Typical Applications of TVS in Circuits

With the rapid development of electronic information technology, intelligent life has moved from concepts to a reality. The corresponding products have also become increasingly popular. The precision design of products and the application of advanced process IC devices are becoming more sensitive to the transient interference in circuits. To prevent products from being interfered by Surge, EFT and ESD, it is necessary to increase the protection devices to improve the reliability of products, thereby enhancing the EMS performance of the product system.

1. Description of Surge Test Standards

The surge impacts caused by random transient over voltage will cause serious damage to products. For different application environments, the corresponding transient surge suppression specifications are formulated. The surge test standard IEC61000-4-5 test criteria have clearly defined four test levels up to 4KV. The test criteria have different requirements for different types of ports. The power port uses the 1.2/50us & 8/20μs combined wave test (Figure 1, 2); the communication port uses the 10/700μs waveform test (Figure 3). In automotive electronics, tests are carried out according to the industry standard ISO 7637-2. As shown in Figure 4, it is a load dump 5a/5b test waveform. To prevent interference such as surges introduced by the transient over voltage, it needs to add TVS to protect the circuits.

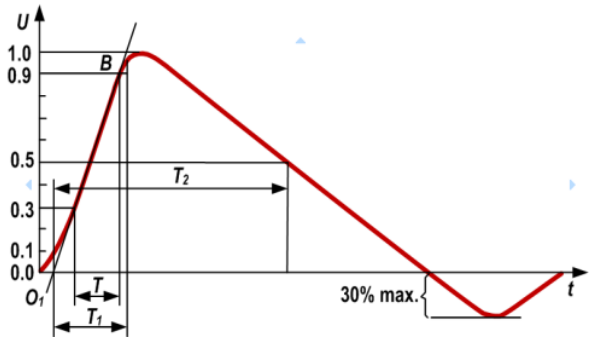


Figure 1. 1.2/50μs Voltage Waveform

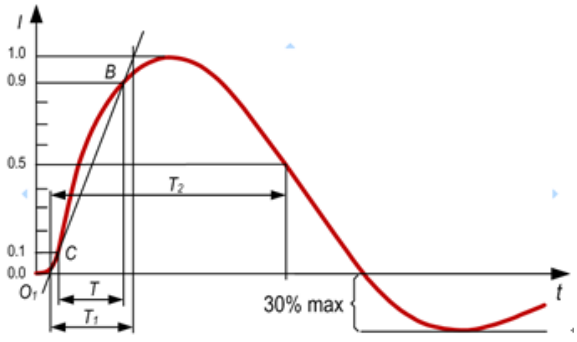


Figure 2. 8/20μS Current Waveform

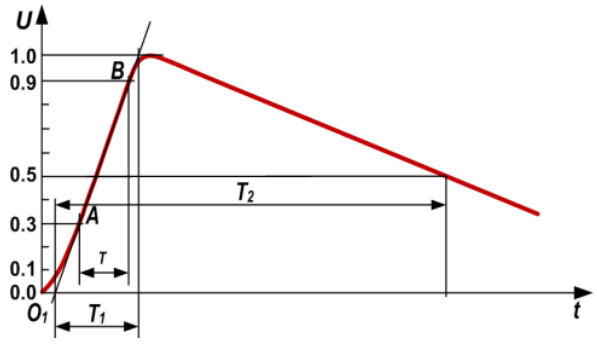


Figure 3. 10/700μs Voltage Waveform

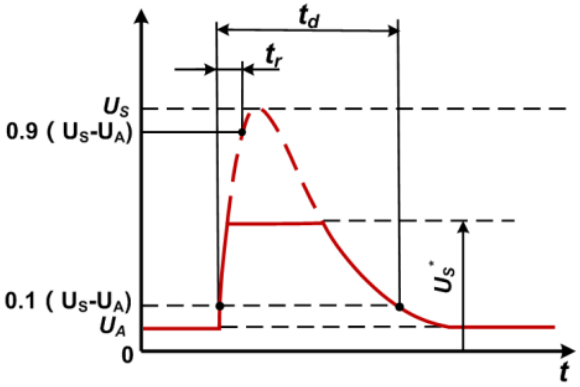


Figure 4. Load Dump 5a/5b Waveform

	12v System	24v System
U_A	13.5V	28V
U_S [a]	79-101V	151-202V
Us*	35V	65V
td	40 - 400ms	100-350ms
Ri	0.5-4Ω	1-8Ω

2. Device Description of TVS

TVS, also known as the avalanche breakdown diode, is a device of a single PN junction or multiple integrated PN junctions fabricated by the semiconductor diffusion process. The protection principle is shown in Figure 5.

