

## TRANSIENT PROTECTION SOLUTIONS: Transil™ diode versus Varistor

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Since the seventies, electronic modules are more and more present in our life. This is the case for our entertainment, automotive, telecommunication, production tools, house access equipment, and it is not really a secret that these smart functions are very sensitive to transients coming from human body itself (ESD<sup>1</sup>), electromagnetic part switching and industrial transients (EOS<sup>2</sup>), atmospheric effects (lightning). These surges are more often lethal for the electronic functions and the constant decrease of silicon elementary cell size (transistor) makes them more and more compact but more and more fragile.

To assume a correct definition of a protection stage, we have to ask the two following questions :

- what we have to protect?
- against what we have to be protected?

The answer to the first question depends on both the technology used to realize the part to be protected and normal operating waveform of the signal on the line to be protected. Needed parameters are the maximum voltage that technology can withstand, the type of normal operating signal (unidirectional :  $0-V_{CC}$  or bi-directional :  $\pm V_{CC}$ ), the maximum and minimum voltages of this signal and its frequency. The answer to the second one is closely linked to the environment where modules are operating. In each application we have to focus on one type of disturbances, i.e. in telecom we are faced to atmospheric effects, in domestic and industrial worlds, disturbances are EOS while in computer or mobile phones, the main surge cause is due to ESD.

To avoid dramatic consequences on systems submitted to over voltage transients, the best way is to use protection devices based on clamping action.

In this kind of products we have the choice between two technologies :

- silicon devices named Transil™ - so called TVS<sup>3</sup>
- and ceramic components - Varistor for instance.

Figure 1 shows the electrical characteristics of a clamping device, this curve has two areas.

The first one located between 0V axis and  $V_{RM}$ <sup>4</sup> is the normal operating zone; in this area the signal is not be affected by the transient suppressor (low leakage current and negligible intrinsic capacitance).

The second one is the surge suppression zone in which the surge is clamped at  $V_{CL}$ <sup>5</sup>.

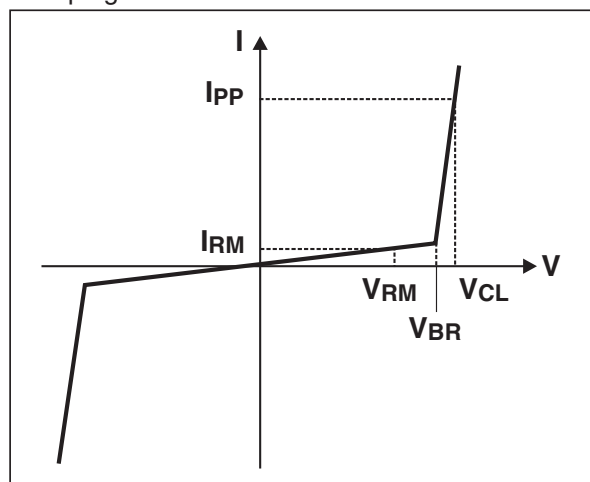
$$V_{CL} = V_{BR} + R_d \times I_{PP}$$

$V_{BR}$ <sup>6</sup>: knee voltage of the I/V curve

$R_d$ : dynamical resistance.

$I_{PP}$ : current value during surge.

**Fig. 1:** Electrical characteristics of bi-directional clamping devices.

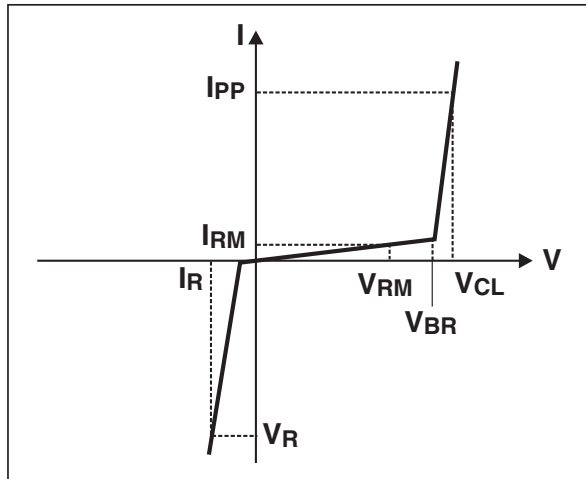


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In this zone, the main property of the protection device is to have a clamping voltage as close as possible to the operating voltage. This property is defined by the clamping factor  $C_F$ .

