground and the maximum DC voltage when all cells are connected, the system's working voltage can be determined by the designer and used to obtain the isolation breakdown voltage and the creepage distance required. However, an approximation of the working voltage can be obtained only knowing the total DC voltage supported by all the combined cells or battery packs. Then the selection of a correct isolation transformer module is a choice of the module with the nearest, but higher, working voltage and the preferred number of channels, size and shape. Having a broad range of products, as offered by Pulse Electronics, makes the selection of isolation transformers more precise and simple.

Insulation Levels Needed for BMS

As EV's are closed systems, the use of safety standards associated with Ethernet for IT equipment, such as IEC/UL/EN60950, are no longer technically relevant. Using more relevant standards such as IEC61140, ISO6469-3, IEC60664, and LV123 means the new products are optimized in size and insulation performance as well as providing a 15 year life on the insulation.

In these safety standards, the components and physical barriers that provide isolation are referred to as insulation. For most BMS applications, equipment is considered *Class I*, whose minimum protection level is basic insulation. Some BMS applications come under *Class II* equipment, which may require *Supplementary or Reinforced Insulation*.

| | Protection | Protection | Comment |
|---------------------------|-----------------------|--------------------------|-------------------|
| Equipment Class I | Basic Insulation | Potential Equalization | |
| Equipment Class II | Basic Insulation | Supplementary Insulation | Double Insulation |
| | Reinforced Insulation | | Single Insulation |

Having determined the Equipment Class and the system working voltage, the insulation breakdown, also known as Hi-Pot or withstand voltage ($V_{withstand}$) can be determined by the following equation:

$$V_{withstand} = (2 \times V_{WorkingVoltage} + 1000V) \times 1.41V$$

There is some debate about the use of the RMS value when the EV powertrain is DC. However, with the life expectancy of 15 years, degradation of insulation of the windings with time is accounted for—and supported by—all the modules passing the AEC-Q200 automotive accelerated reliability stress testing standard.

To provide the serial port safety isolation and EMI noise rejection necessary in the BMS application, [Pulse Electronics offers a full line of isolation modules](#) for small to large battery pack systems. Encompassing both transformers and common mode chokes designed to support a working voltage of 1000Vdc and a breakdown/ Hi-Pot voltage of 4300Vdc, covering lower voltage systems of 600Vdc with the same set of products.

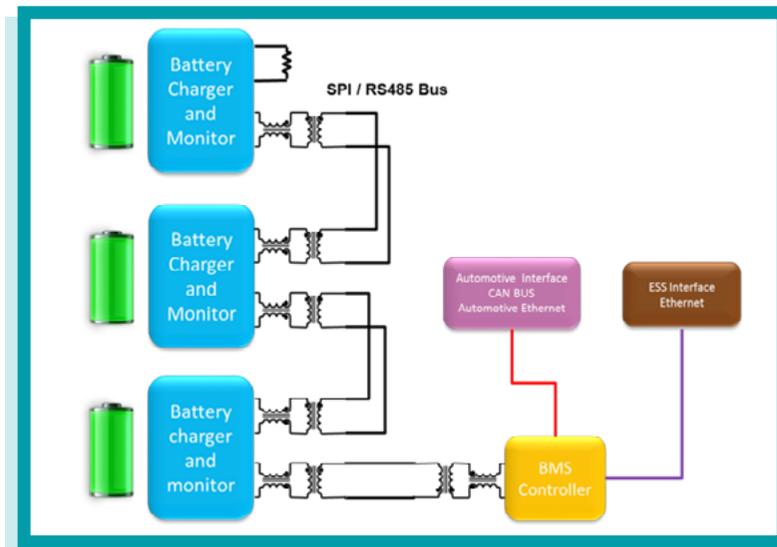
Pulse Electronics offers a full line of isolation transformers and common mode chokes for small to large battery pack systems for serial port safety isolation and EMI noise rejection application. In large battery pack applications with daisy chain connections, the number of cells connected in series is very high, and the large voltage differences demand component-to-component isolation. The serial communication links between boards need to be isolated by transformer coupling circuits instead of capacitor coupling.

Pulse Electronics BMS Transformer modules exhibit the following features and benefits:

- Supports major BMS isolation and EMI solutions
- Supports serial Daisy Chain isoSPI, SPI and other signal isolation
- Meets AEC-Q200 requirements for automotive application
- Operational temperature ranges from -40C up to +150C
- Multiple options covering 600Vdc – 1600Vdc working voltages
- High Voltage Breakdown and fixed Creepage distances

Applications

- Electric Vehicle
- Energy Storage System
- Data Center UPS
- Solar energy storage
- Green – Renewable
- Marine



Generic BMS solution showing Daisy Chain of Battery Packs with Charge Controller and Isolation Transformer in each link of the chain and the master controller which links to the Driver Display and Centralized Network

[VIEW ALL PULSE ELECTRONICS BMS TRANSFORMERS](#)

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