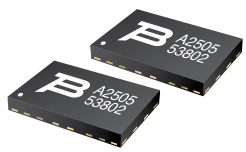
APPLICATION NOTE

Using Bourns® TBU® High-Speed Protectors as Gate/Switching Drivers

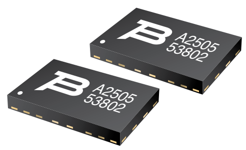


Bourns® TBU® High-Speed Protectors (HSPs)

Introduction

Voltage swell events, or the occasional incorrect wire connection (miswire) can cause significant damage to downstream components within electronics systems. These events are typically considered high-energy, slow-moving waveforms that are difficult to mitigate within an electronic system using traditional means of Overvoltage Protection (OVP) or Overcurrent Protection (OCP). An innovative application using Bourns® TBU® High-Speed Protectors (HSPs) provides a solution to protect against voltage swell and miswire events. These devices are Electronic Current Limiters (ECLs) and are designed to provide robust circuit protection when power source disconnection is needed to protect circuitry from an overcurrent event.

In its traditional application, a TBU® HSP is a series-connected, self-powered semiconductor device that acts as a current sense element protecting against overcurrent events. These devices feature ultra-fast response characteristics compared to Positive Temperature Coefficient (PTC) resettable fuses or other fuse types, in that TBU® HSPs respond to transients within a few microseconds. This application note presents a Bourns® TBU® HSP as an overvoltage protection device in a DC circuit. The method outlined illustrates how to implement an effective solution that features extremely fast response times in order to protect sensitive high-voltage-based systems when a fault condition arises.



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Typical DC Circuit Protection Approaches

For this application note, the system example employs a loosely regulated 24 V nominal power supply with temporary voltage that can reach 30 V. For this system, the normal operating current is approximately 100 A. In the fault condition, it is not unusual for a system to be exposed to voltages of 100 V and 100 A for up to 12 seconds.

This condition poses a real challenge to system designers as a 100 A, 100 V fault for 12 seconds is an incredible amount of energy. However, options exist for handling transients and extended fault waveforms. This paper provides a few applicable protection approaches.

It is very common for system designers to employ an MOV (Metal Oxide Varistor) as a first line of circuit protection defense. This is a valid choice for fast-moving transients induced onto power lines from lightning or loads dumping back to the grid. The characteristics of an MOV dictate that the clamping voltage, in the event of a sustained high-current, high-voltage swell event, may rise with input current and exceed the system's maximum input voltage. In this scenario, the system is left unprotected, or worse, subjected to a failed MOV.

Another valid transient protection solution option is Power TVS (PTVS) Diodes. These are semiconductor components and feature very predictable, stable clamping voltage with the ability to sink high currents for relatively short periods of time in the microsecond range. Similar to MOVs, PTVS Diodes are not designed for extended periods of conduction and current sinking.

It is evident that using an absorption component like an MOV or PTVS Diode is not an option for such a high energy fault event. The clear path is to sense and disconnect the load from the input in order to protect the load from the transient. One consideration would be to use a device like a contactor or relay driven by a current sense device. The architecture of such an implementation resembles that of an eFuse used in cloud server systems. This approach offers incredibly robust voltage and current carrying capability. The biggest challenge to a system like this is response time. When subjected to the 100 V/100 A swell, the disconnect response time measured several AC cycles representing a time frame of 20 to 30 milliseconds. Depending on the load, this time can be the difference between system survival or failure. The section below discusses a compromise for protecting against DC swell.

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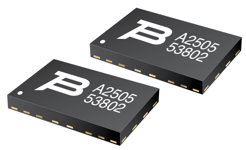

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Gate Driver Solution

Working with its customers, Bourns has developed a unique circuit that utilizes its TBU® HSP as a gate driver. The circuit employs a Bourns® TBU® device that features a 50 mA $I_{trigger}$ whenever the incoming voltage rises above 33 V (fault is 100 V, but designed to shut off when surpassing 33 V). When the current through the TBU® HSP exceeds the $I_{trigger}$ threshold of 50 mA, the device reacts by transitioning to its blocking mode. In blocking mode, the TBU® HSP disconnects downstream electronics from the input. In the case of this specific application, when the TBU® HSP enters its blocking mode, it turns off the MOSFETs (Q1, Q2) as shown in Figure 1 below.