TVS can be divided into two types, including one-way TVS and two-way TVS. One-way TVS is generally applied to DC power supply circuits and two-way TVS is applied to circuits with an alternating voltage. The V-I characteristic curve is shown in Figure 6. In a DC circuit, the one-way product is reversely parallel to the circuit. When the circuit is working normally, TVS is in the off state (high-impedance state) and it won't affect the normal operation of the circuit. When an abnormal over voltage occurs in the circuit and reaches the TVS (avalanche) breakdown voltage, TVS will change from the high resistance state to the low resistance state rapidly, discharging the transient over current caused by the abnormal over voltage to the ground. Besides, the low clamping voltage between both ends of the PN junction will be maintained, thus preventing the circuit of the back-end from damage caused by the abnormal over voltage. When the abnormal over voltage disappears, the resistance of TVS will return to the high impedance state.

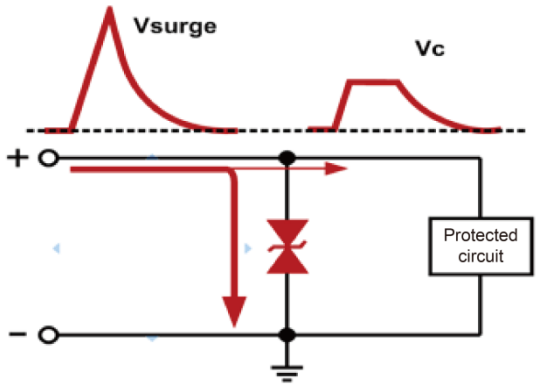


Figure 5. Diagram of Surge Absorption

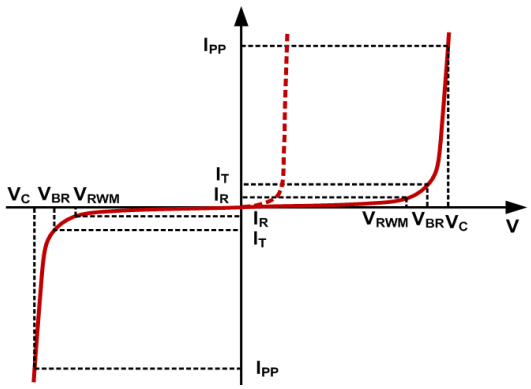


Figure 6. TVS Characteristic Curve and Parameter Description

2.1 Main Parameters of TVS

1) Cut-off Voltage (V_{RWM})

It is the highest operating peak voltage or DC peak voltage that can be applied continuously without causing TVS degradation or damage.

2) Leakage Current (I_R)

It is also known as the standby current, which is the maximum current flowing through TVS under a specified temperature and the highest operating voltage. It should be measured at the cut-off voltage.

3) Breakdown Voltage (V_{BR})

It is the voltage across TVS that is measured at a specified pulse direct current IT or a current condition close to avalanche.

4) Peak Pulse Current (I_{PP})

It is the peak value of a given pulse current waveform. Generally, TVS uses a 10/1000μs current waveform.

5) Clamping Voltage (V_C)

It is the peak voltage measured across TVS when the peak pulse current I_{PP} of a specified waveform is applied.

2.2 Considerations for TVS's Type Selection

1) Cut-off Voltage

In the normal working condition of the circuit, TVS is in the off-state, so the cut-off voltage of TVS should be selected to be greater than the highest working voltage of the protected circuit so as to ensure that TVS will not affect the operation when the circuit is working normally.

