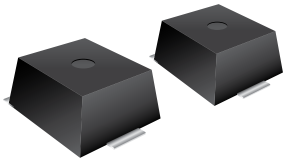
APPLICATION NOTE

Delivering Three Levels of Protection in Space-Constrained Systems

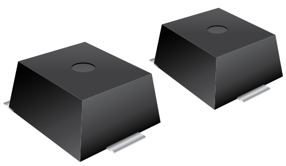


Bourns® Model PTVS1-240C-M TVS Diode

Introduction

Designers challenged with implementing high voltage transient suppression (TVS) technologies in space-constrained systems encounter a multi-faceted challenge: how to balance space restrictions, high voltage, and manufacturability to adequately protect critical power systems. Traditionally, higher voltage TVS devices are offered in through-hole packages that consume space and require multiple solder steps, which demands that designers make compromises when implementing desired solutions. Delivering a no-compromise solution, Bourns has engineered its next-generation Model PTVS1-240C-M TVS Diode that offers 240 V, 1 kA power support in a surface mount package.

Helping designers achieve effective protection in increased power density and reduced board space power systems, this application note outlines the Model PTVS1-240C-M features that meet these particular requirements. It also presents how Bourns' latest PTVS diode can be designed to safeguard the three levels of rectified AC found commonly in national power grids in order to deliver an advanced level of protection for these critical applications.



Bourns® Model PTVS1-240C-M TVS Diode

Past TVS Diode Design Challenges

Designers that are concerned with overvoltage protection have probably encountered the issue with most Surface Bount Device (SMD) TVS diodes. That is, the rated voltage is typically too low for most AC mains, rectified, and DC bus systems. Because of this, designers normally have two options: series connect multiple SMD TVS diodes or use a through-hole component. With board space already at a premium, a series connection of multiple TVS diodes can be an expensive and cumbersome implementation that increases parasitic inductances through the length of copper traces added to the circuit (see Figure 1).

Through-hole components, although having higher voltage clamping features, disallow the use of pick and place assembly and reflow processes versus a SMD solution. Through-hole components, similar to SMD, do not escape lead inductance issues. Finding a TVS diode solution that combines both SMD packaging and higher clamping voltage is difficult to find.

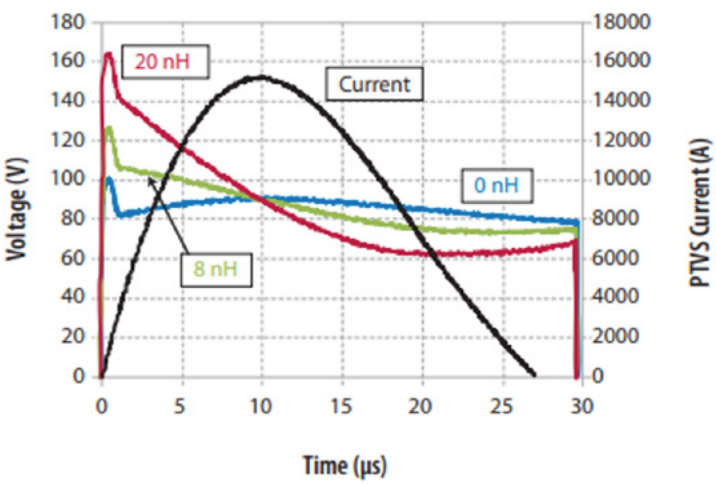
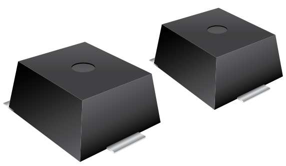


Figure 1. *Effects of increased lead (or copper trace) inductance on the clamping performance of a TVS diode.*

APPLICATION NOTE

Delivering Three Levels of Protection in Space-Constrained Systems

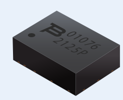
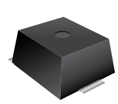
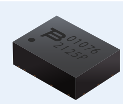
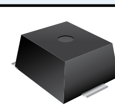
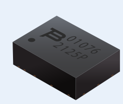


