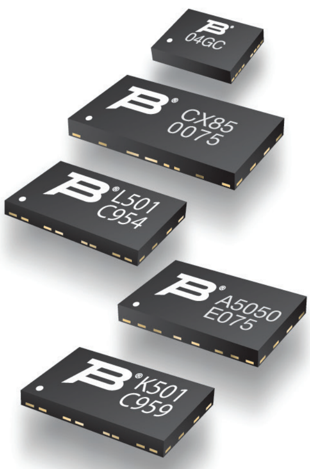
Application Note

Power Cross Testing with Bourns® TBU® High-Speed Protectors (HSPs)



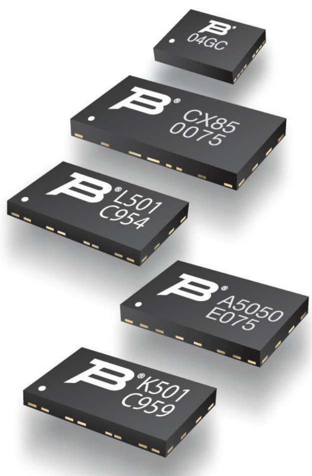
TBU® High-Speed Protectors

Introduction

Bourns® TBU® High-Speed Protectors (HSPs) are devices that change rapidly from a low impedance state to a high impedance state when the current through the device reaches a specific limit. This fast switching characteristic makes the device a nearly ideal protector against an AC mains power cross condition. Standards such as GR-1089-CORE specify the level of protection needed for such a condition.

Testing this type of protection characteristic is done in the laboratory environment using variable and isolating transformers to recreate stress conditions similar to the worst case real world scenarios of abnormal voltage and current. Unfortunately, the transformers used for power cross compliance testing normally introduce high levels of stray inductance in the test circuit path. This inductance, in turn, can create dangerously high voltage "flyback" pulses when the circuit current is rapidly interrupted, such as by a switch, or by the TBU® HSP device itself. Such high voltage pulses may exceed the absolute maximum rating of protection components such as the TBU® HSP, as defined in each device's data sheet.

It is important to note that under real world power cross conditions, the source inductance will almost certainly be very low and there is little to no possibility of experiencing a resonant flyback pulse. Therefore, it is preferable that only non-inductive components be used in AC mains power cross testing. However, the use of only non-inductive test components is difficult to implement in practice.



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Consequently, to obtain a true reading of the TBU® HSP device's protection capabilities against an AC mains power cross condition, precautions should be taken during testing to eliminate high levels of stray inductance in the test circuit path. These precautions will ensure that an artificially created flyback pulse does not damage the tested TBU® HSP device. This article will discuss some commonly recognized preventive measures to obtain more accurate, real world AC mains power cross test results for a TBU® HSP device. Let's start by taking a look at what can happen in the typical power cross test circuit shown in figure 1 below using a typical lab isolation transformer:

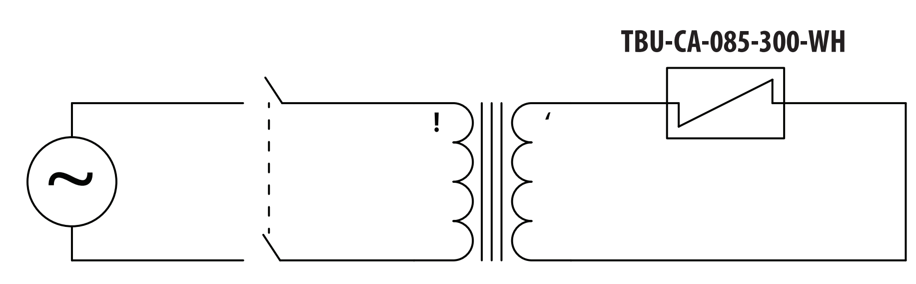


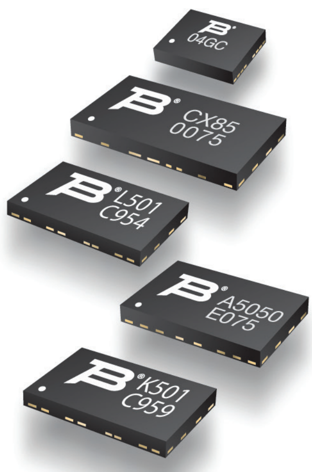
Figure 1: Potentially Hazardous Test Circuit

