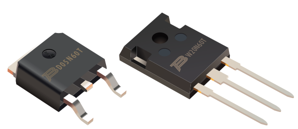
APPLICATION NOTE

Why Trench-Gate IGBTs are the Optimal Choice for Solar Inverter Voltage Conversion



Bourns® BID Series IGBTs

INTRODUCTION

In a solar inverter, Insulated Gate Bipolar Transistors (IGBTs) are known as excellent solutions for converting a DC voltage generated from the solar array panels to AC voltage. The resulting AC voltage is used to power AC loads or various electrical equipment, or as in the case of a Photovoltaic (PV) inverter, to be fed into an AC grid. The most common topologies in an inverter are half-bridge and full-bridge utilized in single-phase systems, or neutral point clamped topology employed in 3-phase systems. These topologies use IGBTs as the power discrete semiconductor of choice for achieving high efficiency and high reliability.

This application note presents how Bourns® Trench-Gate Field-Stop (TGFS) IGBTs with co-packaged Fast Recovery Diodes (FRDs) can be used in a solar inverter application to enable efficient power conversion. It also outlines the optimal IGBT features necessary for superior thermal performance while delivering low power dissipation.

LOWERING BOM COSTS IN SOLAR APPLICATIONS

IGBTs are a combination of a Metal Oxide Semiconductor (MOS) transistor and a Bipolar Junction Transistor (BJT). The input side is a MOS transistor, while the output is a BJT. The input is, therefore, voltage controlled, whereas the output is driven by the high current carrying capabilities of the BJT. The combination of these two functions enables high speed and low saturation voltage characteristics which, along with the built-in fast soft recovery diode, are ideally suited for solar inverter applications. Another key feature for solar applications is the reduction of total Bill of Material (BOM) costs.

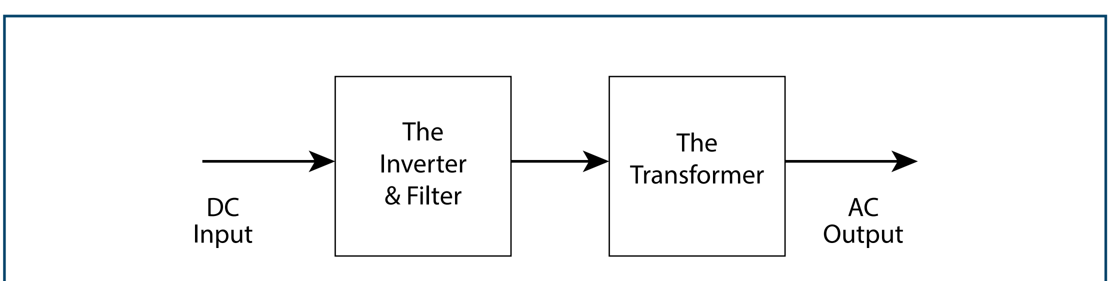
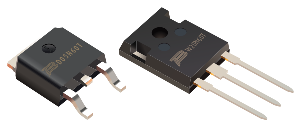


Figure 1. | *A block diagram for DC to AC voltage conversion*

Figure 1 is a block diagram that illustrates how an IGBT converts the DC input into an AC output.



Bourns® BID Series IGBTs

LOWERING BOM COSTS IN SOLAR APPLICATIONS (Continued)

The latest generation of Bourns® Trench-Gate Field-Stop (TGFS) IGBTs can support up to 50 kHz. This increase in operating frequency enables lower cost power generation with smaller and lighter magnetics, which is important for solar applications as passive components generally represent a high percentage of the total BOM costs.

A typical implementation of a solar inverter uses a full-bridge topology with four switches, as shown in Figure 2. Switches Q1 and Q3 are high-side IGBTs while switches Q2 and Q4 are low-side IGBTs through an output filter (formed by L1, L2, and C1) and are required to produce a single-phase high quality low-harmonics AC sinusoidal voltage waveform because power is being injected into the grid when it is directly connected to the mains.