Bourns® Model PTVS1-240C-M TVS Diode

Past TVS Diode Design Challenges (Continued)

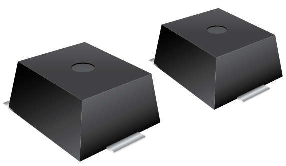
With the increased clamping voltage in the Bourns® Model PTVS1-240C-M that combines through-hole capabilities with SMD packaging technology, this new product opens the door for designers looking to protect DC busses rectified off AC mains connections. Boasting a 66 % reduction in traditional SMD TVS diode component count (see Figure 2), the Bourns® Model PTVS1-240C-M is a bidirectional Power TVS (PTVS) Diode capable of handling 1 kA of surge current (8/20 µs). With a repetitive standoff voltage (V_{WM}) of 240 V, this device is suitable for snubbing and protecting DC bus powered systems and subsystems.

Table 1. | *The three levels of protection offered by the Model PTVS1-240C-M and the resulting reduction in component count compared to traditional 86 V surface mount PTVS devices.*

Voltage Levels	Device	Product Example	Number of Components
70 - 120 V_{AC} 100 - 170 V_{DC}	PTVS1-240C-M		1
	86 V Surface Mount PTVS		3
120 - 240 V_{AC} 170 - 340 V_{DC}	PTVS1-240C-M		2
	86 V Surface Mount PTVS		6
240 - 480 V_{AC} 340 - 700 V_{DC}	PTVS1-240C-M		3 - 4
	86 V Surface Mount PTVS		9 - 12

To show the capabilities of the Model PTVS1-240C-M, Figure 2 gives the breakdown of three voltage levels commonly found in AC mains applications that have high voltage DC bus systems. Due to its high standoff voltage of 240 V, the capability to protect the DC bus with minimal components is showcased against traditional 86 V surface mount TVS diodes. To further examine the three levels of protection that the Model PTVS1-240C-M can offer with the benefit of a reduced component count, below is an example application that illustrates the various voltage levels shown in Table 1.

Delivering Three Levels of Protection in Space-Constrained Systems



Bourns® Model PTVS1-240C-M TVS Diode

Level 1 Protection

The first level of protection encompasses North American, South American, Japanese, and several other national power grids. AC mains of these locations are stepped down to 120 V_{AC} or lower for single-phase applications. After standard rectification, this typically requires a DC voltage of ~170 V to be present on a main DC bus. The solution is for a single Model PTVS1-240C-M to be used for protection with a repetitive standoff voltage of 240 V.

A common application that uses single-phase voltage is signaling equipment used for railway and automotive traffic control. These systems are crucial to public safety and business continuity. They are also used mostly in rugged, outdoor conditions that are susceptible to voltage transients. As a result, these systems need to be designed for reliability and require multiple stages of protection against overvoltage surges. As seen in Figure 2, the Model PTVS1-240C-M can easily be integrated within a design for applications that must meet stringent reliability requirements.

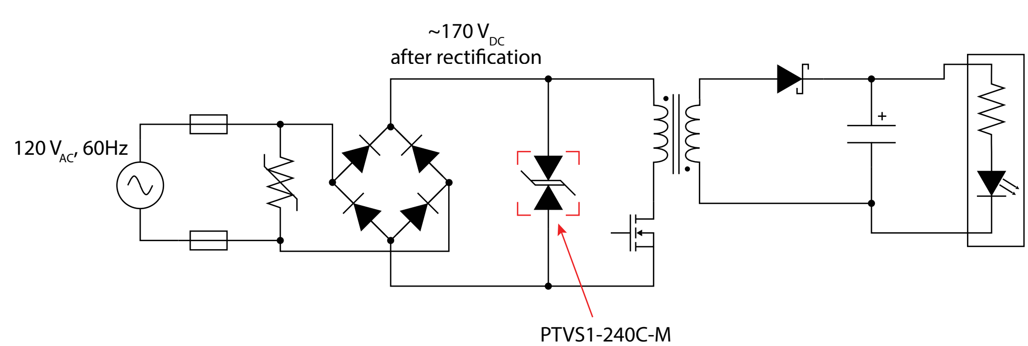
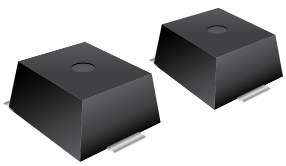


