BMS Transformers for High-Energy Storage

How to Select the Right Transformer for High Voltage Applications

It is no surprise that analysts have predicted continued growth in the usage of Lithium Ion (Li-Ion) battery cells for energy storage and automotive applications through 2025 with growth rates of up to 30 percent forecasted to support China's transportation market alone. In various forms of mobility applications, Battery Management Systems (BMS) are used to connect to high-energy battery packs and manage the charging, discharging of the pack. The BMS also monitors vital operational factors such as temperature, state of the charge along with the battery pack's overall health. If needed, the BMS can connect and disconnect the battery from the load or charging source for added protection.

This article highlights the specifications that high voltage battery systems and BMS transformers need to have in order to meet industry standards for insulation.

BMS IC and Transformer Functionality

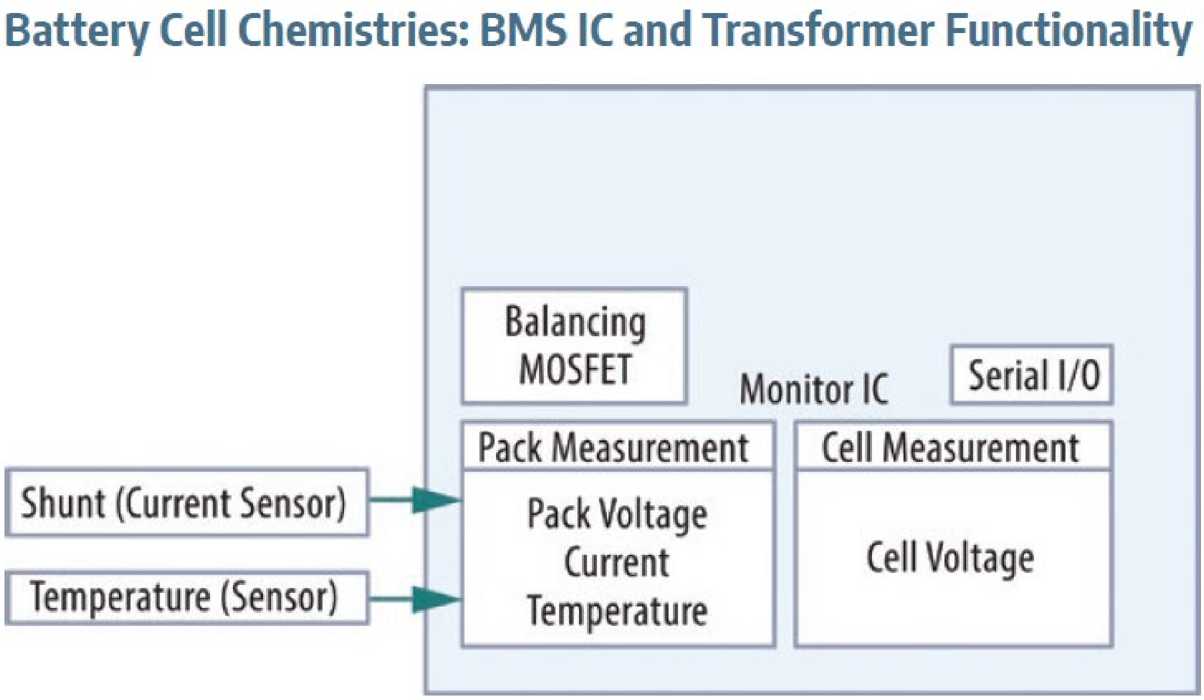

Figure 1

This block diagram of a typical Battery Management System shows the functions for monitoring essential battery pack health

A typical IC used as a monitoring device in a BMS functions to measure cell voltage, pack temperature and to perform cell balancing shown in Figure 1. High-voltage battery pack IC designs do not require a current sense function. That is because these packs need only one current sensing chip and several hundred monitoring ICs to monitor the individual cells in the pack. A simple way to determine the number of monitoring ICs required is if each monitoring IC can check 10 cells, then at least 130 monitoring ICs will be needed. Another consideration in high-voltage battery packs is that the BMS IC module or board needs to be located on top of the shunt resistor, which may pose a mechanical design challenge.