Figures 2a and 2b show the TBU® HSP voltage and current waveforms when subjected to 230 V_{rms}. A peak flyback voltage of 580 V is generated after the current through the TBU® HSP device reaches its threshold (~300 mA) and the device switches to a high impedance state. The peak flyback voltage (V_p) is defined by the equation:

$$V_p = I_p \sqrt{\frac{L}{C}}$$

Where I_p = peak current
L = the circuit inductance
C = the circuit capacitance

Note that the peak flyback voltage is directly proportional to the peak current through the inductance and the square root of the circuit inductance, and that it is inversely proportional to the square root of the circuit capacitance.



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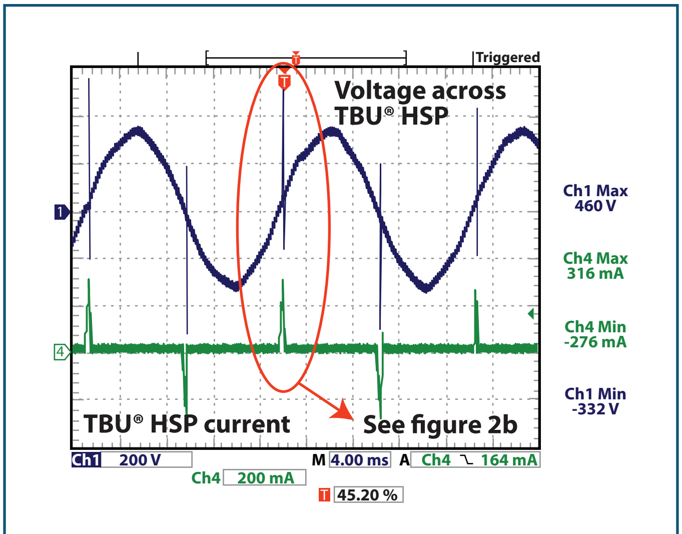


Figure 2a: TBU® HSP Under a Power Cross Condition

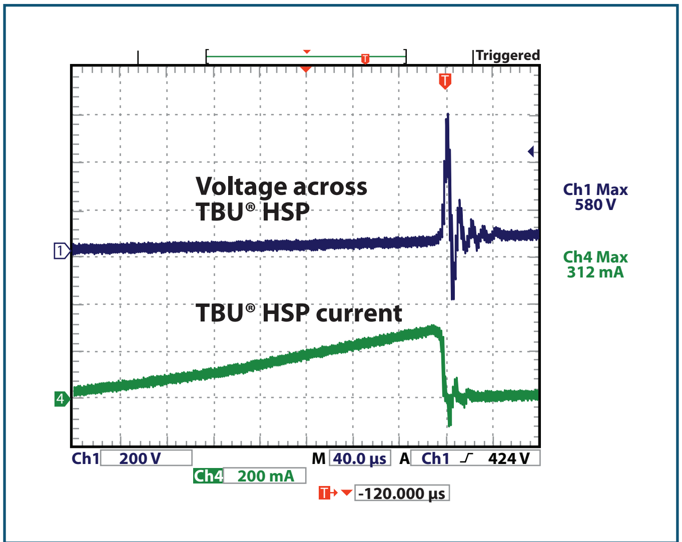
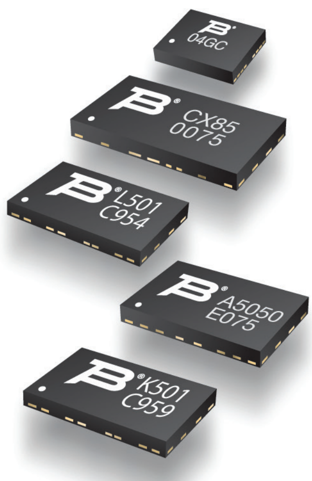


Figure 2b: Figure 2a Magnified (100x)



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Figures 3 and 4 show the potential voltage across the TBU® HSP device when the AC power is switched off and switched on, respectively. Note that in both cases the peak exceeds the 850 V peak voltage rating of the TBU® HSP device. The actual peak voltage is dependent on where in the power cycle the power is switched on or off.

