Power and Signal Magnetics Solutions for Battery Management Systems

WHITE PAPER

Bourns® Model HCT Series Transformers

Bourns® Model SM91501AL Dual Channel Isolation Transformer

Bourns® Model SM91502AL Single Channel Isolation Transformer

Designers have discovered that there is much to be considered when designing an isolation transformer for a battery management system. For the most effective design, it is important to outline application functionality expectations, the certification levels required, and to determine what feature options will make all the difference in a successful BMS deployment.

CONSIDERATIONS IN BMS DESIGNS

Battery Management Systems (BMS) connect to battery packs and manage the charging and discharging of the pack. These systems also monitor a number of safety factors that relate to the pack's state of health. A BMS provides application protection by connecting or disconnecting the battery from the load or charging source, as well. These highly critical components are being used with all newer battery technologies such as lithium-ion or LiFePO4 batteries, which are highly susceptible to damage from overcharging, undercharging, and overheating.

When designing a BMS system, note that there are two primary sections to consider: the power level circuitry used with the line drivers, and the design's signal line driver segments. Also, where is the best location to install isolation and safety into the BMS? To do this from a magnetic component's perspective, the transformer is usually tasked to provide the isolation between the low- and high-voltage sides while also meeting safety and isolation requirements.

HOW TO SELECT THE RIGHT TRANSFORMER

Specifying the right transformer for use in a BMS requires knowing the key points about the circuit. Peak working voltage, or the highest input voltage the circuit will see, includes any transient effects for an open-circuit or closed-circuit condition. Depending on which state, the circuit might need to be placed in an overvoltage category. This would translate into the need for an increased distance between windings over a standard design or the requirement for a higher Hi-Pot test voltage in the specifications. Knowing what specific standard or standards that must be met is also critical. Standards to consider might include IEC, UL, VDE, CSA, or a combination of these.

Next, what additional level of insulation is needed to protect the user, or can the transformer operate at simply a functional level—within the electronic circuitry alone? This is where galvanic isolation comes into play, making sure that electrical circuits are kept separated in order to eliminate stray currents, and reducing the changes of unwanted ground loops. By reinforcing insulation, this provides additional levels of protection for the user.

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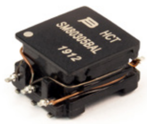

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OTHER CONDITIONS THAT AFFECT TRANSFORMER SELECTION

Further operating conditions that might affect the design include environmental aspects such as altitude, a particular pollution degree, dirt and grime, or humidity that the selected transformer must operate within. It is important to consider other specific test requirements that might need to be fulfilled as well, such as a partial discharge test or long-term reliability tests needed to meet a specific standard. For the topic of distance with regard to transformers, this refers to creepage and clearance. Creepage is the distance between two points as measured along the surface of those two points. Clearance is the distance between two points with only an air gap between them (see Figure 1).

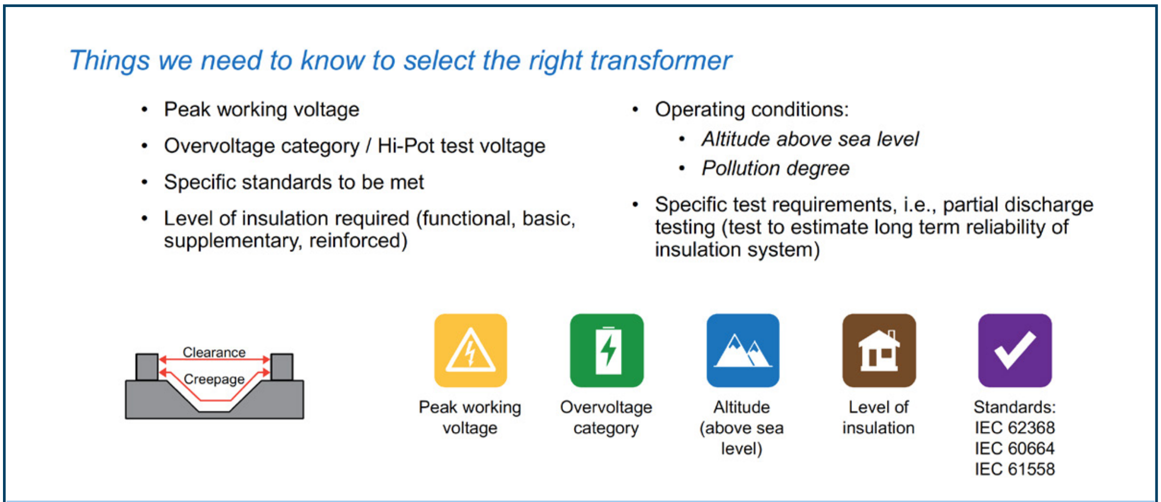
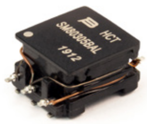


Figure 1. This illustration covers the most common elements we need to know prior to designing a transformer for a BMS.