This is a common topology of most solar inverters with single phase, 60 Hz, 208 V or 240 V_{RMS} voltage output in the 1 to 5 kW power output range. A target efficiency is set (such as ≥95 %), limiting the total device losses to specific watts. Corresponding IGBTs are then selected to meet the efficiency requirement. Conduction losses that impact efficiency are obtained from the IGBT's forward characteristics. Switching losses that impact efficiency are obtained from the IGBT's dynamic characteristics. Both types of losses contribute to total power loss and power dissipation. Bourns® IGBTs have been designed to reduce power dissipation by up to 3 kW for solar applications.

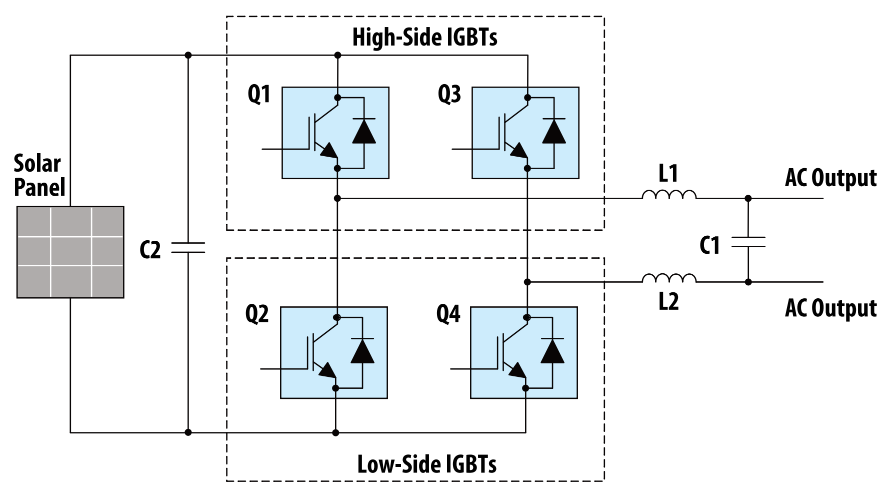
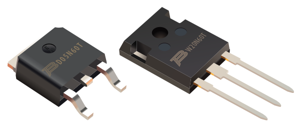


Figure 2. | *A typical solar inverter circuit using a full-bridge IGBT topology*



Bourns® BID Series IGBTs

SELECTING THE RIGHT IGBT FOR SOLAR INVERTER APPLICATIONS

For solar inverter applications, Bourns offers a 650 V rated trench-gate co-packaged IGBT+FRD as an excellent choice. The Model BIDW50N65T provides superior thermal performance, low $V_{CE(sat)}$, and offers high efficiency due to lower total power dissipation. The end result of these advanced features is higher reliability as compared to typical previous generation planar IGBTs.

Encapsulated in a TO-247 package along with a freewheeling diode or Fast Recovery Diode (FRD), the Bourns® IGBT Model BIDW50N65T can handle a continuous current of 50 A at a case temperature of 100 °C. The TO-247 package is thermally efficient due to its very low package thermal resistance (see Table 1), allowing continuous operation of the IGBT.

Table 1. Thermal resistance of IGBTs

Parameter	Symbol	Maximum	Unit
IGBT Thermal Resistance Junction - Case	$R_{th(j-c)\_IGBT}$	0.3	˚C/W
Diode Thermal Resistance Junction - Case	$R_{th(j-c)\_Diode}$	0.65	˚C/W

Furthermore, the Bourns® Model BIDW50N65T uses TGFS technology that enables low $V_{CE(sat)}$ voltage for the rated current of 50 A. This, in turn, leads to a lower ON-state power loss or conduction loss during normal operation of the IGBT. The device has a positive temperature coefficient for $V_{CE(sat)}$, which makes it well-suited for parallel switching that will increase the load current and, thus, the maximum output power.

