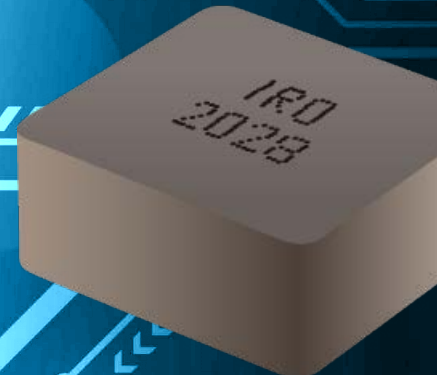# BOURNS®

Magnetic Solutions for Power, EMC and Signal Line Applications

Contents

A dvancements in battery-powered vehicle technologies, updated communication networks, renewable energy infrastructure, next generation cloud computing and Internet of things (IoT) applications continue to drive demand for innovative, reliable, safe and more efficient power, signal and EMC magnetic components.

Over the last decade, the global semiconductor industry has made significant progress in developing new integrated circuits (ICs) for power conversion applications. While these new ICs offer higher switching speeds and reduced switching losses, they need to be supported by equal advancements in magnetic components to meet the requirements of new demanding designs.

As a magnetic component industry leader, Bourns is the ideal partner to help customers succeed in this exciting and forward-looking technology landscape. Bourns offers a broad portfolio of high-quality, reliable, standard and custom magnetic components such as power transformers, inductors and Electromagnetic Interference (EMI) components such as common mode (CMC) and differential mode (DMC) chokes. These magnetic components are proven solutions for automotive, industrial, residential, communication, computer, consumer and many other applications.

Typical growth applications include high-voltage Battery Management Systems (BMS) for automotive, industrial and renewable energy markets, on-board and off-board charging for advanced Li-Ion batteries, DC-DC conversion systems, new generations of advanced computer memory modules with power management requirements, advanced driving assistance systems (ADAS) and smart connected appliances.

Bourns continues to innovate and expand its portfolio of advanced magnetic components. Offering a comprehensive magnetic components portfolio allows circuit designers to select the right components to meet their increasingly complex and demanding customer requirements. Bourns products are designed for superior conversion efficiency, increased power density, miniaturization and low noise. And, Bourns automotive grade components are manufactured in accordance with the International Automotive Task Force (IATF) 16949 standard in ISO 14000 certified factories.

Demonstrating its commitment to service and quality even after its components get integrated into electronics designs, Bourns works with its customers throughout the approval process to provide the necessary documentation for required approvals and supports their efforts to meet quality targets.

In the following pages, you will see how Bourns magnetic components help circuit designers meet advanced technical and safety challenges.

Achilles Chiotis is the Magnetics Marketing Vice President of the Bourns Magnetics Division. He is responsible for identifying unmet customer needs enabling Bourns to lead with new Magnetic product definitions and growth through innovation. Prior to Bourns, Achilles Chiotis held a senior leadership position with the Raychem Circuit Protection business unit at TE Connectivity.

Optimal Transformers for Isolated Power DC-DC Converters

Introduction

DC-DC converters produce very efficient circuits by utilizing high-frequency switching and energy storage components such as the inductor and the capacitor. DC-DC converters have many high-voltage applications such as ultra-capacitor energy banks, motor drives, high-voltage battery systems and solar inverters. Another important function of a BMS is to help enhance the life expectancy of battery cells and protect them from damage. To achieve maximum efficiency and long battery cell life, the BMS needs to determine the state of charge (SOC) to govern the capacity remaining in the battery, and also to control the rate of charging or discharging.

DC-DC converters are important elements of power designs and are used to 'condition' voltage from one level to another, i.e., they can either step-up or step-down a voltage. Push-pull DC-DC converters are becoming more and more common in electric vehicle applications where galvanic isolation is a requirement. They produce low EMI emissions, are high efficiency and occupy a small footprint, so they are extremely attractive for automotive applications. The push-pull configuration can be used to produce power for battery management systems (BMS), on-board chargers and traction inverters that need to isolate high-voltage circuits from low-voltage circuits.

This application note will highlight why the Bourns® Model HCTSM8 series transformers are excellent solutions to isolate power in DC-DC converter systems. It will cover the benefits of the push-pull topology and how Model HCTSM8 transformers can also be used to supply the bias voltage for an isolated insulated gate bipolar transistor.

Bourns® HCT transformers are qualified to be used with Texas Instruments' SN6501 and SN6505 transformer drivers, which have a maximum operating voltage of 5 V for isolated power supplies. In theory, the model HCTSM8 series can operate at much higher voltages. This application notes examines how this is achieved using the SN6501 IC chip. The solution involves inserting a pair of FETs in between the transformer and the SN6501, which protects the chip from experiencing high voltages within the specified design limits.
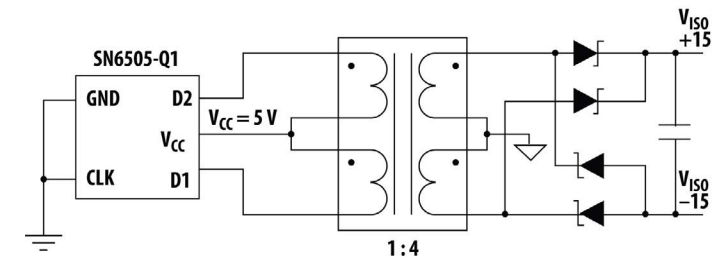

Figure 1 Isolated bias supply for gate driver of IGBTs.

Figure 2 Operation of a push-pull converter with the red lines indicating output current.

Push-Pull Converter Background

Figure 1 shows a typical application where a push-pull transformer is used to generate the +/- 15 V to turn on and off the IGBTs. One disadvantage of this power supply is that the input supply voltage is limited to 5 V, and consequently, this limits the range of applications that operate above 5 V such as 12 V or 24 V.

DC-DC converters are a necessity in industrial environments, and examples of this include interface/bus isolation and isolation of digital circuits. 12 V is a common industrial voltage and the proposed application could be used for a DC/DC 2:1 12 V power rail in a communication interface system. Here, the DC-DC converter system would provide galvanic isolation between the signal isolation unit and the transceiver unit.

The push-pull converter is a two-switch topology that has very high efficiency. It requires a transformer, so it transfers power from primary to secondary in each switching cycle. Figure 2 shows the switching operation. When the switch M1 is closed, current flows through the coil L1. At the same instance, current is flowing through coil L4 and diode D4 is conducting. The opposite occurs when M2 is closed and M1 is open; current flows through L2 and D1 starts conducting through L3. It is worth mentioning that there is a dead time where both switches are turned off to prevent the chance of a short circuit occurring.

Electrical and Mechanical Advantages

The Bourns® HCT series transformers have many electrical and mechanical advantages. For example, they provide high efficiencies at a stable input and output current. The series' push-pull transformer design is used in open-loop configuration, so it requires no feedback, thus permitting a simpler design. In addition, the transformer offers good core utilization as it draws current from both halves of the switching cycle. Plus, it has low EMI emissions due to the push-pull converter's balanced configuration. This feature is an advantage in automotive applications where there are strict regulations on EMI.
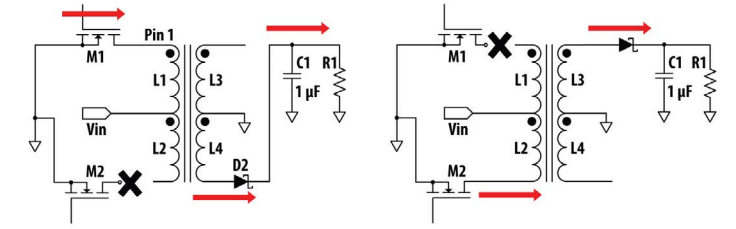
Moving to the mechanical advantages, the HCT series has a small footprint and it boasts a high clearance and high creepage design. Its innovative design maximizes the creepage distance. The transformer's core is located in a special compact housing that increases the path length for current to flow between the primary and secondary. For a transformer with a small footprint, the creepage distance is similar to a flyback transformer that has a much larger footprint.

Circuit Description

Shown in the circuit schematic in Figure 3, the FETs are located between the transformer primary winding and the drains of the internal FETs of the TI SN6501 device. The FETs will protect the chip from voltages above 5 V, while not affecting the efficiency of the circuit. A linear regulator is used to supply the voltage to the SN6501 driver from the input voltage and a separate voltage source is used to bias the gates of the FETs.

The gate voltage is set to 5 V to maximize efficiency. Higher gate voltage results in higher drain current and requires more current draw from the input voltage source. Additionally, it is advised to carefully select an FET with low output capacitance and low $R_{ds(on)}$. If the FET's output capacitance is too large, the voltage on the drain of the SN6501 device will start to float up and this phenomenon may damage the chip. An FET with low $R_{ds(on)}$ must be chosen as the FETs are in a continuous on-state. The lower the $R_{ds(on)}$ the more efficient the circuit.
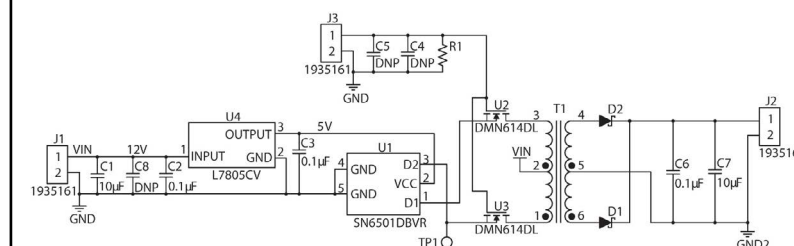

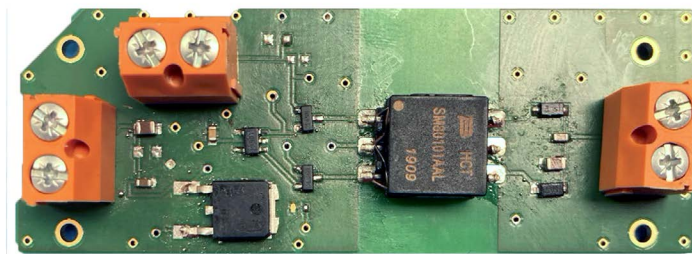Figure 3 Model HCTSM8 higher voltage application schematic

Figure 4 Model HCTSM8 Board

Bourns performed circuit testing in the company's magnetics design center using a DC power supply, a DC electronic load and an oscilloscope. Table 1 includes a list of the equipment used. The turns ratio of the transformer and the applied input voltage dictate the output voltage. Two transformers with different turns ratios were used: a 1:1 and a 2:1 configuration. The input voltage applied throughout the testing was 12 V and 15 V. The results of the Bourns internal tests are provided in the next section.
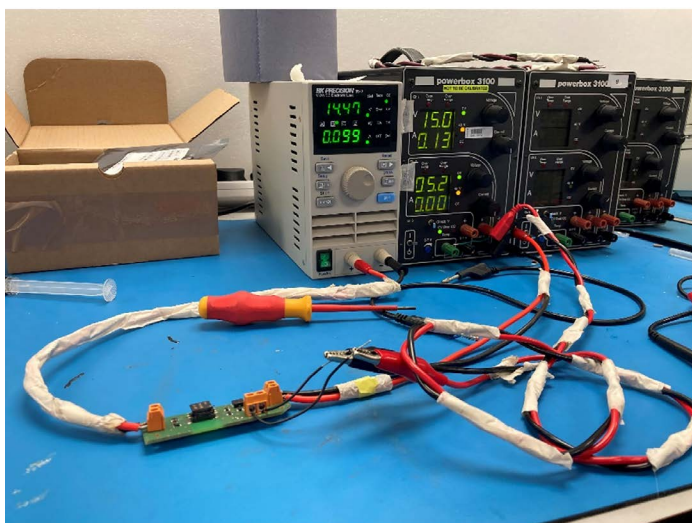

Figure 5 Testing set-up

Bourns Circuit Test Results

Bourns engineers performed two tests using the same transformer but with different turns ratios: 1:1 and 2:1. The circuit test set-up was performed as described in the previous section.

Equipment	Manufacturer	Part Number
Oscilloscope	LeCroy	WaveACE101
DC Power Supply	Powerbox	PB3100
DC Load	BK Precision	8540
Digital Multimeter	Fluke	179

Table 1 Equipment

Model HCTSM8 series transformers in 1:1 configuration

Test 1 used the 1:1 configuration, and the transformer was tested at an input voltage of 15 V. Figure 6 displays the efficiency of the circuit over a load current of 0-100 mA. The optimal efficiency occurs at the largest load current of 100mA. For efficiency improvements, designers should select an FET with low $R_{ds(on)}$ to minimize power loss as the FETs are always on.

