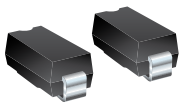
APPLICATION NOTE

The Benefits of IGBT Switching Protection Using TVS and PTVS Diodes

Bourns® BID Series IGBTs



Bourns® Transient Voltage Suppressor (TVS) Diode Series

Bourns® Power TVS Products (PTVS)

IsoMOV™ / GMOV™ Hybrid Protection Components

SinglFuse™ SMD Fuses

INTRODUCTION

As power conversion hardware is redesigned to be more efficient using Insulated Gate Bipolar Transistors (IGBTs), some areas need additional design attention to help avoid damage to components from voltage surges. This extra design activity applies to virtually all types of applications where IGBTs are used as power conversion switches. Application examples include: PFC (Power Factor Correction) rectifiers, frequency changers, DC to AC inverters, Uninterruptable Power Supplies (UPS), solar energy converters, Pulse Width Modulation (PWM) motor drivers, battery chargers, and battery voltage boost stages.

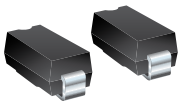
In these applications, Transient Voltage Suppressor (TVS) and Power Transient Voltage Suppressor (PTVS) diodes are employed to prevent high voltage surges from damaging IGBTs and other components. When IGBTs are switching currents through chokes, transformers, motors, and other inductive loads, voltage surges are a common occurrence at the switching times. Chokes and transformers are used in switching circuits as the central method for power conversion in many applications while other applications use capacitors to accomplish the power switching function. All of these applications are subject to voltage surges during operation due to stray and leakage inductance as well as voltage surges present on the AC power line.

This application note will show the reader the ways that TVS and PTVS diodes can protect IGBT switches and prevent catastrophic breakdown due to overvoltage and transient surges. It explains methods for protecting the IGBT collector-emitter and gate-emitter interfaces. The application note also will make engineers aware that some surge threats are not immediately obvious, such as motor kickback and high voltages entering control electronics from the sensing circuits used for feedback, so additional care is necessary in selecting the right surge protection for switching applications.

APPLICATION NOTE

The Benefits of IGBT Switching Protection Using TVS and PTVS Diodes

Bourns® BID Series IGBTs



Bourns® Transient Voltage Suppressor (TVS) Diode Series

Bourns® Power TVS Products (PTVS)

IsoMOV™ / GMOV™ Hybrid Protection Components

SinglFuse™ SMD Fuses

POWER FACTOR CORRECTION (PFC) RECTIFIER

The partial schematic of a PFC AC line rectifier in Figure 1 illustrates the method of protecting the IGBT gate by keeping the voltage relative to the emitter within the data sheet limits, which is commonly ±20 V. This is accomplished by attaching a bidirectional TVS diode such as the Bourns® Model P6SMB16CA (D8 and D9) TVS diode between the gate and the emitter. This particular TVS diode is capable of limiting the voltage between the gate and emitter to a maximum of 18 to 20 V. An additional benefit of using the Bourns® TVS diode in this example is that the device can also limit voltage surges induced on the gate from the Miller capacitance and rapid voltage rise on the collector, which limits or prevents spurious gate activation.

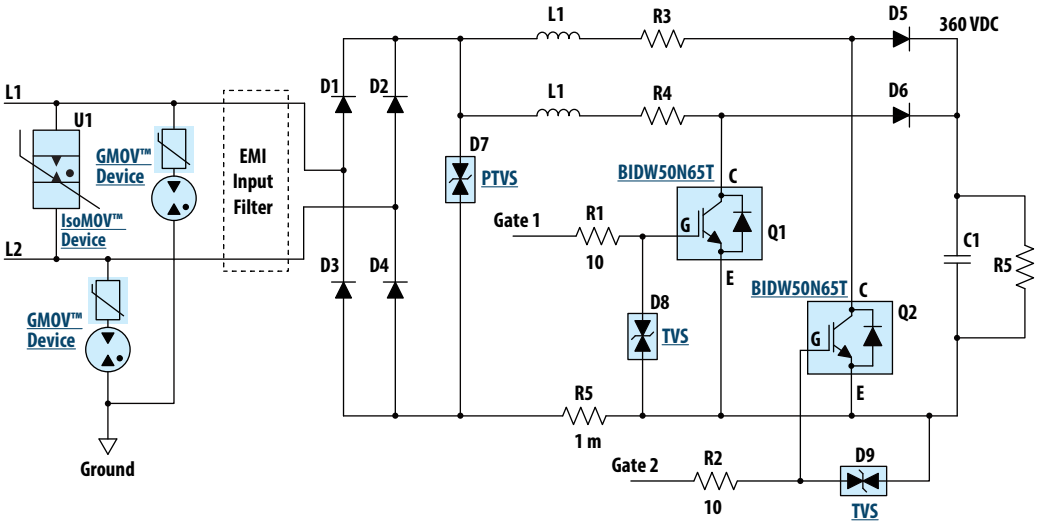


Figure 1. | *Shows a partial schematic of one type of PFC that has IGBT protection using both a TVS diode and PTVS diode along with a Bourns® IsoMOV™ hybrid protector and a Bourns® GMOV™ protector for primary protection.*

