1. General Description

Factors such as high-amplitude signal noise, electromagnetic interference (EMI), electrostatic discharge (ESD) increase the peak of the voltage amplitude in the transmission line to higher values. These surges can damage the normal operation of unprotected circuit elements on the transmission line and ultimately cause permanent damage. In order to prevent these damages, different types of diode protection are used in circuit designs. One of these diode types is TVS (Transient Voltage Suppression) diodes. Their symbols are shown in **Figure 1**.

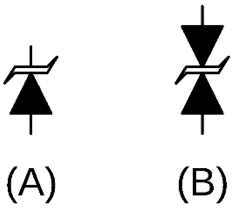


Figure 1: *Unidirectional TVS Diode*, ***(B)*** *Bidirectional TVS Diode.*

2. Protection Options From Voltage Surges

Figure 2, shows a schematic representation of diode types that provide protection against voltage surges. Each of these schemes can be used to suppress the surges. However, each option offers different protection features.

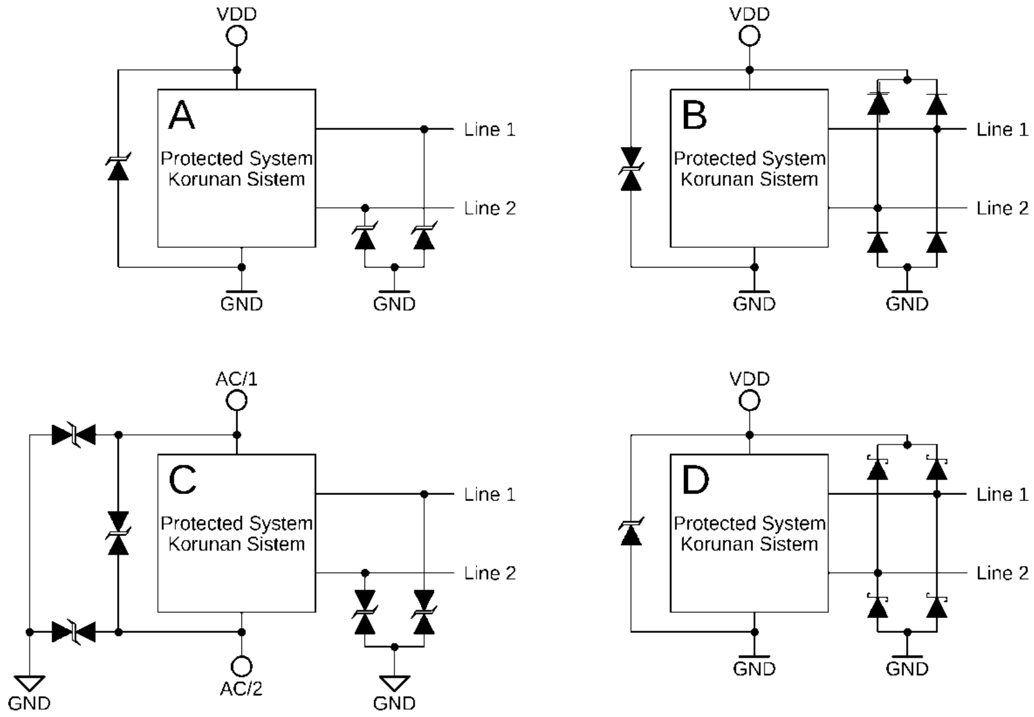


Figure 1: *Representation of Protected Systems and Lines 1&2 (Digital / Analogue Data, Switching, Power Supply) with* ***(A)*** *Unidirectional TVS Diodes,* ***(B)*** *Bidirectional TVS and Array Diodes,* ***(C)*** *Bidirectional TVS Diodes,* ***(D)*** *Unidirectional TVS and Schottky Diodes.*

3. TVS Diodes

TVS Diodes are circuit elements that are ideal for applications requiring ESD protection and immunity to power surges or data lines. These devices provide protection by clamping a surge voltage to a safe level. They function as a variable impedance to directly absorb the surge energy and maintain a constant clamping voltage.