Figure 7 shows the output voltage versus the load current. The output voltage remains relatively stable as the load current increases and it doesn't drop below 14.5 V. There is no closed loop control or LDO used, so it is normal to see the output voltage slightly drop as the load current magnitude is increased.
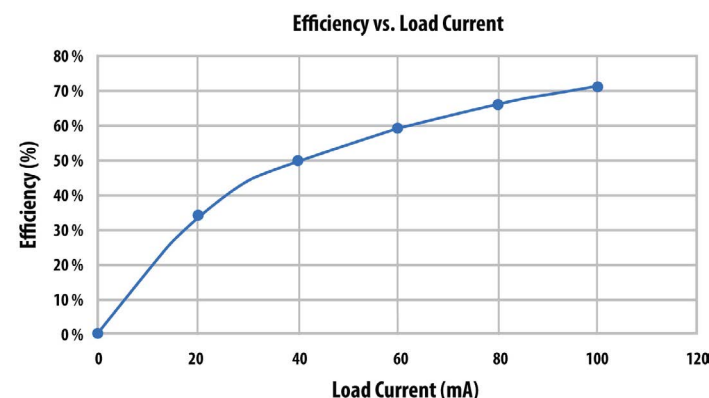

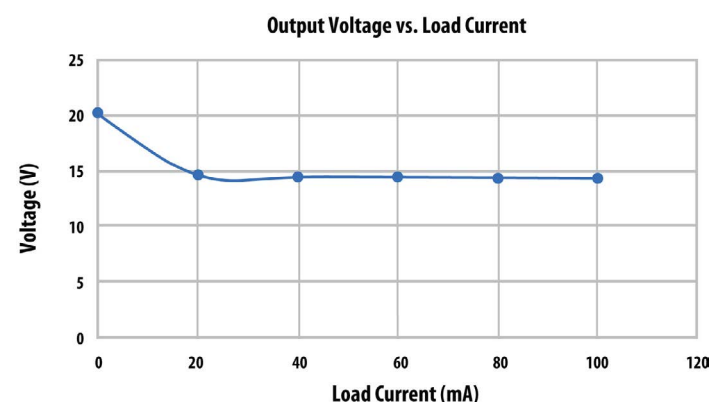Figure 6 HCT series 1:1 efficiency vs. load current plot

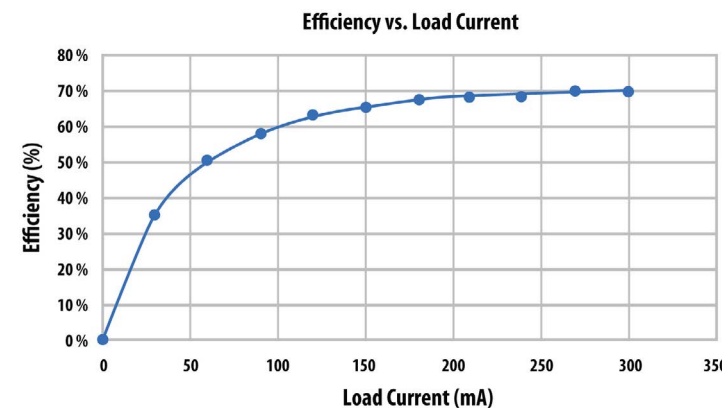Figure 7 HCT series 1:1 output voltage vs. load current plot

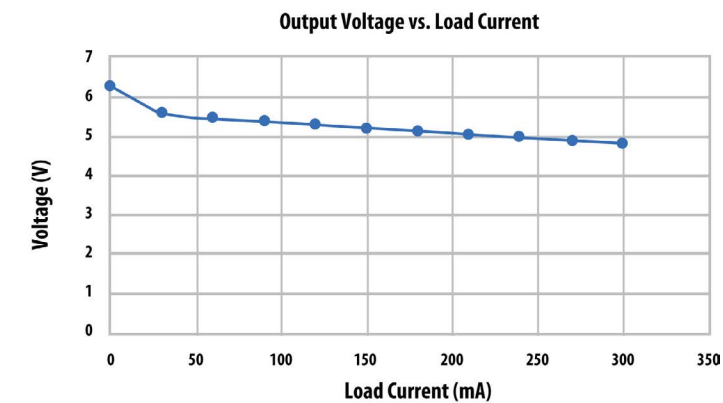Figure 8 HCT series 2:1 efficiency vs. load current plot

Figure 9 HCT series 2:1 output voltage vs. load current plot

Model HCTSM8 series transformers in 2:1 configuration

The second test uses the same transformer with a 2:1 turns ratio. The input voltage applied is 12 V and it is very similar to a 12 V rail in a communications power supply. The load current was increased from 0-300 mA and the results were recorded. The test result in Figure 8 is similar efficiency to the previous one illustrating where the highest efficiency at the largest load current is achieved. Additionally, Figure 9 shows that the output voltage tapers slightly with the load current. enabling the IC to monitor the battery cell safely again. This is useful if the battery cell tap lines have been miswired.

Conclusion

The test results illustrate adequate performance for both push-pull circuits. They also show that the addition of the FETs has little impact on the efficiency, but it is still important to choose an FET with low RDS(ON) or efficiency will decrease. Demonstrated with the proposed circuit, it shows that the TI SN6501 chip can be used at higher voltages than 5 V. The examples provided also highlight that the combination of the Bourns® Model HCTSM8 series transformers along with the TI SN6501 drivers are ideal solutions to isolate a 12 V bus rail in a communications system, or a power supply for the switching of IGBTs.

Figure 1 Forecasted Growth in Lithium-Ion Sales[1]

Essential BMS Transformer Features for High Voltage Energy Storage

Introduction

Battery Management Systems (BMS) connect to high-energy battery packs and manage the charging and discharging of the pack. They also monitor essential safety factors including temperature, state of charge and the pack's state of health. Providing additional application protection, the BMS is able to connect the battery and disconnect it from the load or charging source, as required.

This application note provides an overview of the key features of battery monitoring Integrated Circuits (ICs) typically specified in BMS. It includes background information on

battery cell chemistries as they relate to the requirements for communications in high voltage BMS. An application example will be used to explain the technology benefits that Bourns® transformers deliver to meet these specifications.

Overview of Lithium-Ion Battery Chemistries

Consulting and market research firm Avicennes[1] has predicted that the usage of lithium-ion (Li-ion) battery cells for energy storage and automotive applications will continue to grow significantly through 2025 with compound annual growth rates up to 30 percent forecasted in China's transport sector. As Li-ion usage grows and expands into new applications, it is important to understand the nature and

use of various battery chemistries. Table 1 shows a summary of the most popular chemistries by energy density, cell voltage and charge rate for 48 V and higher voltage battery packs. These next-generation packs match the power density required to drive new electronics and motor designs. The latest battery cell developments in different chemistries deliver the increased power energy over longer periods of time necessary for full electric battery power.

There are several factors to consider when choosing the chemistry for a battery powered application. As can be seen in Table 1, Lithium Nickel Manganese Cobalt (NMC) with Graphite has the highest energy density among the

commonly-used chemistries. This is advantageous for heavy loads such as consumer energy storage or plug-in electric vehicles. The disadvantage, however, of this chemistry is that it creates a higher risk of lithium plating on the anodes, which can reduce battery life and lead to thermal runaway (fire or explosion). The potential for these harmful conditions can be exacerbated with today's faster charging connectors.

Lithium Titanate (LTO) has a lower energy density than NMC and does not suffer from the problem of cracking graphite, which together improve the estimated battery life. The lower internal resistance of LTO facilitates faster charging rates making this battery chemistry beneficial for

Cathode	Anode	Energy Density	Cell Voltage	Charge Rate
NMC	Graphite	150 – 220 Wh/Kg	3.6 – 3.7	1 C Max.
LFP	Graphite	100 –120 Wh/Kg	3.2 – 3.3	1 C Max.
NMC	LTO	50 – 80 Wh/Kg	1.8 – 2.5	5 C Max.
LMO	LTO	100 – 150 Wh/Kg	2.4 – 2.6	3 C Max.

Table 1 Summary of Most Common Li-ion Chemistries for Battery Applications

plug-in electric vehicles. The downside is the higher cost for heavier battery packs as more cells are needed to provide the necessary energy in kilowatt hours (kWh).

Lithium chemistries have very narrow operating temperature ranges, typically from 20 °C to 40 °C. Operating outside these temperatures leads to a loss of capacity and a shorter lifespan. Elevated temperatures can also cause further degradation and a thermal runaway condition. A paper by NASA[2], which studied the protection within 18650 cells found that the interrupt devices in all the cells connected in series and parallel were not as effective as single cells in preventing thermal runaway during fault conditions. This study illustrates the strong need for a Battery Management System when multiple cells are interconnected.

Overview of Battery Management ICs and Transformers

A typical battery monitor IC (shown in Figure 3) measures cell voltage and pack temperature and performs cell balancing. In some models, there is also a current sense input port for shunt-based current measurement. Including this feature makes sense in 48 V systems that use a limited number of battery cells and do not experience hazardous voltage levels, and, hence, monitoring ICs.

Conversely, it does not add a lot of value to integrate a current sense function into an IC for high voltage battery packs. These packs require only one current sensing chip and several monitoring ICs to monitor the individual cells in the pack. For instance, the 2011 Nissan® Leaf® has a working voltage of 360 V and energy of 24 kWh (NMC technology)[3]. The structure of the pack is 96S2P (192 cells). Or, a simpler way to put it: if each monitoring IC can check 10 cells, then at least 20 monitoring ICs will be need-

ed. Another consideration in high voltage battery packs is that the BMS IC module or board must be located on top of the shunt resistor, which may pose a mechanical design challenge.

BMS High Voltage Communications

The BMS typically has two ports for isolated communications, allowing 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. The transformer, with a rated working voltage of several hundred volts, provides 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 needed for isolated communication from board to board.

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
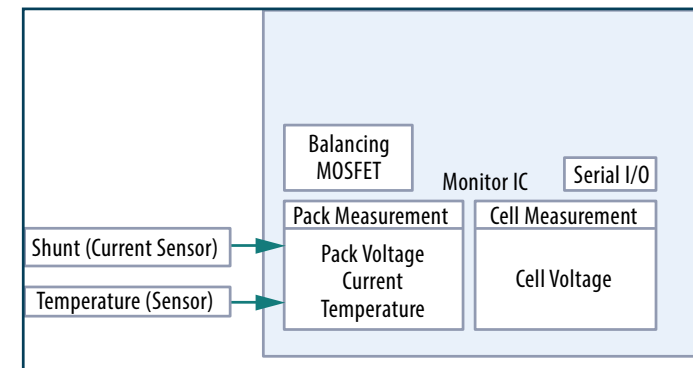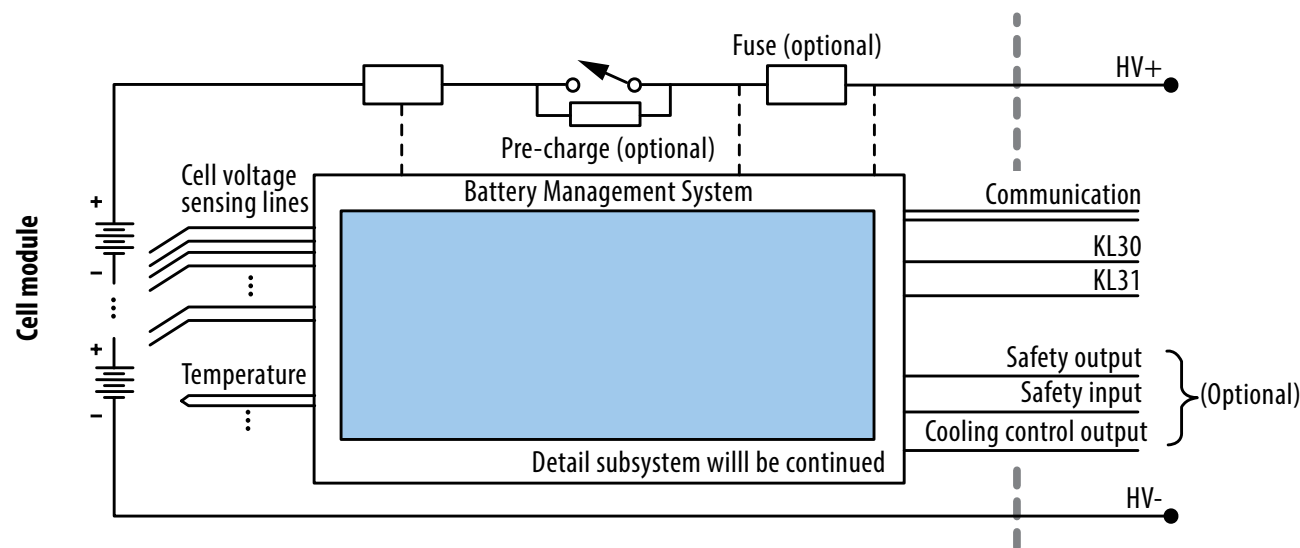