$$C_F = \frac{V_{CL}}{V_{BR}}$$

**Fig. 2:** Electrical characteristics of unidirectional clamping devices.



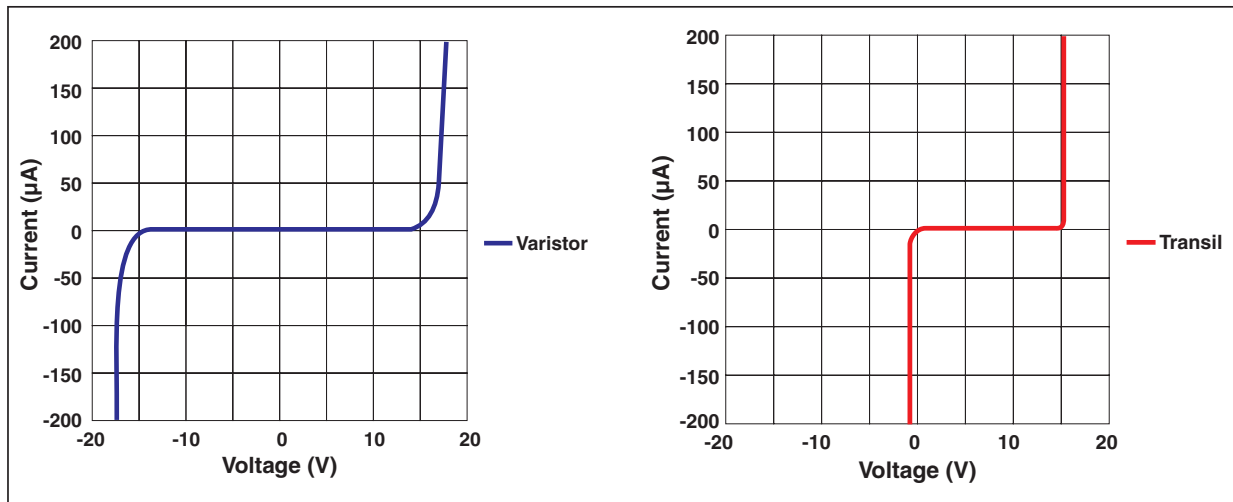
When the signal moving through the line to be protected is unidirectional (0 to  $+V_{CC}$  or  $-V_{CC}$  to 0) the surge suppressor has to be unidirectional, otherwise the protection function is not optimized.

Figure 2 shows the electrical characteristics of a unidirectional clamping device. In this case the positive behavior of the device is still the same while the negative one is totally different.

Negative over voltage occurring on the protected line is clamped to a typical forward drop voltage of a diode.

Figure 3 gives the electrical characteristics of both Transil™ diode and Varistor measured on curve tracer. Both tested components have been chosen in the same power and voltage (14V) ranges in order to make an accurate comparison.

**Fig. 3:** Electrical characteristics measured on curve tracer.



The first remark we can do, regarding these curves, is that the Varistor operates uniquely in bi-directional mode while the Transil™ diode can be both uni or bi-directional (here this is a unidirectional type). The second point is the leakage current which is higher for the Varistor particularly close to the knee of the curve. The third point to focus on is the slope of these characteristics in the clamping zone (vertical part of the curve after  $V_{BR}$ ), here one can easily see that the Transil™ diode slope is tighter than the Varistor one.

And taking into account that the curve slope represents  $\frac{1}{R_d}$ , so for the same surge current the clamping voltage will be lower for the Transil™ and then its clamping factor will be better.

To verify this point we performed measurements on both Transil™ and Varistor during EOS and ESD surge test conditions. The EOS tests are based on IEC61000-4-5 1.2/50µs (8/20µs current) composed waveform while ESD surges were performed in accordance with IEC61000-4-2 system standard.