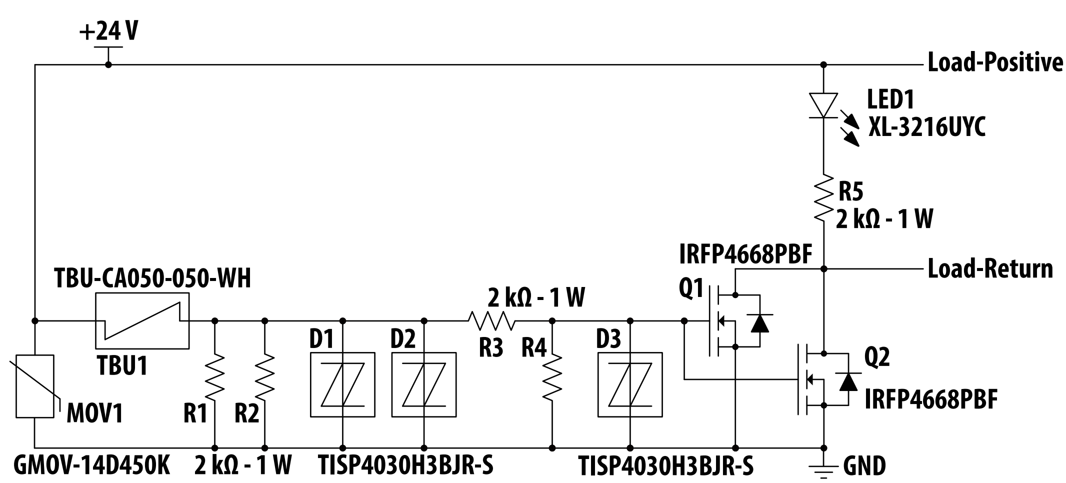
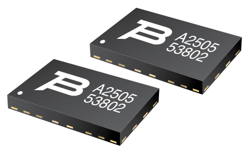


Figure 1. | *Bourns' protection solution shown in the example application's DC circuit block diagram.*



Bourns® TBU® High-Speed Protectors (HSPs)

Circuit Operation Review

In this circuit's normal operation with a 24 V input, the TBU® HSP will be conducting approximately 35 mA and have a resistance of approximately 15 Ω. The normal operating power consumption of a TBU® HSP is less than 0.5 W, so using it on standby circuits will not add unwanted parasitic draws to the system. Resistor R1 is 1 kΩ when R2 is not installed, otherwise both R1 and R2 will need to be 2 kΩ. The voltage on the gate of the NMOS will allow current to flow from Load-Positive to Load-Return. Subsequently, the Thyristor Diode, D3, should be a 30 V device to protect the MOSFET's 30 V gate. Please refer to the MOSFET manufacturer's data sheet for maximum gate voltage information in order to select the Thyristor Diode, D3, accordingly. There are some NMOS that may have a higher V_{gs} voltage, so the Thyristor Diode can be chosen based on the type and model of the NMOS. When the voltage exceeds 33 V, the Thyristor diodes (D1,D2) will start to conduct and force the current through the TBU. Once the TBU device exceeds the $I_{trigger}$ set, the TBU will transition to blocking mode. Once in blocking mode, the device will remain in blocking mode until the voltage to the TBU® HSP falls below 14 V (V_{reset}).

Based on this circuit example and fault conditions causing the TBU® HSP to enter blocking mode, the load is disconnected from the source in less than 50 µs. In the scope image shown below in Figure 2, the system response is highlighted with the blue line as the MOSFET Gate Voltage, and the yellow line as the Drain to Source Voltage (V_{ds}), or Load Voltage. In Bourns' tests represented below, engineers used a fault condition of 100 V/10 A. However, it is easy to scale current handling capability by adding more MOSFETs in parallel.

