Surge Protection Solutions for the ADM3055E/ADM3057E CAN FD Transceiver

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INTRODUCTION

Controller area network with flexible data rate (CAN FD) is a 2-wire differential serial communication protocol that enables a network of microcontrollers and other devices to communicate without a dedicated host controller. Each node in the network requires a CAN FD transceiver to convert between the local single-ended signals used by microcontrollers and the differential signals required for robust off-board communication.

The conversion function requires the CAN FD transceiver to be physically inserted between sensitive electronics and the outside world. In industrial and instrumentation applications, large transient voltages caused by mishandling, electrically noisy operating environments, and even lightning strikes can be significant stresses causing damage to communication ports and underlying electronics. The signal and power isolated ADM3055E/ADM3057E CAN FD transceiver is a device that can withstand many of these transient voltages and protect sensitive electronics.

Transient voltages are categorized as electrostatic discharges (ESD), electrical fast transients (EFT), and surges under the applicable IEC standards and rated by level based on the magnitude of the transient. Level 4 IEC 61000-4-2 ESD protection, IEC 61000-4-4 EFT immunity, and Level 4+ cross barrier IEC 61000-4-5 surge protection is achieved by the on-chip integrated protections of the ADM3055E/ADM3057E isolated signal and power CAN FD transceivers.

While cross-barrier surges are absorbed across the *i*Coupler® isolation barrier, surges returning through the bus side ground dissipate a substantial amount of power across the transceiver unless diverted. This application note discusses characterized solutions for IEC 61000-4-5 surge protection on the ADM3055E/ADM3057E transceiver CAN FD ports. Design options have been characterized depending upon the level of surge protection required, the common-mode range requirements, and available PCB area.

Component testing for this application note was performed with the ADM3055E/ADM3057E. Other devices such as the ADM3050E, ADM3056E, and ADM3058E share the same transceiver die, and the information covered in this application note is generally applicable to these devices also.

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REVISION HISTORY

3/2022—Revision 0: Initial Version

OVERVIEW

CAN FD STANDARD

The controller area network with flexible data rate (CAN FD) is a standard for distributed communications with built-in fault handling, specified for the physical and data link layers of the open systems interconnection (OSI) model in ISO-118981-2:2016. CAN FD, while developed originally for automotive applications, has been widely adopted in industrial and instrumentation applications due to the inherent strengths of the communication mechanisms used by CAN FD.

The ADM3055E/ADM3057E isolated signal and power transceiver has an extended common-mode range of ±25V. The common-mode range exceeds the requirements of ISO 11898-2:2016 and offers reliable communication even when large ground offsets between network nodes are present. The isolated transceiver also greatly exceeds the timing requirements of ISO 11898-2:2016 in full speed mode. The low loop delays enable the designer to dedicate a greater portion of each bit to settling time. The extended common-mode range and timing specifications enable more robust communication over longer distances for industrial applications.

More information on CAN FD can be found in AN-1123.

ADM3055E/ADM3057E CAN FD TRANSCEIVER

In field installations, direct contact, wire damage, inductive switching, power source fluctuations, arcing, and even nearby lightning strikes, all have the potential to cause damage to networks. Designers must ensure that equipment not only operates in ideal conditions, but also operates reliably in adverse real-world environments. In order to ensure that these designs can survive in electrically harsh environments, various government agencies and regulatory bodies have imposed EMC regulations. Compliance with these regulations assures the end user that designs operate as desired in these harsh electromagnetic environments.

The isolated signal and power ADM3055E/ADM3057E CAN FD transceiver is a CAN FD physical layer transceiver. The device employs Analog Devices, Inc., *i*Coupler technology to combine a 3-channel isolator, a CAN FD transceiver, and Analog Devices *iso*Power® isolated dc-to-dc converter into a single, surface-mount, small outline integrated circuit (SOIC_IC) package.

EFT and ESD transients have similar energy levels, and protecting against ESD and EFT on the ADM3055E/ADM3057E is accomplished with the on-chip protection structures. The surge waveform has much higher energy levels, and the surge transient voltage can be applied either across the isolation barrier or across the transceiver die. The integrated *i*Coupler isolation barrier technology provides reinforced protection for surge transients occurring across the barrier. The integrated protection levels are provided in Table 1. Protecting the transceiver against high levels of surge requires external protection devices, which are discussed in this application note.

