FAQ TVS

Introduction

This document contains a list of frequently asked questions (FAQ) on TVS and TVS calculator. Our experts replied to these questions during the webinar: *Select the right TVS in record time*.

1 FAQ and answers

1.1 What are the key parameters to select a TVS?

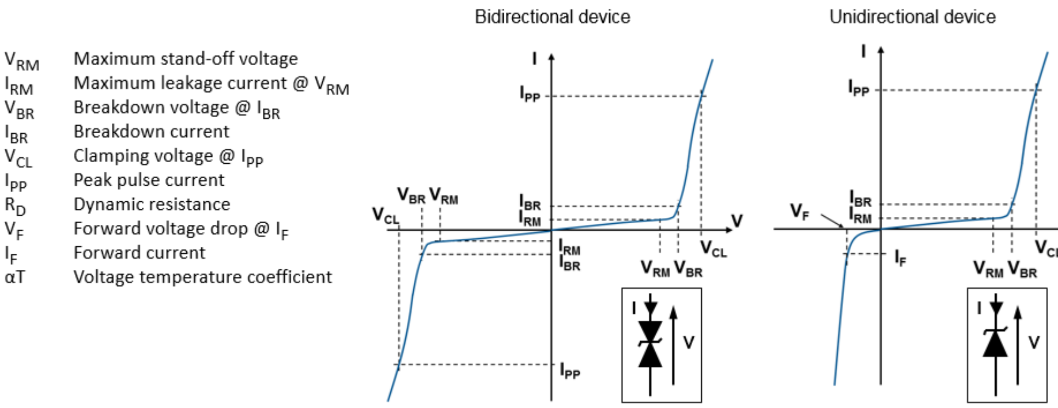
The key parameters are:

V_{RM}: in normal operating (when there is no surge) the voltage on the line must be lower than the V_{RM}.

I_{PP}: During the surge, the TVS must withstand the surge current. It should be lower than the I_{PP} given in its datasheet (for the same duration).

V_{CL}: During the surge, the voltage across the TVS increases. This voltage increase must remain below the maximum voltage of the circuit to be protected.

Figure 1. Electrical characteristics - parameter definitions



1.2 What is V_{RM} (maximum reverse voltage also called maximum stand-off voltage)?

In theory, the voltage across the TVS should be lower than V_{RM} when there is no surge. Qualification tests are performed at V_{RM}.

1.3 What is the I_{RM} (leakage current)?

This is the leakage current specified at V_{RM}. It is specified as a maximum value. Some other values may be specified in the datasheet for a voltage lower than V_{RM}. In this case this is I_R specified at V_R.

1.4 What is V_{BR} (breakdown voltage)?

V_{BR} is the value for which we consider the TVS starts to clamp. V_{BR} is generally measured at I_{BR} = 1 mA.

1.5 What is I_{PP} (peak pulse current)?

I_{PP} is the surge current that the TVS can withstand in non-repetitive mode. Datasheets generally provide two conditions: 8/20 µs and 10/1000 µs surge.

1.6 What is V_{CL} (clamping voltage)?

This is the voltage across the TVS during a surge. It is generally given as a maximum value in our datasheet. To protect efficiently an IC, this value must be lower than the absolute maximum voltage that the IC can withstand (consider that absolute maximum ratings (AMRs) are based on DC voltage levels, which are typically lower than transient voltage peaks). For consistency, it should be under the same conditions, especially regarding the surge duration. As the surge current in the application may differ from the I_{PP} given in our datasheet, a formula is provided to calculate V_{CL}, according to the surge current.

1.7 What is R_D (dynamic resistance)?

Basically, a TVS is equivalent to a voltage source in series with a resistance called R_D. R_D varies from one TVS to another one and with the surge duration. It is important to get this value to calculate the clamping voltage during the surge. A formula is given in our datasheets.

1.8 What is P_{PP} (peak pulse power)?

P_{PP} is given for a specific surge duration, typically 10/1000 µs, and in some cases, for 8/20 µs. It corresponds to I_{PP} x V_{CL}. This can be tricky because with a very efficient TVS, the V_{CL} is low, and the PPP is also low.

1.9 What is αT (temperature coefficient)?

The characteristics of silicon products vary with temperature. The temperature coefficient, αT, allows V_{BR} or V_{CL} to be calculated at any temperature within the junction temperature range specified in the datasheet.

