APPLICATION NOTE

Using Push-Pull Transformers to Isolate Power in 12 V Applications

HCT Series

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.

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 SN6505B 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.

APPLICATION NOTE

Using Push-Pull Transformers to Isolate Power in 12 V Applications

HCT Series

Push-Pull Converter Background

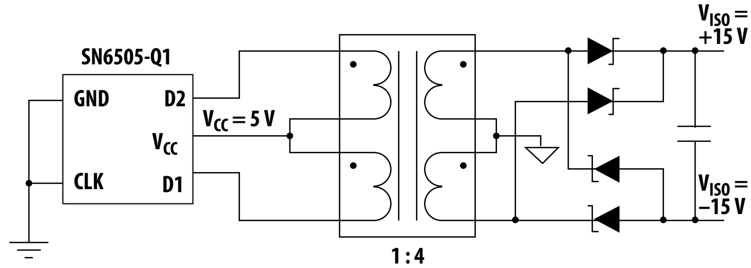

Figure 1. | *Isolated bias supply for gate driver of IGBTs*

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.

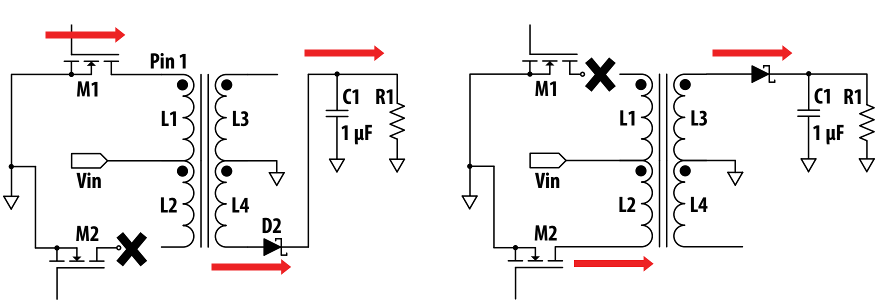

Figure 2. | *Operation of a push-pull converter with the red lines indicating output current.*

APPLICATION NOTE

Using Push-Pull Transformers to Isolate Power in 12 V Applications

HCT Series

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 Rds(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 Rds(on) must be chosen as the FETs are in a continuous on-state. The lower the Rds(on) the more efficient the circuit.

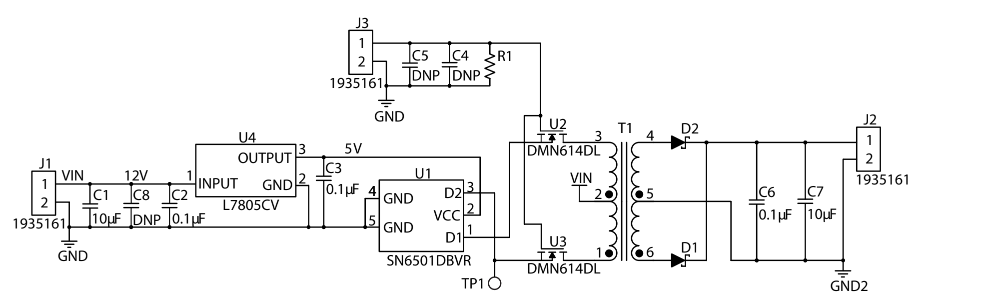

Figure 3. | *Model HCTSM8 higher voltage application schematic*

Using Push-Pull Transformers to Isolate Power in 12 V Applications

HCT Series

Circuit Description *(Continued)*

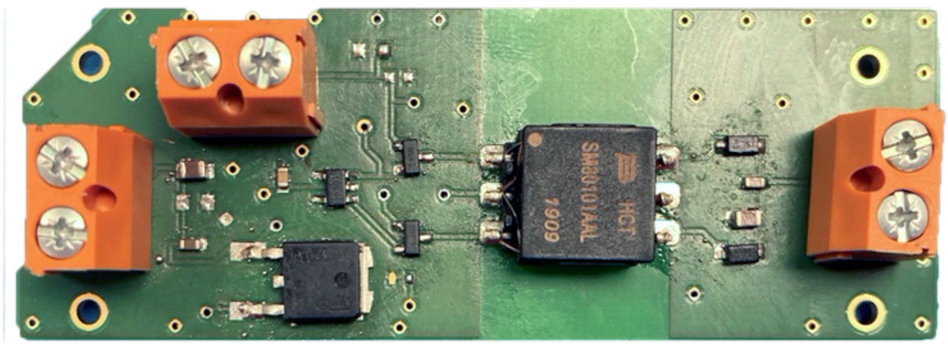

Figure 4. | *Model HCTSM8 Board*

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.

