Surge Protection for RS-485 Networks

Industrial networks using RS-485 communication often operate in harsh industrial environment. These networks are exposed to strong electromagnetic interference in the form of large transient overvoltages caused by electrostatic discharge, electrical fast transients, and lightning strikes.

While low-energy transients, such as ESD and EFT, are dealt with by the RS-485 transceiver internal transient protection circuitry, high-energy transients (known as surge transients) require the addition of external transient voltage suppressors (TVS) to prevent the transceiver from lethal damage.

This tutorial provides a brief overview of the most common overvoltage transients, explains the operation of a TVS device, and provides five transceiver/TVS combinations that protect RS-485 bus nodes against overvoltage transients. All transient protection designs have been tested by Semtech Inc., a certified TVS manufacturer.

Contents

1. Most Common Overvoltage Transient Types

The following are the three most common overvoltage transient types:

- Electrostatic Discharge (ESD)

An ESD transient is typically caused by the electrostatic discharge of a human onto electronic equipment. The transient has a short rise time of about 1ns and lasts less than 100ns, which makes it the transient with the lowest energy content (Figure 1).

- Electrical Fast Transients (EFT)

EFT are switching transients caused by inductive switching, relay contact bounce, and other factors. Therefore, they always occur in the form of a sequence of pulses known as a burst. A single transient has a short rise time of 5ns and lasts about 400ns. Its energy content is about 300 times that of an ESD transient.

- Surge Transient

A surge is a transient caused by lightning and by switching heavy inductive loads. Test generators simulating this transient produce a waveform that combines a high open-circuit voltage transient with a high short-circuit current transient. Both waveforms are defined by different rise and fall times in the range of tens of microseconds. The combination of high voltage, high current, and a pulse duration of 1000-times longer than either the ESD or EFT transient makes the surge transient the most energetic transient of all.

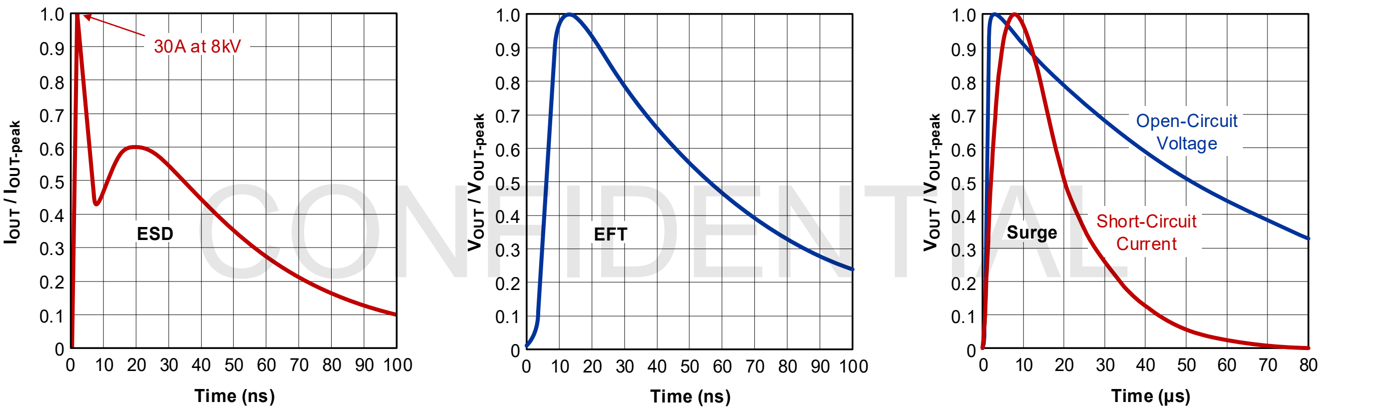

Figure 1. In Comparison to ESD and EFT Transients, Surge Transients Possess Much Higher Energy

Figure 2 depicts the energy level of each transient type versus the transient or pulse peak voltage. This clearly presents a surge as the most energetic, and therefore, a lethal transient to the bus pins of RS-485 transceivers. In numbers, for any given pulse-peak voltage, the energy of a surge transient is about 100-times higher than that of an EFT pulse train, and about 10-million times higher than the energy of an ESD pulse.