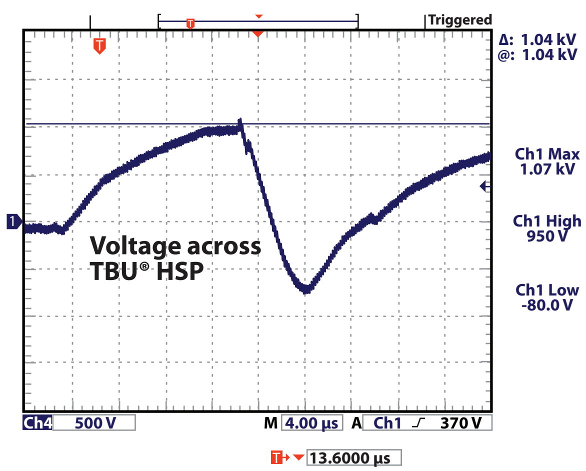


Figure 3: Potential Flyback Voltages when AC Power is Switched Off

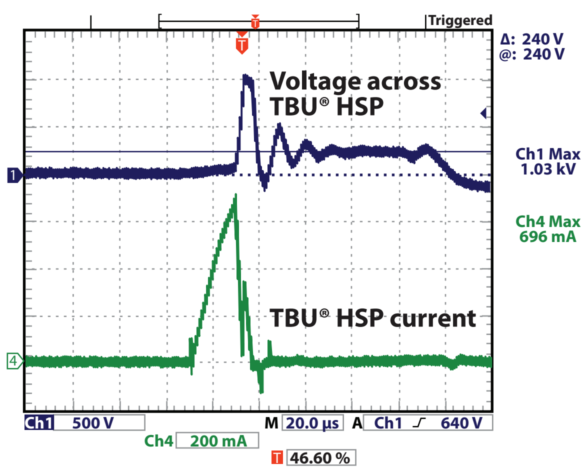
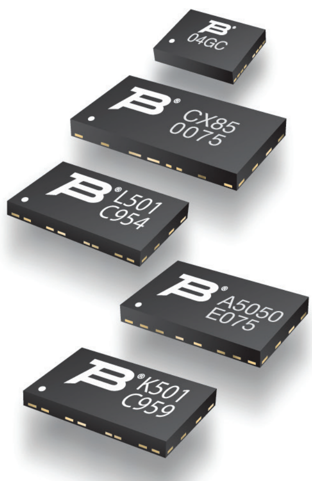


Figure 4: Potential Flyback Voltages when AC Power is Switched On



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Avoiding Test Problems

There are at least two ways to avoid possible damage to a TBU® HSP device during power cross testing:

1) Add a capacitor across the transformer secondary (see figure 5); and/or
2) Add a Metal Oxide Varistor (MOV) across the secondary of the transformer to clamp the flyback pulse (see figure 8).

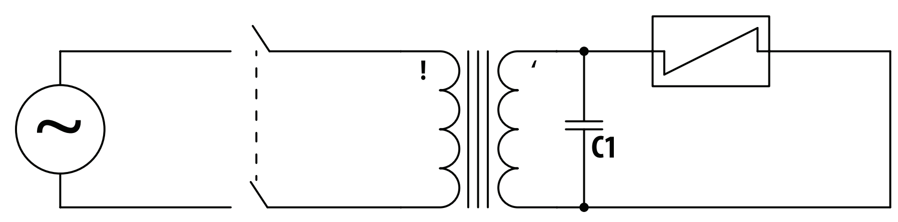


Figure 5: Test Circuit with Capacitor Added

Adding a Capacitor

Figure 6 shows the reduction in the peak flyback voltage with 230 V_{AC} applied across the TBU® HSP device when a 100 nF capacitor is added across the transformer secondary. Compare this to the peak voltage without the capacitor that is shown in figure 2b. This result is much closer to a power cross waveform seen in the real application.