There are a number of topologies that can be used when designing a BMS, depending upon the application and the certifications needed. In comparing the different transformer topologies, there is no right or wrong direction of which to use. One topology might align better with a given application than another. In determining a topology, the primary concern at this point is with the hysteresis loops for the material as opposed to the operational mode for each type of topology (see Figure 2).



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OTHER CONDITIONS THAT AFFECT TRANSFORMER SELECTION (Continued)

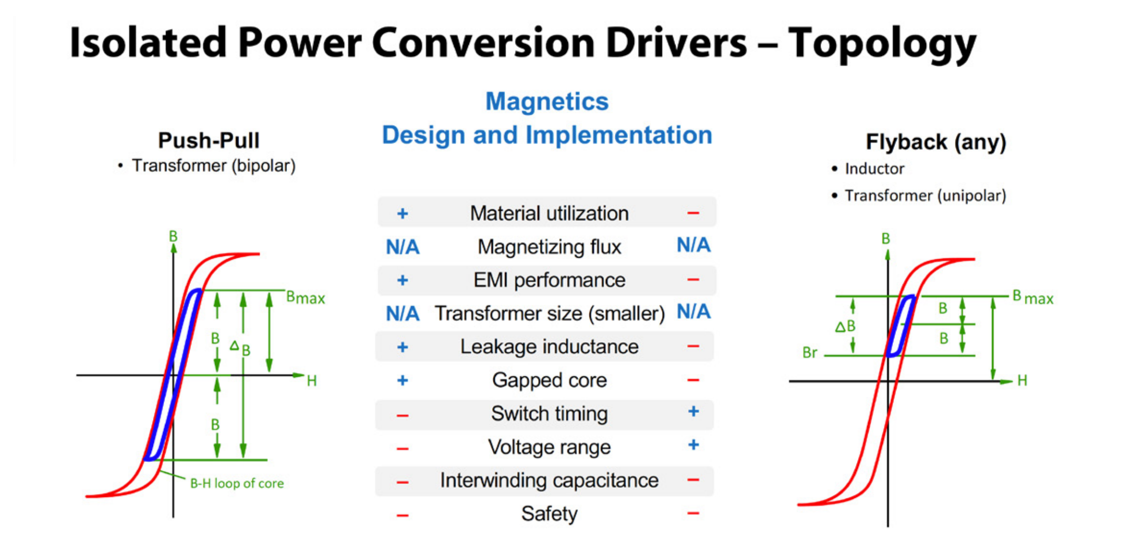

Figure 2. Shown here are the hysteresis loops (in red) for the material opposed to the operational mode (in blue) for each topology.

The push-pull operation practically uses the entire hysteresis loop whereas the flyback transformer uses a smaller portion of the hysteresis loop. The flyback transformer is considered to have a single quadrant operation mode. For a more specific comparison based on topology, Bourns has developed a comparison chart (see Figure 3). As we continue, we'll primarily discuss the new Bourns® HCT line of push-pull type topology transformers.

Isolated Power Conversion Drivers – Topology

Comparison of Isolated Power Topologies

Parameter	Conventional Flyback	PSR Flyback	Open-Loop Push-Pull	Closed-Loop Push-Pull	Isolated Power Module	Isolated Power With Digital Isolator
Output Power Level	Flexible (Transformer and PWM controller dependent)	5 W to 7 W	5 W	Flexible (Transformer and PWM controller dependent)	0.5 W	0.65 W
Input Voltage Range	Up to 42 V/65 V	Up to 42 V/65 V	Up to 5.5 V	Up to 75 V	Up to 5.5 V	Up to 5.5 V
Output Regulation	1 % or less	1 %	5 to 10 %	1 % or less	1.5 %	1 %
No. of Discrete Components	More than 30	21	10	46	Less than 10	Less than 10
Isolation Rating	Flexible (Transformer dependent)	Flexible (Transformer dependent)	Flexible (Transformer dependent)	Flexible (Transformer dependent)	5000 Vrms reinforced	5000 Vrms reinforced
Emission	High	High	Low	High	Low	Moderate to high

Figure 3. This comparison chart covers a number of isolated power topologies that can be used in designing a BMS.

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OTHER CONDITIONS THAT AFFECT TRANSFORMER SELECTION (Continued)

The HCT line of push-pull power line drivers can operate in unregulated or regulated system environments. As shown in Figure 3, Bourns also offers a number of flyback solutions. The Company also has solutions for signal level operations for SPI bus or CANbus or any methodology you're looking to use for communications in your BMS. The HCT line offers low profile components with extremely high creepage and clearance distances built into their structure—greater than eight millimeters—which complies with the most stringent standards found in IEC.