Figure 3 Block Diagram of BMS IC

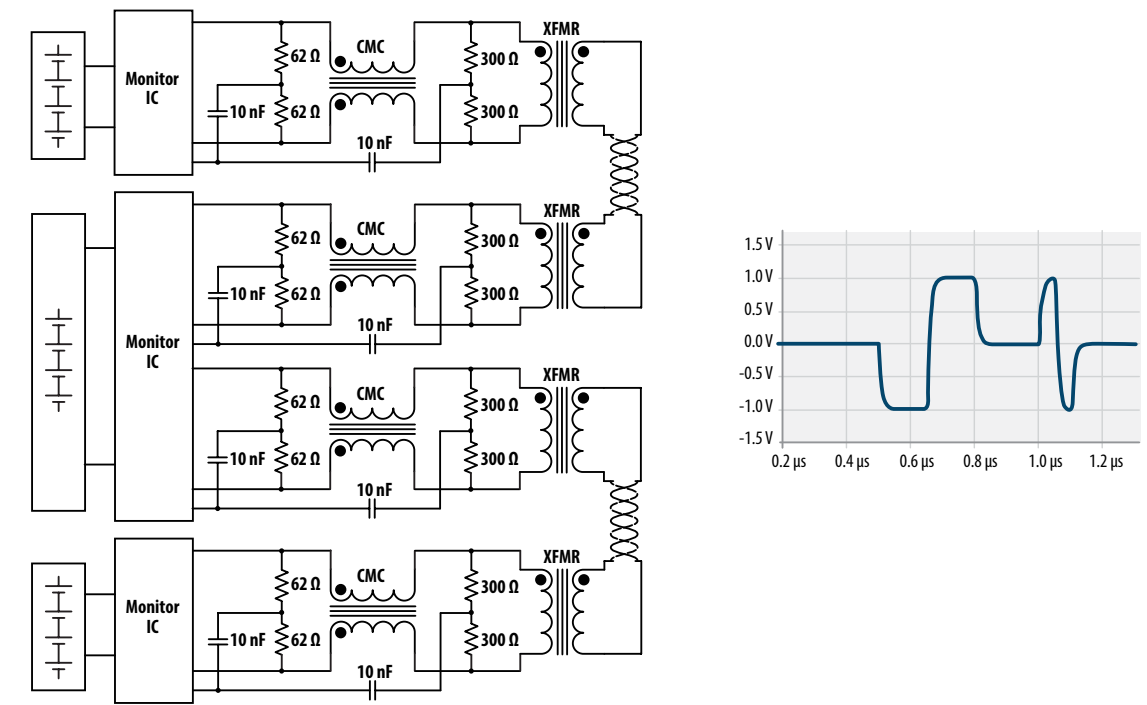Figure 2 Block Diagram Showing the Battery Management System in Relation to the Battery Pack

Figure 4 BMS Transformer with Center Tap Capacitor and Resistor. Right: Image of SPI Signal.

from the master or if the control bit is inverse, transmits its data on the data line. In this way, a central battery controller IC (master) can interrogate each monitoring IC (slave) in turn and retrieve necessary voltage and temperature information from the whole pack. In addition, the transformer and integrated common mode choke filter out common mode noise from the daisy-chained network.

Although BMS ICs have balanced currents on their I/O pins, most manufacturers recommend a center-tapped transformer. These have been found to improve Common Mode Noise Rejection (CMNR) if a filter capacitor and termination resistor are used, as shown in Figure 4.

Bourns® BMS Transformer Safety Features

The windings inside the Bourns® Model SM91501AL transformer use enamelled fully-insulated wire (FIW) that passes the dielectric strength (Hi-POT) test of 4.3 kV (1 mA, 60 seconds). Per Table 2N of IEC 60950[4], the minimum creepage distance for material group I, pollution degree 2 of functional insulation for a working voltage of 1600 V is 8 mm. The Bourns® Model SM91501AL transformer data sheet shows a minimum 10 mm creepage distance. This is because the actual tracking distance over the surface of the transformer and chokes has been calculated at 10.4 mm in the samples measured.

The replacement test for IEC 60950 (IEC 62368-1)[5], which becomes mandatory in June, 2019 for audio/video, information technology and communication equipment will

recognize FIW in the future. The use of FIW may qualify the device as having reinforced insulation with a lower working voltage (depending on the standard) of approximately 800 V. This may allow the device to meet UL Listing requirements and may enable its use in additional applications such as consumer energy storage, which mandate reinforced insulation.

Recommended Electrical Characteristics

The recommended primary inductance values by some IC manufacturers will depend on the voltage of the communication signals, the pulse widths and the frequency. Bourns designed its Model SM91501AL transformer with a primary inductance span between 150 µH and 450 µH over an operating temperature range of -40 °C to +125 °C. The inductance is directly proportional to the permeability of the core. The permeability of the ferrite core of a transformer is temperature-dependent and tends to increase with temperature. Therefore, the primary inductance in the Bourns® model will drift up towards 450 µH at the upper end of the temperature range. This is the reason for the large variation in the inductance value as specified on the data sheet.

The noise immunity of the BMS IC and transformer can be evaluated using a bulk current injection (BCI) test. The BCI test injects current into the twisted-pair lines at set levels over a frequency range of 1 MHz to 400 MHz with the bit error rate being measured. A 40 mA BCI test level is sufficient for most industrial applications. The 200 mA test level is typically used for automotive testing. The Bourns® Model

SM91501AL and SM91502AL have been evaluated by certain BMS IC manufacturers for select automotive applications and have successfully passed requirements for BCI.

Summary and Conclusions

The demand for Li-ion battery power is predicted to grow at a CAGR of 20 - 30 percent over the next eight years[1]. Battery Management Systems that integrate isolated communications are expected to be an important part of the safety and security of the battery system. An effective and reliable BMS will help increase the lifespan of Li-ion cells while also enhancing safe operation for end users.

Offering an optimal protection solution for isolated communications in industrial and consumer BMS applications, Bourns engineered its latest Model SM91501AL and SM91502AL BMS transformers with the higher working voltages of 1600 V and 1000 V, respectively. They feature an inductance value of 150 µH and 450 µH over an operating temperature range of -40 ˚C to + 125 ˚C which meets higher voltage BMS requirements. Additionally, the transformer windings use fully insulated wire passing the dielectric strength (Hi-POT) test, further increasing electrical insulation protection for overvoltage transients.

Bourns® Model SM91501AL and SM91502AL have been tested by several BMS IC companies in their test laboratories who found them to function well with their chipsets, passing the necessary BCI tests.
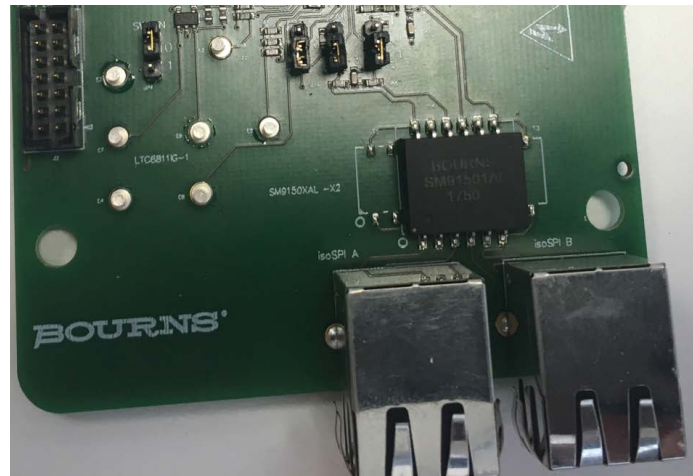

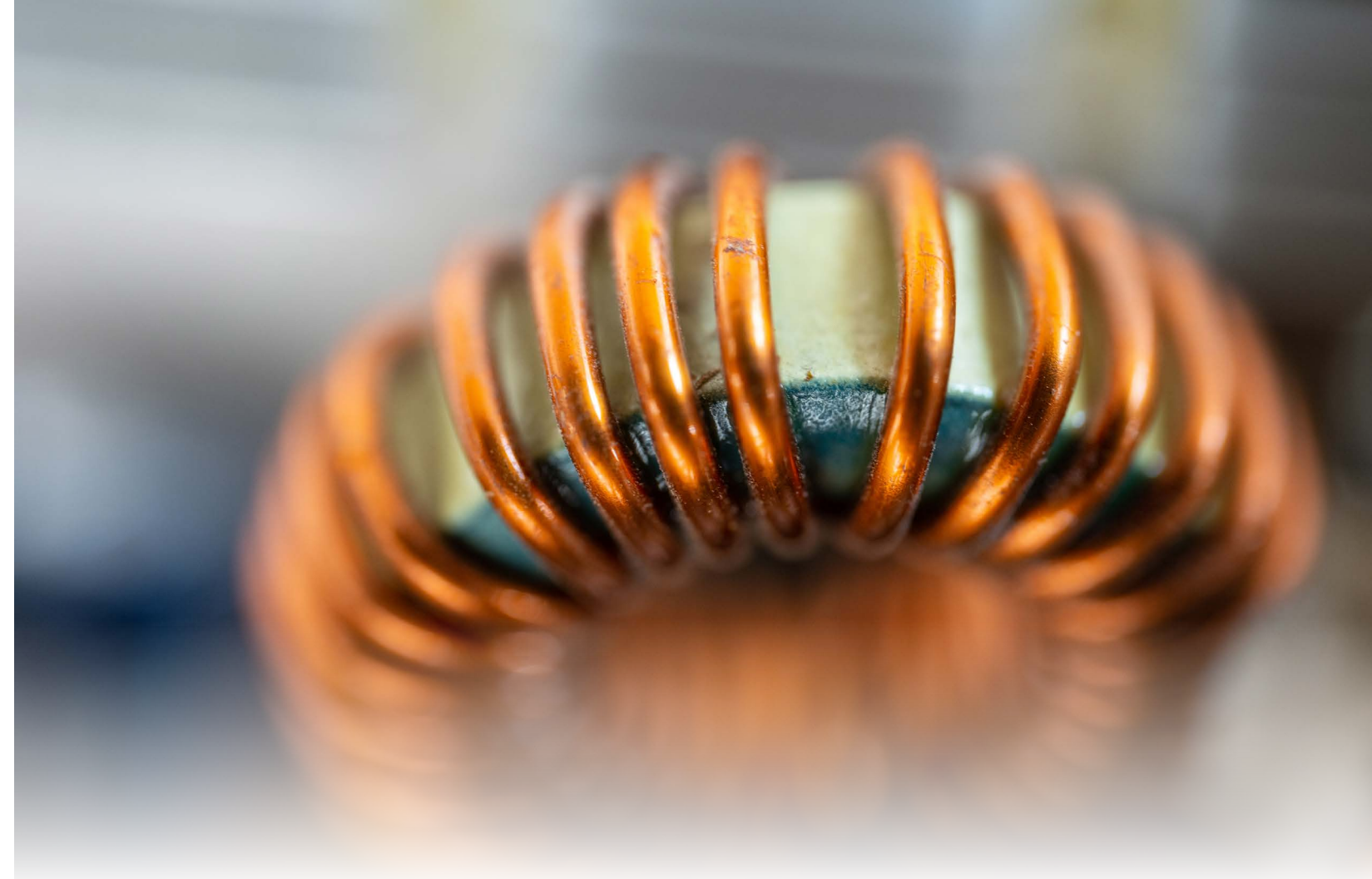Figure 5 Bourns® Model SM91501AL Transformer on Bourns' BMS Demonstration Board

SM91501AL

SM91502AL

Bourns Part Number	Description	BMS IC
SM91501AL	2 Channel BMS Transformer 1600 VDC	LTC6811 MC33771

References
[1] Avicennes, Christophe, Pillot, Rechargeable Battery Market 2017-2025 The Battery Show, Hannover, May 15, 2018
[2] NASA, Jeevarajan, Judith A., Safety Limitations Associated with Commercial 18650 Lithium-ion Cells presented at Lithium Mobile Power and Battery Safety 2010, Boston, MA
[3] Hayes, J. G., & Goodarzi, G. A. (2018). Electric powertrain: Energy systems, power electronics and drives for hybrid, electric and fuel cell vehicles. Hoboken, NJ: John Wiley & Sons.
[4] International Electrotechnical Commission, Information technology equipment – Safety – Part 1: General requirements IEC 60950-1 Edition 2, 2005
[5] International Electrotechnical Commission, Audio/Video, Information and Communication Technology Equipment- Part 1: Safety Requirements IEC 62368-1 Edition 2.0 2014-02

Guide to Selecting DC-DC Converter Power Inductors

Introduction

Buck and boost converters (Figure 1 and Figure 2) are common forms of DC/DC converters used in a wide variety of consumer automotive and industrial applications. Bourns® PQ Series power inductors are ideally suited for DC/DC converters operating at powers greater than 100 W. This Design Note provides a guide to selecting the right power inductor by providing design rules and key inductor values as well as the equations needed to determine peak and RMS currents.

Key Parameters Required

The following questions need to be answered in order to calculate the correct inductor value:

1. Operating frequency F_{sw} (kHz)
2. Output Power (watts)
3. Input and Output Voltages (volts)
4. Ripple Current in Inductor ΔI_{pp} (amps)
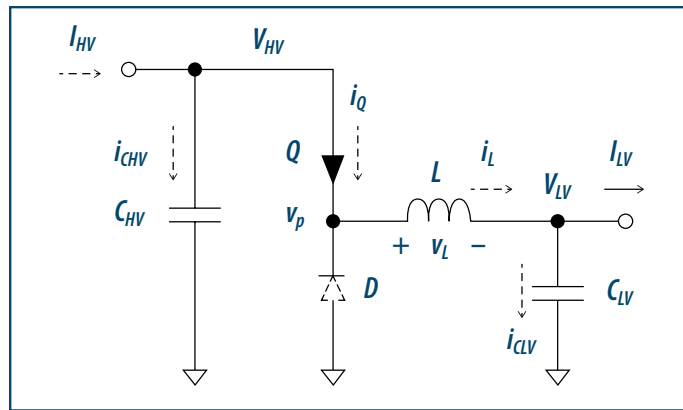5. Operating Mode (CCM, BCM, DCM)

Figure 1 Buck Converter

Figure 2 Boost Converter

Design Steps

The calculations and steps below are necessary to determine the inductor that best meets the application requirements.