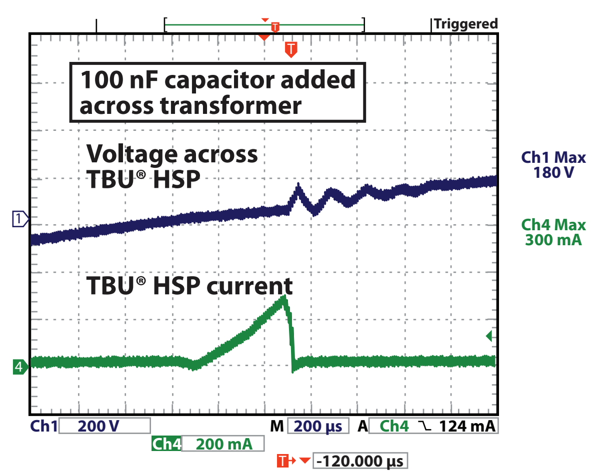
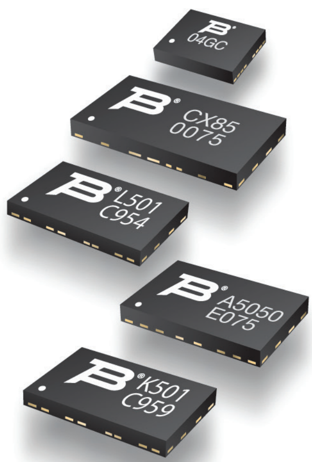


Figure 6: Peak Voltage Reduction with Capacitor



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Adding a Capacitor *(Continued)*

While adding a capacitor eliminates any flyback voltage issues when power is applied and during power-off, there is still a potential problem when power is first applied to the device. Figure 7 shows the peak voltage across the TBU® HSP device during power-on when the AC is near its maximum value. The inductance of the transformer and the circuit capacitance cause a ringing waveform with a peak value close to 2x the peak AC voltage. In the waveform shown, this voltage does not exceed the rating of the device that was tested but it could be above the rating of other devices with the same switching current in the product family. Again, the peak voltage is dependent on where in the power cycle power is applied to the device.

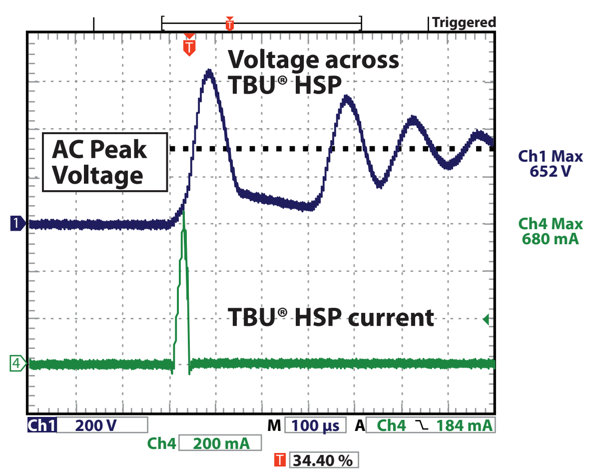
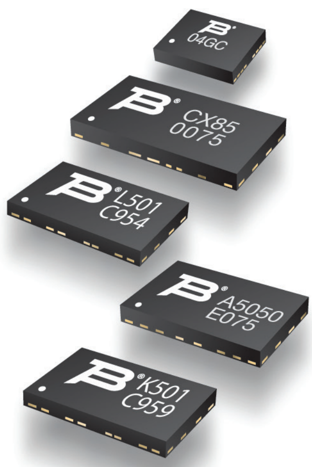


Figure 7: Possible Peak Voltage during Power-on with Capacitor



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Adding an MOV

A Metal Oxide Varistor (MOV) can be used to limit the peak voltage across the TBU® HSP device. Figure 9 shows how the peak voltage across the TBU® HSP device is limited by the MOV during a power-on condition. Comparing figure 9 to figure 4 we can see that the MOV limits the peak voltage to 532 V vs. 1.03 kV with approximately the same peak current. Figure 10 shows how the MOV limits the peak voltage when the AC voltage is removed from the device under test. Note that it is limited to a peak of 524 V.

When selecting an MOV, it is important that its breakdown voltage is above the potential line voltage that would be seen under a power cross condition, and below the breakdown voltage of the TBU® HSP device being used. The purpose of the MOV is to limit the voltage stress on the TBU® HSP device. The TBU® HSP device will prevent the applied AC voltage from damaging any downstream circuitry.