Although the transformer was originally designed for the TI SN6501 and SN6505 push-pull driver chipsets, the latest version of the HCT transformer works with any IC chipset that corresponds to the input and output voltages and power levels of the TI chipset family. For example, Model HCTSM110103HAL is automotive grade and AEC-Q200 compliant. For vehicle applications that must meet EHNS requirements for RoHS and REACH halogen free, lead-free operation with an extended temperature range, this model is an excellent solution.

What makes the HCT line most unique, in reference to competitive products, is in meeting high creepage and clearance distances in a compact package. As illustrated in Figure 4, the design of the header runs around the internal core and windings to the pins on the other side of the header. This produces what is called a "lid", an enclosure around the coil that extends the creepage and the clearance paths as opposed to only the distance between the two pins (the purple line).

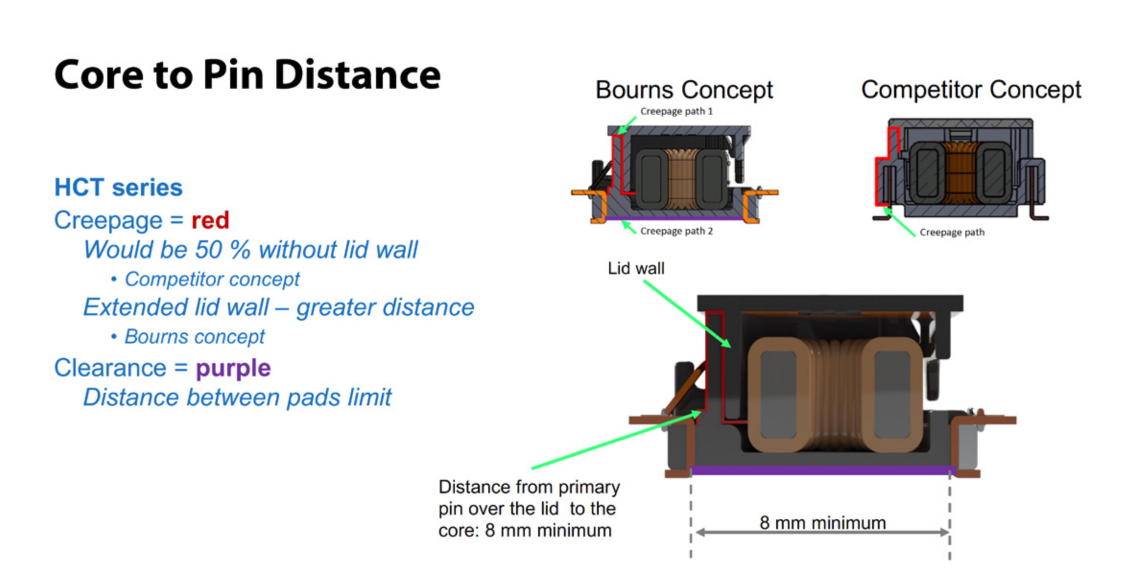
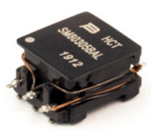


Figure 4. Note that creepage and clearance in the Bourns® HCT product are maintained even in the more compact package.



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OTHER CONDITIONS THAT AFFECT TRANSFORMER SELECTION (Continued)

The type of header, then, is no longer the gating factor for reaching creepage and clearance limits. It's actually the pin spacing, so to meet a 10 mm creepage and clearance distance, all that has to happen is for the designer to choose to extend the header slightly and to increase the distance between the two sets of pins.

Specifically in reference to the TI chipset, the push-pull timing to the unregulated and regulated portions and the alternating switching of the FET, Figure 5 points A and B, show that you get out what you put in. This means that point C becomes an unregulated operation. The design could provide a one-to-one signal or a voltage conversion from A and B to D. Either way, there is no output that would bring the signal up to a DC level with ripple. To do that, the designer would have to add an LDO or small output inductor. The result would be a true DC voltage with ripple output from the push-pull driver itself.