1. Calculate Average Current I_{out} (amps)
2. Calculate Duty Cycle D (Equations 1, 2, 8, 10)
3. Calculate the Inductance Value (μH) (Equations 3, 9)
4. Calculate Inductor Max. Current (Amps) (Equations 4, 5)
5. Calculate Inductor RMS Current (Amps) (Equations 6,7)
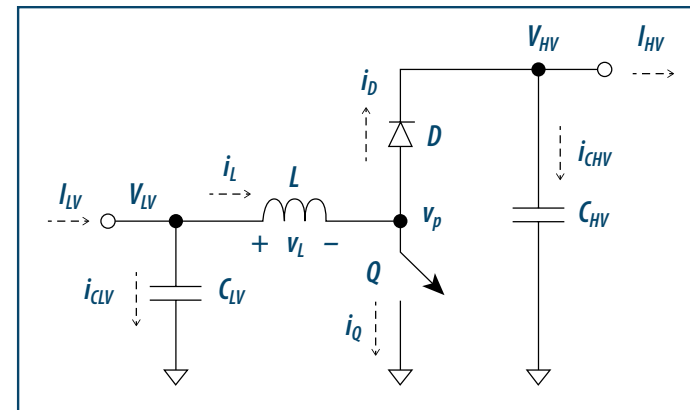6. Search for Suitable Inductor with Correct Inductance, I_{sat} and RMS Currents

Calculate Average Current I_{out}	$I_{out} = \dfrac{264}{12} = 22 \text{ A}$
Calculate Duty Cycle D (Equations 1, 2, 8, 10)	$D = \dfrac{12}{48(1 - 0.1)} = 0.3125$ $Dcm1 = 1 - 0.3125 - 0.1 = 0.587$
Calculate the Inductance Value (Equations 3, 9)	$L = \dfrac{(48\text{ -}12) * 0.3125}{(50 * 200,000)} = 1.1 \text{ μH}$
Calculate Inductor Max. Current (Equations 4, 5)	$I_{max} = 50 \text{ A}$
Calculate Inductor RMS current (Equations 6,7)	$I_{rms} = 50\sqrt{\dfrac{0.3125 + 0.587}{3}} = 27.37 \text{ A}$

The Optimum Power Inductor that Meets Inductance, I_{sat} and RMS Current Requirements	Part Number	Inductance	RMS Current	Peak Current (I_{sat})
	PQ2614BLA-1R5K	1.5 μH	30.0 A	100 A

Table 1

Buck Converter Design Example

The following inductor characteristics are typically required for a buck converter:
1. F_{sw} = 200 kHz
2. Power = 264 watts
3. V_{in} = 48 V_{dc} , V_{out} = 12 V_{dc}
4. Ripple Current Δ I_{pp} = 50 A
5. Operating Mode = DCM (DCM2 = 0.1)

Calculating a Solution

Design Steps 1 through 6 are shown in Table 1 with the provided equations:

Bourns® PQ Series Power Inductors

Bourns designed the following features into the PQ Series power inductors to deliver considerable application benefits for high-power buck and boost converters.

Features	Benefits
Coil Made with Stamped Flat Wire	Low DC and AC Resistance
High Frequency Ferrite Core	• Low Core Losses at High Frequency • High Permeability Material Requiring Fewer Turns than Iron Powder which means lower DC resistance
Automated Production Line	High Quality
Available for Selection in LTpowerCAD®	Recognized by Leading Power Vendors

Summary of Equations and Waveforms

Reference	Equation	Description	Waveform (if applicable)
1	$D = \dfrac{V_{out}}{V_{in}}$	Duty Cycle Buck in CCM and BCM	
2	$D = \dfrac{V_{out}}{V_{in}(1 - Dcm2)}$	Duty Cycle Buck in DCM	Inductor Voltage
3	$L = \dfrac{(V_{in} - V_{out}) * D}{F_{sw} * \Delta I}$	Inductance	
4	$I_{Lmax} = I_o + \dfrac{\Delta I}{2}$	Max. Current CCM	Inductor Current

Reference	Equation	Description	Waveform (if applicable)
5	$I_{Lmax} = \Delta I$	Max. Current CCM and DCM	
6	$I_{Lrms} = \sqrt{I_{o^2} + \dfrac{\Delta I^2}{12}}$	RMS Current CCM and BCM	
7	$I_{Lrms} = \Delta I \sqrt{\dfrac{D + Dcm1}{3}}$	RMS Current Buck DCM and Boost DCM	
8	$D = 1 - \dfrac{V_{in}}{V_{out}}$	Duty Cycle Boost Converter	
9	$L = \dfrac{V_{in}D}{F_{sw}\Delta I}$	Inductance Boost Converter	
10	$Dcm2 = 1 - \dfrac{V_{out}D}{V_{out} - V_{in}}$	DCM Duty Cycle	

Waveform (Reference 5): Inductor Current — i_L vs t, showing $\Delta I_{L(p-p)}$, $I_{L(min)}$, $I_{L(max)}$, I_{LV}

Bourns Portfolio of Magnetic Components

The *broad portfolio* of Bourns® magnetic components lets engineers select the right power conversion solution.

- **Transformers**
  - Signal Insulation
    - LAN 10 / 100 / 1000 Base-T (Integrated / Discrete)
    - BMS Isolation
  - Power Insulation
    - Power SM/BS Series
    - High Isolation HCT Series

- **Through-hole Inductors**
  - Inductors
    - Axial Series
    - Radial Series
  - High Current
    - Axial Series
    - Radial Series
    - Toroid Series
    - Common Mode Series

- **SMD Inductors**
  - Common Mode Inductors
    - Power → SRF Series
    - Signal Line → Sector Wound Bifilar Wound → DR331, DR221, SRF4530, SRF3225
  - Chip Inductors
    - Multilayer
      - Ferrite → Standard CS Series
      - Ceramic → Standard CI / CE Series
    - Wirewound
      - Open CW Series
      - Sealed CM Series, CMH Series, CC Series
  - Power Inductors
    - Non-Shielded → SDE Series, SDR Series
    - Semi-Shielded → SRN Series
    - Shielded → SRR Series, SRU Series
    - High Current → SRP Series, PQ Series

Improving Power Supply Efficiency with Planar Flyback Transformers

Introduction

The emphasis on improving industrial power supply efficiencies is both environmentally and economically motivated. Even incremental improvements in efficiency can result in electrical usage savings that contributes to cost reductions and the ability to minimize heat, and thus wasted energy in the application.

Adding to the challenge of making power supplies more efficient is the fact that today's designs are becoming more integrated, packing an increasing amount of functionality into smaller and smaller form factors. These complex, higher density applications create a much larger power envelope that is more difficult to manage effectively.

AC/DC power supplies of less than 100 W typically use flyback topologies to convert electrical power efficiently as they are the simplest and lowest cost of all isolated topologies. Planar magnetics are commonly the high-frequen-cy application converter of choice for designs because they offer a low number of turns in helical windings and very low resistance. Using a planar transformer in a high voltage application provides several advantages including a reduced or lower mechanical profile. However, there are technical challenges to overcome with this approach that include considerations for high inductance values and the level of isolation needed for safety reasons.

This paper describes a planar flyback transformer designed by Bourns to meet the efficient conversion needed in high voltage applications. This customized planar transformer was tested on an AC/DC adaptor with an output of 5 V and delivered a peak efficiency of 91.05 % in this test.

Planar Magnetics Advantages

Planar transformers have some distinct advantages over wound transformers. The cores have wider surface areas than traditional E, EC or EP cores which allows for smaller numbers of turns in the windings. The wider core areas also enable lower DC resistance of the copper.

The rigid structure of the planar transformer's PCB (standard thickness 1.3 mm) eliminates the need for a plastic carrier or bobbin. Therefore, it can be made thinner and lower in profile than wound transformers. Another benefit is the repeatability allowed in PCB manufacturing that ensures higher tolerances in transformer specifications, such as inductance, resistance and turns ratios.

There are disadvantages to planar transformers, as well. Typical PCB substrates like FR4 are not considered as meeting safety requirements for insulation in high voltage applications. Differential surges can also jump across from vias to cores causing damage. Also, implementing multiple layers can be problematic in the design phase and expensive, especially if thick copper plating is required.

Planar Transformer Design Considerations

Winding Structure
Bourns designed its custom planar flyback transformer for applications such as a USB power delivery system, which can deliver up to 100 W (20 V, 5 A) with the understanding that a continuous conduction mode is recommended for powers greater than 10 W. This is to avoid peak currents that can cause high switching losses and overheating of the core. Using the Bourns planar transformer solution, the main contributing factor to losses will be from the copper and not the core. An optimum primary inductance value of 530 µH was selected to keep peak currents to under 2.3 A, so as not to overstress the external 650 V MOSFET. The number of turns of 30, on the primary side, was calculated based on the saturation current, inductance value and area of the core (EC26).

The design uses 12-layer winding incorporating a primary and secondary winding produced using 2 oz. copper and FR4 material and two identical substrates (shown in Figure 1). The planar transformer PCBs form a split primary winding enclosing the secondary made from triple insulated wire.
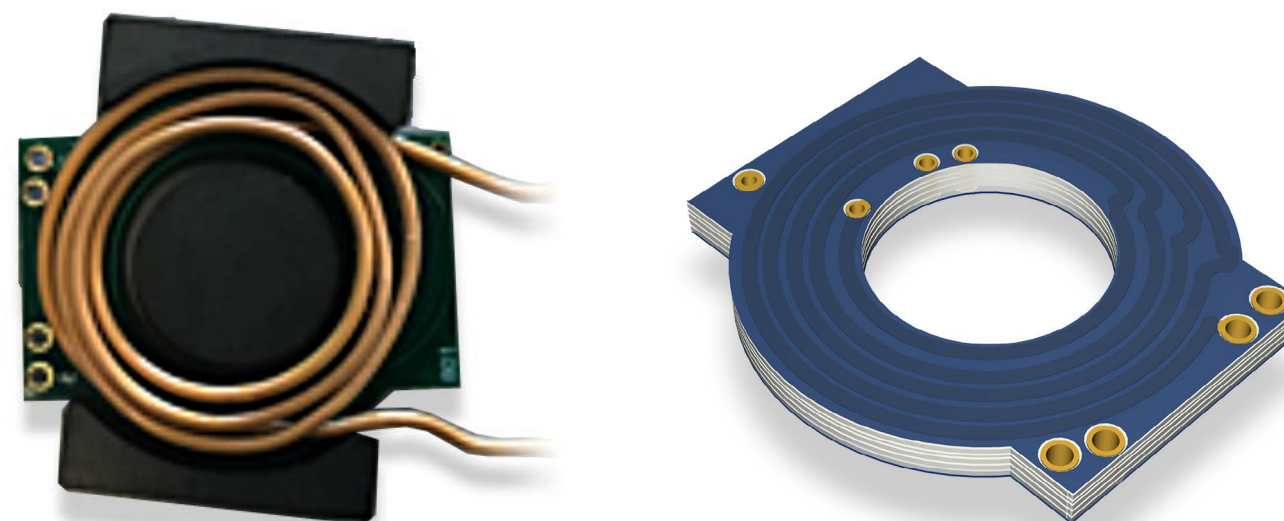

Figure 1 Photo of Secondary Winding and Isometric View of Planar Primary PCB

The triple insulated wire on the secondary side provides the reinforced insulation between primary and secondary windings. As the design uses just four turns, it fits in a spiral shape around the core and between the two PCBs as shown in Figure 1.

Core Losses
The flux density is highest at the edge of the core as shown in Figure 2. The flux must travel through the side wall of the core to complete its path. Therefore, the flux density will increase at the side. However, the flux density in the center leg is well below saturation.

Leakage Inductance
The leakage inductance is a source of energy waste in a flyback converter and needs to be kept to a minimum to increase overall efficiency. The inductance value of this leakage depends on the magnetic field between the primary and secondary winding. According to Ampere's Law, the ampere turns across the interwinding region is the same as the ampere turns in either winding. In the Bourns® planar transformer, the winding width was kept at a maximum to reduce the field strength (H) in this region.

$$H = \frac{IN}{Wb}$$

The permeability of the interwinding region is that of air (4π.10-7) and so the flux density in this region is as follows:

$$B = \mu H$$

The energy density in this interwinding region is, therefore:

$$\frac{Energy}{Volume} = \frac{BH}{2}$$

Energy is calculated at energy density multiplied by the interwinding volume, but it can also be shown as:

$$Energy = \frac{1}{2} LI^2$$

Therefore, the inductance value of this region is estimated by:

$$L = 2\frac{Energy}{I^2}$$

In the Bourns transformer design, the volume of the interwinding region was kept as small as possible to reduce leakage. Increasing the winding breadth (Wb) also reduces leakage inductance.

The effective winding breadth can be increased by interleaving the layers, if possible, which is what has been done in this transformer. For this particular design, there are four turns on the secondary and was implemented using insulated wire on a single layer. This eliminates the need
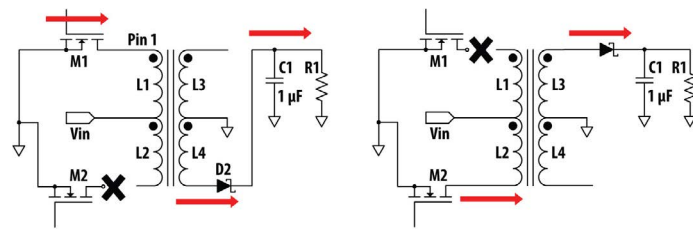

Figure 2 Flux Density in Transformer Using 2D FEA

for creepage and clearance distances between the primary and secondary windings. The secondary was interleaved with the primary, which effectively doubles the winding breadth of the primary and, therefore, cuts the leakage inductance value in half.