2) Clamping Voltage

The clamp voltage of TVS should be less than the maximum transient safety voltage that can be withstood by the back-end protected circuits. V_C is proportional to the avalanche breakdown voltage of TVS and I_{PP}. For TVS of the same power class, the higher the breakdown voltage, the higher the V_C.

3) Leakage Current

For communication circuits and low-power circuits, special attention should be paid to the fact that I_R shouldn't affect the efficiency and normal operation of the system. TVS with a low voltage (V_{RWM}＜10V) has a large leakage current. If the voltage permits, try to select TVS with a voltage above 10V to obtain a small leakage current.

4) Junction Capacitance

Generally, the junction capacitance of TVS is in the range of dozens of picofarads to dozens of nano-farads. For TVS of the same power class, the lower the voltage, the larger the capacitance value.

In some communication circuits, attention should be paid to the junction capacitance of TVS, which shouldn't affect the normal operation of the circuits.

5) Package Form

The power of TVS can also be reflected from the package form. Because the chip area of TVS directly determines its power level, the smaller the package volume, the smaller the power. The suitable package of TVS devices can be selected in accordance with the circuit design and test requirements.

3. Typical Applications of TVS

3.1 DC Power Port

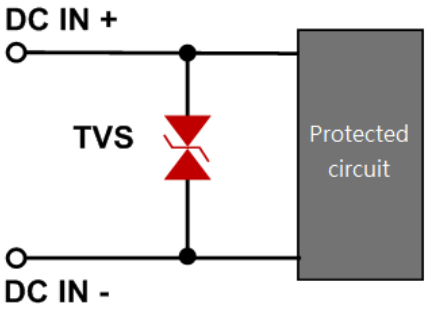
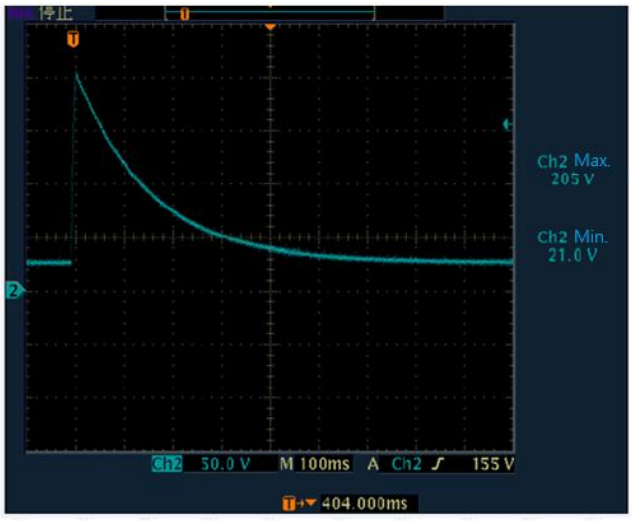


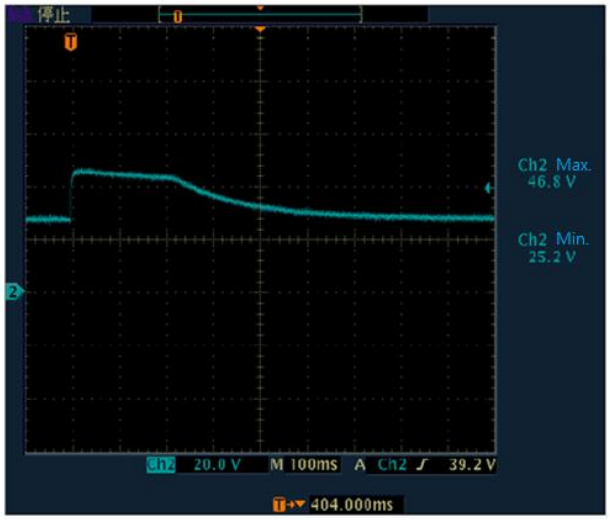
Figure 7

As the input port of the front-end of the device, the power port faces various random transient over voltage interference. The paper takes the common DC power port as an example. The protection scheme is shown in Figure 7. The device can be selected as MOV or TVS. While realizing the transient interference protection, MOV will also generate a high residual voltage due to its own characteristics. Its suppression effect is not obvious for some voltage spikes that rise rapidly. There is an unrecoverable aging phenomenon after the action. The reliability cannot be guaranteed along with time and the increasing number of actions. The package volume cannot meet the miniaturization requirement of products. In view of the characteristics above, TVS has become a key protection device to for applications with high protection requirements for automotive electronics because of its fast speed, high reliability, low clamping and small package.