1.10 How do you calculate instantaneous power and the maximum allowable overpowering?

Instantaneous power is calculated as I_{TVS} x V_{TVS}. The maximum allowable power P_{PP} is defined on the datasheet, typically by a $P_{PP} = f(t_P)$ curve, or by calculating t_j with a $Z_{th} = f(t_P)$ curve. P_{PP} is calculated as $P_{PP} = I_{PP}$ x V_{CL}, where I_{PP} is the peak pulse current, and V_{CL} is the maximum clamping voltage.

1.11 How does a transient voltage suppressor (TVS) work in circuit protection? How to properly select and apply TVS to achieve optimal protection in record time?

TVSs are parallel protections, which means they are placed in parallel with the circuit to be protected. When the voltage is higher than V_{BR} (breakdown voltage), the TVS conducts to limit the voltage, and the remaining voltage is V_{CL} (clamping voltage).

1.12 How can you select the appropriate rate power for a TVS device?

First, you must determine the standards that the application product needs to pass. If there is no standard, you can try to measure the maximum surge energy to facilitate better selection and use the TVS calculator webtool or refer to the AN316 application note.

1.13 What is the fastest response suppression speed of a TVS?

The fastest response time for a TVS diode is typically within the picosecond range, providing near-instantaneous suppression of transient voltages.

1.14 What is the response time of TVS?

The response time of TVS is in the range of picoseconds. However, for ESD surge PCB tracks may influence response time.

1.15 What considerations are important when choosing a TVS diode's clamping voltage for IC protection?

For optimal IC protection, ensure the TVS diode's clamping voltage is less than the IC's maximum transient voltage threshold. Consider that absolute maximum ratings (AMRs) are based on DC voltage levels, which are typically lower than transient voltage peaks.

1.16 When choosing a TVS, how should the current and voltage be selected?

The V_{RM} working voltage of TVS is greater than or equal to the maximum working voltage of the protected circuit.

1.17 How much voltage can this instantaneous voltage suppressor suppress?

Power is the parameter to size a TVS. The TVS voltage is defined by the TVS clamping voltage. So, current is the parameter to size a TVS.

1.18 How stable is the voltage suppressor?

The transient voltage suppressor, or TVS, uses a very stable silicon process. It does not suffer from attenuation or degradation after repeated surge unlike the metal oxide varistor (MOV). When TVS selection is correctly done, the lifetime is much longer than MOV.

1.19 In the overvoltage protection circuit, what is the impact of the parasitic capacitance of TVS on the subsequent circuit?

On the DC signal, the TVS capacitance has no impact on the circuit. On the AC signal, as a discrete capacitor, it is equivalent to a low pass filter.

1.20 Is there any way to eliminate the capacitor introduced by TVS?

No, however it can be minimized by using bidirectional TVS. This is why it is important not to oversize that TVS as its capacitance increases with power.

1.21 Under what circumstances is the transient voltage suppressor automatically cut off?

When voltage is lower than V_{BR} the TVS is cut off, by considering the leakage current is negligible.

1.22 Why are TVS clamping voltages so high? They are almost always higher than the max voltage allowed on an IC input pin.

Selection of the TVS is done with the V_{RM} to be higher or equal to the maximum voltage on the line. TVSs are not perfect (whatever the supplier is) as they have a dynamic resistance (R_D). During the surge, the current (I_{PP} in application) flows through the TVS, the voltage is V_{CL} in application = I_{PP} in application x R_D + V_{BR}.

The V_{CL} in application must be lower than the absolute maximum voltage of the IC. However, the absolute maximum voltage of the IC is given in DC. Only a few manufacturers give absolute maximum voltage during surge.

1.23 Can TVS diodes suppress static electricity? How do you choose?

Yes, TVS can protect against ESD. Specific TVS series to protect against ESD are available. The P/N begins with ESD. Pay attention to the parasitic capacitance of the data line, working voltage, and the maximum ESD protection that can be tolerated, such as 8 kV or 15 kV air or contact discharge.

1.24 What are the advantages over gas discharge tube?

TVS provides a lower and more stable clamping voltage.

1.25 How do the TVS compare with GDTs?

TVS clamping voltage is lower than GTD. However, GTD can withstand more current. Also, GTD degrades with the number of surges, whereas there is no variation with TVS.