Designing for Isolated Communications

Isolated communications in a BMS is typically handled with two ports that allow battery monitoring modules to be daisy-chained throughout the battery pack. The source and sink currents of the serial port drivers are balanced enabling the IC to drive a transformer without saturating it. A transformer with a rated working voltage of several hundred volts is required to provide the necessary protection of the communications line from any hazardous voltage coming from the battery pack. Furthermore, the drivers on the IC encode a four-line serial peripheral protocol into the differential signal to enable isolated communication from board to board.

The Serial Peripheral Interface (SPI) is an interface bus commonly used to send data where one device or "master" transmits a clock pulse and control bit to a series of slaves. On each clock pulse, the slave either reads a command from the master or if the control bit is inverse, transmits its data on the data line. This enables a central battery controller IC (master) to interrogate each monitoring IC (slave) in turn and, hence, retrieve necessary voltage and temperature information from the whole pack. In addition, the transformer and integrated common mode choke are employed to filter out common mode noise from the daisy-chained network.

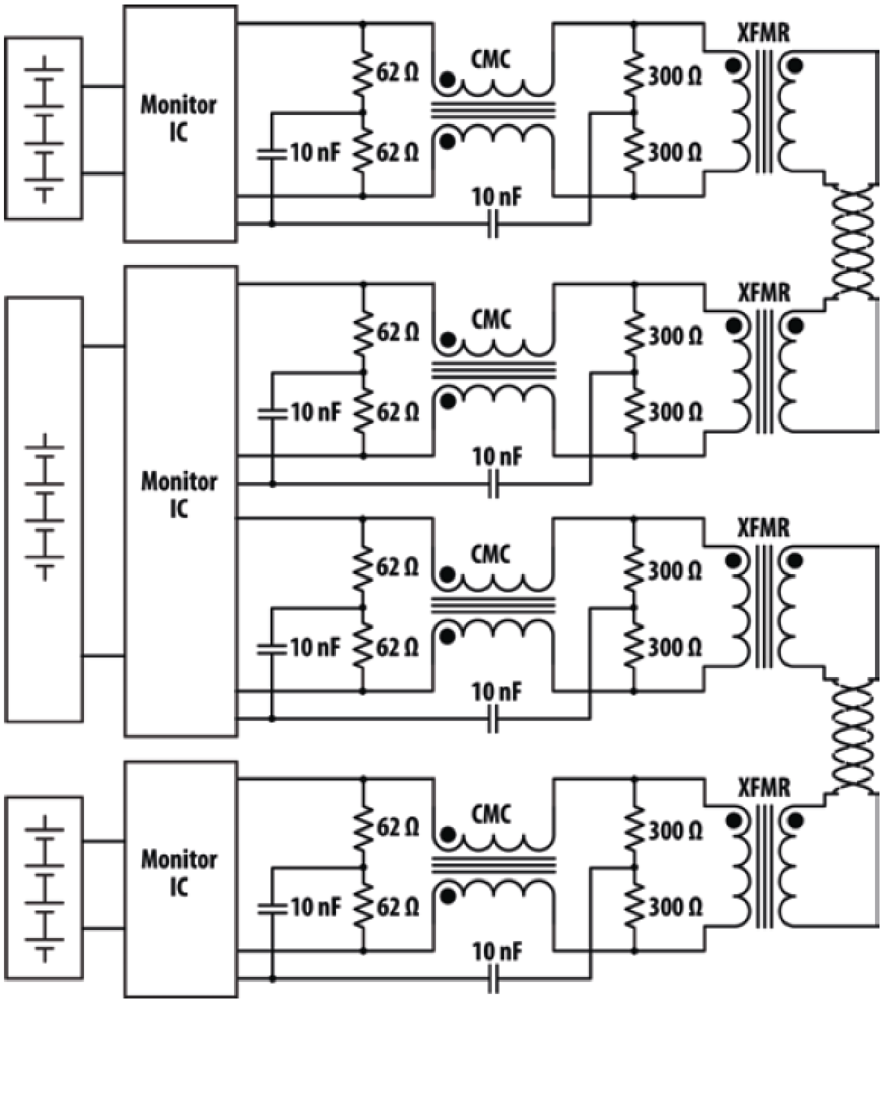

Figure 2

A BMS transformer with a centre tap capacitor and resistor can improve Common Mode Noise Rejection

Although BMS ICs have balanced currents on their I/O pins, most manufacturers recommend a centre-tapped transformer shown in Figure 2. These have been found to improve CMNR if a filter capacitor and termination resistor is used.

