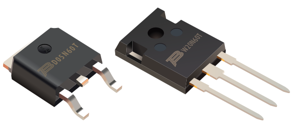
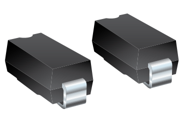
APPLICATION NOTE

Meeting Higher Power Density/Efficiency Using Discrete IGBTs in Electrical Spot-Welding Applications



Bourns® BID Series IGBTs



Bourns® Transient Voltage Suppressor (TVS) Diode Series

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INTRODUCTION

Insulated Gate Bipolar Transistors (IGBTs) are excellent solutions for providing the functional blocks necessary to perform the electronic switching functions in industrial welding equipment. For example, IGBTs are particularly well-suited to take power from the AC power line and control the welding energy and pulse times. An electrical spot-welder is primarily used to join pieces of metal by applying calibrated pulses of current to make molten spots between the welded pieces. When these molten spots cool, the work pieces are bonded together. Effective spot-welding depends on the force applied to the work pieces during the current pulses and the total energy delivered into the weld spot by the machine's tips.

This application note outlines the many advantages of using discrete IGBTs as the switching elements in an electrical welding unit. It also highlights how IGBTs benefit the design of the electrical spot-welder industrial machine, enabling it to be smaller, lighter weight, and more efficient due to the IGBTs' reduced power losses and enhanced thermal performance. The result is a simplified circuit design that requires fewer components and helps to reduce the overall Bill of Material (BOM) costs. Additionally, this application note will present why designing with IGBTs also contributes to increased operational reliability and a higher Mean Time Between Failure (MTBF) for the completed design.

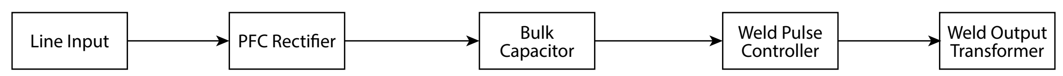

Figure 1. Electrical spot-welder power flow

A spot-welder requires two power stages, as shown in Figure 1. The first is a Power Factor Correction (PFC) rectifier to take power from the AC line of 208 to 250 VAC_{rms} at 50 or 60 Hz. The second is a switch to supply power at the desired pulse width and energy level to the weld output transformer. This application note uses the example of one design implementation of a spot-welder machine that supplies 10 kW maximum pulse welding power.

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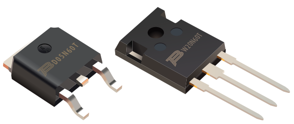

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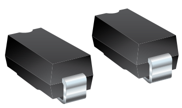

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HOW THE PFC AFFECTS AC LINE CURRENT

As shown in Figure 2, the PFC rectifier stage supplies the required power to the bulk storage capacitor as it maintains the line input harmonic current at a low level and the AC line power factor at near unity. The PFC section takes power from the AC line of 208 to 250 VAC_{rms} at 50 or 60 Hz to charge the bulk capacitor to a maximum 360 VDC. The controller achieves a near-unity power factor by shaping the input line current waveform to correspond to that of the AC input line voltage. The controller for the PFC stage implements an average current mode control using inputs from the input AC voltage, input line current, and output DC voltage. This control method approach helps to maintain low distortion sinusoidal line current, which, in turn, minimizes the input harmonic distortion.