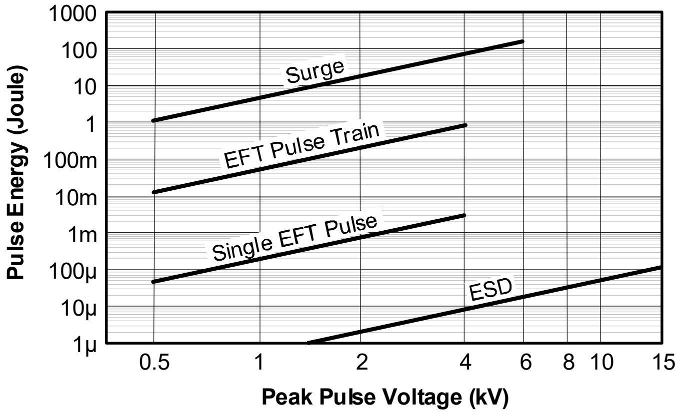

Figure 2. Transient Energies in Comparison

2. Transient Voltage Suppressor Device (TVS)

To protect the bus terminals of an RS-485 transceiver, most often bidirectional transient voltage suppressors (TVS) are applied. While there exists a wide variety of TVS designs, the principle of its operation is best explained on the simplest and most often applied design structure, which uses two back-to-back Zener diodes (Figure 3).

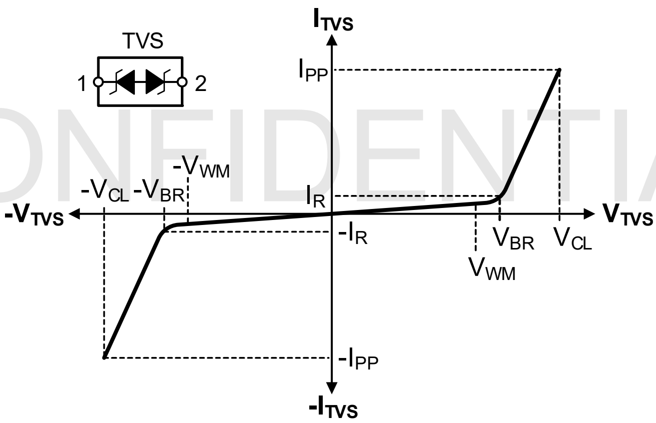

Figure 3. TVS Voltage-Current Characteristic

In a bidirectional TVS, the V-I characteristic is symmetrical. If there is no transient occurring, the TVS can be operated up to the working mode voltage, VWM. In this range, the TVS is high-impedance and only a leakage current of I_{TVS} < 1µA flows through it. During a transient event, however, the TVS starts conducting at the break down voltage, V_{BR} (I_{TVS} = 1mA), before it rapidly becomes low-impedance (R_{TVS} < 0.5Ω). In this state, the TVS absorbs the full transient current up to the peak pulse current, I_{PP}. At this current, the maximum clamping voltage, $V_{CL} = I_{PP} \times R_{TVS}$, is reached. The product of $V_{CL} \times I_{PP}$ is also the rated peak pulse power, P_{PK}, of the TVS.

3. Practical TVS Application

3.1 General Use Case

As a TVS turns low-impedance during a transient event, it must be connected in parallel to the device to be protected (Figure 4). Only then is it possible for the TVS to divert high transient currents to ground.

One important aspect during transient protection design is to ensure that the TVS clamping voltage remains below the standoff-voltage, V_{STO}, of the device to be protected.

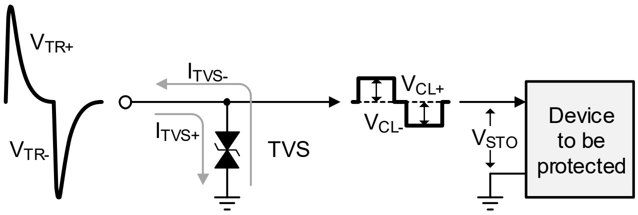

Figure 4. TVS Clamping Action During a Transient Event

3.2 RS-485 Use Case

Protecting the differential bus terminals of RS-485 transceiver requires the protection of each bus terminal against transient voltages referenced to ground (Figure 5). As most TVS devices applied in RS-485 network have a clamp voltage of V_{CL} > 20V, the condition that V_{STO} > V_{CL} requires the use of fault-protected transceivers of the ISL324xxE families, which possess standoff voltage of ±40V and ±60V (Table 1).