Fig. 4: Varistor and Transil™ diode EOS electrical behaviors.

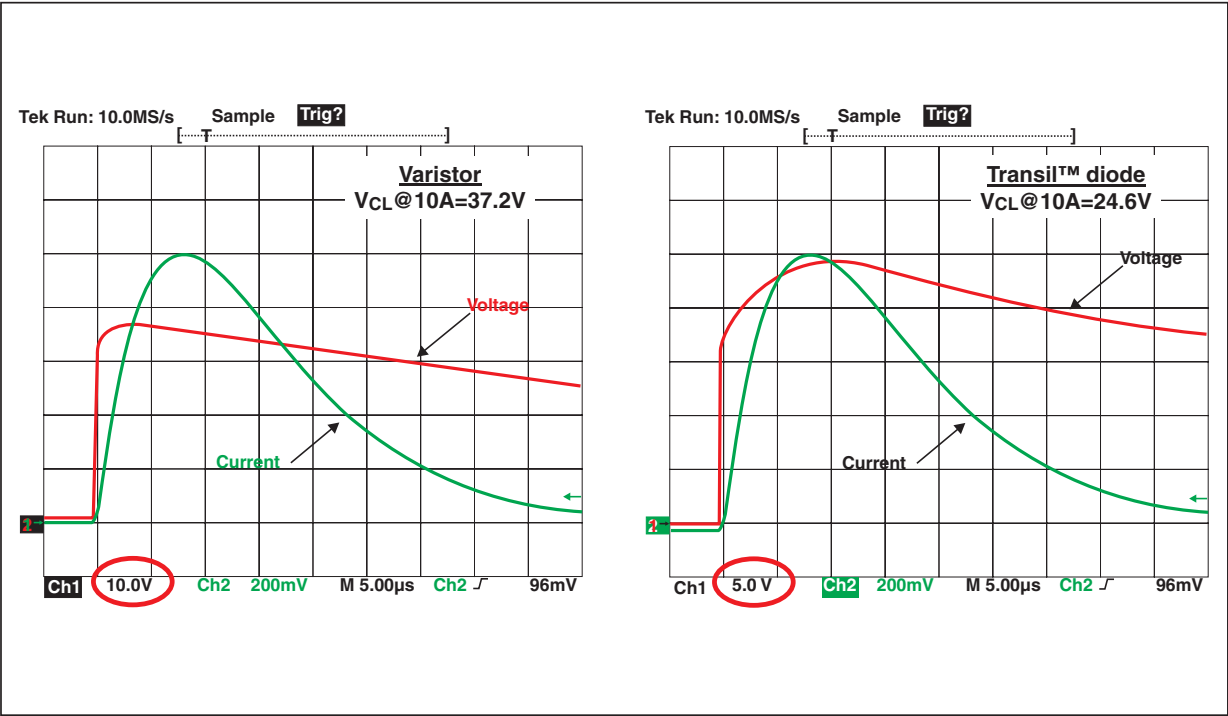
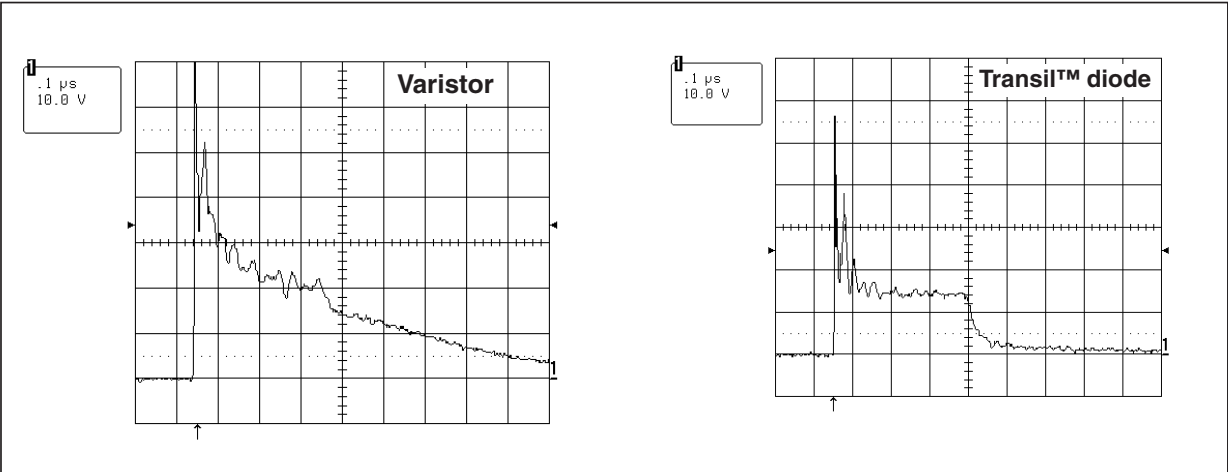


