Application Note

Protecting Automotive Can Bus Systems from ESD Overvoltage Events

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ABSTRACT

Controller Area Network (CAN) is a communication protocol that is widely used in many automotive applications. Like any other interface with exposed connectors, CAN interfaces are subject to high voltage transient events such as electrostatic discharge (ESD). Placing an ESD protection diode on the CAN bus connector will not only protect the CAN transceiver, but it will also protect all downstream and neighboring systems from coupled ESD energy. To ensure robust system-level protection, it is important to understand the basic operating conditions of the CAN bus and how to select a proper ESD protection diode for the CAN bus.

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Trademarks

1 CAN Bus Overview

CAN is a 2-wire differential communications interface which has its physical layer defined by the ISO 11898-2 standard. The physical layer consists of the CAN transceiver and the twisted pair cabling that connects all the CAN nodes together. The two lines connecting the CAN transceiver to the cabling are referred to as CANH and CANL. It is also recommended to terminate the CANH and CANL lines with a split termination to avoid signal reflections and high frequency noise. Figure 1-1 illustrates the typical CAN bus setup.

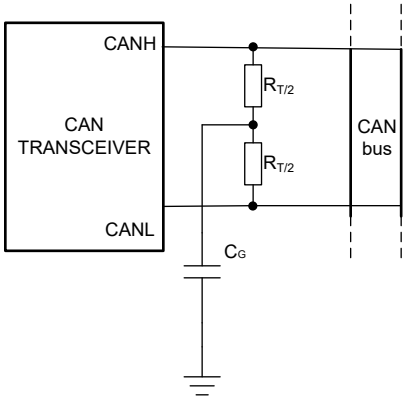

Figure 1-1. CAN Bus Typical Setup

The CAN protocol can come in many different flavors and speeds. These flavors include:

- Low speed (LS CAN): Up to 125 kbps
- High speed (HS CAN): Up to 1 Mbps
- Flexible data rate (CAN FD): Up to 5 Mbps
- Signal Improved capable CAN (CAN SIC): Up to 8 Mbps
- CAN XL: Up to 10-20 Mbps (not yet released)

2 Causes of ESD

ESD can happen to any system with exposed connectors, including CAN bus interfaces. Typically, these connectors are exposed during vehicle assembly and maintenance. For example, when a car is going through assembly, the cabling needed to connect the control modules in the car can accumulate an excess amount of charge on them as they move through the factory. When it comes time to connect these cables to the control modules that hold the CAN transceivers, the excess charge will flow from the cable to the module and into the CAN transceiver. Depending on the environmental conditions in the factory and how the cabling is handled, these discharges can get up to 30 kV and permanently damage the CAN transceivers, making the vehicle inoperable. This can also happen if a mechanic is performing maintenance on a car and has to disconnect and reconnect this cabling. In short, any time the cabling is manipulated in the system, there is a chance for ESD to occur.

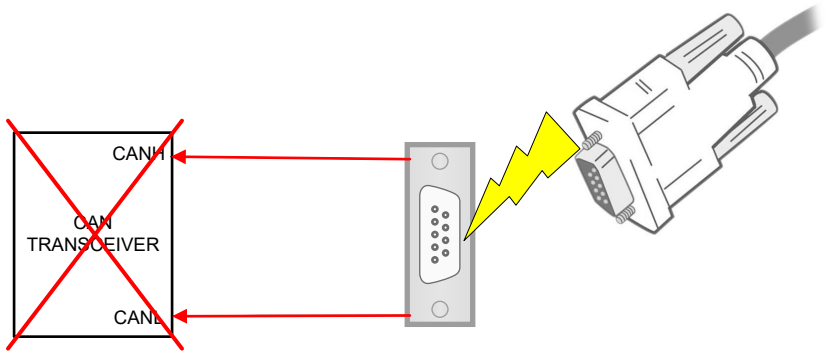

Figure 2-1. CAN Bus ESD Event

3 ESD Protection Requirements

Many CAN transceivers have built-in ESD protection cells, but to keep the size of the chip down, most of them only protect up to 8 kV. As it was previously mentioned, depending on the environment, some ESD strikes can get up to 30 kV. Due to this, an external ESD protection diode is needed to increase the system-level ESD performance. Below are the key considerations and parameters needed to select a proper ESD protection diode:

