AN1978
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Surge Protection for Intersil's Standard RS-485 Transceivers

Introduction

This application note presents various protection methods for Intersil's standard RS-485 transceivers.

AN1977 explained, connecting TVS devices directly to the transceiver bus terminals introduces the risk of damaging the transceiver's ESD structures during a surge event. Adding current limiting components in series with the bus terminals lowers the risk. In doing so, the type and number of components being added depends on the surge protection level required for the application. Refer to AN1976, "Important Transient Immunity Tests for RS-485 Networks" for the assignment of protection levels to specific installation classes.

Level 2 (1kV) Surge Protection

An artifact of standard RS-485 transceivers is their asymmetric stand-off voltages of -9V and +14V, which necessitate the use of bidirectional TVS devices with asymmetric breakdown voltages. The only device satisfying this requirement is the SM712, originally designed by Semtech Corporation in 2004.

The SM712 is a bidirectional TVS with asymmetric breakdown, rated with 400W for an 8/20µs current pulse. Table 1 shows the most relevant device parameters.

TABLE 1. SM712 DEVICE PARAMETERS AT +25°C

PARAMETER	SYMBOL	12V TVS	7V TVS	UNIT
Stand-Off Voltage	V_{WM}	12	7	V
Breakdown Voltage	V_{BR}	13.3	7.5	V
Clamping Voltage at I_{PP}	V_C	26	12	V
Peak Pulse Current	I_{PP}	17		A
Derating Factor (Pulse)	DF	0.8 at +85°C		-
Junction Capacitance	C_J	75		pF

When operating the SM712 at the industrial temperature range maximum of +85°C, its power and hence, peak pulse current capability must be derated. While the datasheet provides a derating factor of DF = 0.5 at +85°C, this factor is mainly applicable for average powers of long pulse durations. For short pulses, such as the 8/20µs pulse however, Semtech provides a much higher factor of DF = 0.8, thus allowing for higher pulse currents at +85°C. The derated test voltage of the surge generator is then calculated via Equation 1:

$$V_{PK} = I_{PP} \bullet DF \bullet 84\Omega = 17A \bullet 0.8 \bullet 84\Omega = 1.14kV \quad \text{(EQ. 1)}$$

This voltage exceeds the IEC61000-4-5, protection Level 2 of 1kV.

To limit the bus currents into the transceiver during a surge event, carbon composite or pulse-proof thick-film resistors should be inserted between the TVSs and the transceiver. Due to their voltage divider action with the bus termination resistors, their value should be 10Ω or less to minimize bus voltage attenuation during normal operation.

Figure 1 shows a Level 2 surge protection example for Intersil's ISL315xE and ISL848xE families of standard transceivers, and Table 2 shows the associated Bill of Materials (BOM).

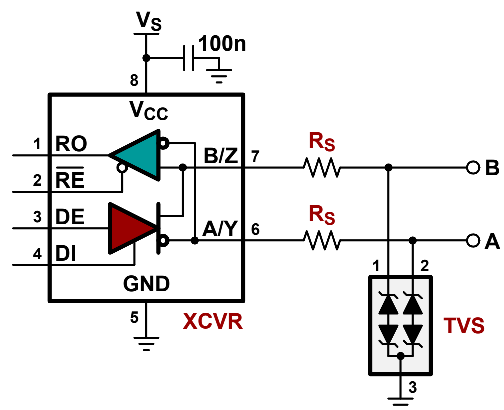

FIGURE 1. IEC61000-4-5, LEVEL 2 (1kV), SURGE PROTECTION

During network planning, the SM712 junction capacitance of 75pF must be considered as it adds an equivalent of seven bus transceivers to each bus node protected. This might require a reduction in bus nodes, or data rate, or both.