For example, the DC power input port of the automotive electronics products with a 24V system will generate a large interference pulse during the load dump due to the complicated use environment and the variability of driving environmental factors, which will cause damage to the back-end DC/DC and integrated circuits of the automotive electronics. For the safety and service life of vehicles, it is necessary to respond quickly when the load dump occurs. TVS can suppress interference for the first time with its picosecond response speed and precise voltage clamping. As shown in Figure 7, the DC power port of the automotive electronics 24V system uses SMEJ33AG. Under the test condition of 202V 4ohm 350ms, the residual voltage is about 46V, which can effectively suppress the load dump interference and realize the protection of the back-end circuits. The following figure

shows the comparison between products before and after adding the TVS protection device:





3.2 Communication Interface

As a representative of low-speed communication port, RS-485 communication bus has been widely used in industrial control, instrumentation, security monitoring and other industries because of its simple control, long communication distance and low cost. RS485 has a long communication transmission distance and its transmission lines are usually exposed outdoors, so it is easy to introduce transient over voltage interference due to the lightning strikes and other reasons. The RS485 transceiver usually works in a low-voltage state (about 5V), its own anti-interference is weak. There is no path to divert the transient voltage interference. The communication interface chips are easy to be damaged without a proper protection. As an over voltage protection device, TVS can be used as the preferred device for the RS485 surge protection because of its advantages such as fast response and low clamping voltage.

The RS485 protection scheme is shown in Figure 8. SMBJ6.5CA is used between A and B buses of RS485 to achieve the differential mode and the common mode surge protection for RS485. This protection scheme can satisfy the 10/700us 2KV surge test. SMBJ6.5CA can obtain a lower residual voltage under the 2KV surge test so that it can realize the clamping protection of the transceiver. Two stages of protection can be used so as to achieve a high protection level, as shown in Figure 9. The front-end uses the BK12000702 SPG and the back-end uses the SMBJ6.5CA TVS. The power resistance, power inductor or

PPTC can be selected as the decoupling devices in accordance with the current in circuits so as to make these two stages work together. The scheme can satisfy the 10/700us 6KVsurge test and obtain a low residual voltage.

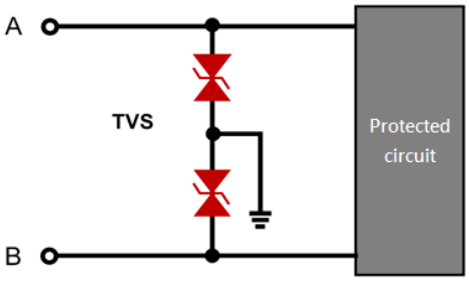


Figure 8

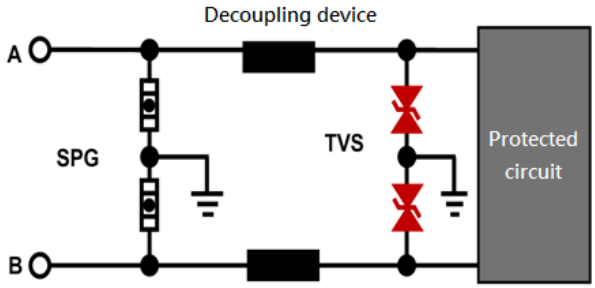


Figure 9

4. Conclusion

TVS does not work nor generate losses when the circuit voltage is normal or fluctuates slightly. When there is an instantaneous high voltage pulse, TVS will absorb the instantaneous large current. The voltage clamping protects the back-end circuits at a voltage slightly higher than that of the operating time. Right types of products should be selected based on the application and protection requirements so as to suppress the transient interference generated in the circuits. TVS won't have the ageing phenomenon. It has a long service life and a good reliability. At present, TVS has become a key component for the protection design of industrial equipment, automotive electronics, and security electronic products.