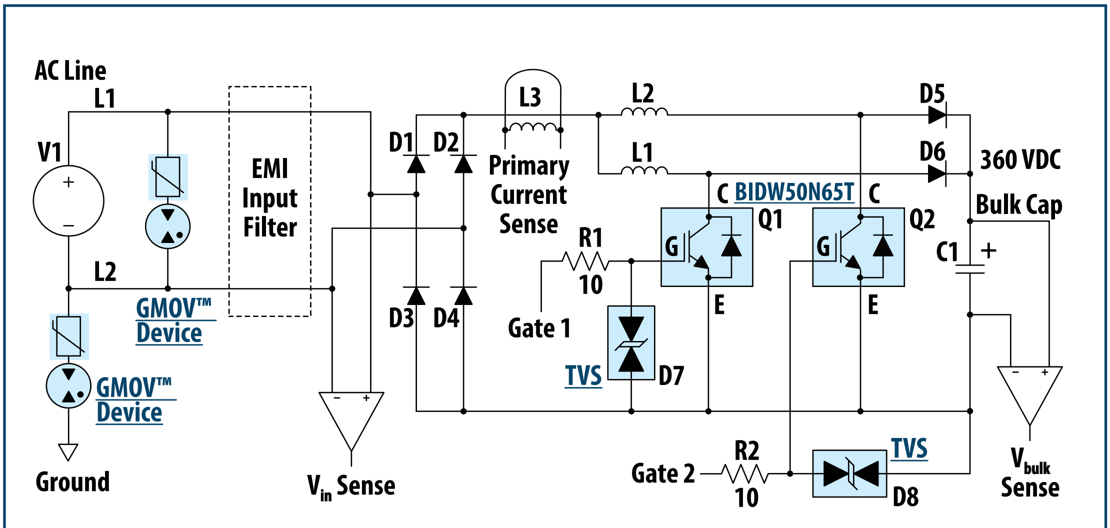
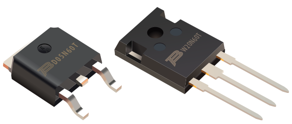


Figure 2. Block diagram of the spot-welder PFC rectifier and voltage regulator stage

Figure 2 illustrates the PFC switching section for the offline rectifier. It begins with protection against power line surges by using a Bourns® GMOV™ Hybrid Protector, has an EMI filter to help with line harmonic energy compliance, and includes a full wave bridge rectifier (D1 through D4). Two chokes (L1 and L2) are included to operate with the IGBT switches (Q1 and Q2) implemented using Bourns® Model BIDW50N65T IGBTs to allow current to pass. The bulk capacitor C1 stores the welding pulse energy.



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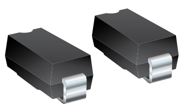

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HOW THE PFC AFFECTS AC LINE CURRENT (Continued)

The Bourns® IGBTs are well-suited for the PFC switches because of the ease of driving the gate as a capacitor in the same way a MOSFET would. They also feature a wide Safe Operating Area (SOA), and excellent thermal performance provided by the devices' TO-247 package. The IGBTs' peak pulse current and high blocking voltage specifications allow effective power factor correction using the chokes and diodes as shown in Figure 2.

In addition to keeping the harmonic current and power factor within acceptable ranges, the PFC section provides a variable 80 to 360 VDC on the bulk capacitor. This sets the maximum voltage on the welding tips at 2.5 to 11 V, which together with the length of time the current pulses are applied, effectively controls the energy delivered.

In this design, the Gate 1 and Gate 2 control signals are timed so that the IGBTs pass current when the line voltage is available to supply it. The gates are enabled by calculating when the AC line can deliver current to the bulk capacitor and using the Pulse Width Modulation (PWM) technique to regulate the voltage on the bulk storage capacitor C1. Current is taken from the line in phase with the voltage, thus providing a phase-corrected load on the line. The PFC active periods are calculated from a constant frequency, which is typically around 20 kHz.

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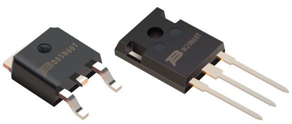

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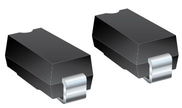