Table 1. ESD and EFT Protection Levels of the ADM3055E/ADM3057E

EMC Specification	Protection Level
IEC 61000-4-2 ESD	
Contact	±8 kV, Level 4
Air	±15 kV, Level 4
IEC 61000-4-4 EFT	±2 kV, Level 4
Cross Barrier IEC 61000-4-5 Surge	±6 kV, Level 4+, V_{IOSM} reinforced

SURGE IMMUNITY TEST

Surge transients are caused by overvoltages from switching or lightning transients. Switching transients can result from power system switching, load changes in power distribution systems, or various system faults, such as short circuits and arcing faults to the grounding system of the installation. Lightning transients can result from high currents and voltages injected into the circuit from nearby lightning strikes. IEC 61000-4-5 defines the waveform, test methods, and test levels for evaluating the immunity of electrical and electronic equipment when subjected to these surges.

Figure 1 shows the 1.2 μs/50 μs surge transient waveform. The waveforms are specified as the outputs of a waveform generator in terms of open-circuit voltage and short-circuit current. Surge transients are considered the most severe of the EMC transients as its energy levels are three to four orders of magnitude larger than the energy in an ESD or EFT pulse. Therefore, external protection devices are often required to improve the high surge immunity level due to its high energy.

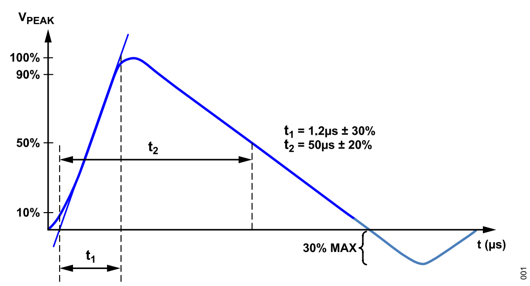

Figure 1. IEC 61000-4-5 Surge 1.2 μs/50 μs Waveform

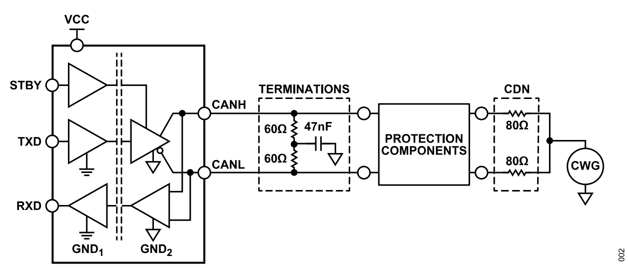

Figure 2. Surge Coupling Network for CAN FD Transceiver

Figure 2 shows the coupling network for the CAN ports used for surge testing in this application note. The total parallel sum of the resistance is 40 Ω. For the half-duplex device, each resistor is 80 Ω. Note that the termination network for high speed CAN bus is also included during the surge testing.

During the surge test, 10 positive and 10 negative pulses are applied to the data ports with a maximum time interval of ten seconds between each pulse. The device is set up in three conditions, that is, unpowered mode, normal operating mode, and standby mode for the duration of the test. Leakages on the CANH and CANL pins are checked prior to and post application of the surge pulses stress while the switching signals and I_{CC} currents are also monitored before, during, and after the test. Surge testing is carried out to ensure performance Criteria B as described by the IEC 61000-4-5 standard. Criteria B allows a temporary loss of function or temporary degradation of performance but self recovery must occur without operator intervention.

SURGE TRANSIENT PROTECTION SOLUTIONS FOR CAN FD

EMC transient events vary in time. Careful design, characterization, and an understanding of the dynamic performance of the input/output stage of both the protected device and the protection components is required to ensure that the circuit meets EMC standards. Component data sheets generally only contain dc data, which is of limited value given that the dynamic breakdowns and I/V characteristics can be quite different from the dc values.