The interwinding volume could be better controlled if the secondary was also implemented in the PCB material. Though, using insulated wire on the secondary removes the need for creepage and clearance distances between the primary and secondary windings. This is particularly important in high voltage applications. Furthermore, interwinding capacitance is adversely affected as their distances decrease. This is a serious concern for high voltage applications as it worsens the coupling of AC power line noise through to the power supply output.

The leakage inductance on the Bourns® planar flyback transformer was recorded by shorting the secondary wire and measuring the primary inductance. The leakage was recorded as 14μH at 130kHz in this test.

AC Losses
In a flyback transformer, there is no benefit to the AC resistance in interleaving the primary and secondary windings as these windings are out of phase. If they were in phase, the magnetic field strength would dip to zero at every boundary, which would keep AC resistance low in an interleaved structure. The AC resistance on the primary side can be controlled by keeping the copper at less than the skin depth at the switching frequency. In this case, the skin depth is 0.2 mm while the thickness of copper is 0.07 mm.

At maximum load, the secondary AC current is 7.3 A due to the pulsating nature of current on the secondary side. This would lead to copper losses of 1.5 W on the secondary

side due to the thickness of the wire (0.8 mm diameter).

Finite Element Analysis (FEA) shows the conductor closest to the gap experienced a hot spot due to the high circulating AC currents and eddy currents induced by fringing effects as shown in Figure 3.

Bourns found that to reduce the copper losses at high frequencies, the insulated secondary wire would have to be replaced with a helical winding. As FR4 is not considered safe in this application, a barrier such as mylar or polyimide tape must be bonded to the PCB substrate.

Satisfying International Safety Standards

Bourns followed the IEC 61558 international safety standard for its design. IEC 61558 specifies the creepage and clearance between primary and secondary windings according to:

A.   Working Voltage
B.   Level of Insulation (Functional, Basic, Reinforced)
C.   Degree of Pollution
D.   Material Group

The design complies with IEC 61558 through the following features:

A.   The secondary winding is made of UL listed triple insulated wire. According to the standard, there is no requirement for extra clearance or creepage between the primary, secondary and auxiliary.
B.   The secondary winding is a flying lead. The required creepage and clearance between the conductive pin of the secondary and the conductive core with a working voltage of 300 V is 5.5 mm. The insulated secondary wire is kept at least 5.5 mm from the core.

IEC 61558 also specifies the Dielectric Isolation (also known as Hi POT) between the primary and secondary windings, which was also followed.

AC/DC Adaptor Application Example

The Bourns® planar flyback transformer was tested on an AC/DC adaptor shown in Figure 4. The design is based on a Discontinuous Conduction Mode (DCM) Flyback Converter topology with valley switching and synchronous rectification. Both the valley switching and synchronous rectification reduce power losses in the external MOSFET and rectifier, respectively. Operating in DCM mode meant that there would be zero ampere turns in the transformer for a period every switching cycle.
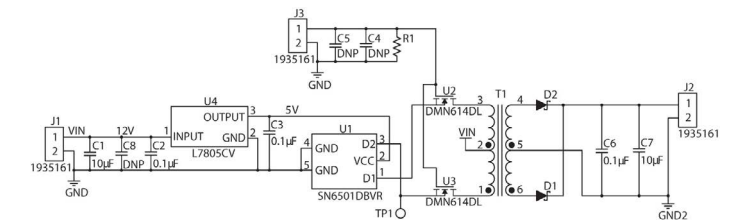

Figure 3 Current Density in Transformer Using FEA

Figure 4 View of an AC/DC Adaptor with a Planar Transformer and other Bourns® Components

The operating mode of the transformer is shown by the voltage across the drain of the MOSFET. Figure 6 shows the drain voltage and secondary Pulse Width Modulation (PWM) waveform of the Bourns® AC/DC adaptor. The voltage across the drain consists of the bulk voltage across the primary plus the reflected output voltage from the secondary. However, once the secondary current reaches zero, there are no more ampere turns in the windings meaning that the mutual inductance collapses. This leads to a period of oscillation around the bulk input voltage. The controller IC senses this from the auxiliary voltage and switches off the synchronous rectifier (blue line in Figure 6) to save energy. If the load is increased, this period of resonance is reduced until it disappears and the converter passes into continuous conduction mode.
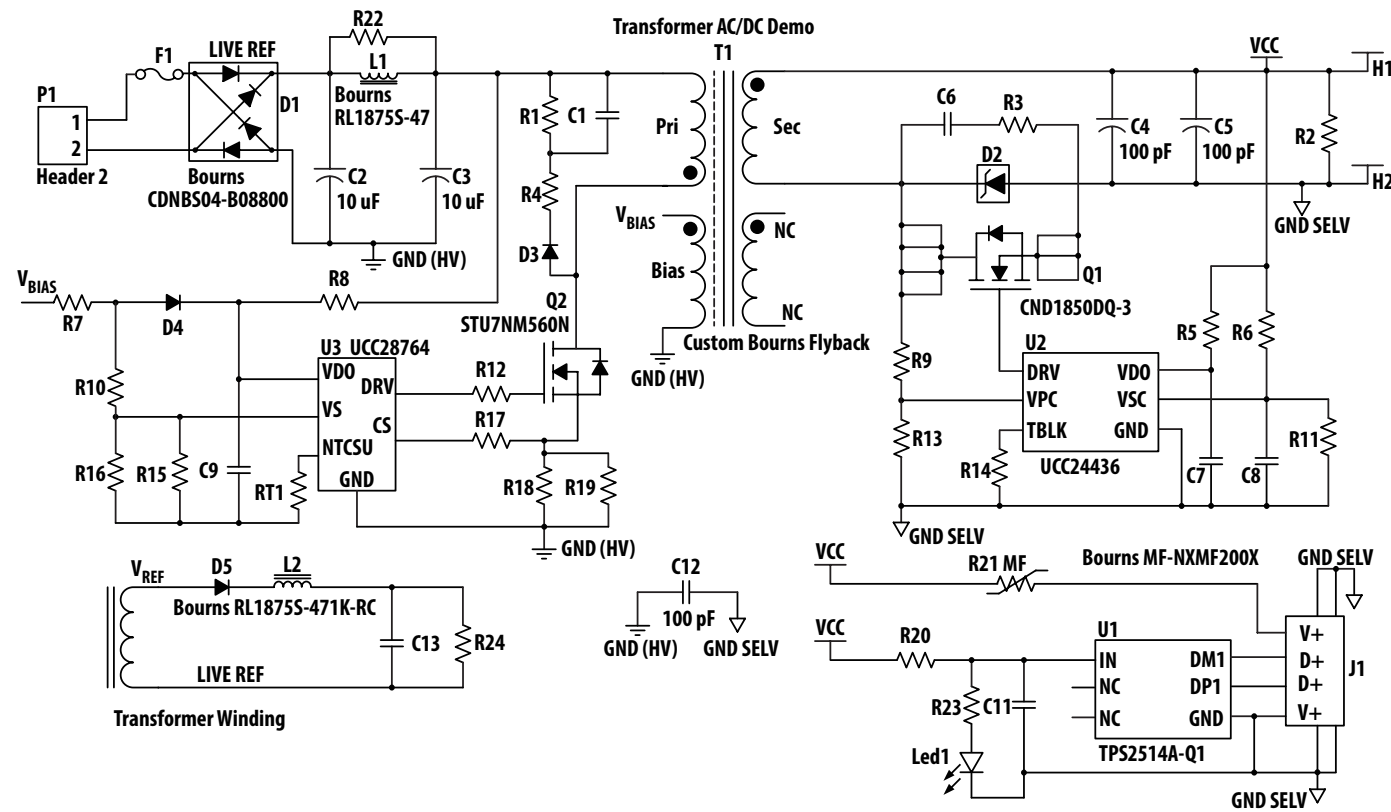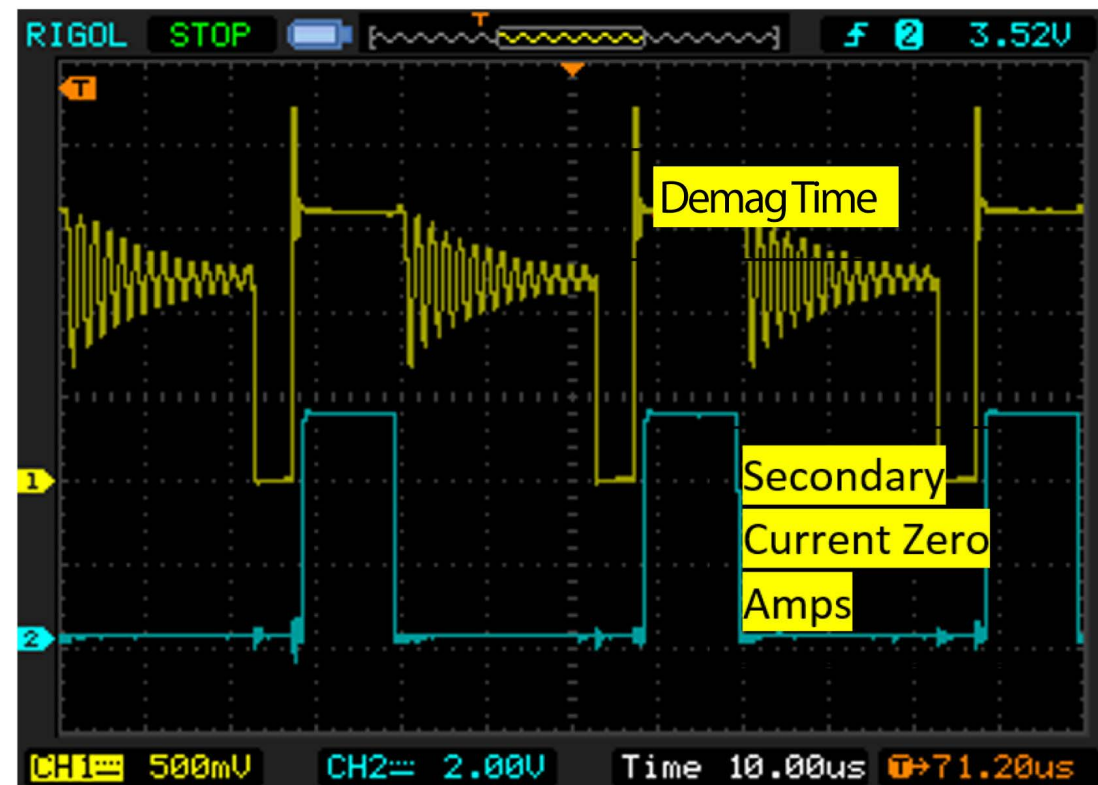
Figure 5 Schematic Diagram of an AC/DC Adaptor

Figure 6 Drain Voltage and Secondary Rectifier Activation Waveforms

Increasing Power Supply Efficiency

In this example, the power supply operated at 115 V AC input with a 5 V output. Bourns measured the efficiency at different output powers as shown in Figure 7.

The thermal image shown in Figure 8 captures where the inefficiencies lie at 10 W where the external MOSFET, inductor and the secondary winding of the transformer are at their warmest state.