BMS Transformer Safety Testing

The safety standard which system engineers refer to for battery is UL1973. The most common standards referred to for insulation are IEC 60664 (insulation coordination for low voltage systems) and IEC 62368 (Audio, Video and Communication Technology Equipment). IEC60664 refers to tests which are necessary for systems with working voltages higher than 700V which are partial discharge and impulse over voltage. Both tests check the long term reliability of the insulation. Partial discharge tests requires specialist equipment designed to measure miniscule levels of electrical charge generated if micro voids develop inside the insulation material over time.

Recommended Electrical Characteristics

The recommended primary inductance values provided by various IC manufacturers will depend on the voltage of the communication signals, the pulse widths and the frequency. For example, Bourns designed its Model SM91051AL transformer with a primary inductance span between 150uH and 450uH over an operating temperature range of -40C to +125C. Since inductance is directly proportional to permeability of the core, the permeability of a transformer's ferrite core is temperature-dependent, and tends to increase with temperature. Therefore, the primary inductance of the Bourns transformer cited will increase to approximately 450uH at the upper end of the temperature range. This demonstrates why there can be large variations in inductance values that suppliers specify on their datasheets.

Evaluating the noise immunity of the BMS IC and transformer can be done with a bulk current injection (BCI) test. The BCI test injects current into the twisted-pair lines at set levels over a frequency range of 1MHz to 400MHz with the bit error rate being measured. A 40mA BCI test level is sufficient for most industrial applications, where a higher 200mA test level typically needed for automotive BMS designs.

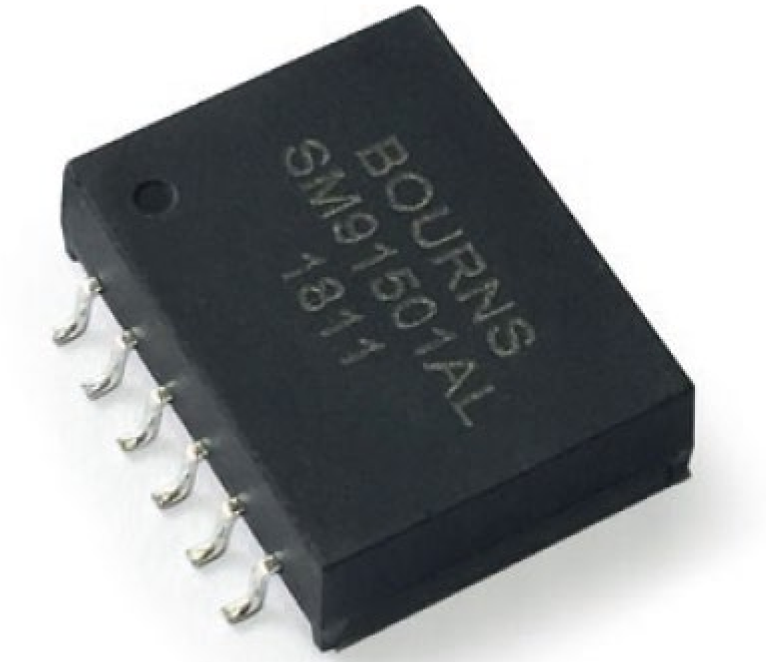

Fig 3

Bourns Model SM91051AL and SM91051AL transformers have been evaluated by BMS IC manufacturers for automotive applications and have successfully passed requirements for BCI

Ensuring Reliable Isolated BMS Communications

Along with increased demand and subsequent growth for Li-Ion battery power, Battery Management Systems with reliable isolated communications are expected to be an important part of the safety and security of the energy system. An effective BMS is an essential design element that will help increase the lifespan of Li-Ion cells and contribute to enhanced safe operation for end users.

For high-voltage BMS designs, it is essential to specify transformers with the elevated working voltages of 1600V and 1000V as well as those with ideal inductance values of 150 μH and 450 μH over an operating temperature range of-40 ˚C to + 125 ˚C to match higher voltage BMS requirements. In addition to enhance the safety features of the BMS, it is important to select a transformer designed with insulation that complies with IEC60664. Doing so further increases the electrical insulation protection from overvoltage transients making them ideal solutions for isolated BMS communications in automotive, industrial and consumer energy storage applications.

References

NASA, Jeevarajan, Judith A., Safety Limitations Associated with Commercial 18650 Lithium-ion Cells presented at Lithium Mobile Power and Battery Safety 2010, Boston, MA