The V/I characteristic curve of TVS diodes is similar to zener diodes, while Zener diodes are designed for voltage regulation, while TVS diodes are specifically designed to suppress transient voltage fluctuations. In other words, TVS diodes are specially designed to protect other circuit elements connected to the transmission line from the harmful effects of transient voltage fluctuations.

TVS diodes serve as parallel protection elements (**Figure 3**). Under normal operating conditions, the TVS diode presents a high impedance to the protected circuit. Ideally, the device appears as an open circuit, although a small amount of leakage current is present. When the normal operating voltage of the protected circuit is exceeded, the TVS diode junction avalanches providing a low impedance path for the transient current. As a result, the transient current is diverted away (To the Energy Source or the loads where energy can be consumed) from the protected components and shunted through the TVS diode. The voltage across the protected circuit is limited to the clamping voltage of the TVS diode. The device returns to a high impedance state after the transient threat passes. The power required to absorb against these surges is directly proportional to the cross-sectional area of the diode package and the points where the connection of the TVS diode on the PCB occurs.

A primary attribute of the TVS diode is its reaction time. Avalanche breakdown theoretically occurs in picoseconds. This is very difficult to measure however. Therefore, TVS diodes are often specified as responding “almost instantaneously”.

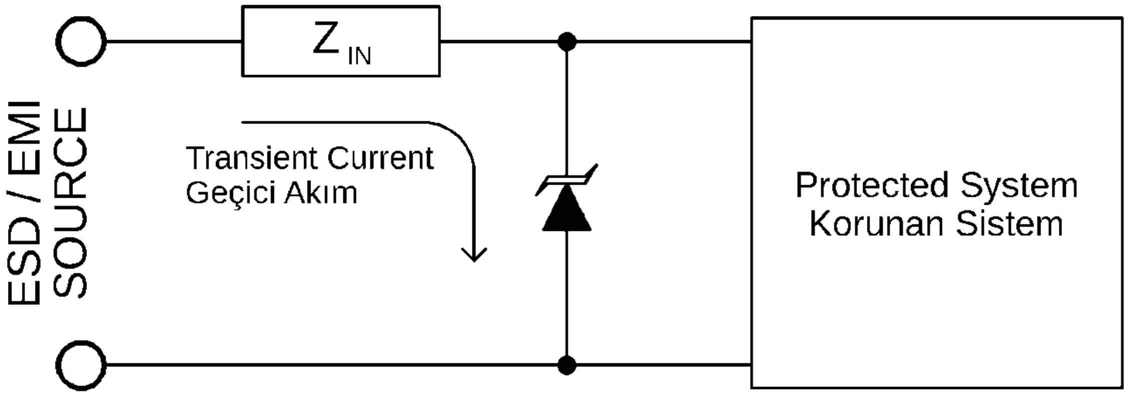


Figure 2: *Operation of TVS Diode.*

The TVS diodes fast response time and low clamping voltages make them ideal for use as board level protectors for semiconductors and other sensitive components.

4. Diode Arrays

Diode arrays are constructed by combing switching, avalanche and Schottky diodes. Diode arrays typically have a moderate power rating and low capacitance. These features make this a popular TVS device for data line ESD protection. The effective minimum operating voltage of a diode array is limited only by the forward voltage drop of a diode. These diodes direct the fluctuating voltage to the power source, as shown in **Figure 4**.