- Working Voltage (Vrwm) and Polarity
  - The Vrwm of the diode is dependent on the application they will be used in. Under ideal conditions, the CAN bus voltage levels swing between Vcc (5 V or 3.3 V) on CANH and 0 V on CANL. However, in vehicles, there is a common mode voltage present depending on the battery voltage. Smaller vehicles will use 12 V batteries and larger vehicles like 18-wheelers will use 24 V batteries. In addition to this common-mode voltage, there is also the risk of an improper jumpstart if the vehicle's battery is almost dead. The proper way to jumpstart a vehicle is to connect a battery of another car in parallel with the dead battery. A person that does not know this might connect both batteries in series, doubling the overall voltage of the car. In the case of a 12 V battery, a 24 V ESD diode is needed to ensure that it does not burn up in this series jumpstart scenario. In the case of a 24 V battery that consists of two 12 V cells, a 36 V diode is needed since the cells are charged individually. All diodes need to be bidirectional to account for line faults and miswiring.
- IEC 61000-4-2 Rating
  - The IEC 61000-4-2 standard defines a waveform that simulates a real-world ESD strike, contrary to waveforms like human body model (HBM) and charged device model (CDM) that simulate ESD events in a controlled environment. Since certain environmental elements such as humidity and temperature make ESD strikes more strenuous, it is recommended that the ESD diode has a minimum contact rating of 15 kV.
- ISO 10605 Rating
  - The ISO 10605 standard defines a waveform that simulates a real-world ESD strike in an automotive environment. This waveform defines many different capacitance and resistance combinations, contrary to IEC 61000-4-2 that only calls for 150 pF/330 Ω. The most strenuous of these combinations is the 330 pF/330 Ω, which is more strenuous than an IEC 61000-4-2 waveform. To survive ESD strikes in harsh automotive environments, it is recommended that the ESD diode has a minimum contact rating of 15 kV.
- Capacitance
  - An ESD diode should have a low capacitance to minimize signal degradation. The maximum allowable diode capacitance can vary between signal speeds (LS CAN vs CAN FD), transceiver capacitance, network size, and other components on the CANH and CANL lines like filtering capacitors. Generally, it is recommended to keep the diode capacitance below 15 pF. However, system architects look for diodes with the lowest possible capacitance to maximize their total capacitance budget for the system.
- Clamping Voltage
  - Clamping voltage requirements can vary depending on the CAN transceiver being used. The important thing to note is that the clamping voltage should be less than the abs max rating of the CANH and CANL pins.
- Package
  - For CAN applications, many systems require automatic optical inspection for their boards to confirm that all components are soldered on properly. To allow for this, leaded packages like SOT-23 and SC70 are recommended for ESD diodes.

4 System Level Solutions

TI offers an array of ESD diodes know as the ESD2CANxx devices to protect all different types of CAN transceivers in many different environments. They come in leaded, dual-channel packages with matched capacitance designed specifically for CAN bus ESD protection.

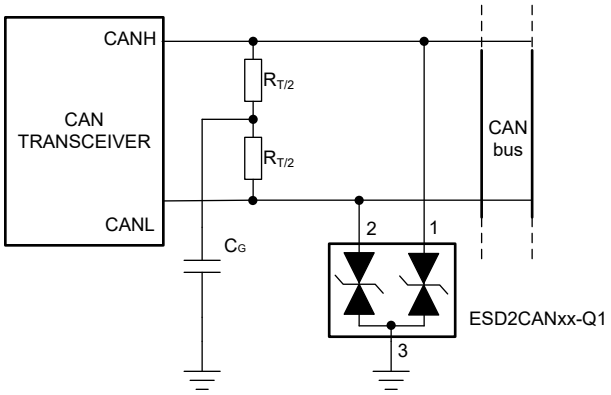

Figure 4-1. Protected CAN Transceiver

Here, ESD2CAN24-Q1 was paired with a TCAN1042V-Q1 CAN transceiver to demonstrate how it provides system-level ESD immunity in a 12 V automotive environment. Two boards were used for this experiment: one board with just the TCAN1042V-Q1 and the other board with both the ESD2CAN24-Q1 and the TCAN1042V-Q1.