1.26 How does TVS protection differ from the thyristor-based protection against the same transients?

TVS is a device which clamps the voltage, and when the voltage is lower than V_{BR} (breakdown voltage), TVS stops clamping. For thyristor surge suppressor (TSS) the behavior is almost a short-circuit during the surge and once triggered, the current needs to be lower than I_H (holding current) to stop conducting. TSS cannot be used on DC power supply lines. However, TSS can withstand more current than TVS for the same package.

1.27 What is the difference between ambient and junction temperature?

Junction temperature is the die temperature, inside the package.

Ambient temperature is the temperature outside the package.

When no power is dissipated on TVS (TVS is not clamping), junction temperature is equal to ambient temperature (T_J = T_{amb}):

- $T_J = T_{amb} + (V_{RM} \cdot I_{RM}) \cdot R_{TH(J-a)}$

I_{RM} is typically in the nA range.

For long pulse duration (see $Z_{TH(J\text{-}a)} = f(t_P)$), junction temperature is calculated by the formula:

- $T_J = T_{amb} + (V_{CL} \cdot I_{PP}) \cdot Z_{TH(J-a)}$

For long pulse duration, T_J must be lower than T_{Jmax}.

1.28 Why footprints are different from one supplier to another one?

ST footprints are given according to package dimensions (often JEDEC standard) and IPC7531 standard. Package dimensions vary from one manufacturer to another one. Some manufacturers are not following the IPC7531 standard.

1.29 Can we use a TVS in place of a zener?

TVSs are dedicated to clamp transient voltage and cannot be used in DC mode for voltage regulation. TVS cannot replace a zener.

1.30 For automotive TVS selection what would you use for a 4 step selection?

The selection is done according to the following steps:

1. Select an AEC-Q101 TVS
2. V_{RM}: in normal operating (when there is no surge) the voltage on the line must be lower than the V_{RM}
3. P_{PP}: During the surge, the TVS must withstand the power (V_{CL} x I_{PP}), maximum power is defined by $P_{PP} = f(t_P)$ curve
4. V_{CL}: During the surge, the voltage across the TVS increases. This voltage increase must remain below the maximum voltage of the circuit to be protected (V_{CL} max).

1.31 How do you choose suitable specifications?

1. Select the standards related to your system such as ISO 7637 or ISO 16750 for automotive, EN 55024 for telecom equipment, etc.
2. Calculate the surge power according to the energy of the surge (duration, I_{PP} value)
3. Consider the maximum withstand voltage of the protected system.

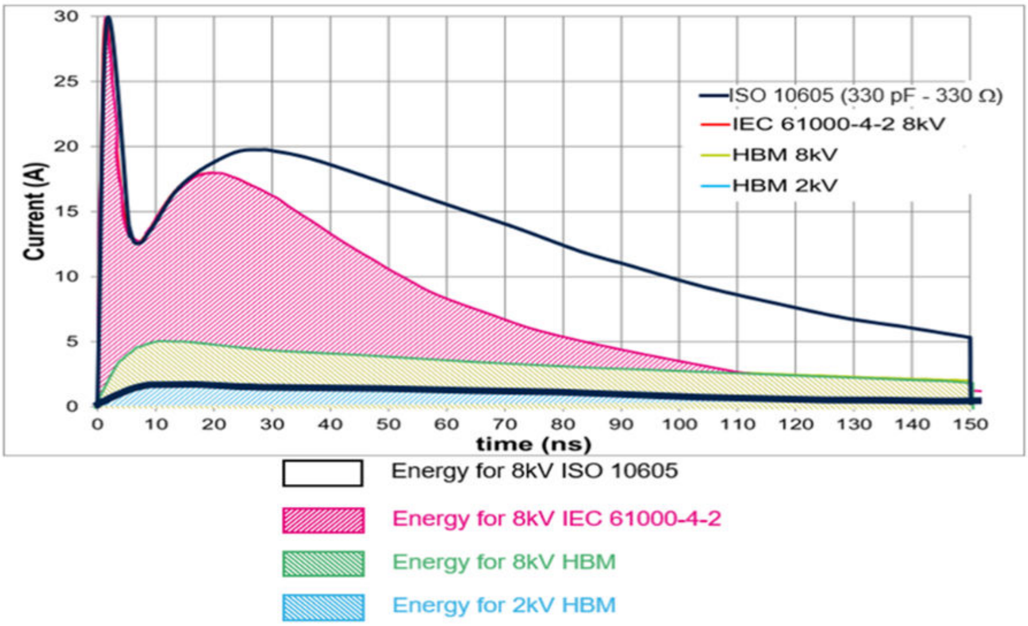
1.32 What are the differences between the various ESD standards?