Table 1. | *Equipment*

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

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.

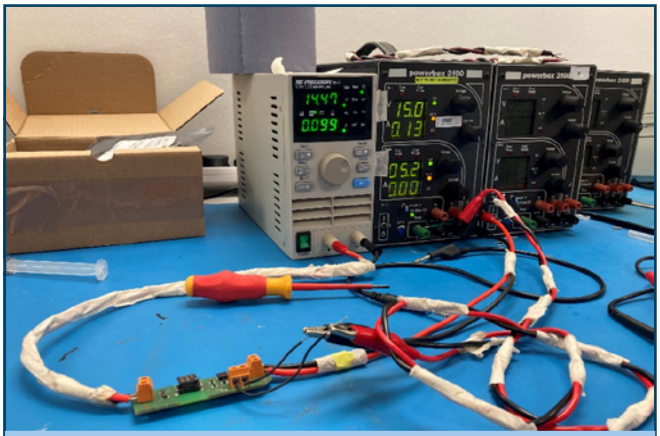

Figure 5. | *Testing set-up*

APPLICATION NOTE

Using Push-Pull Transformers to Isolate Power in 12 V Applications

HCT Series

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 100 mA. For efficiency improvements, designers should select an FET with low Rds(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.

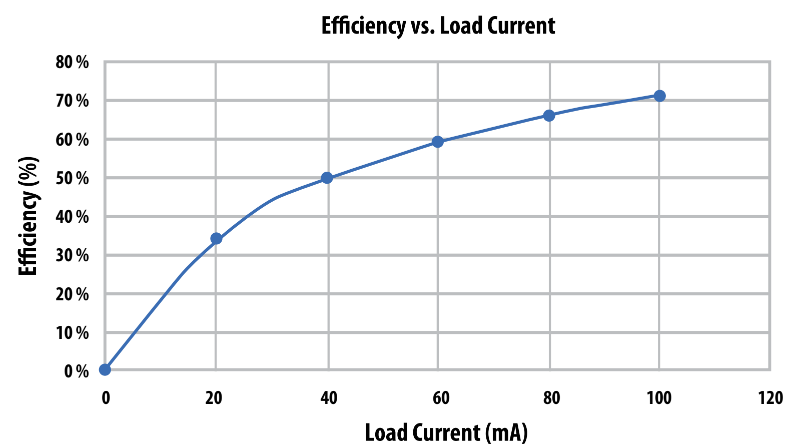

Figure 6. | *HCT series 1:1 efficiency vs. load current plot*

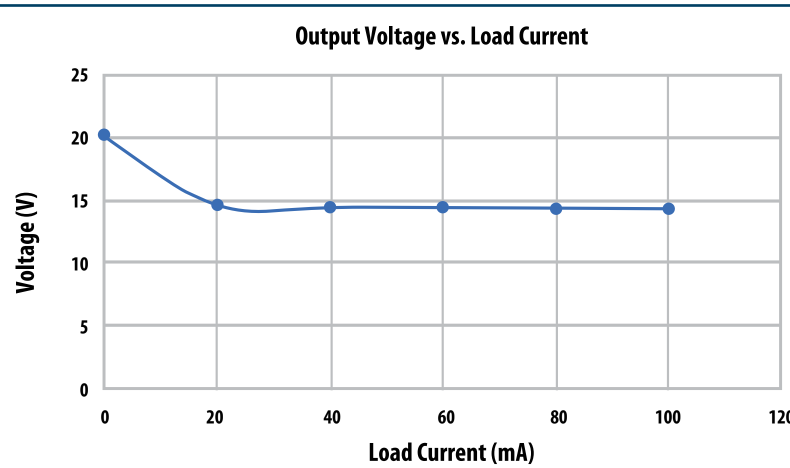

Figure 7. | *HCT series 1:1 output voltage vs. load current plot*

HCT Series

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. This test showed similar efficiency results to the previous one where Figure 8 illustrates 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.