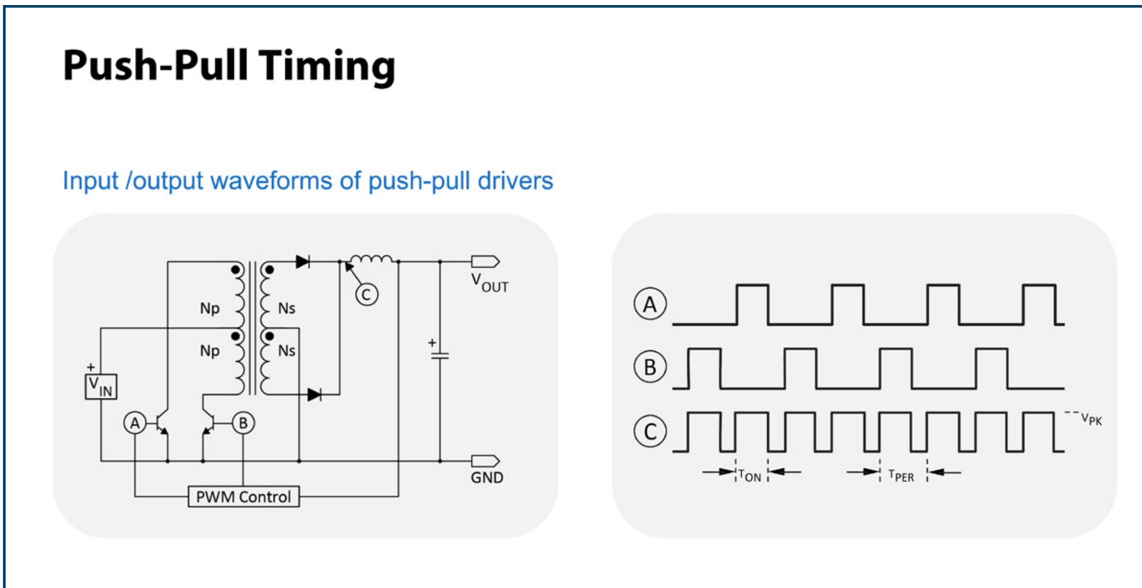

Figure 5. Note the relationship between these input/output waveforms for a typical push-pull driver.

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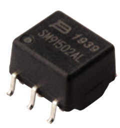

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OTHER CONDITIONS THAT AFFECT TRANSFORMER SELECTION (Continued)

Bourns® isolation transformers used for BMS-SPI interface are basically an extension of an isolated transformer with some type of transmission line requirements such as a common mode choke; common mode choke plus capacitor; or common mode choke, capacitor, and inductor combination built into one body (see Figure 6). The Bourns® Model SM915xxAL Series signal transformers for single and dual channel applications meet all the requirements needed through an automotive capable package. The Company has similar solutions that meet similar requirements in a combination of either an isolation transformer or a small chip-based common mode choke.

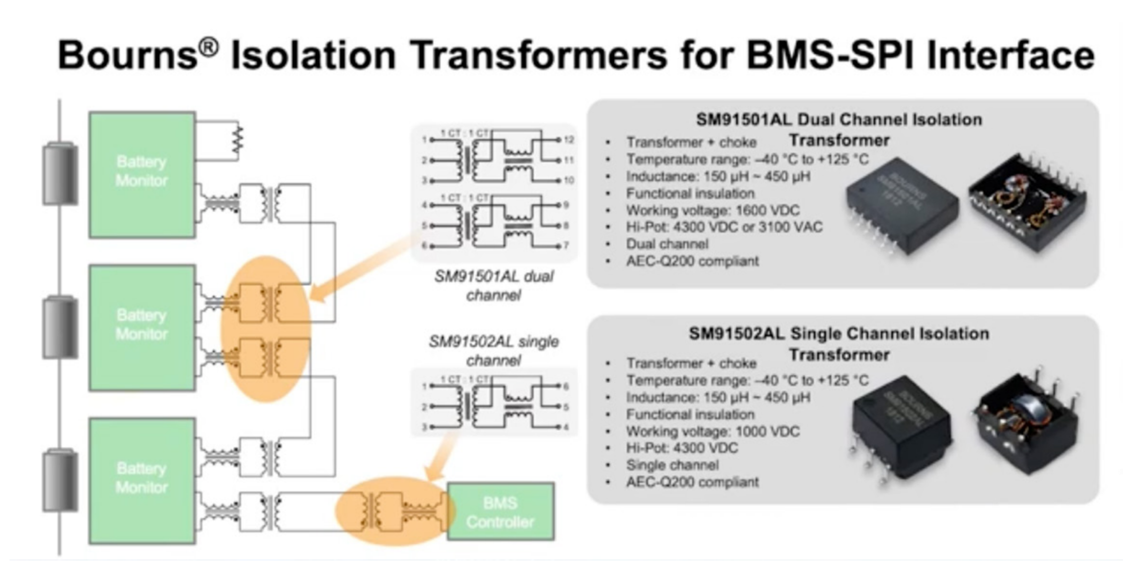

Figure 6. Bourns has a number of options for single and dual channel isolation transformers for BMS-SPI interfaces.

Safety and isolation play a large part in the design process for a BMS. The separation requirements between low and high voltage can be approached in different ways. Even so, it's typically up to the transformer to meet the stringent safety requirements. Because Bourns has been building solutions to meet unique performance and safety requirements for power level and signal level BMS for years, their magnetic components can provide the ideal BMS isolation solution no matter the specific application.

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