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WELD CURRENT PULSE SWITCH AND OUTPUT TRANSFORMER

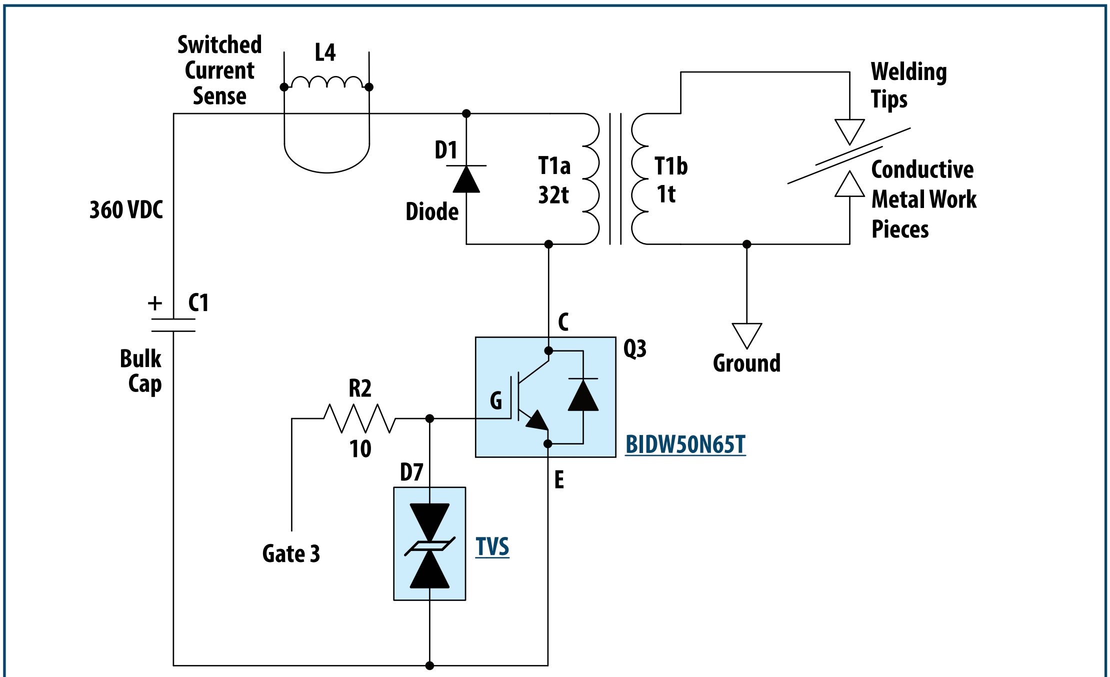

Figure 3. | *Weld current pulse switch and output transformer*

The weld pulse controller controls the energy that flows to the work pieces by switching current pulses at 12.5 kHz and 50 percent duty cycle. The total energy is set by the operator as an input to the weld pulse controller. The current pulses are applied to the work pieces by welding tips which apply pressure while the current is flowing. Figure 3 implements the flyback topology and shows the IGBT switch charging the primary of the welding transformer during every 40 µs ON period. The bulk capacitor voltage and transformer primary inductance are coordinated so the maximum current needed to achieve the peak pulse energy is within the IGBT SOA.

The welding pulse energy is determined by the number of current pulses that flow through the 32:1 stepdown transformer. The Bourns® transformer used in this solution example is constructed using a ferrite core that stores 0.8 joules in 40 µs for the maximum individual pulse energy. Table 1 shows the transformer's primary and secondary characteristics.

Table 1. Welding transformer characteristics and operating conditions

Welding Transformer Details	Primary	Secondary
Number of turns	32	1
Pulse peak voltage	80 to 360 V	2.5 to 11 V
Pulse peak current	1 to 32 A	32 to 1000 A

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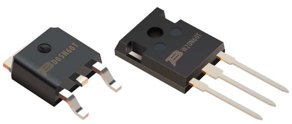

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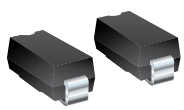

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WELD CURRENT PULSE CONTROLLER

The total weld pulse energy is controllable from 0.01 joules to 100 joules by changing the maximum pulse voltage and length of time that the current pulses flow. To apply the minimum energy, the weld pulse controller makes three pulses with the minimum peak voltage for 200 µs. For the maximum 100 joules, the weld pulse controller enables 40 µs pulses for 10 milliseconds with the maximum peak pulse voltage. The Bourns® IGBT has enhanced thermal conduction and can remove heat generated by the switching and conduction losses during the 10 milliseconds maximum pulse time. During the time required for the bulk capacitor to recharge, the IGBT is able to transfer the heat produced by the losses to a simple and small heatsink.