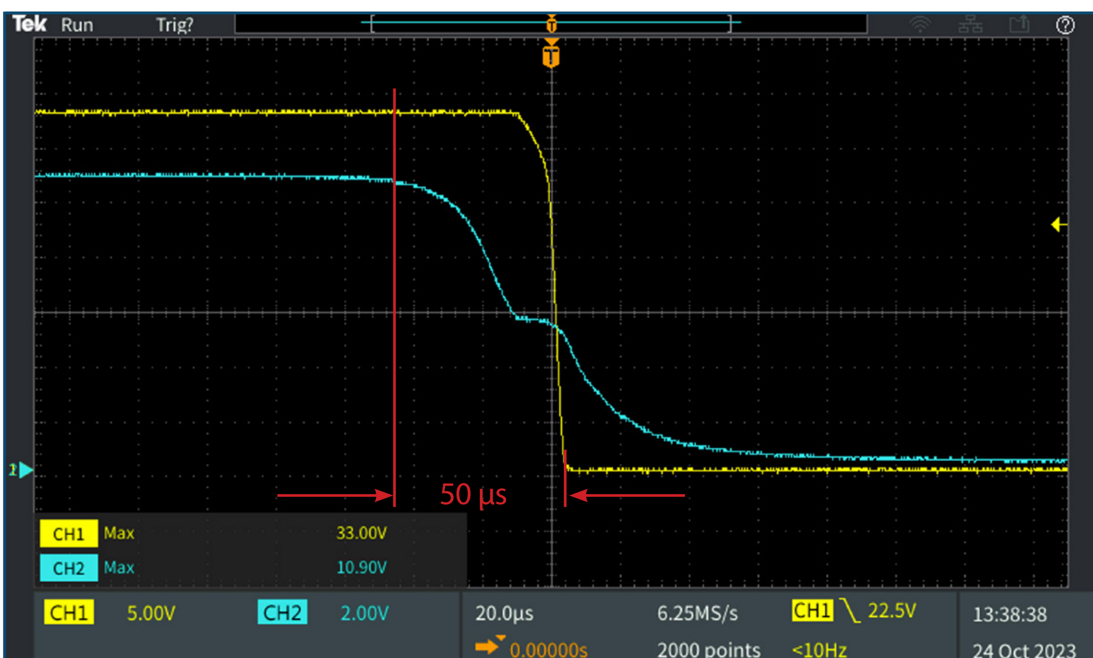
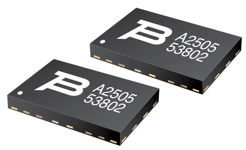


Figure 2. *This scope image illustrates how the Bourns® TBU® HSP has effectively and quickly blocked damaging voltage.*



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Circuit Operation Review (Continued)

As noted, this circuit is almost entirely passive in its behavior. The TBU® HSP self-powers and the rest of the circuitry, except for the MOSFETs, are passive devices. Therefore, this approach is a robust, cost-effective solution against DC swell protection or miswire events.

Table 1. Bourns® Components

Bourns® Component	Description	Part Number	Comment
TBU1	TBU® HSP	TBU-CA050-050-WH	
D1, D2, D3	TISP® Thyristor Surge Protector	TISP4030H3BJR-S	D2 is optional and only for redundancy or tuning.
R1, R2, R4, R5	2 kΩ Resistor – 1 watt	CR2512-JW-202ELF	
R3,	1 kΩ Resistor – 1 watt	CR2010-JW-102ELF	
Q1, Q2*	N-Channel MOSFET	IRFP4668PBF (Not a Bourns Product)	Q2 is optional and used for increased load current capability.
MOV1	Hybrid Protection Component	GMOV-14D450K	Component is application dependent.

Components not listed on the table are either generic or not offered by Bourns.
**Q1 is listed for the convenience of testing purposes. Other N-Channel MOSFETs may be used.*

Benefits Of Using Bourns® TBU® HSP as a Gate/Switching Driver

- Fast switching speed (less than 20 µs)
- Cost-effective
- Efficient solution for high current protection
- Superior overvoltage protection alternative

Applications

- Power Supplies
- Battery Charging
- Battery Management Systems
- Motor Control
- Industrial Automation

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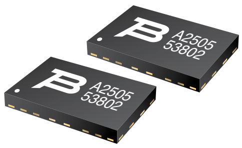

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Conclusion

This application note has shown that Bourns® TBU® HSPs can be used as gate/switching drivers due to their response time characteristics and can react 1,000 times faster than a contactor or relay. This ultra-fast response provides a straightforward, reliable method to protect equipment from high-energy overvoltage events. Bourns® TBU® HSPs are reliable and proven protection solutions that have been designed into millions of units to-date. This demonstrates customers' confidence in adopting Bourns® TBU® HSPs to help ensure their applications are protected against damaging DC swells or miswiring.

www.bourns.com

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

EMEA: *Tel* +36 88 520 390
Email eurocus@bourns.com

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

Mexico: *Tel +52 614 478 0400*
Email mexicus@bourns.com

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