Figure 2. | *Simplified LED driver for traffic lights with an integrated Model PTVS1-240 for overvoltage clamping.*

Figure 2 showcases an LED driver circuit for a traffic light that accepts a 120 V_{AC} input. After rectification, the DC bus is ~170 V_{DC} and subsequently stepped down to a required voltage for the LED lights by a switched-mode power supply. The front-end protection consists of dual in-line fuses with a Metal Oxide Varistor (MOV) to protect the circuit from harsh transients, but does not offer strict voltage clamping. MOVs are also notorious for degradation with successive voltage clamping events, which is not present with TVS diodes. As such, MOVs should be carefully considered if they are to be the sole overvoltage protection in a system that requires high reliability. Bourns recommends using the Model PTVS1-240C-M for extended protection to critical systems that need precise and repetitive voltage clamping capabilities.



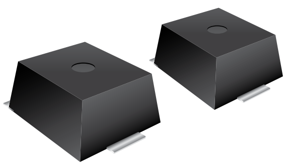
Bourns® Model PTVS1-240C-M TVS Diode

Level 2 Protection

While the first level of protection offered by the Model PTVS1-240C-M is ideal for 120 V_{AC} AC mains, designers can extend its usage by applying series connected Model PTVS1-240C-M devices when enhanced protection of higher voltage applications is needed. Specifically, for most geographical areas of the world, AC mains typically operate at ~240 V_{AC}. This voltage dominates the eastern hemisphere with 220 – 240 V_{AC} as the standard value for most electrical wall plugs. As a result, most designs will incorporate a "universal AC input" that allows both 120 and 240 V_{AC} input. This will rectify to ~340 V_{DC} on the DC bus, which is easily protected by two Model PTVS1-240C-M in series.

Along with being used as AC mains for single-phase applications, much of the world also offers this voltage range for three-phase applications. This will typically be found in commercial and industrial settings that require high power usage for critical operations. Motor drive systems, HVAC, elevators, and many other applications have requirements for safe and reliable operation. The Model PTVS1-240C-M offers this by protecting critical components from certain harsh overvoltage events. The explanation that follows demonstrates the extra protection the Model PTVS 1-240C-M can offer in a critical, three-phase application.

For controlling torque and speed of AC motors, Variable Frequency Drives (VFDs) are used commonly in industrial settings for production purposes. Fed by 120 – 480 V_{AC} single or three phase systems, these drives are highly prone to damaging effects of overvoltage transients. Because VFDs are critical for industrial production, failures caused by induced voltage can be costly. These drives are typically protected with a Surge Protection Device (SPD). However, the added benefit of having a Model PTVS1-240C-M on the DC bus can extend the reliability of downstream systems by clamping harmful transients at voltages below maximum ratings. A simplified VFD circuit is shown in Figure 3.