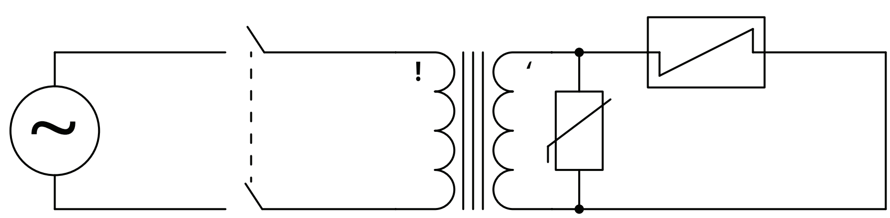
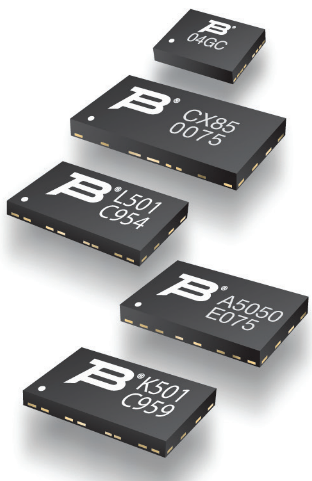


Figure 8: Test Circuit with MOV Added



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Adding an MOV *(Continued)*

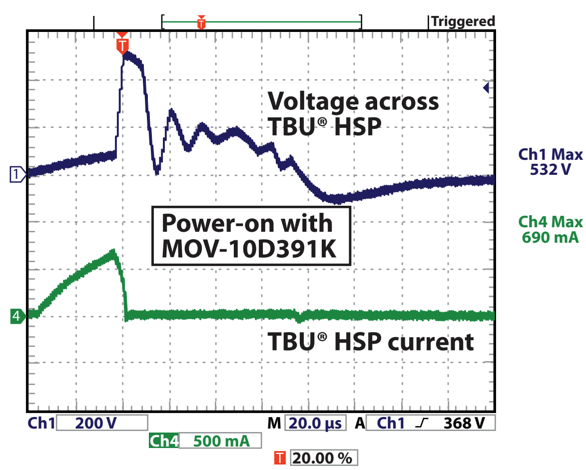


Figure 9: Power-On Peak Voltage Reduction with an MOV

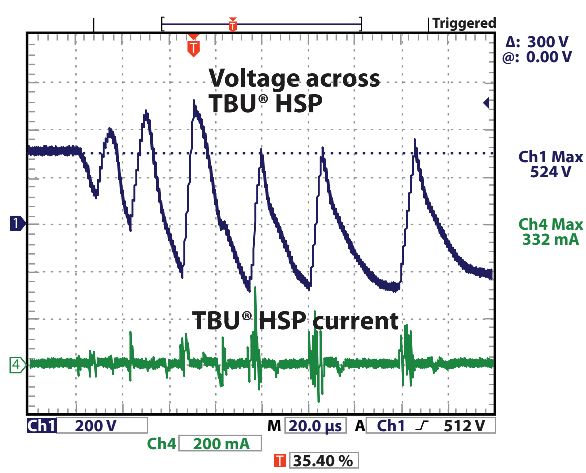
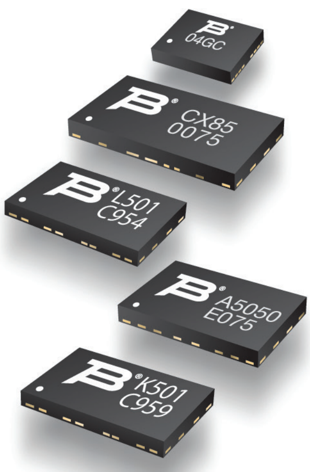


Figure 10: Power-Off Peak Voltage Reduction with an MOV



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Conclusion

In this brief article we looked at the operation of a TBU® HSP device in a typical power cross test setup. We learned that the source impedance (specifically the inductance) of the power source of typical lab isolation equipment can contribute to generate high flyback voltages when the power is initially applied to or removed from the TBU® HSP device that is being tested. In an actual power cross condition, a TBU® HSP device can protect a circuit against damage for an unlimited amount of time. In the power cross test circuit, special attention must be paid to ensure that the peak flyback voltages generated when power is either applied to or removed from the device under test, do not exceed the voltage rating of the TBU® HSP device. Adding a capacitor and/or MOV to the test circuit will accomplish this goal and make the test circuit closely resemble conditions in a typical application.

For more information on TBU® HSP devices and other circuit protection products from Bourns, please visit

www.bourns.com

Americas: *Tel* +1-951 781-5500
Fax +1-951 781-5700

EMEA: *Tel* +36 88 520 390
Fax +36 88 520 211

Asia-Pacific: *Tel* +886-2 256 241 17
Fax +886-2 256 241 16