The current monitor (L4) in series with the IGBT collector allows the weld pulse controller to monitor the individual pulse current and adjust the complete weld pulse length to achieve the specified weld energy. The current monitor is also able to detect overcurrent conditions and can disable the IGBT switch within the short circuit withstand time of 10 µs. Even if there is a problem that causes the collector current to exceed design standards, this design approach provides the IGBT with sufficient time to protect itself while the weld pulse controller detects the condition and sets a fault alarm.

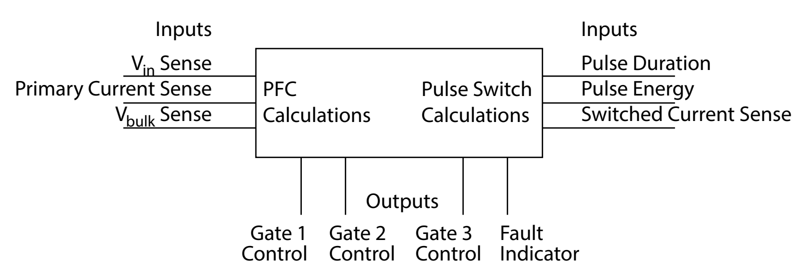

Figure 4. | Weld pulse controller

Figure 4 shows the outline for a controller that is implemented by analog or digital methods to control the functionality of the welder in this example. The controller detects the voltage and current at the line input and maintains the voltage on the bulk capacitor at a predetermined value by means of switching the IGBT gates as shown in Figure 2. Another part of the controller takes the user input for the duration and energy of the weld pulses, and enables the IGBT in Figure 3 to conduct current from the bulk capacitor to the primary of the weld transformer. The weld pulse controller in this example uses the 20 kHz reference frequency to control the gate drives for the IGBTs. The number of discrete pulses that are used for each weld is calculated from the desired total weld pulse energy in coordination with the voltage on the bulk capacitor. In addition, the weld pulse controller monitors the transformer's primary current pulses and maintains a consistent weld pulse energy for any line voltage and work piece variation.

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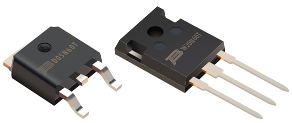

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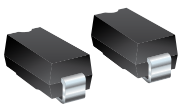

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CONCLUSION

Using the advanced features of Bourns® IGBTs as switching elements in spot-welders for PFC and current switches provides many user benefits. It enables rugged thermal conduction, wide SOA protection areas, and robust short circuit performance. The controller circuit monitors the IGBT current and protects the IGBT devices from an overcurrent condition. Because Bourns® IGBTs offer lower switching and conduction losses and enhanced thermal design, they require less volume in the heat sink. This helps reduce the size and weight of the completed application. All of these factors reduce the number of required components and can lower the BOM cost, thereby yielding more efficient and higher reliability equipment. Employing IGBTs to perform as switches, together with various diodes and magnetic components, offers an efficient and lighter weight design approach that can help increase the robustness of industrial equipment. Taking the approach outlined in this application note also helps streamline the control and tuning of the gate controls in the switching circuits so that higher equipment efficiency can be achieved.

A common assumption is that IGBT modules are useful only in welding machines rated at more than 250 amps. However, the thermal performance of the TO-247 package used for Bourns® IGBTs meets the growing demand for higher power density and higher efficiency using discrete IGBTs by paralleling individual devices. Paralleling TO-247-packaged IGBT devices allows them to handle power levels typically achieved only by IGBT modules in high power applications. Bourns® Model BID Series IGBTs offer the advanced features necessary to allow the switching circuits to function with minimal high frequency noise. Combined with the ease of driving the gates in the same way as MOSFETs to maximize efficiency, utilizing Bourns® IGBTs significantly aids in making the design of complete industrial machine application circuits a streamlined and straightforward process.

ADDITIONAL RESOURCES

- Technical Library: Bourns® Discrete IGBTs
- Product Page: Bourns® Discrete IGBTs
- Product Page: Bourns® Model P6SMB16CA TVS Diode
- Product Page: Bourns® Magnetics (Transformers and Common Mode Chokes)
- Product Page: Bourns® Rectifier Diodes
- Product Page: Bourns® SinglFuse™ SMD Fuses
- Product Page: Bourns® GMOV™ Hybrid Protection Component
- 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

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