The biggest loss came from the snubber diode. The image in Figure 9 shows it is the hottest component reaching 51.3 °C. Optimization of the snubber resistor value and reduction of the leakage inductance in the transformer will help to improve power loss in this area.
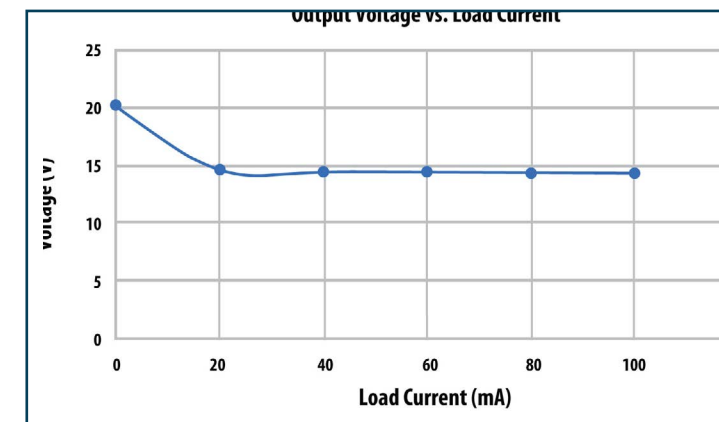

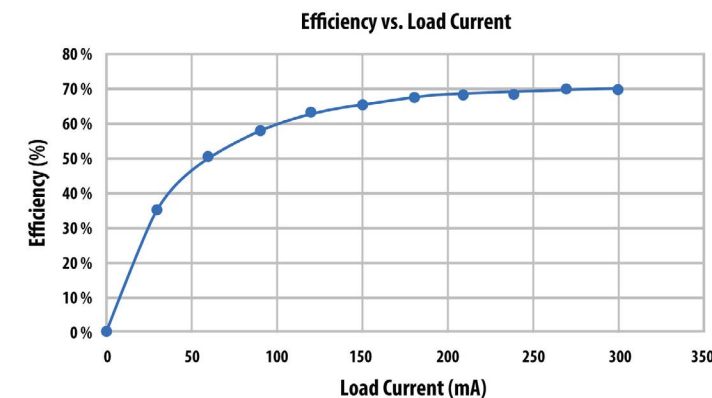Figure 7 Efficiency versus Power Curve of an AC/DC Adaptor

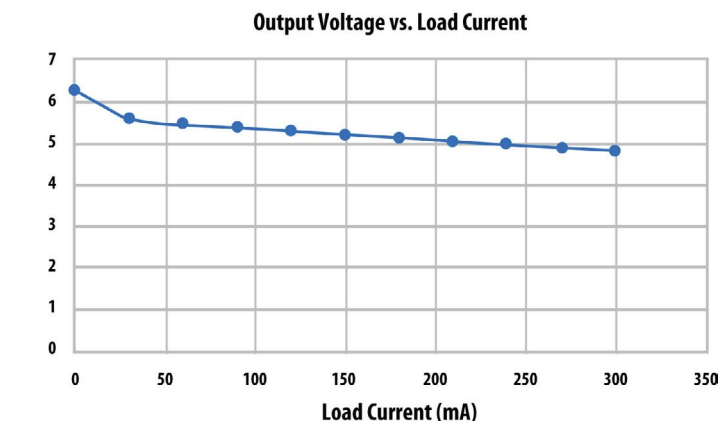Figure 8 Thermal Image of an AC/DC Adaptor during Testing

Figure 9 Thermal Image Highlighting the Heat from the Snubber Diode

Figure 10 Test Bench Showing Input and Output Power (91.05 % Efficiency)

Conclusion

Using the Bourns® planar flyback transformer design in this paper has illustrated that planar magnetics can be optimal conversion solutions for high frequency, high current applications including high voltage applications such as AC/DC adaptors. The planar transformer example provided the advantages of a compact, low profile design combined with PCB construction for high quality manufacturing.

Bourns developed this planar transformer with reinforced insulation, which was created by splitting the primary into two PCBs and sandwiching a four-turn secondary using triple insulated wire providing a necessary barrier between primary and secondary. Since the leakage inductance of a transformer is a source of wasted energy in a power supply, Bourns split the primary resulting in a leakage reduction of 50 %. Using this structure and testing it on an AC/DC flyback in DCM mode with 5 V output provided a peak efficiency of 91.05 % in the test conducted by Bourns.

The AC currents circulating in the secondary coil generate losses that could be mitigated if planar coils embedded in PCBs were used. By controlling the distances between the primary and secondary PCB, reductions in leakage inductance can also be achieved. Further transformer design improvements can be realized by focusing on reducing leakage inductance.

Bourns has extensive experience in supporting customers with custom transformer design for any topology in switch mode power supplies. The company's extensive use of 2D Finite Element Analysis allows them to achieve optimal magnetic and thermal performance in the design phase. Bourns' state-of-the-art laboratory enables its team to quickly assemble prototypes and test (Hi POT, Climatic, EMI, Impedance) according to customer specifications. Layout and test application board capabilities are also available to support customers, and Bourns' manufacturing facilities are TS16949 certified.

Additional Resources

Please contact your local Bourns Application Engineer or Bourns Sales Representative for additional information. Visit Bourns online at: www.bourns.com

Ways to Optimize and Expedite Custom Magnetic Prototypes

Introduction

The application-specific features in today's high frequency power converters and EMI filters have resulted in a growing demand for customized high-power magnetics designs. These types of complex customized designs require an experienced engineering team that can supply both the software (magnetic component design and Finite Element Analysis, or FEA) and hardware (prototyping tools) from a single power electronics laboratory. The cumulative result of being able to supply this combination of engineering expertise in a single location also leads to time-to-market and configuration benefits in expediting a customer's converter prototype design.

This application note presents the additional power advantages that can be achieved in using Finite Element Analysis to identify the optimum winding order prior to building physical prototypes. And, because actual

prototype measurements to simulations can vary, the application note also demonstrates why creating prototypes in the same location as the simulation software has become an essential custom design requirement.

Determining the Initial Specification

The initial step in a magnetic component design requires a preliminary specification of the power supply itself including additional information such as the topology, for example, a flyback topology. The manufacturer and power management chip series to be used must also be taken into consideration. A basic electrical block diagram of the system will indicate the number of windings involved.

Figure 1 shows an isolated AC/DC 70 W flyback power supply with reinforced isolation. The control loop consists of secondary voltage feedback, as well as primary current sensing. The coordination of the MOSFET and synchronous rectifier is done using the auxiliary (AUX) winding and the controller IC for measuring the demagnetization time. In this case, the leakage inductance measurements will determine the length of time that the leakage inductance spike lasts and will determine the cycle time of each oscillation when the secondary is completely demagnetized. Designing the transformer to ensure optimum leakage inductance with multiple windings is important in such a design.

If there is an application note from the power controller supplier, it can help determine the electrical parameters of the transformer including the primary inductance and peak saturation current (in the case of a flyback transformer). For this case study example, the primary inductance will be calculated using the energy equation for a flyback transformer:

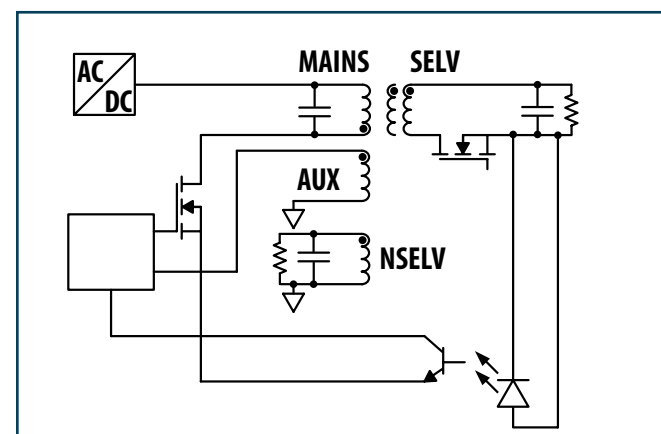$$L = \frac{2\,(V_{out} + V_F) * I_{out}}{f_{sw} I_p^2}$$

Figure 1 Efficiency versus Power Curve of an AC/DC Adaptor

Where:

f_{sw} = Switching Frequency
I_p = Peak Current in the Primary
V_F = Synchronous Rectifier Voltage Drop

The dimensions of the transformer will be determined first and foremost by the target power to be dissipated in the transformer, as well as the specified operating temperature range. Also important are the customer's board and enclosure, which are strictly dictated by safety requirements as stipulated by the customer. In Europe, Bourns uses SOLIDWORKS® for mechanical design. Figure 3 shows one example of a Solid Works transformer design. The blue line highlights the shortest distance between a secondary SELV pin and winding. SOLIDWORKS® supports its partners in helping to meet safety standards such as IEC 62368-1 Edition 2.0 2014-02.
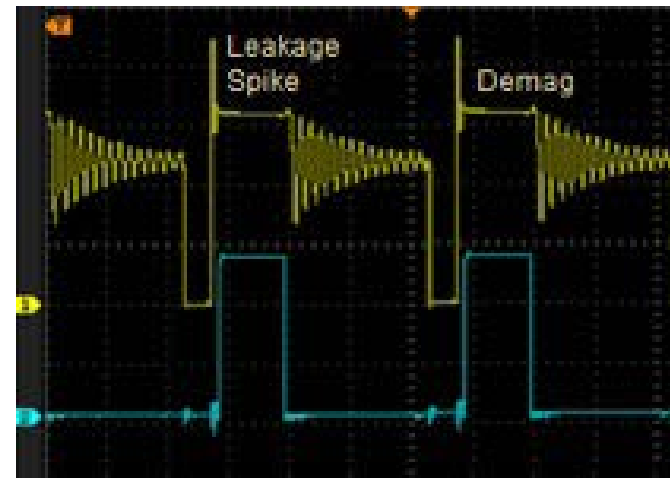

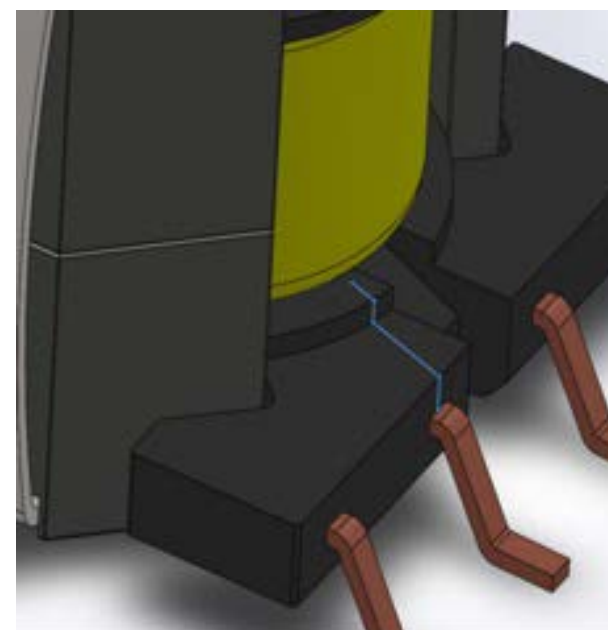Figure 2 Auxiliary Winding Voltage and Synchronous Rectifier Control Voltage (Blue) in a Flyback Power Supply

Figure 3 Calculation Example for Creepage and Clearance

Ideal Prototype Support

If a customer requires urgent engineering samples, having all materials in stock is a clear advantage to help avoid delays. Typically, Bourns stocks more than 179 different shapes and sizes of MnZn ferrite cores for new designs. These cores are "un-gapped", although custom laboratory machines can produce a flat uniform gap in less than 30 minutes. In addition, a Formlabs 3D printer is typically able to create various types of plastic bobbins within four hours.

Optimized Simulation Software

The time-consuming trial and error of assembling and testing different prototype variations can be simplified by first relying on tools such as ANSYS for identifying optimum structures. The flyback transformer example in Figure 1 is designed for 12 V /6 A isolated output (SELV) with a non-regulated, non-isolated 12 V/0.18 A output (NSELV).

Some controller manufacturers will have a maximum time allowed for the leakage inductance spike on the AUX winding. Figure 2 (in yellow) shows the AUX winding voltage, which is sampled by the controller. The peak-to-peak variation (ringing) will also have a minimum value and is dependent on the leakage inductance. The coupling between the NSELV in figure 1 and AUX may also need to be controlled. This can be necessary in standby power situations with the NSELV output being switched on or off. The control loop stability could be affected in these situations without optimum coupling between the AUX and NSELV windings. Therefore, placing the NSELV close to the AUX is necessary in this situation to maximize their coupling.

Figure 4 shows three different winding structures that have been analyzed by ANSYS. The leakage inductance
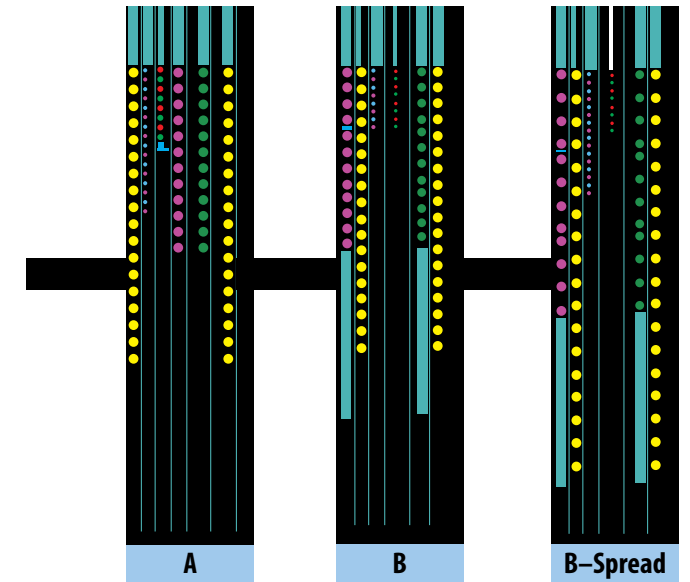

Figure 4 Diagram of Winding Order for Three Different Scenarios

is plotted in figure 5 and figure 6.

The software will optimize the layout of the windings, but also allows for manual placement of the windings, as well. It also allows for insulators such as tape and margin tape that can have an effect on leakage inductance. The isolation requirement between two non-isolated windings (500 Vac) is not possible if the windings are placed side by side, which would be more efficient. They must be separated by at least one layer of tape. The spacing between turns can also be adjusted. The Primary to SELV leakage in a high-power flyback transformer with auxiliary winding using secondary regulation is halved by splitting the Primary winding. This will double the magnetic field path length and the magnetic field intensity will be halved..