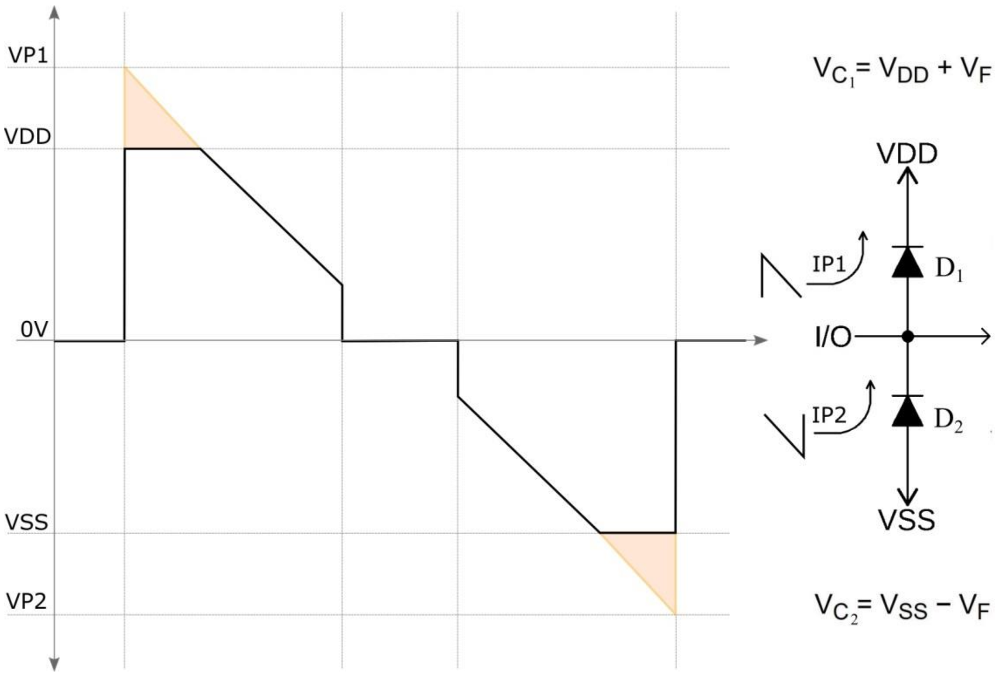


Figure 3: *Representation of Diode Arrays Directing Voltage Surges to The Source.*

Another popular option for diode arrays is to use low turn-on voltage Schottky diodes to create an effective TVS device for low voltage applications.

5. Differences Between Unidirectional and Bidirectional TVS Diodes

TVS diodes are available in either a uni- or bidirectional configuration. In contrast, diode arrays are typically used only as a unidirectional protection device. Uni and bidirectional devices both provide protection against positive and negative surges; however, the magnitudes of the breakdown voltages are different, as shown in **Figure 5**.

A unidirectional device has a clamping voltage equal to the breakdown voltage when reversed biased and a forward diode drop if forward biased. A bidirectional device typically has a symmetrical VBR for both positive and negative voltages.