This application note presents five different fully characterized surge solutions. Each solution provides different cost/protection levels for the Analog Devices ADM3055E/ADM3057E CAN FD transceivers with enhanced surge protection using a selection of external circuit protection components. The two types of external circuit protection components used consist of transient voltage suppressors (SM712-02HTG, CDNBS08-T24C, and TCLAMP1202P) and thyristor surge protectors (TISP7038L1 and TISP4P035L1N).

TVS PROTECTION DEVICE OPTION

The first solution uses different transient voltage suppressor (TVS) arrays. A typical TVS array consisting of two bidirectional TVS diodes is illustrated in Figure 3. Table 2, which shows details on voltage levels protected against surge transients, common-mode voltages, and the PCB footprint of the package.

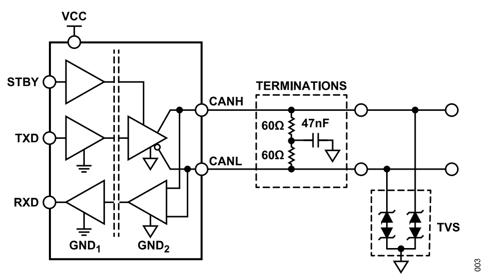

Figure 3. TVS Protection Scheme

A TVS is a silicon-based device. Under normal operating conditions, the TVS has high impedance to ground; ideally, it is an open circuit. The protection is accomplished by clamping the overvoltage from a transient to a voltage limit. This is done by the low impedance avalanche breakdown of a PN junction. When a transient voltage larger than the breakdown voltage of the TVS is generated, the TVS clamps the transient to a predetermined level that is less than the breakdown voltage of the devices that it is protecting. The transients are clamped instantaneously (< 1 ns) and the transient current is diverted away from the protected device to ground.

The I/V characteristic for a typical bidirectional TVS is demonstrated in Figure 4. V_{RWM} of the TVS must match the common-mode voltage of the CAN FD ports. It is also important to ensure that the breakdown voltage V_{BR} is outside the normal operating range of the pins protected. Lower R_{DYN} and V_{CLAMP} at I_{PP} are often preferred to shunt majority surge current to ground and clamp the voltage below the failure voltage of the pin.

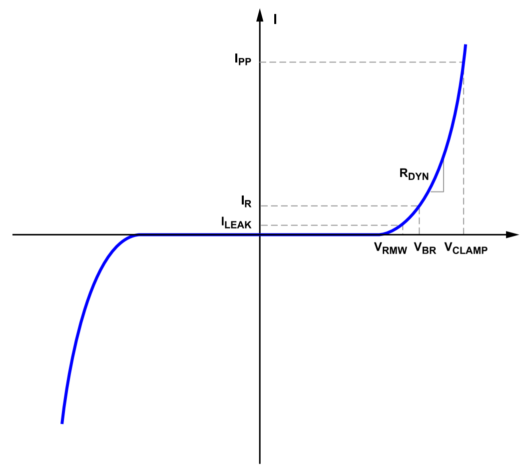

Figure 4. Typical Bidirectional TVS I/V Characteristic

Table 2. TVS Protection Options

Device Name	V_{RWM} (V)	No. of Units[1]	Footprint Area[2] (mm^2)	Height[2] (mm)	IEC 61000-4-5 Surge	
					Voltage (kV)	Level
SM712-02HTG	+12/−7	1	8.23	1.12	±1	2
CDNBS08-T24C	±24	1	31.68	1.75	±1	2
TCLAMP1202P	±12	2	8.82	0.60	±4	4

1 Number of protection devices required for a CANH/CANL port pair.

2 Values are from the device data sheet.

TISP PROTECTION DEVICE OPTION

Another type of surge protection device is a snapback device, for example, the total integrated surge protector (TISP). Two Bourns TISPs are investigated as the external surge protection devices illustrated in Figure 5. These devices provide more options with different common-mode voltage ranges and cost/surge performance levels given in Table 3.

The nonlinear voltage-current characteristic of the TISP limits overvoltage by diverting the resultant current. As a thyristor, a TISP has a discontinuous voltage-current characteristic caused by the switching action between high and low voltage regions. Figure 6 shows the voltage-current characteristic of the device. Before the TISP device switches into a low voltage state, with low impedance to ground to shunt the transient energy, a clamping action is caused by the avalanche breakdown region.