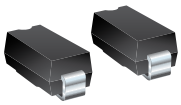
The Bourns® PTVS Diode (D7) across the full wave bridge rectifier DC voltage output prevents surge voltages (up to the device's rated limits) that are let through the IsoMOV™ and GMOV™ primary line protectors from reaching the IGBT switches. These primary line protectors prevent lightning induced surges or harmonic voltage peaks from reaching the rectifier and switching stages. The voltage rating needed for the PTVS diode to protect the IGBTs depends on the maximum line voltage to be used by the application:

- Bourns® Model PTVS3-430C-TH for 240 V single-phase applications
- Bourns® Model PTVS3-380C-TH for 208 V 3-phase applications

The protection components shown for the PFC stage in Figure 1 are applicable to other line input configurations and IGBT application areas.

The Benefits of IGBT Switching Protection Using TVS and PTVS Diodes

Bourns® BID Series IGBTs



Bourns® Transient Voltage Suppressor (TVS) Diode Series

Bourns® Power TVS Products (PTVS)

IsoMOV™ / GMOV™ Hybrid Protection Components

SinglFuse™ SMD Fuses

BATTERY CHARGER

This same configuration using TVS and PTVS diode protection can also be used in other IGBT switching applications. For example, a battery charger configuration is shown in Figure 2 that utilizes a PTVS diode (D5) on the output of the bridge rectifier and also employs a TVS diode on the IGBT gate (D6).

Another TVS diode, for example, the Bourns® Model 1.5SMC82A TVS diode (D8), is used in the snubber circuit to clamp high voltage surges from the transformer. This TVS diode can be a unidirectional device because of its interaction with D7, a power rectifier diode, which is usually used in snubber circuits. The L3 output winding in this configuration conducts the heavy current to charge the battery.

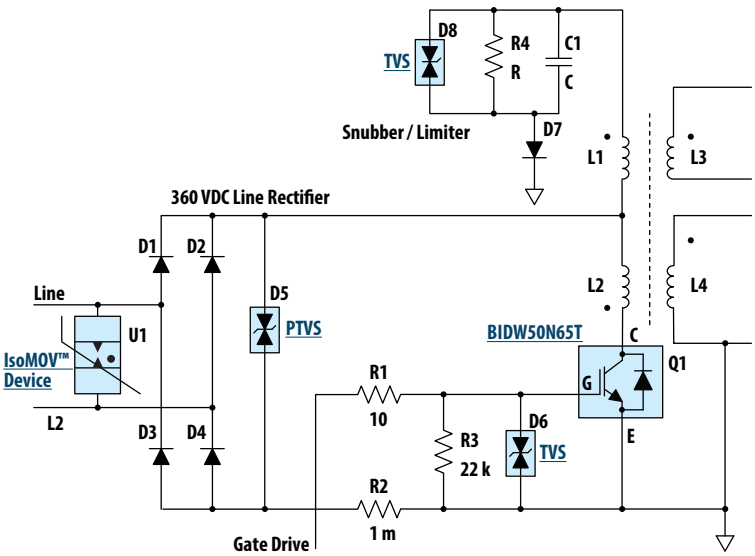


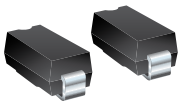
Figure 2. | *Partial schematic of battery charger application circuit that uses a PTVS diode to protect the IGBT from line surges and a TVS diode for gate protection.*

A Bourns® IsoMOV™ protector (U1) Model IsoM5-300 is connected across the AC line to prevent up to 5 kA lightning surges from entering the rectifiers. The ratings for the IsoMOV™ and GMOV™ components used in all line-connected applications depend upon the surge current level and the AC line connections. Both single-phase and 3-phase power connections in this protection scheme are protected effectively.