Bourns® Model PTVS1-240C-M TVS Diode

Level 2 Protection (Continued)

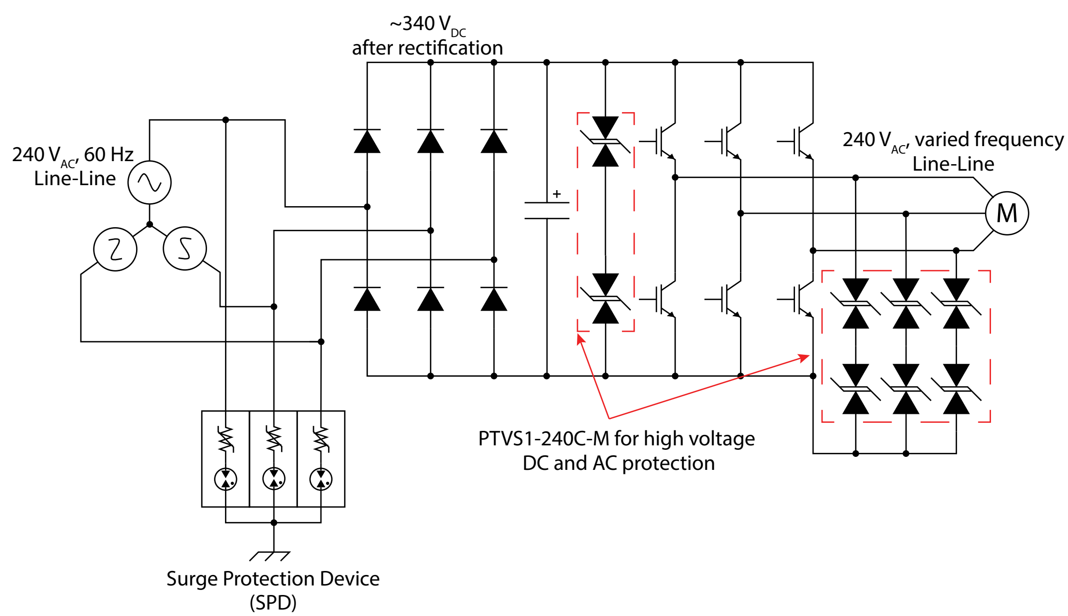
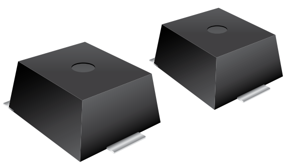


Figure 3. Simplified VFD circuit displaying the multiple capabilities of the Model PTVS1-240C-M.

As seen in Figure 3, this system shows a VFD fed by a 240 V_{AC} three-phase system that rectifies to ~340 V_{DC}. Two Model PTVS1-240C-M in series can properly protect the DC bus and act as voltage protection for flyback transients caused by inductive properties of motors. With a total of two diodes, the repetitive standoff voltage is raised to ~480 V, which protects the 340 V_{DC} bus with 140 V buffer. Along with the dual Model PTVS1-240C-M that provides the necessary overvoltage protection, the parts count compared to traditional 86 V surface mount TVS diodes is significantly reduced. This also lessens the parasitic inductance through PCB traces and allows for tighter voltage clamping, enabling higher reliability and business continuity in crucial designs.



Bourns® Model PTVS1-240C-M TVS Diode

Level 3 Protection

Employing the Model PTVS1-240C-M in a three-tiered system is an excellent example that showcases not only the benefits of a reduced parts count, but the considerable surge handling capabilities of these new diodes. The 240 – 480 V_{AC} category comprises the entirety of three-phase systems in most of the world. These systems, as previously explained, are for industrial production, commercial operations, and other high reliability and safety-needed applications. Although the Model PTVS1-240C-M may not act as a primary protector in these cases, it does allow designers to incorporate secondary protection for minimal board space in high power density applications.

A common application where three-phase voltage is utilized is in industrial power supplies. These systems will take three-phase input and convert to a low voltage DC output. As the name implies, an industrial power supply is essential for powering important equipment within a system. Without extreme reliability, these supplies can lead to downtime, safety hazards, and costly maintenance fees. It is recommended that designers carefully consider protection that will allow these systems to perform under even the harshest conditions. The Model PTVS1-240C-M for secondary DC bus protection is a superior solution here. Figure 4 explains how to implement the Model PTVS1-240C-M for boosted protection of an industrial power supply.