TABLE 2. BOM FOR CIRCUIT IN Figure 1

NAME	FUNCTION	PART NUMBER	VENDOR
XCVR	5V, 115KBPS TRANSCEIVER	ISL3152EIBZ	INTERSIL
TVS	400W (8, 20µs), BIDIRECTIONAL TVS	SM712.TCT	SEMTECH
R_S	10Ω, 0.2W, PULSE-PROOF THICK-FILM RESISTOR	CRCW0603-HP e3 SERIES	VISHAY

Level 3 (2kV) Surge Protection

Higher surge protection levels require overcurrent and overvoltage protectors in addition to the TVS. The Overcurrent Protector (OCP) protects the TVS from high currents exceeding the TVS peak pulse current rating, while the Overvoltage Protector (OVP) protects the OCP against high transient voltages that are above its withstand voltage. Figure 2 on page 2 depicts the principle of a higher level surge protection scheme.

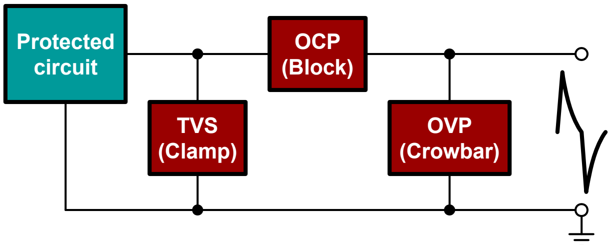

FIGURE 2. HIGH-LEVEL SURGE PROTECTION WITH OVERCURRENT AND OVERVOLTAGE PROTECTORS

The Overcurrent Protector (OCP)

The overcurrent protector consists of a current limiter and an electronic output switch, with predefined levels for trigger current and reset voltage. Its switching characteristic is shown in Figure 3.

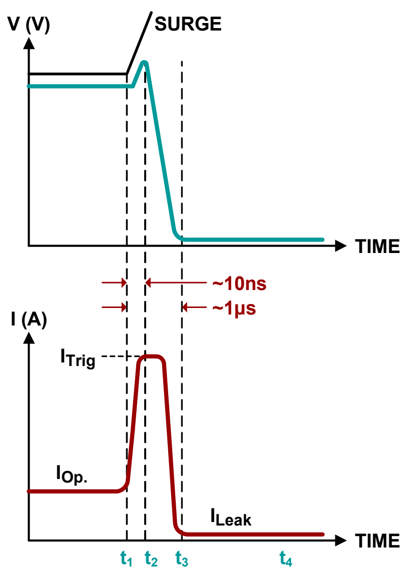

FIGURE 3. OCP SWITCHING CHARACTERISTIC

During normal operation, the device is in the off-state presenting a low resistance to the signal path. When a surge occurs (t_1), the current through the OCP increases up to the trigger level, I_{TRIG}, (t_2). At that point the current limiter activates the internal switch, changing the device resistance from low-impedance to high-impedance. Within 1µs the OCP current drops to less than 1mA (t_3). The device is now in the on-state and remains there for the duration of the transient (t_4). When the transient recedes and the voltage across the OCP drops below the reset threshold, the device returns to the off-state, allowing for normal system operation to proceed.

To match the dynamic characteristic of the OCP with the ones of the TVS and the transceiver, the Bourns overcurrent protector, aka transient blocking unit, TBU-CA065-200-WH was selected for the protection circuit in Figure 5 on page 3. This device provides minimum and maximum current trigger levels of 200mA and 400mA respectively. The 200mA level is well above the maximum line current during normal operation, and the 400mA threshold is low enough to prevent excessive joule heating within the TVS and transceiver ESD structures during a surge event. The device also has an off-state resistance of less than 10Ω, which attenuates the bus voltage by less than 10%.

The Overvoltage Protector (OVP)

The overvoltage protector is a crowbar device that short-circuits the signal line to ground, thus diverting the majority of the transient energy away from the overcurrent protector. Crowbar devices have a snap-back characteristic, allowing them to conduct huge currents at low voltage drops across the device. This characteristic is utilized in two different technologies: gas discharge tubes and solid-state Thyristor Surge Protection Devices (TSPDs).

The protection scheme in Figure 5 uses the Bourns TSPD TISP4240M3BJR-S as overvoltage protector. Its V-I characteristic is shown in Figure 4.