APPLICATION NOTE

The Benefits of IGBT Switching Protection Using TVS and PTVS Diodes

Bourns® BID Series IGBTs



Bourns® Transient Voltage Suppressor (TVS) Diode Series

Bourns® Power TVS Products (PTVS)

IsoMOV™ / GMOV™ Hybrid Protection Components

SinglFuse™ SMD Fuses

PWM VARIABLE FREQUENCY MOTOR DRIVES

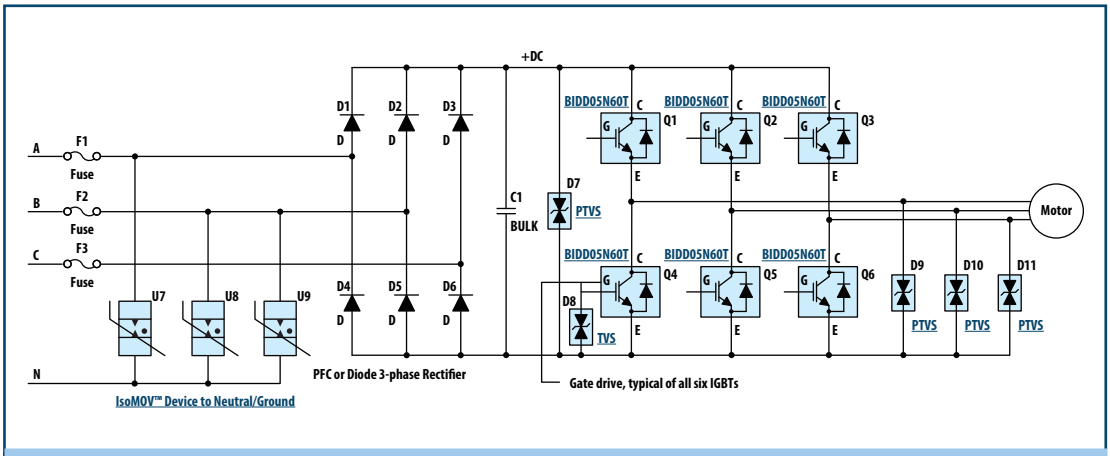


Figure 3. | *Online 3-phase motor drive circuit, with voltage surge and gate drive protection.*

Figure 3 shows the surge protection in the Variable Frequency Motor Drive (VFD) by using a PTVS diode (D7) across the bulk capacitor. Other TVS diodes, such as the Bourns® Model P6SMB16CA TVS diode (D8 for Q4), placed across each IGBT gate emitter help prevent voltages above the specified gate-emitter voltage V_{ge} from reaching the IGBT. The Bourns® TVS diode is designed to limit the voltage between the gate and emitter at a maximum of 18 to 20 V and also is able to limit voltage surges induced by ESD and the Miller capacitance due to the rapid rate of voltage rise on the collector. This protection solution is also applicable to DC to AC inverters, as well as the output stage of a frequency changer and Uninterruptable Power Supplies (UPS) that operate at 50, 60, or 400 Hz.

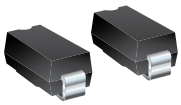
When high voltage is available on the output of a variable frequency motor drive and a UPS inverter application, the collectors of the IGBT switches are protected by PTVS diodes. The PTVS diode current requirement needs to be sized for the expected surge currents and the voltage rating is set above the working voltage for the motor or line output and below the maximum IGBT V_{ce}.
IsoMOV™ (or GMOV™) Hybrid Protectors employed for line surge voltage protection need to be sized for the expected lightning surge current and line voltage and configuration:

- Bourns® Model IsoM5-300 for 240 V single-phase applications
- Bourns® Model IsoM5-275 for 208 V 3-phase applications

The line fuses (F1, F2, and F3) are selected from Bourns® SinglFuse™ SMD Fuse product offering. For this application, the recommended fuses are the Bourns® Model SF-3812F1000T-2 SinglFuse™ SMD Fuse that can provide 10 amp protection for the 208 to 250 VAC line input. Safety capacitors and common mode chokes are also suggested for use on the input line side and high voltage outputs when EMI compliance is required.

The Benefits of IGBT Switching Protection Using TVS and PTVS Diodes

Bourns® BID Series IGBTs



Bourns® Transient Voltage Suppressor (TVS) Diode Series

Bourns® Power TVS Products (PTVS)

IsoMOV™ / GMOV™ Hybrid Protection Components

SinglFuse™ SMD Fuses

AC VOLTAGE AND CURRENT SENSE PROTECTION

An inverter that changes high voltage DC to AC line frequency output is shown in Figure 4. This protection solution employs all the protection methods previously discussed including TVS diodes to protect the gates, for example, the Bourns® Model P6SMB16CA TVS Diode, for D2, D3, D4, and D5. In addition to these components, this design uses TVS diodes on the voltage and current sense transformers to clamp the voltages used as feedback to regulate the 220 VAC output. The integrated digital controller typically requires an analog-to-digital converter (ADC) to sense the AC output voltage and current through the transformers T1 and T2. The suggested TVS diodes D6 and D7 are low voltage bidirectional types with a clamping voltage to protect the ADC inputs. For example, the Bourns® Model SMA6J5.0CA TVS diode has the capability to clamp pulse voltages that propagate through these transformers to approximately 7 to 8 volts.