In limiting an overvoltage, the protected circuitry is exposed to a high voltage for the brief time period that the TISP device is in the breakdown region, before it switches into a low voltage protected on-state. When the diverted current falls below a critical value, the TISP device automatically resets allowing normal system operation to resume.

Regarding the selection of this type of device, a few points need to be considered. First, the breakdown voltage of TISP must be higher than the common-mode voltage of the port. Besides, TISP often provides a high I_{PP} due to its excellent power density efficiency. However, the voltage overshoot at the rising edge of the pulse may be quite high and may damage the port under test, which normally is a limiting factor of the surge protection level. Nevertheless, the low holding voltage of TISP may cause some latch-up issues during IEC ESD testing. The TISP solutions listed here have been tested against the IEC 61000-4-2 ESD to eliminate this concern.

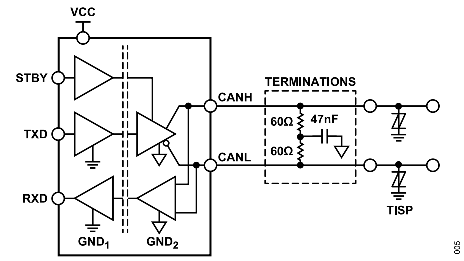

Figure 5. TISP Protection Scheme

Table 3. TISP Protection Options

Device Name	V_{RWM} (V)	No. of Units[1]	Footprint Area[2] (mm^2)	Height[2] (mm)	IEC 61000-4-5 Surge	
					Voltage (kV)	Level
TISP7038L1	±28	1	32.63	1.75	±1	2
TISP4P035L1N	±24	2	18.72	1.35	±2	3

1 Number of protection devices required for a CANH/CANL port pair.

2 Values are from the device data sheet.

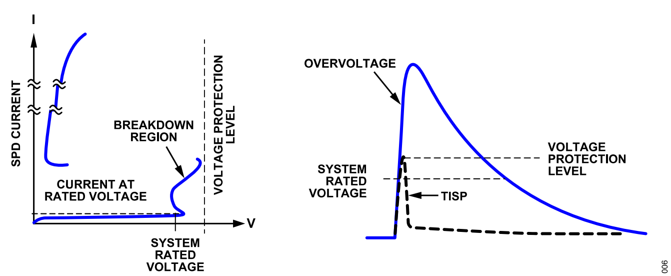

Figure 6. TISP Switching Characteristic and Voltage Limiting Waveshape

CONCLUSION

The key challenge in designing EMC compliant solutions for CAN FD networks is matching the dynamic performance of the external protection components with the dynamic performance of the input/output structure of the CAN FD transceiver. This application note describes five surge protection solutions for the ADM3055E/ADM3057E isolated signal and power CAN FD transceivers, giving the designer options depending on the level of protection, common-mode range, and cost requirements. These protection device options are summarized in Table 4.

Although these design tools do not replace the due diligence or qualification required at the system level, they allow the designer to reduce risk due to EMC problems at the start of the design cycle, avoiding known pitfalls, and reducing overall design time.

Table 4. Surge Protection Solutions for Different System Requirements IEC 61000-4-5 Surge Levels

Device Name	V_{RWM} (V)	No. of Units[1]	Footprint Area[2] (mm^2)	Height[2] (mm)	IEC 61000-4-5 Surge Voltage (kV)	IEC 61000-4-5 Surge Level
SM712-02HTG	+12/−7	1	8.23	1.12	±1	2
CDNBS08-T24C	±24	1	31.68	1.75	±1	2
TISP7038L1	±28	1	32.63	1.75	±1	2
TISP4P035L1N	±24	2	18.72	1.35	±2	3
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[1] Number of protection devices required for a CANH/CANL port pair.

[2] Values are from the device data sheet.

REFERENCES

More information regarding interface and isolation products is listed in this section (also see the Analog Devices website).

Electromagnetic Compatibility (EMC) Part 4-5: Testing and Measurement Techniques—Surge Immunity Test (IEC 61000-4-5:2005 (Edition 2.0)).

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