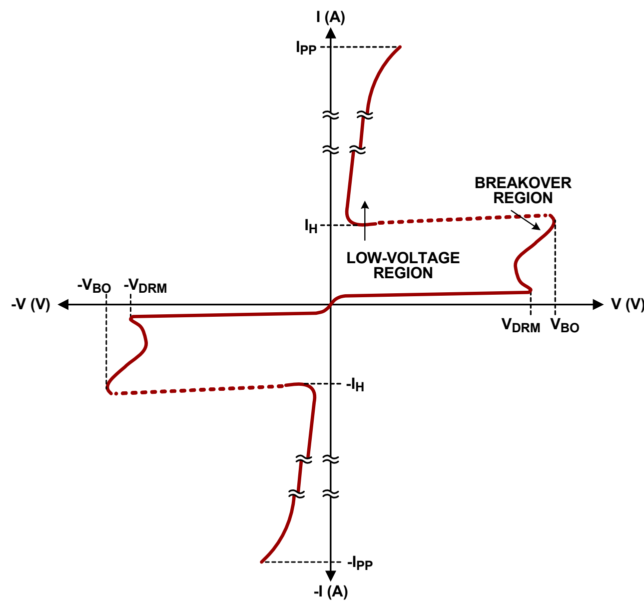

FIGURE 4. V-I CHARACTERISTIC OF THE THYRISTOR SURGE PROTECTION DEVICE

Here, V_{DRM} is the maximum working voltage up to which the TSPD remains in high-impedance (off-state). Above this voltage the device enters the breakover region. When a surge exceeds the breakover voltage, V_{BO}, the device turns on and transitions into the low-voltage region, where it conducts high currents. The TSPD returns to the off-state when the transient current drops below the holding current, I_H.

Unlike TVS devices, whose response time is in the sub-nano seconds range, TSPDs require time to transition from the breakover to the low-voltage region. During this time the overcurrent protector shields the downstream circuitry (TVS and transceiver) from the high currents resulting from the high V_{BO}.

Figure 5 shows the circuit of a Level 3 (2kV) surge protection scheme and Table 3 lists the associated BOM.

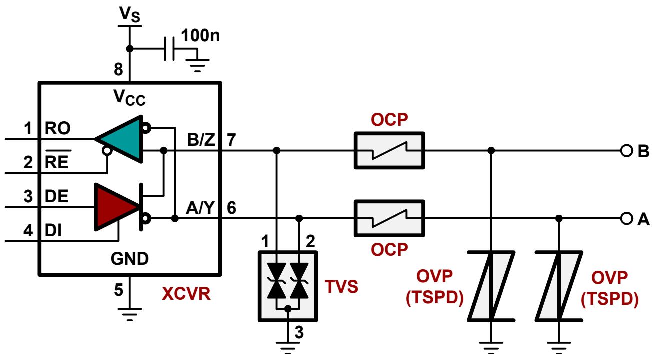

FIGURE 5. IEC61000-4-5, LEVEL 3 (2kV), SURGE PROTECTION

TABLE 3. BOM FOR CIRCUIT IN Figure 5

NAME	FUNCTION	ORDER NO.	VENDOR
XCVR	5V, 115KBPS TRANSCEIVER	ISL3152EIBZ	INTERSIL
TVS	400W (8, 20µs), BIDIRECTIONAL TVS	SM712.TCT	SEMTECH
OCP	200mA TRANSIENT BLOCKING UNIT	TBU-CA065-200-WH	BOURNS
OVP	220A THYRISTOR	TISP4240M3BJR-S	BOURNS

Level 4 (4kV) Surge Protection

While industrial applications rarely demand surge protection above Level 3, communication lines between buildings will benefit from higher protection levels.

The circuit in Figure 7 therefore shows the protection scheme for surge Level 4 (4kV) protection. This circuit is almost identical to the one in Figure 5 with the exception that the thyristor protection devices, rated for 220A, have been replaced by a gas discharge tube, 2038-15-SM-RPLF, rated for 5kA. GDTs typically provide protection to higher overvoltage and overcurrent stress than TSPDs.