In the event of a short circuit, the IGBT must withstand the short circuit current and several kW of power dissipation until a controller or driver detects the condition and turns it off. The disadvantage of a high short circuit withstand capability is generally a higher $V_{CE(sat)}$, and, therefore, higher loss. The lower saturation voltage of the Model BIDW50N65T (1.65 V typical at 50 A) while withstanding a 10 µs short circuit event, however, is a key advantage that addresses the reliability and ruggedness needed for a solar inverter application. Figure 3 shows the actual V_{CE}, V_{GE}, and I_C waveforms for Model BIDW50N65T IGBTs.

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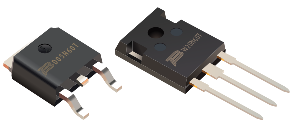

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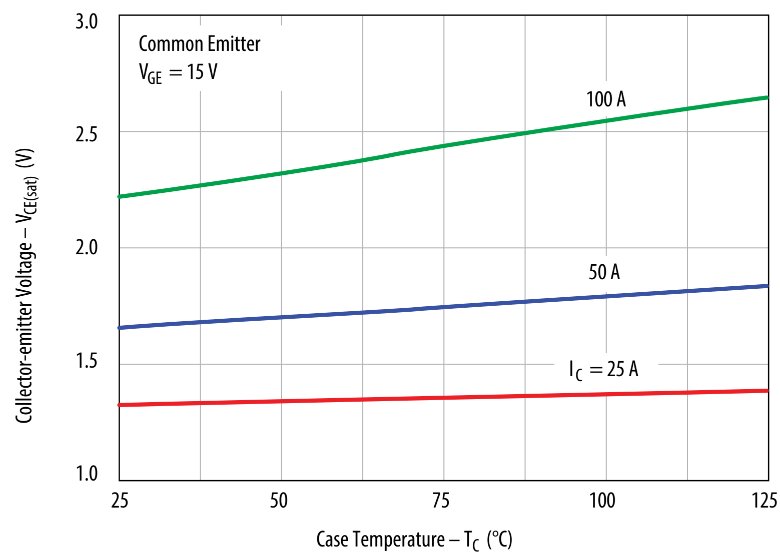

Figure 3. | *Typical $V_{CE(sat)}$ vs. case temperature*

The use of TGFS technology helps in reducing the tail current during the switch-off stage of the device. This helps lower the switching losses. The Model BIDW50N65T IGBT has a typical total switching energy loss of 4.1 mJ. In addition, the 650 V rated Model BIDW50N65T features anti-parallel diodes for fast switching and low switching loss, while supporting a maximum operating junction temperature of +150 °C. Plus, this model series is qualified to JEDEC standards to meet the high efficiency and high reliability requirements of a solar inverter application.

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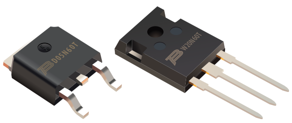

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CONCLUSION

A solar inverter is a challenging application with conflicting demands of high performance, efficiency, and device robustness that can be best satisfied with the latest generation of TGFS high-conductivity IGBTs. Because TGFS IGBT devices have lower switching losses coupled with low conduction losses and provide higher efficiency, reducing the size of the unit and the cost of power generation to the end user can be achieved. In addition, the internal ultra-fast soft recovery diode further improves efficiency and reduces EMI.

These benefits have been independently researched repeatedly and have been tested using new 650 V IGBTs in solar inverter applications. Based on this research, there are claims that current density is improved by as much as 30 % compared to typical prior generation IGBTs.

For more information on Bourns' high-performance discrete IGBT product offering, please refer to the additional available resources on the Bourns website:

ADDITIONAL RESOURCES

- Product Page: Bourns Discrete IGBTs
- Technical Library: Bourns Discrete IGBTs
- White Paper: Understanding IGBT Data Sheet Parameters
- White Paper: Achieving Fast IGBT Reverse Recovery Loss
- White Paper: Measuring IGBT Conduction Loss to Maximize Efficiency
- White Paper: Bourns® IGBT vs. MOSFET - Determining the Most Efficient Power Switching Solution

www.bourns.com

BOURNS®

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