Winding Order B provided the optimum balance between the Mains to SELV and AUX to NSELV leakage. Winding Order A has the lowest leakage inductance

Winding	Layer	1	2	3	4	5	6
A	Name	Winding Mains	Winding AUX	Winding NSELV	Winding SELV 1	Winding SELV 2	Winding Mains
B & B–Spread		Winding SELV 1	Winding Mains	Winding AUX	Winding NSELV	Winding SELV 2	Winding Mains

Table 1 Winding Layers

between Mains to SELV but had a higher AUX to NSELV leakage. Spreading out the windings actually increased the leakage inductance, despite the fact that the path length increases through this approach, hence, lowering the field intensity (Ampere Turns Per Meter). Increasing the distance between the turns allows uncoupled flux to pass into the space between windings. However, there is a trade-off in the space between turns and the overall length of the winding. Therefore, margin tape was used to keep the turns close together when making initial samples. The measured results confirmed that Winding Order B was the better option. The measurements demonstrated that spreading the winding across the bobbin had the opposite effect on the leakage inductance.
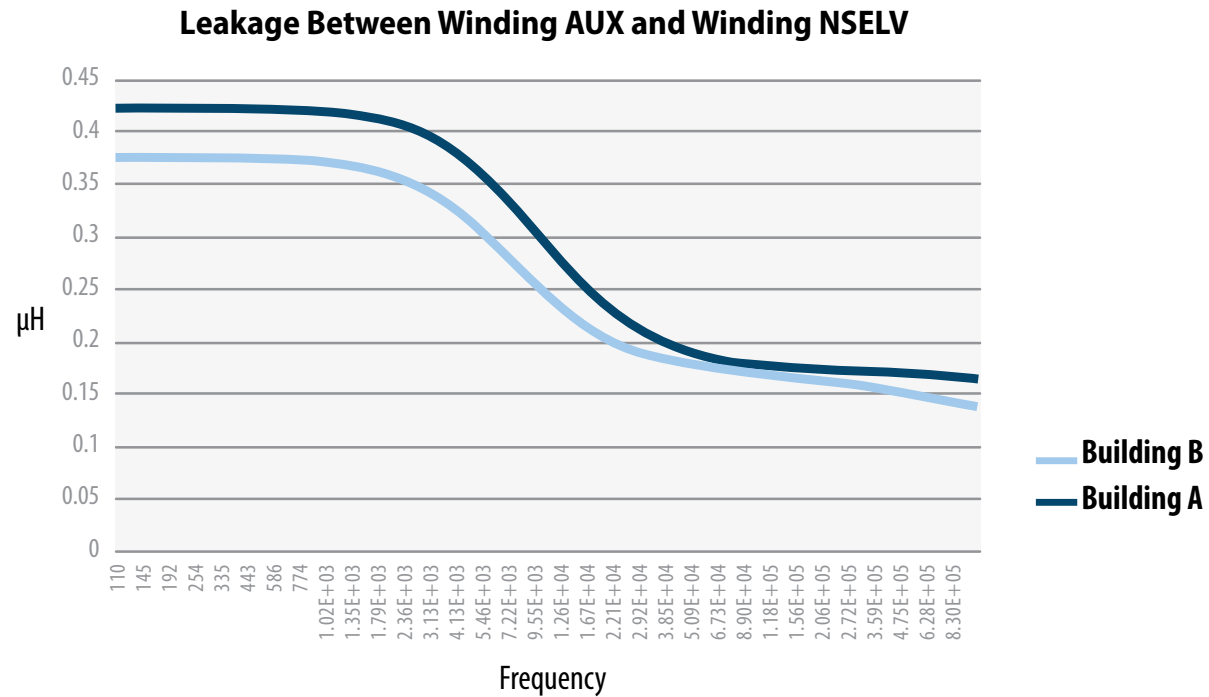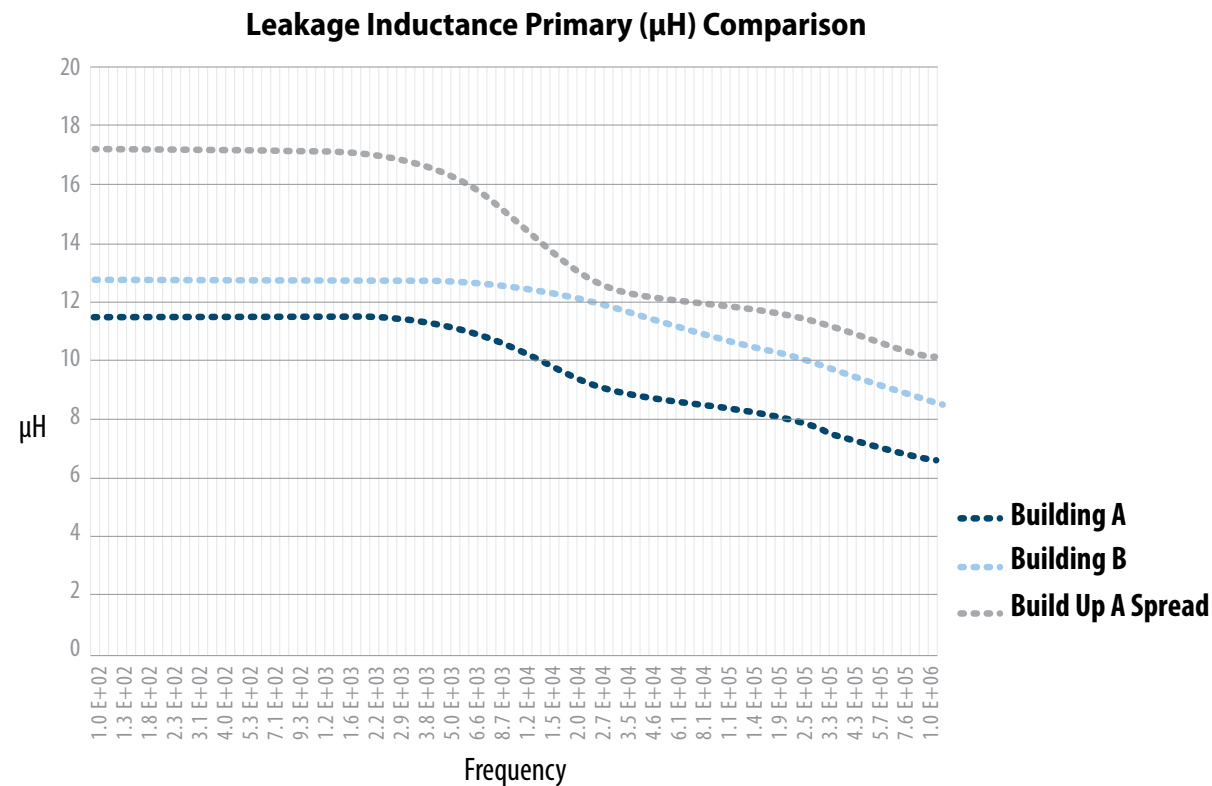
Leakage Between Winding AUX and Winding NSELV

Figure 5 ANSYS Finite Element Analysis

Leakage Inductance Primary (µH) Comparison

Figure 6 ANSYS Finite Element Analysis

Winding Buildup	Leakage Primary	Leakage AUX Winding
A	5.1 µH	0.98 µH
B (Margin Tape)	5.5 µH	0.45 µH
B Spread Out	6.5 µH	1.05 µH

Table 2 Physical Measurements of Prototypes Made with Three Different Scenarios (80 KHz HP 4285)

The differences in real and simulated measurements of leakage inductance can be partly due to the following factors:

A. Short circuit bar resistance
B. Distribution of coil along surface of bobbin
C. Tolerance in insulation material thickness

It is important to note that while simulation helps to compare different scenarios and select the appropriate winding structure, it is imperative to build a sample and test it thoroughly.
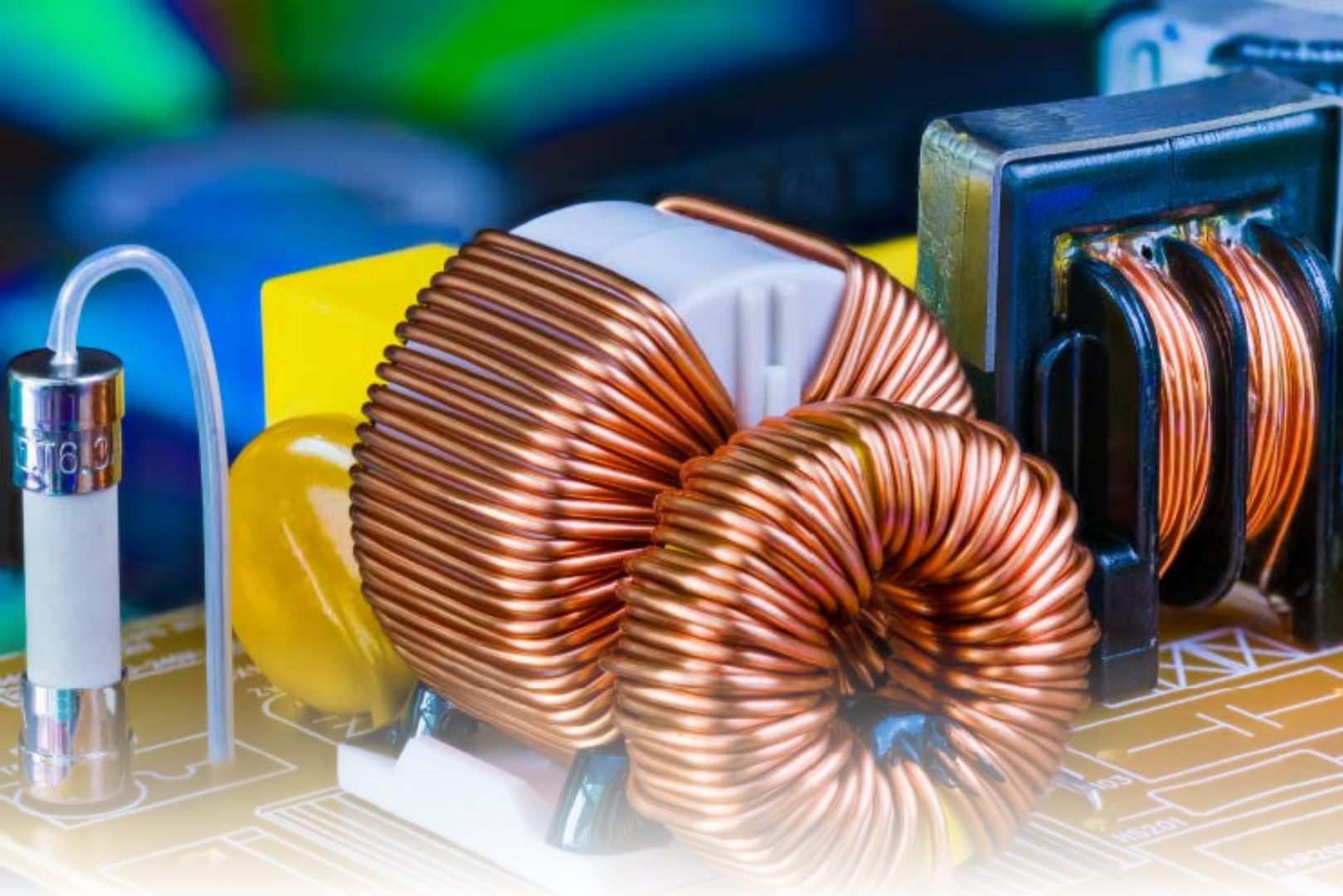
Bourns Power Electronics Laboratory Capabilities

Customers sometimes require transformer testing support on application boards under certain conditions. For instance, Bourns has a license for Altium Designer® for circuit and PCB design. The laboratory has a range of power sources and electronic loads together with a temperature chamber and infrared camera for testing boards. Bourns also can assist customers with EMI board testing.

Key to successful custom magnetics designs, Bourns'

production facilities are certified to IATF 16949 with automated manufacturing both for high volume, low power transformers as well as more complicated magnetics assemblies. This includes high-power converters (toroidal or split cores) such as power factor corrected soft switched half bridge converters. The company's experienced application engineers ensure that prototypes are meticulously and efficiently transferred from initial engineering to production using industry standard AQCP (Advanced Quality Control Procedures) so that the design maintains the highest quality levels.

Bourns has set up its power electronics laboratories to best support customers with design, simulation and engineering samples of high frequency power magnetics. Our expertise in advanced software design tools allows us to select the optimum magnetics design for each customer before making engineering samples. Having mechanical and electrical engineering in the same location, as well as available stock of ferrite cores and 3D printing capability allows Bourns the advantage of offering quick, sometimes as fast as 24-hour turnaround on engineering samples. While simulation tools save time by identifying the optimum design, there is still no substitute for testing actual samples and verifying results.

ty of the application:

- Functional—isolated output, but no protection from electric shock
- Basic—contains a physical barrier, offering shock protection if the barrier is intact
- Supplementary—adds a redundant barrier to basic isolation for added safety
- Reinforced—highest-safety choice; input and output windings are separated by a large distance or two physical barriers (like supplementary)

Push-Pull

Push-pull is a type of DC converter topology that uses a multiple winding transformer coupled with two transistors to convert DC voltage. Voltage is applied to the primary transformer circuit as the well timed transistors are alternated between on and off states. This design draws current during both halves of the switching cycle, smoothing the input current supply. As a result, push-pull converters provide a steadier input current, create less noise on the input line, and enjoy higher efficiencies in higher-power applications than alternative styles.

Market Data

Isolated DC-DC converters are used in high-voltage circuits, power metering, healthcare technology, battery management systems, onboard charging, and CAN receivers. With such a wide span of applications, market researchers expect the isolated DC-DC converter market to reach $2.7 billion (USD) by 2024.