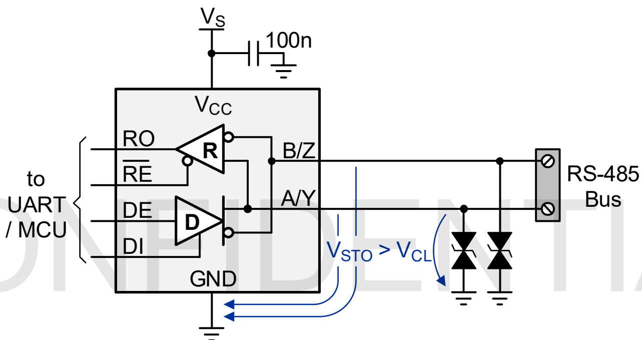

Figure 5. Typical RS-485 Transient Protection

Table 1. Transceivers with High Standoff Voltage that are Ideal for Transient Protection Designs

Part #	Vcc (V)	V_{STO} (V)	CMVR (V)	Hot Plug
ISL3243xE	3 - 5	±40	±15	No
ISL3245xE	3 - 5	±60	±20	No
ISL3247xE	5	±60	±15	Yes
ISL3249xE	5	±60	±25	Yes
Transceivers with Cable Invert Function				
ISL32437E	3 - 5	±40	±15	No
ISL32457E	3 - 5	±60	±20	No
ISL32459E	3 - 5	±60	±20	Yes
ISL3248xE	5	±60	±25	Yes

4. RS-485 Transient Protection Schemes

Figure 6 and Figure 7 show the two transient protection schemes, A and B, with one and two TVS devices respectively. Table 2 lists the scheme-corresponding components and their protection levels.

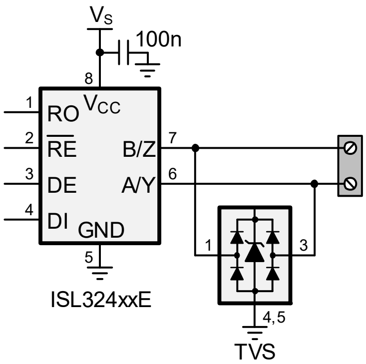

Figure 6. Single TVS Transient Protection (Scheme A)

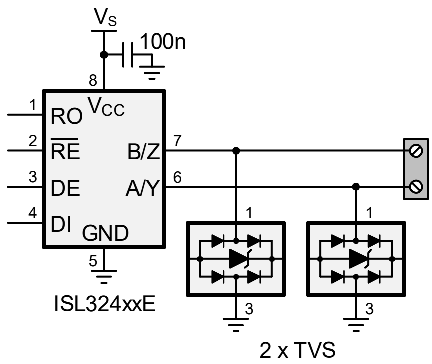

Figure 7. Dual TVS Transient Protection (Scheme B)

Table 2. TVS Devices with Corresponding Protection Levels When Used with Renesas ISL324xxE Transceivers

Protection Scheme	Semtech TVS Part Number	Working Mode Voltage	IEC 61000-4 Protection Levels			Line-Ground Capacitance
			Surge	EFT	ESD (Contact /Air)	
A	1 x TClamp1202P	12V	±3.25kV	±2kV	±15kV / ±20kV	12pF
B	2 x TClamp1202P	±12V	±6.0kV	±2kV	±15kV / ±20kV	6pF
B	2 x TClamp2482S	±24V	±2.25kV	±2kV	±30kV / ±30kV	1.8pF
A	1 x TClamp3602P	±36V	±1.75kV	±2kV	±30kV / ±30kV	2.6pF
B	2 x TClamp3602P	±36V	±3.0kV	±2kV	±25kV / ±30kV	2.3pF

For more detailed information on transient protection, read the application notes listed in References.

5. References

- AN1976: Important Transient Immunity Tests for RS-485 Networks
- AN1977: Transient Voltage Suppressors: Operation and Features
- AN1978: Surge Protection for Renesas' Standard RS-485 Transceivers
- AN1979: Surge Protection Simplified with Renesas' Overvoltage Protected (OVP) Transceivers

6. Revision History

Revision	Date	Description
1.00	Nov 8, 2023	Initial release.

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