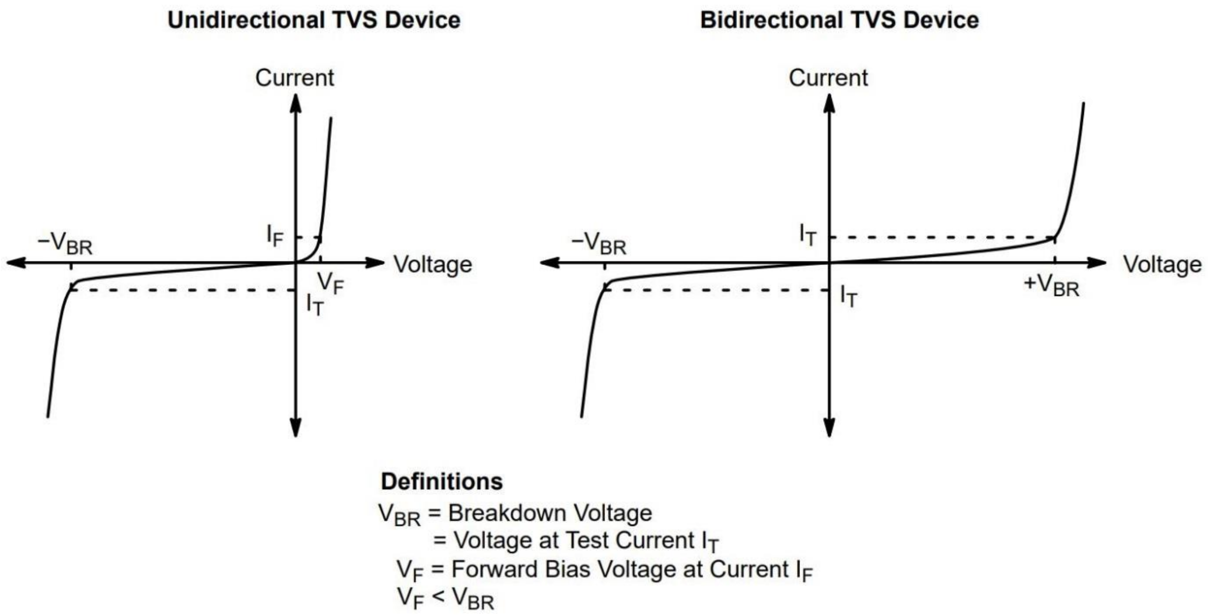


Figure 4: *V/I Characteristics of Unidirectional and Bidirectional TVS Diodes.*

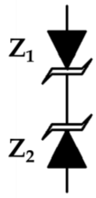
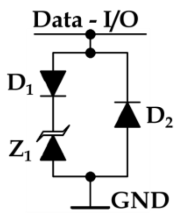
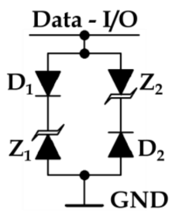
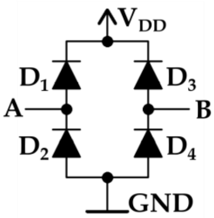
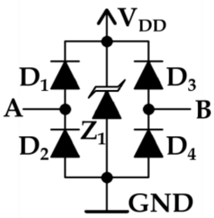
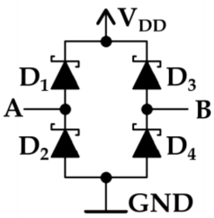
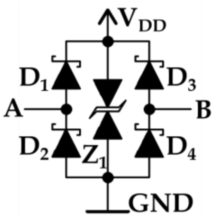
Although both uni- and bidirectional devices can often be used in the same application, there are many applications where one of the clamping options provides a distinct advantage. In applications such as the protection of a DC power supply or a logic IC, a unidirectional diode device offers a lower clamping voltage (i.e. −VF) for negative surge voltages. Bidirectional TVS devices offer several advantages, including solving a common mode offset voltage problem. Often bidirectional TVS diodes are selected simply because they are replacing metal oxide varistors (MOVs) which are inherently bidirectional.

In summary, Unidirectional TVS Diodes used in DC power supply lines, data lines with short cables (GND1 = GND2), logic device protection. Bidirectional TVS diodes are used in AC power lines and long-distance data lines (GND1! = GND2).

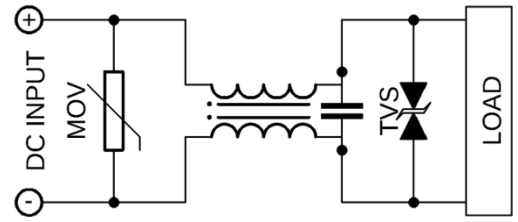
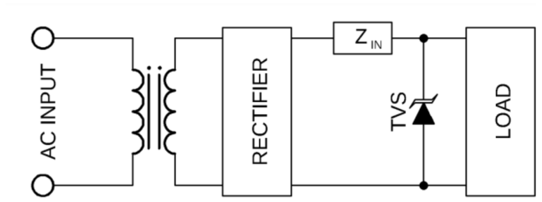
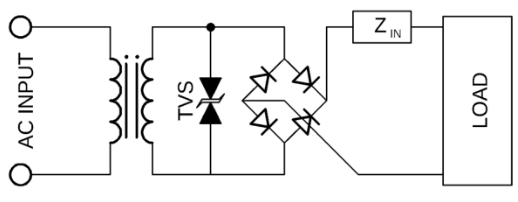
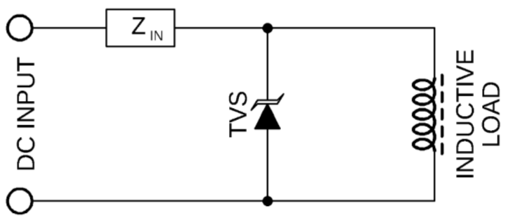
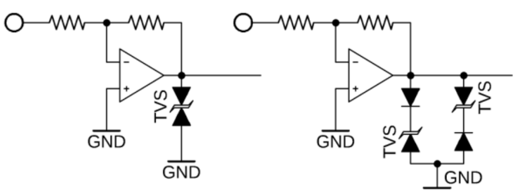
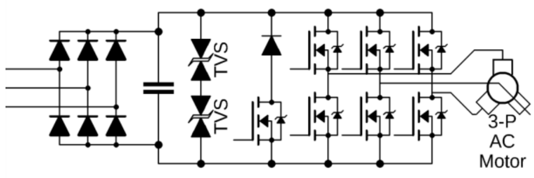
6. Selecting TVS Diodes