Figure 6 shows the switching characteristic of a GDT. When a transient voltage reaches the impulse spark-over voltage, the GDT transitions from the off-state (high impedance) to Arc mode (virtual short). In this mode, the GDT provides a crowbar current path to ground, thus diverting the transient current away from the protected device.

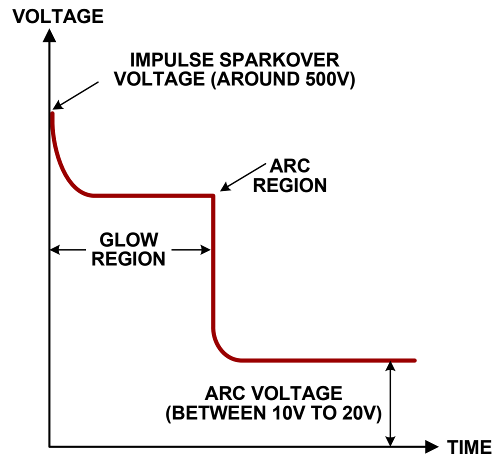

FIGURE 6. GDT SWITCHING CHARACTERISTIC

With increasing voltage across the GDT, the gas in the tube starts ionizing due to the charge developed across it. In this region, known as the glow region, the increasing current flow generates an avalanche effect, transitioning the GDT into a virtual short. During the short-circuit event, the voltage developed across the device is known as the arc voltage. The transition time between the glow and arc region is dependent on the physical characteristics of the GDT.

Figure 7 shows the protection scheme for a Level 4 (4kV) surge protection and Table 4 lists the associated BOM.

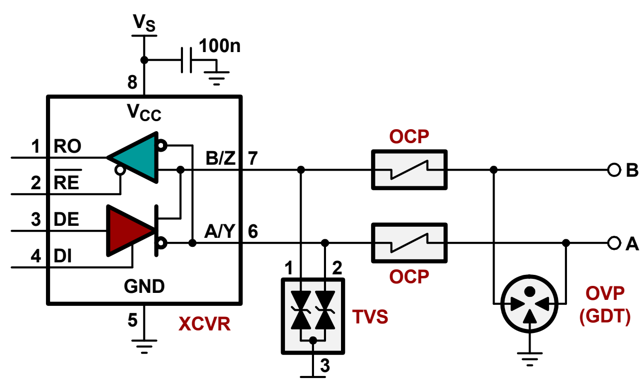

FIGURE 7. IEC61000-4-5, LEVEL 4 (4kV), SURGE PROTECTION

TABLE 4. BOM FOR CIRCUIT IN Figure 7

NAME	FUNCTION	ORDER NO.	VENDOR
XCVR	5V, 115KBPS TRANSCEIVER	ISL3152EIBZ	INTERSIL
TVS	400W (8, 20µs), BIDIRECTIONAL TVS	SM712.TCT	SEMTECH
OCP	200mA TRANSIENT BLOCKING UNIT	TBU-CA065-200-WH	BOURNS
OVP	5kA GAS DISCHARGE TUBE	2038-15-SM-RPLF	BOURNS

Summary

The circuits presented in this application note, provide solid protection against low and high level transients. High-level protection schemes however, have a high component count, thus leading to increased design cost and board space. Table 5 provides a comparison between protection circuits.

TABLE 5. COMPARISON OF PROTECTION SCHEMES

PROTECTION LEVEL	COMPONENT COUNT	BOARD AREA (mm^2)	SOLUTION COST AT 1ku ($)
1 (500V)	3	8.5	0.37
3 (2kV)	5	91	2.77
4 (4kV)	4	97	3.00

Simpler circuit designs, protecting against surge transients and DC faults, over standard and wide common-mode voltage ranges, can be accomplished using overvoltage protected transceivers. This is discussed in AN1979, "Lightning Protection Simplified with Intersil's Overvoltage Protected (OVP) Transceivers".

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