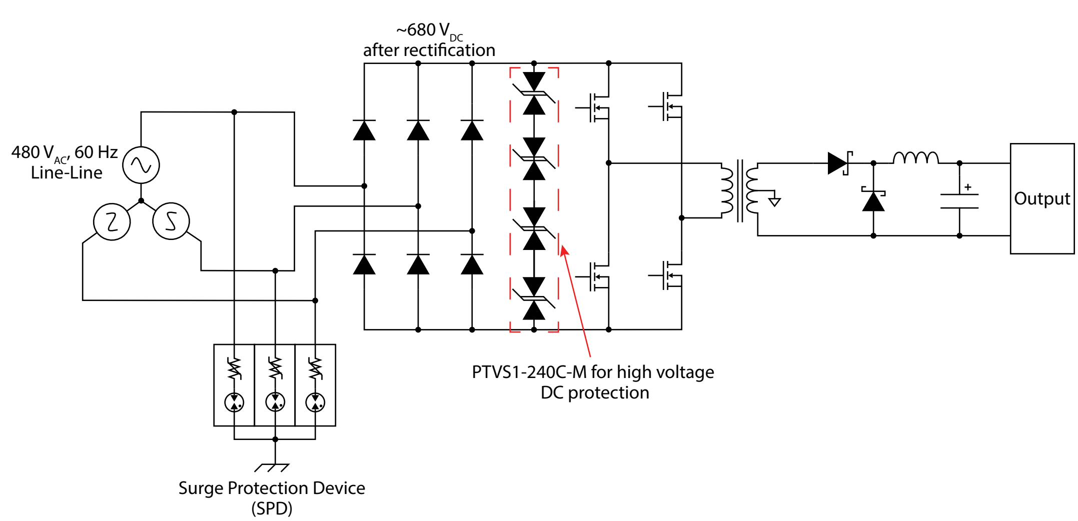
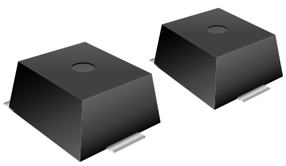


Figure 4. | *Simplified industrial power supply with integrated Model PTVS1-240C-M DC bus protection.*

Delivering Three Levels of Protection in Space-Constrained Systems



Bourns® Model PTVS1-240C-M TVS Diode

Level 3 Protection (Continued)

In Figure 4, an industrial power supply is being powered by 480 V_{AC}. After rectification, this will leave ~680 V_{DC} on the DC bus. By using four Model PTVS1-240C-M devices for protection, they provide effective overvoltage clamping that can protect downstream systems that are prone to failure from surge events. Also, similar to the VFD example, the amount of parasitic inductance prevented by using the Model PTVS1-240C-M over traditional TVS diodes provides increased sharp clamping action operation. Figure 5 also shows that the semiconductor switches (MOSFETs, in this case) are directly connected to the DC bus. These devices are the most prone to damage from overvoltage. Protecting semiconductors from going over their maximum ratings is key to helping ensure reliable operation and allows the industrial power supply to remain operational. The bottom line is that using the Model PTVS1-240C-M allows designers to include secondary protection without sacrificing board space or performance to ensure reliability of their most crucial designs.

Conclusion

The introduction of the Bourns® Model PTVS1-240C-M PTVS Diode gives designers a powerful, overvoltage protection solution in a space-saving package. With its increased clamping capabilities and rugged current handling features, this PTVS diode rivals current SMD and through-hole components. Adding to its design advantages, the Model PTVS1-240C-M can be used effectively in three levels of voltage ranges found commonly around the world for safeguarding critical applications and decreasing component count compared to traditional TVS diodes. While providing a viable solution for designers looking to increase power density, the Model PTVS1-240C-M delivers the protection needed to help meet increased safety and reliability requirements in the growing variety of complex systems that are prone to damaging overvoltage transients.

www.bourns.com

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

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

BOURNS®

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

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