Figure 4 shows the behavior of both Varistor and Transil™ when submitted to EOS surges. Tests were performed with 10A peak current, in such a condition the Varistor clamps at 37.2V while remaining voltage across the Transil™ in the same condition is only 24.6V. That means in such a surge condition the protected IC's input will see 12.6V less in case of Transil™ diode use; that leads to a better clamping factor for Transil™ diode versus varistor.

Table 1: Clamping factor comparison.

	Varistor	Transil™
V <sub>CL</sub> typ.(V) @ I <sub>PP</sub> = 10A	37.2	24.6
V <sub>BR</sub> typ. (V) @ 1mA	18.4	15.2
C <sub>F</sub> = V <sub>CL</sub> /V <sub>BR</sub>	2.02	1.62

Fig. 5: Varistor and Transil™ diode ESD electrical behaviors.



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Figure 5 gives their behavior when submitted to ESD strikes. In this case the Transil™ diode is much faster than the Varistor to clamp and to derivate surge energy. Turn-on time measured on a Transil is typically below the 10 picosecond level, while a Varistor will be in the range of 500 to 1000 ps at the best. In the first few ns, the parasitic inductance and reaction time generate >70V peak for the Varistor while this value is limited to 55V only for the Transil™. After this phase, the maximum voltage is 30V for the Varistor while we see only 15V across the Transil™ diode (very close to  $V_{BR}$ ).

Another point to take into account is the system reliability. So ensuring device reliability and avoiding ageing phenomena are two major concerns. To check these two points, repetitive ESD tests have been performed (100 pulses versus IEC61000-4-2 system standard 15kV contact).