To measure signal integrity, both boards were powered to 5 V and a 500 kHz (1Mbps) digital signal was forced on the TXD pins to simulate a HS CAN environment. An oscilloscope was connected to the CANH (line 1), CANL (line2), TXD (line 3), and RXD (line 4) to observe the results. As the results in Figure 4-2 and Figure 4-3 show, the ESD2CAN24-Q1 diode does not degrade the CANH and CANL signals at all.

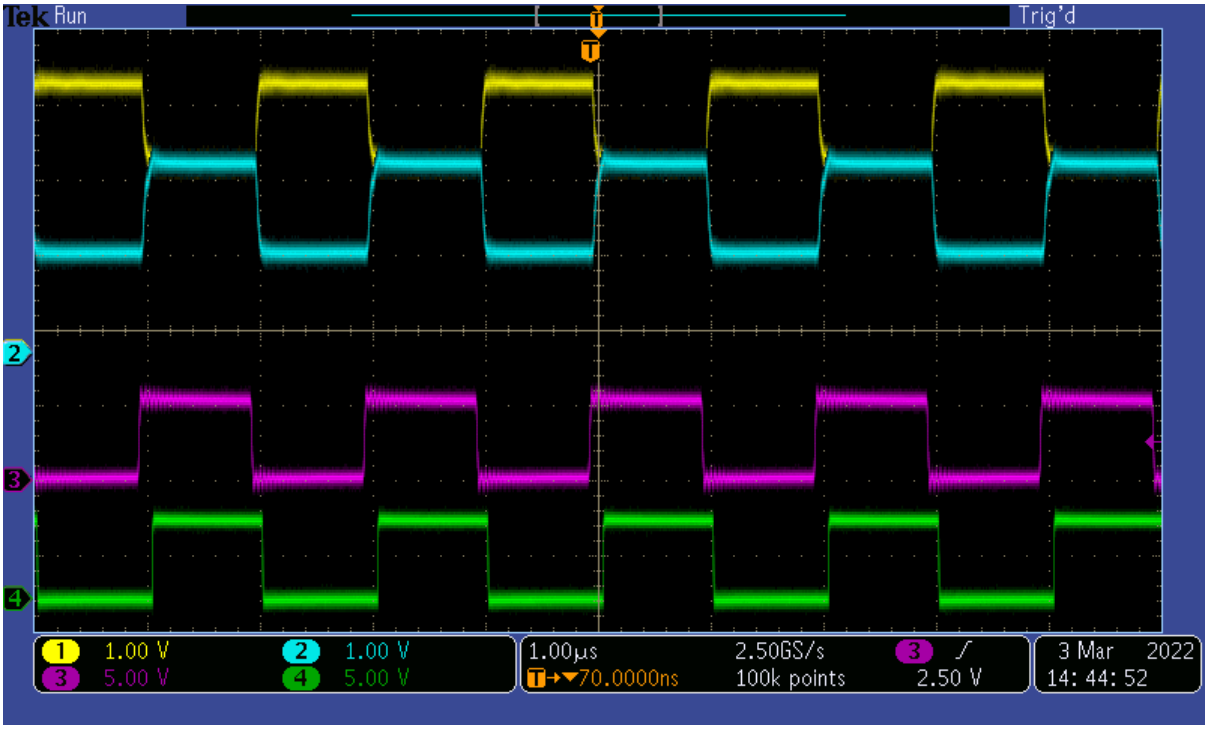

Figure 4-2. No Diode

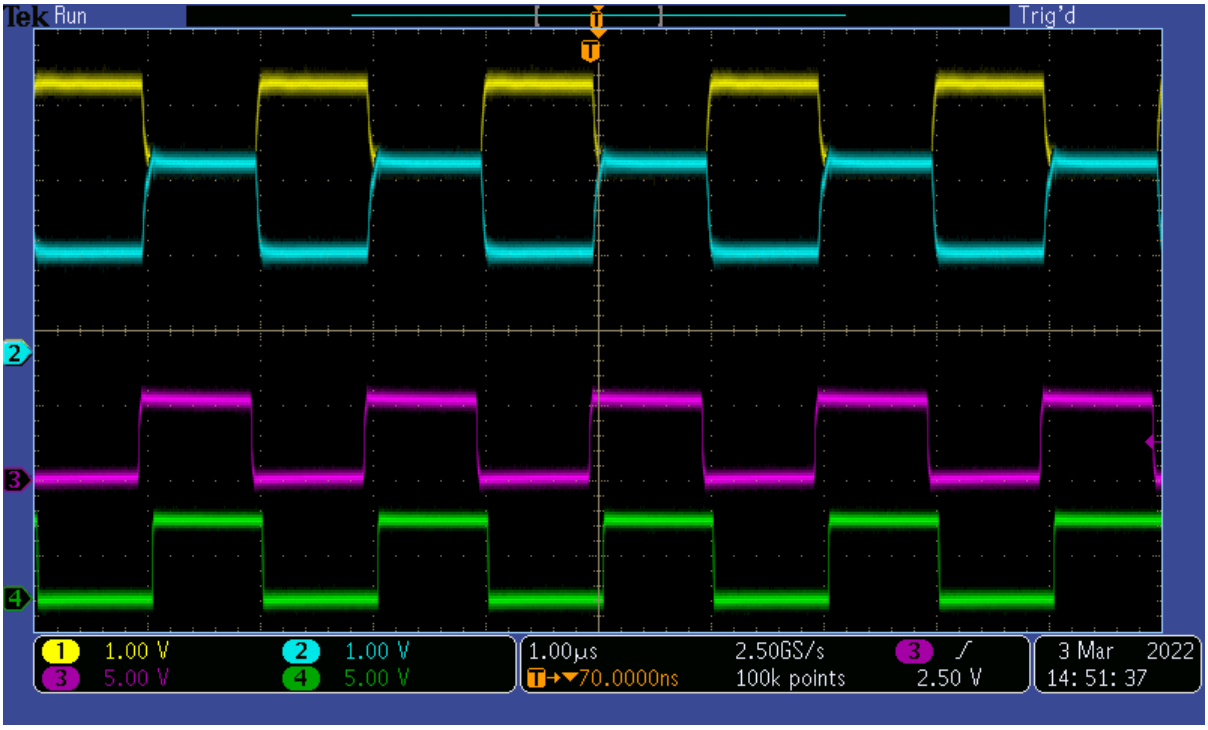

Figure 4-3. With ESD2CAN24-Q1

To measure system-level ESD immunity, the CANH and CANL pins of both boards were struck with +/-30 kV ISO 10605 contact pulses. Since TCAN1042V-Q1 is only rated to withstand 8 kV ISO 10605 pulses, the system without a diode failed. The system with ESD2CAN24-Q1 survived since the ESD2CAN24-Q1 clamped the pulse to a low enough voltage for the transceiver to handle.

5 Summary

The CAN bus is an interface that requires a very robust ESD protection solution to survive in automotive environments. Selecting the proper protection diode is an integral part of ensuring that the system is not only protected from high voltage transients, but also minimizes capacitance to allow for uninhibited signal transmission. TI's ESD2CANxx devices have high ESD ratings and low capacitances to provide superior ESD protection for CAN bus interfaces. For device suggestions, see Table 5-1.

Table 5-1. Device Suggestions

Device	Vrwm	IEC 61000-4-2/ ISO 10605 Rating (contact)	Capacitance	Package	Supported Protocols
ESD2CAN24-Q1	±24 V	30 kV/30 kV	3 pF	SOT-23, SC70	LS CAN, HS CAN, CAN FD, CAN SIC

6 References

- Texas Instruments: *ESD Packaging and Layout Guide*
- Texas Instruments: *Introduction to Controller Area Network*

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