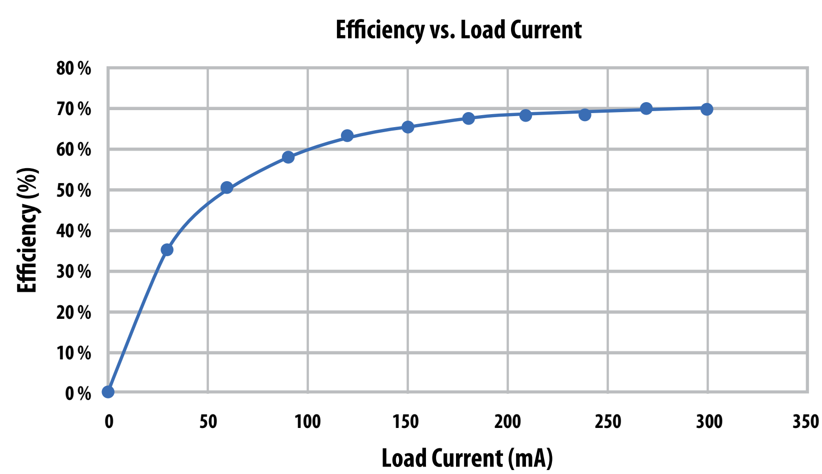

Figure 8. | *HCT series 2:1 efficiency vs. load current plot*

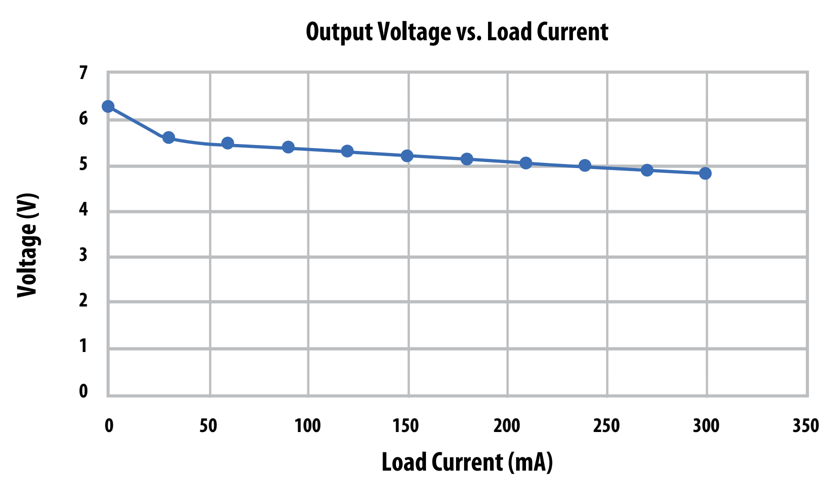

Figure 9. | *HCT series 2:1 output voltage vs. load current plot*

HCT Series

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.

References

[1] A. Kamath, "Push-pull converter simplifies isolated power supply design in HEV/EV systems" Analog Design Journal, Texas Instruments, accessed 13/11/2020, < https://www.ti.com/lit/an/slyt790b/slyt790b.pdf?ts=1605253120349&ref_url=https%253A%252F%252Fwww.google.com%252F >.

[2] C. Sheehan, "How to Select the Right Reinforced Transformer for High Voltage Energy Storage Applications," Application Note, Bourns Electronics, accessed 13/11/2020, < https://www.bourns.com/docs/technical-documents/technical-library/inductive-components/application-notes/bourns-hct-series-transformer-app-note.pdf?sfvrsn=86ff43f6_12 >.

Americas: *Tel* +1-951 781-5500
Email americus@bourns.com

EMEA: *Tel* +36 88 885 877
Email eurocus@bourns.com

Asia-Pacific: *Tel* +886-2 256 241 17
Email asiacus@bourns.com