IC manufacturers often mention ESD without specifying the standards. There are different ESD standards:

- HBM, MM, CDM are related to the manufacturing environment. These are low energy surges as the manufacturing environment is quite safe.
- IEC 61000-4-2 and ISO 10605 (for automotive) are related to ESD generated by the end users and are much more energetic than HBM, MM, CDM.

ST protection and filter devices are specified according to IEC 61000-4-2 and ISO 10605. See Figure 2 HBM, IEC, and ISO standards.

Figure 2. HBM, IEC, and ISO standards



1.33 What are the differences between AEC-Q100, AEC-Q101 and AEC-Q200?

These are 3 standards for automotive:

- AEC-Q100 is related to silicon IC
- AEC-Q101 is related to silicon discrete devices
- AEC-Q200 is related to passive devices such as metal oxide varistors (MOV)

Tests conditions are different for each standard.

1.34 How to choose the appropriate TVS for a specific circuit?

First, check the voltage in the protected circuit. For negative and positive signal, choose a bidirectional TVS. If not, choose a uni-directional TVS. Then, determine the normal operating voltage and maximum withstand voltage of the circuit, and use this to select the V_{RM} (maximum reverse voltage) and V_{CL} (clamping voltage) of the TVS. Finally, roughly evaluate the frequency and amplitude of the voltage spike to determine the power rating or power handling capability of the TVS, and thus its packaging requirements.

All these steps are used in https://eds.st.com/tvs/#/.

1.35 In a digital configurable input or output where I can drive inductive loads or read digital signals, can I use a TVS to protect inputs from disturbances and work as a freewheeling diode when the pin is in output mode?

TVS (transient voltage suppressor) can be used to protect the digital configurable input or output (I/O) from disturbances and as a freewheeling diode when the pin is in output mode.

When the I/O pin is configured as an output and driving an inductive load, the TVS can act as a freewheeling diode to provide a path for the inductive current to flow when the output is switched off. This helps to prevent voltage spikes that can damage the circuit.

When the I/O pin is configured as an input, the TVS can protect the input from voltage spikes and other disturbances that can occur on the input line. The TVS conducts any surge to the ground, protecting the input from damage.

1.36 What models can be used for vehicle-mounted load dump test ISO 7637?

The load dump surge is a standard with various surge parameters: peak value, duration, and serial resistance can vary. This leads to different power then to different TVS. Dedicated curves to load dump surge are provided on 5000 W and 3000 W automotive TVS datasheet. Other surges are specified on datasheet.

Our electro-thermal models provided on ST.com allow the right TVS to be selected.

1.37 What is the difference in peak pulse power compared to similar products?

ST's P_{PP} (peak pulse power dissipation) performance versus junction temperature is more stable than competition. This is given in $P_{PP} = f(T_j)$ in our datasheet.

1.38 According to the characteristics of TVS, is it more appropriate to choose power greater than the rated value?

The selection of a TVS is done with the power capability of the TVS defined in its datasheet. Power is the result of the clamping voltage (V_{CL}) multiplied by the current (I_{PP}).

1.39 Do you recommend them for use in Automobile/Light rail applications?

TVS devices are commonly used in automotive and light rail applications to protect electronic components from voltage transients that can occur in these environments.

Automotive and light rail applications are particularly challenging environments for electronic components due to the presence of high voltage transients from sources such as load dump, alternator kickback, and electrostatic discharge. These transients can cause damage to sensitive electronic components, and TVS devices are an effective way to protect against these transients. A specific Y letter is added at the end of automotive part numbers.

1.40 During EMC tests, does the TVS of the communication port work?

The TVS is active when the voltage is getting higher than the breakdown voltage (V_{BR}). During normal operation, the capacitance may affect a high-speed signal. For this reason, various eye diagrams are provided in the datasheets. If TVS is not clamping signal during EMC test, communication port work. Else, it depends on surge and transceiver characteristic.

1.41 How can one evaluate the pulse train capability?

For repeated pulses, the average power is first calculated. Based on the R_{ja} value and ambient temperature, it is judged whether the T_j junction temperature is exceeded. See the AN316 application note.