1- Select a device with a breakdown voltage greater than the maximum specified voltage to ensure that the TVS device does not turn-on during normal operation.
2- A bidirectional TVS device maybe required for a circuit that has a common mode voltage requirement. The common mode specification is required when there is a significant difference in the voltage potential between the ground reference of the transmitting and receiving nodes.
3- Choose a TVS device that is capable of dissipating the energy of the surge pulse. And it should be noted that this property may lose value with temperature.
4- The capacitance of the TVS devices should be minimized for high-speed circuits in order to reduce signal distortion. In addition, the capacitance of two differential signals must be matched in order to maintain pulse width integrity in the amplifier's output signal.

7. Table 1: Diode Configurations and Clamping Voltages

			Unidirectional TVS Diode	**Bidirectional TVS Diode**	**Low Capacitance** (Array/Switching/ Schottky) **Diode & Uni-TVS Diode**	**Low Capacitance** (Array/Switching/ Schottky) **Diode & Bi-TVS Diode**
Schematic						
$\boldsymbol{V_C}$ (Clamping)		Positive	V_{BR_Z1}	$V_{F\_Z1} + V_{BR\_Z2}$	$V_{F\_D1} + V_{BR\_Z1}$	$V_{F\_D1} + V_{BR\_Z1}$
		Negative	$-V_{F\_Z1}$	$-(V_{BR\_Z1} + V_{F\_Z2})$	$-V_{F\_D2}$	$-(V_{F\_D2} + V_{BR\_Z2})$
			Diode Arrays	**Diode Arrays & Uni-TVS Diode**	**Schottky Diodes**	**Schottky Diodes & Bi-TVS Diode**
Schematic						
$\boldsymbol{V_C}$ (Clamp .Volt.)	***A***	Positive	$V_{F\_D1} + V_{DD}$	$\geq V_{F\_D1} + V_{DD}$& $\leq V_{BR\_Z1}$	$V_{F\_D1} + V_{DD}$	$\geq V_{F\_D1} + V_{DD}$& $\leq V_{BR\_Z1}$
		Negative	$-V_{F\_D2}$	$-V_{F\_D2}$	$-V_{F\_D2}$	$\leq -V_{F\_D2} - 0V$& $\geq -V_{BR\_Z1}$
	B	Positive	$V_{F\_D3} + V_{DD}$	$\geq V_{F\_D3} + V_{DD}$& $\leq V_{BR\_Z1}$	$V_{F\_D3} + V_{DD}$	$\geq V_{F\_D3} + V_{DD}$& $\leq V_{BR\_Z1}$
		Negative	$-V_{F\_D4}$	$-V_{F\_D4}$	$-V_{F\_D4}$	$\leq -V_{F\_D4} - 0V$& $\geq -V_{BR\_Z1}$

8. Table 2: Sample Applications Using TVS Diodes

MOVaristor + Choke + TVS Protection	DC Load Protection
	
AC Power Supply Protection	**Protection of DC Circuits from Electromagnetic Interference**
	
Opamp Output Protection	**Inverter / Mosfet - Variable Frequency Protection of IGBT Module**
	

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