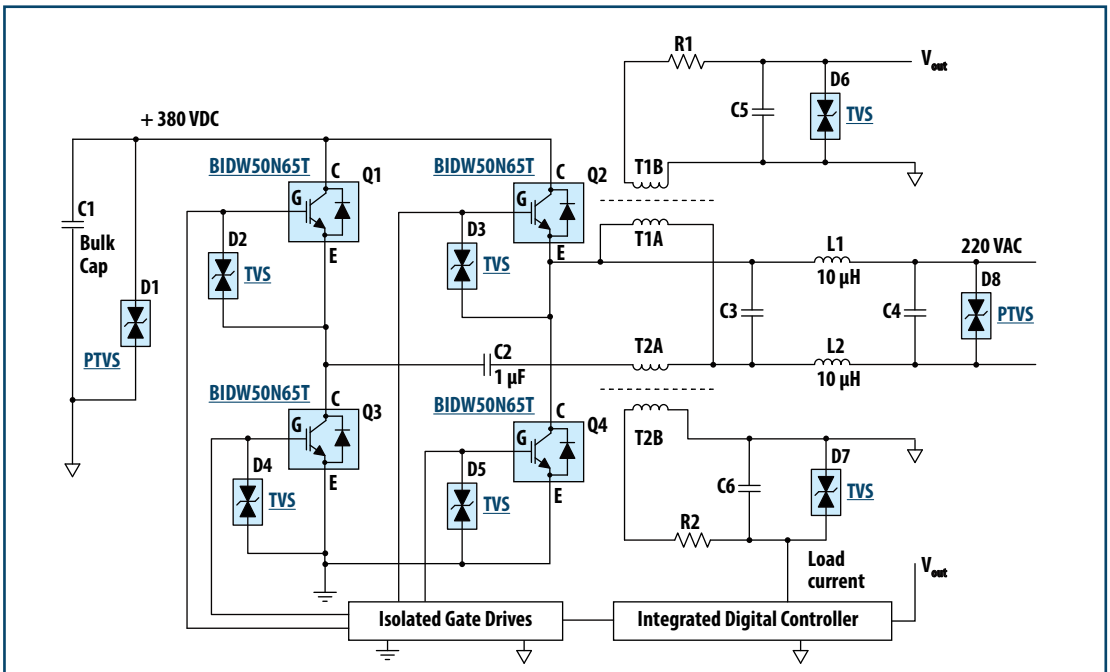
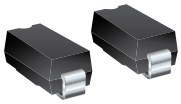


Figure 4. | *DC to AC inverter that has gate drive, output voltage, and sensing circuit surge protection.*

APPLICATION NOTE

The Benefits of IGBT Switching Protection Using TVS and PTVS Diodes

Bourns® BID Series IGBTs



Bourns® Transient Voltage Suppressor (TVS) Diode Series

Bourns® Power TVS Products (PTVS)

IsoMOV™ / GMOV™ Hybrid Protection Components

SinglFuse™ SMD Fuses

CONCLUSION

Utilizing TVS and PTVS diodes to protect IGBTs used in PWM motor drives, DC to AC inverters, and other power conversion applications contributes to a higher reliability design that helps designers meet lower system cost goals and achieve maximum uptime service goals. Voltage surges can come into the switching circuit from the outside, or be generated within it. Using properly-rated PTVS and TVS diodes placed on high voltage inputs and on low voltage control and sense connections keeps these surges from damaging IGBTs and other components necessary for power conversion tasks. This application note also illustrated several methods to keep lightning and other transients on AC power lines away from the switching sections of these power converters.

For more information on Bourns' high-performance discrete IGBT product offering and the Company's comprehensive line of advanced protection components, please refer to the additional resources available through the links below.

ADDITIONAL RESOURCES

- Technical Library: Bourns® Discrete IGBTs
- Product Page: Bourns® Discrete IGBTs
- Product Page: Bourns® IsoMOV™ Hybrid Protection Components
- Product Page: Bourns® GMOV™ Hybrid Protection Components
- Product Page: Bourns® TVS Diodes
- Product Page: Bourns® PTVS Diodes
- Product Page: Bourns® SinglFuse™ SMD Fuses
- Product Page: Bourns® Magnetics (Transformers and Common Mode Chokes)
- 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

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