Electrical Specifications @ 25°C

Bourns Part Number	Primary Inductance @ 100 kHz	Leakage Inductance @ 100 kHz / 0.1 V (All Sec. Pins Shorted)	Turns Ratio P(1-3) : S(6-4)	Pri. (1-3) DCR (Ω) Max.	Sec. (6-4) DCR (Ω) Max.
	L 1-3 (µH) Min.	Lk 1-3 (µH) Max.			
HCTSM80101AAL	250	0.8	1:1	0.30	0.20
HCTSM80102AAL	250	0.6	1:2	0.30	0.35
HCTSM80201AAL	250	1.2	2:1	0.30	0.15
HCTSM80304BAL	300	0.6	3:4	0.30	0.30
HCTSM80305BAL	300	0.6	3:5	0.30	0.30
HCTSM80308BAL	300	0.7	3:8	0.50	0.85
HCTSM80403AAL	250	0.8	4:3	0.30	0.20
HCTSM80803AAL	250	1.8	8:3	0.30	0.15
HCTSM80809AAL	250	0.6	8:9	0.30	0.25
HCTSM80910BAL	300	0.9	9:10	0.30	0.25
HCTSM81017CAL	350	0.9	10:17	0.42	0.48

Figure 1 HCT series part numbers qualified to work with Texas Instrument's chipset. (Source: Bourns Inc.)

Given the importance of physical barriers for isolated DC-DC converters, achieving high-isolation performance in a low-profile, compact design offers design engineers an opportunity to develop an innovative solution. This paper provides an overview of the Bourns® HCT Series AEC-Q200 Compliant Power Transformer, a high-clearance and creepage isolation power transformer that incorporates the latest safety features for DC-DC conversion.

Product Solutions

The HCT series (Figure 1) offers features well-suited for isolated DC-DC conversion applications such as automotive, industrial, communications, and consumer. They have a 6.5mm profile with more than 8mm clearance and creepage, along with reinforced insulation for working voltages up to 800VAC. The transformers are compliant with AEC-Q200, RoHS, and three IEC standards (described in detail on previous page).

This transformer solution for isolated DC-DC conversion comes in a fully AEC-Q200 compliant part, manufactured in an IATF 16949-certified factory. It offers multiple turn ratios (1:1 to 1:2.7), and design engineers can customize the high-voltage isolation performance to specific application requirements, along with additional customization options. HCT transformers are also validated and approved by Texas Instruments for operation with SN6501 and SN6505B.

The HCT series components (Figure 2) run at between -40°C and +125°C operating temperatures, and they provide up to 350mA output. The transformers also accept 3.3V-3.5V inputs and provide 3.3V-15V outputs.

Engineers designed the HCT series transformers specifically for Texas Instruments transformer driver chipsets. On the following page is a summary of TI SN6501 and

Figure 2 HCT transformer Series (Source: Mouser Electronics)

Innovative Transformer Solution Addresses Traditional Challenges

Adam Kimmel at Mouser Electronics

Introduction

An electronic device that changes direct current (DC) from one voltage to another is a DC-DC converter. Typical uses range from low-voltage cell phone and laptop batteries to high-voltage circuits and power metering. As voltage increases, though, maintaining electrical isolation becomes more challenging in DC-DC converters.

Isolation

DC-DC converters employ isolation to ensure safety for operators. This approach reduces the risk of electric shock, avoids ground loops due to different potential levels, and prevents voltage transients from input to output through galvanic isolation. Engineers can achieve isolation through isolation transformers, which contain high-resistance insulation between the primary and secondary circuits to withstand the voltage between the windings. There are varying degrees of isolation, selected based on the severi-

Figure 3 SN6501 transformer driver from Texas Instruments. (Source: Texas Instruments)

Figure 4 SN6505 transformer driver from Texas Instruments (Source: Mouser Electronics)

Figure 5 Creepage Path (Source: Bourns Inc.)

SN6505, two chipsets that work well with the HCT components.

SN6501

The SN6501 transformer driver (Figure 3) is designed for economical, compact, isolated DC-DC converters that use push-pull topology. The driver is used in applications such as CAN, process control, industrial automation, and low-to mediumrisk medical equipment. Used for input and output voltages ranging from 3-5.5V, design engineers recommend implementing a low dropout regulator (LDO) to stabilize the current supply without dependence on load. Including an LDO maximizes efficiency while providing a stable power supply.

SN6505

Like the SN6501, the SN6505 transformer driver (Figure 4) is a push-pull transformer driver, designed for compact, isolated power supplies. Applications of this driver include process control, radio supplies, medical and precision instruments, low-noise filament supplies, and low-noise isolated USB supplies. The SN6505 is low-noise and low-electromagnetic interference (EMI) in addition to push-pull capable and drives low-profile, center-tapped transformer 2.25-5.5V power supplies. Design engineers recommend LDOs with this driver as well, to maximize efficiency while providing stable source current.

In addition to the two chips above Bourns HCT series is qualified for another three automotive grade TI chipsets: SN6501-Q1, SN6505B-Q1, and SN6505D-Q1.

Standards Compliance

As safety is the primary function of an isolation transformer, quality engineers highly value compliance with industry standards. Bourns® HCT series transformers meet the UL/IEC 62368-1 Hazard-Based Safety Standard. The intent of the standard, which takes effect in December 2020, is to provide design engineers added flexibility to incorporate new technology into their product designs.

Complying to UL is a critical gate that establishes credibility with the customer base. UL is often used as the Gold Standard for electronic device compliance and covers a broad scope of highly technical industries, such as computing and networking, consumer electronics, telecommunications, monitors and televisions, and office supplies.

Competitive Benchmark

While being measured against an industry standard, the HCT series outperforms two anonymous competitive benchmark components in several categories:

- High Potential Capability (tested): HCT series transformers withstood up to 7.5kV, while the competitors rated at parity and 6kV
- DC Resistance (DCR): advantage over both competitors, providing a higher degree of isolation to enable increased safety
- Thermal Derating: advantage over both competitors, dissipating more power (without enduring damage) at a given case temperature
- Working Voltage for Reinforced Isolation: the HCT transformers operate at 800VAC, while the competitive products operated between 250-400VAC
- Available Turn Ratios: more than either competitor (11 for HCT, 7 and 9 respectively for competitive parts)
- Creepage Distance: a critical metric for an isolation transformer, the HCT component contains greater than 8mm creepage distance, while the competitive transformers were at parity or 7mm

Innovative Creepage Path Design

The HCT series contains an innovative body design that enables a high minimum creepage path between the terminal and the electronics. The lid contains protrusions that ex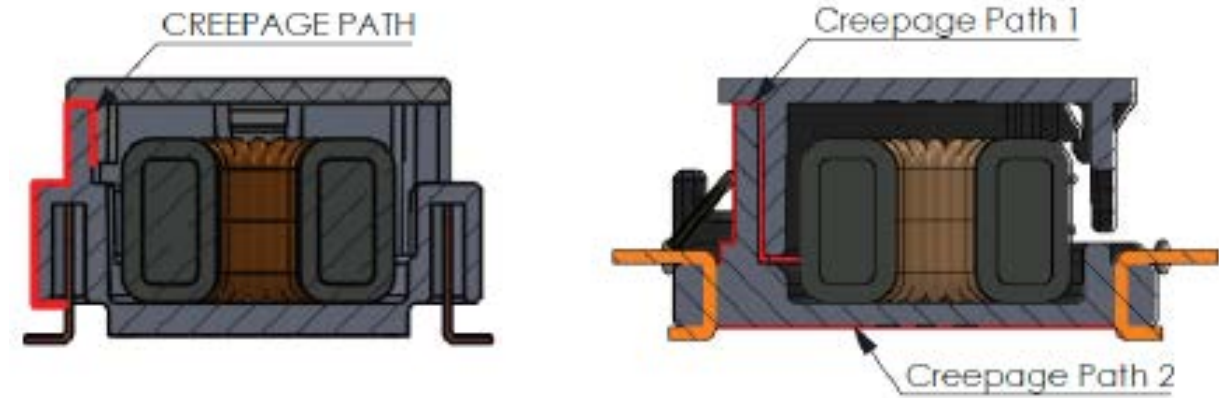tend into the body, providing an elongated, tortuous path for the current to travel. This design increases creepage while maintaining a compact package footprint by adding internal surface area that increases the distance of the current flow path as shown above (Figure 5).

Conclusion

The Bourns® HCT series transformers were designed with reinforced isolation, increasing creepage distance. This series can be used with several of Texas Instruments automotive application chipsets. An innovative body design contains integrated routing paths for the current, creating a compact package that maximizes creepage and overall isolation performance for safe DC-DC conversion. The components have a low-profile form factor, making them ideal for UL/IEC 62368-1 compliance.

For push-pull DC-DC converters with reinforced isolation, the Bourns HCT series offers the best-in-class solution for technical performance while maintaining a small packaging size.
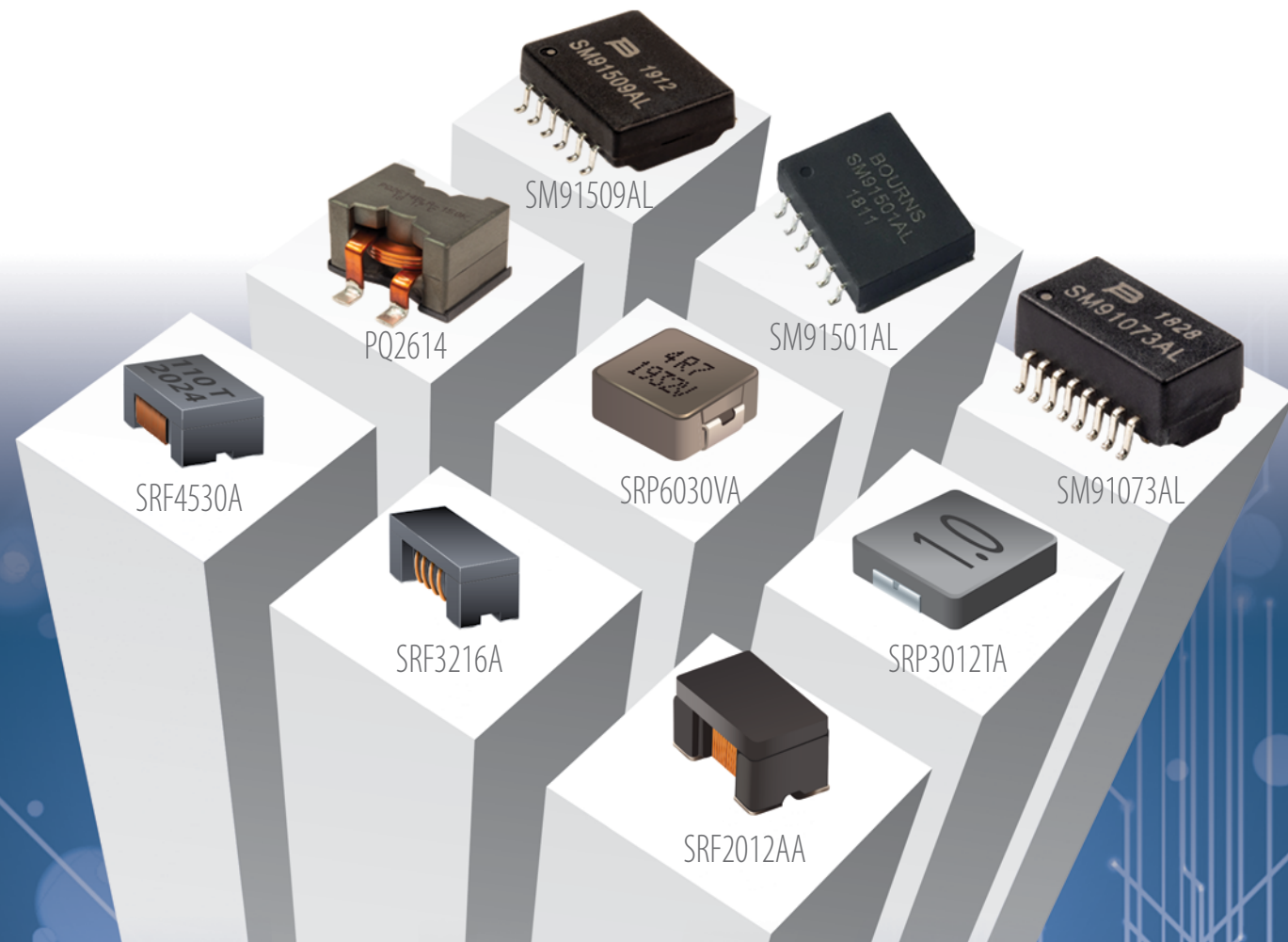
Automotive Grade Magnetic Components

Types Available:
- Transformers
- Inductors
- EMI filters and Chokes

Features:
- Compliant with AEC-Q200 Standards
- Produced in IATF16949 Certified Factories
- Compliant with Advanced Product Quality Planning (APQP) Process

SM91509AL

PQ2614

SM91501AL

SRF4530A

SRP6030VA

SM91073AL

SRF3216A

SRP3012TA

SRF2012AA

Applications
- Battery Management Systems
- On/Off Board Charging
- DC-DC or AC-DC Power Supplies
- Infotainment
- Telematics
- Advanced Driver-Assistance Systems
- Instrument Cluster
- Automotive Audio
- Automotive Cameras
- Ethernet Switches
- USB Power Delivery
- USB 3.X
- GPS and Navigation Systems
- CAN-bus and Ethernet Communication Networks