1.42 How do you add protection to the interface that cannot be hot-plugged with TVS?

TVSs are permanently placed on the interface to be protected. If TVS cannot be placed, then the interface must be resilient to the surge.

1.43 If the peak power is larger, should a parallel connection be used? Is it effective?

Series or parallel connections can be used. In series, the total V_{RM} voltage is distributed among all TVSs.

In parallel, the same TVS need to be used, and a symmetric connection must be used to split equally the current among each TVS.

1.44 In addition to TVS, do other types of lightning protection devices need to be added during product application?

TVS alone ensures a good protection for electronic systems, while the surge current and duration is in line with TVS power capabilities.

1.45 Is it better to place the TVS diode before the input diode or after the diode?

It is always better to place TVS as close as possible to the surge source, the connector.

1.46 The electrostatic discharge effect can release pulses of more than 10,000 V and 60 A, and how long it can last.

TVS can withstand at least +/-30 kV IEC61000-4-2 contact discharge (current is higher than 100 A on the first peak).

1.47 What are the advantages of using TVS diodes for absorption compared to traditional RC?

RC clamping voltage value varies according to pulse current/voltage and duration. With TVS, clamping voltage is defined by breakdown voltage and dynamic resistance, providing small variation on clamping value.

1.48 Is intelligently selected instruments have an error rate and can they be reliably trusted?

All instruments used by STMicroelectronics are certified and calibrated. Reliability of test results is granted.

1.49 Are thermal models compatible with all electric simulators?

Electrothermal models are compatible with OrCAD, LT-Spice, SIMetrix and eDSim.

1.50 How much can ST's design tools and electro-thermal spice models improve development?

The TVS calculator secures the right TVS selection quickly and TVS thermal spice models propose a much more accurate behavior of TVS when simulated than the standard TVS spice model.

1.51 How to shorten suppressor response time?

TVSs are optimized to present an instantaneous response time thanks to the avalanche effect while other protection devices (gas tube or MOV) or other silicon physical effects (Zener) present much longer times.

From a layout point of view, it is key to reduce the length of the leads and traces in the circuit, which can help to minimize the inductance and resistance of the circuit and improve the suppressor's response time.

1.52 How to solve the problem of heat dissipation?

There are two cases:

1. For a single surge there is no need to consider heat dissipation. The parameter to consider is the surge power capability (P_{PP}).
2. For repetitive surge, average power may increase junction temperature. Electro-thermal simulation enables to simulate power on TVS : with $Z_{TH(J-a)} = f(t_P)$ curve, junction temperature can be calculated, and need to be lower than T_{Jmax}.

1.53 In the case of excessive surge is the TVS short or open circuit?

In the case of surge higher than the max capability (I_{PP}) of the TVS, the failure mode is short circuit or high leakage current.

1.54 Is there a possibility of a burnout period if the transient time is unexpectedly long?

Yes, there is a possibility of a burnout period if the transient time is unexpectedly long due to the thermal effect. When very long surges are applied thermal impedance (Z_{th}) and maximal junction temperature must be consider to select the proper TVS.

1.55 What is the failure mode of a TVS?

The failure mode is short circuit or high leakage current.

1.56 What is the operating temperature of ST’s latest TVS diode? Can it work in a low-temperature environment for a long time?

The lowest junction temperature of ST TVS diodes is -55°C. We have not performed tests with lower temperatures due to equipment limitations.

1.57 What is the thermal conductivity of ST's intelligent selection tool and electro-thermal spice model for this design?

On the TVS simulator and TVS electrothermal spice model, thermal conductivity is Z_{th} and R_{th} specified on the datasheet

Appendix A Reference document

This is a list of references used in this document.

Table 1. Reference documents

Document name	Description
IEC 61000-4-2	International Electrotechnical Commission's immunity standard on electrostatic discharge
ISO 7637	Road vehicles - Electrical disturbances from conduction and coupling
ISO 10605	Road vehicles - Test methods for electrical disturbances from electrostatic discharge
AEC-Q100	Failure mechanism based stress test qualification for packaged integrated circuits used in automotive applications
AEC-Q101	Failure mechanism based stress test qualification for for discrete semiconductors in automotive applications
AEC-Q200	Stress test qualification for passive components

Revision history

Table 2. Document revision history

Date	Revision	Changes
29-Apr-2024	1	Initial release.
19-Sep-2024	2	Updated Section 1.43 If the peak power is larger, should a parallel connection be used? Is it effective?.

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