**Fig. 6:** Varistor and Transil™ repetitive ESD test results.

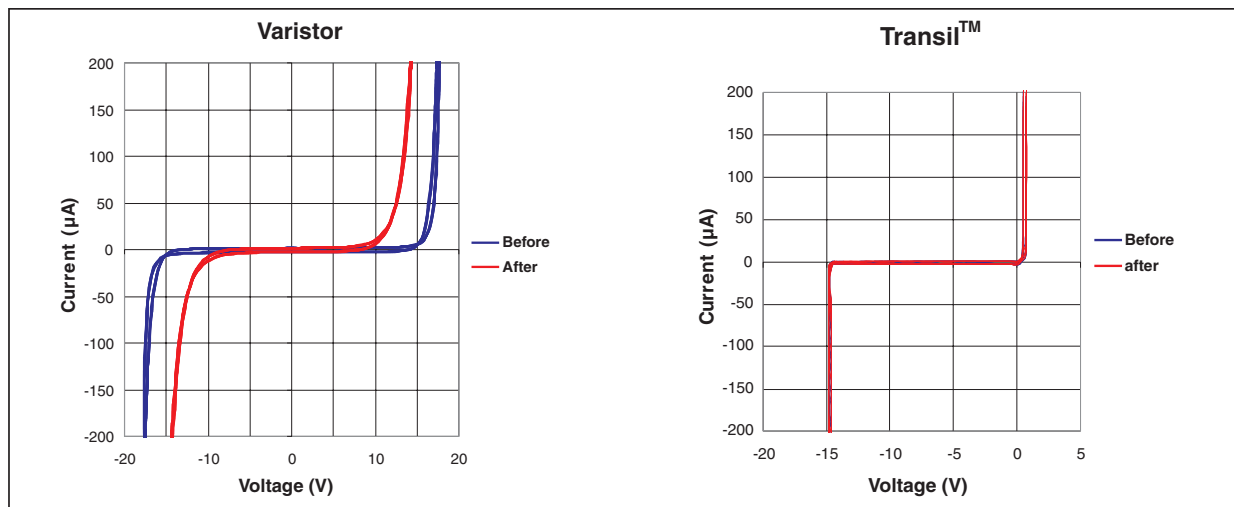
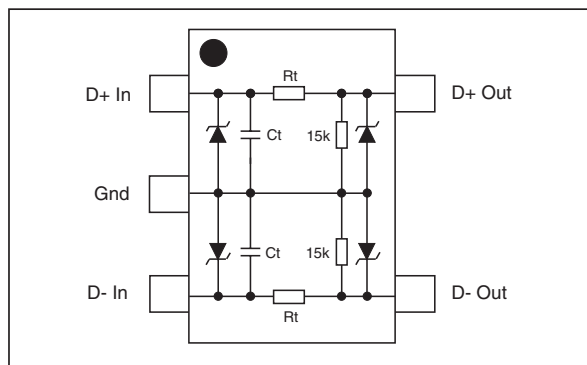


Figure 6 shows after these tests, Varistor leakage current drastically increases, while Transil™ one remains the same. This phenomena is called ageing. So the integrity of the protected system will be greatly dependent on the choice of the protection component.

Transil™ diode technology can be easily used in more complex integration where dedicated ESD protection is required and space saving is a major concern. For instance this is particularly true in computer and mobile phone applications. This is the case for USB link, which is based on plug and play connection. This kind of surges is always omnipresent. Figure 7 gives downstream port dedicated circuit USBDF01W5, which integrates either the ESD protections, the line matching resistors ( $R_t$ ), the filtering capacitors ( $C_t$ ) and the pull down resistors. All this internal component are required by the USB standard.

**Fig. 7:** USBDF01W5 circuit.



**Table 2:** Comparison sum-up.

	Varistor	Transil™
<b>Leakage current</b>	--	++
<b>ESD ruggedness</b>	+++	+++
<b>Protection efficiency</b>	--	++
<b><math>C_F = V_{CL}/V_{BR}</math></b>	-	++
<b>Ageing</b>	---	+++
<b>Security</b>	--	+++

## CONCLUSION

Transil™ devices assume better efficiency in terms of ESD protection and can be uni and bi-directional suppression functions. The MOV<sup>7</sup> are uniquely bi-directional devices and then are not optimized to protect sensitive ICs inputs, because these are 90% of the time dedicated to uni-directional normal operating signals. So IC inputs to be protected will be submitted to high voltages in the negative way during surge clamping.

Remaining voltage ( $V_{CL}$ ) for both EOS and ESD across the line is lower in the case of Transil™ than for Varistor.

Low leakage current for Transil™ device is an important parameter to take into account when portable equipment (as mobile phone or mobile computer) are concerned. This point will improve autonomy of these kinds of equipment. In term of reliability Transil™ device has no ageing phenomena regarding ESD events while Varistors are subjected to it.

In many applications safer failure are requested, this characteristic consists on a failure in short circuit when an over sized surge occurs across the protection device. This is the failure mode of Transil™ which assumes total security of the protected equipment.

<sup>1</sup> ESD: ElectroStatic Discharge

<sup>2</sup> EOS: Electrical Over Stress

<sup>3</sup> TVS: Transient Voltage Suppressor

<sup>4</sup>  $V_{RM}$ : Stand off voltage

<sup>5</sup>  $V_{CL}$ : Clamping voltage

<sup>6</sup>  $V_{BR}$ : Breakdown voltage

<sup>7</sup> MOV: Metal Oxyde Varistor

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