APPLICATION NOTE

Diotec Semiconductor

ESD protection for CAN bus

1. Introduction

The ever-increasing demand for ESD protection in today's fast-growing mobile device market has led Diotec to focus on providing circuit protection solutions.

Whether the end application is portable electronics, a USB device or a CAN bus in the automotive industry, Diotec's portfolio of overvoltage protection products provides a solution for all applications.

2. Evolution of the vehicle network

Yesterday

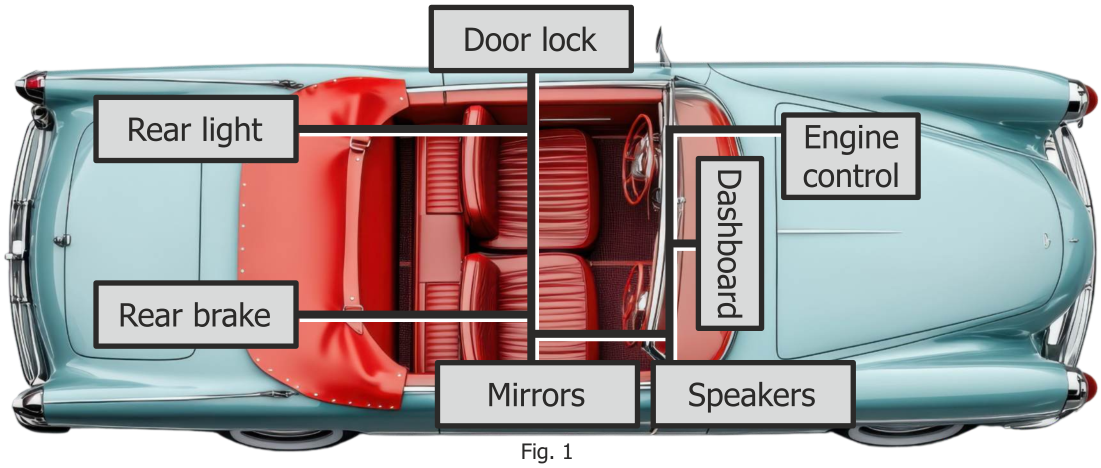


Fig. 1

Today

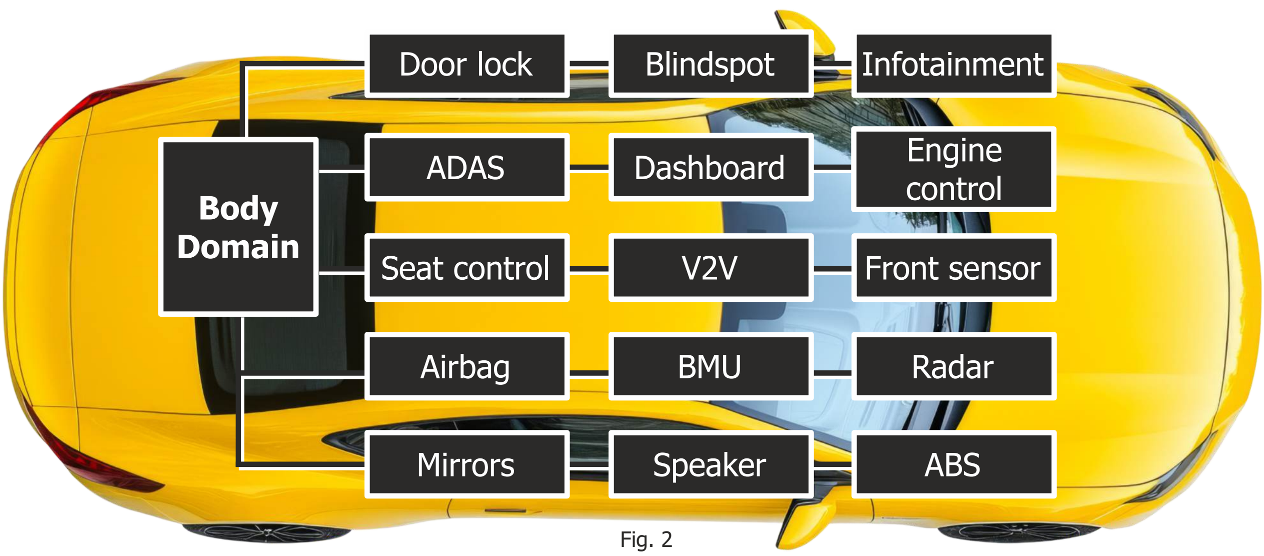


Fig. 2

3. In-vehicle network

In-vehicle networking technologies are essential for enabling faster, safer and more secure communication - both for today's vehicles and the connected, autonomous vehicles of the future. Common in-vehicle network protocols include LIN, CAN and FlexRay, alongside high-speed Ethernet standards such as 100BASE-T1 and 1000BASE-T2.

As vehicles become more complex, with higher computational power, IC miniaturization and varying power requirements in increasingly compact spaces, electronic components and systems are becoming more susceptible to electrostatic discharge (ESD).
As illustrated here, ESD immunity tends to decrease with increasing data transmission speeds. Higher

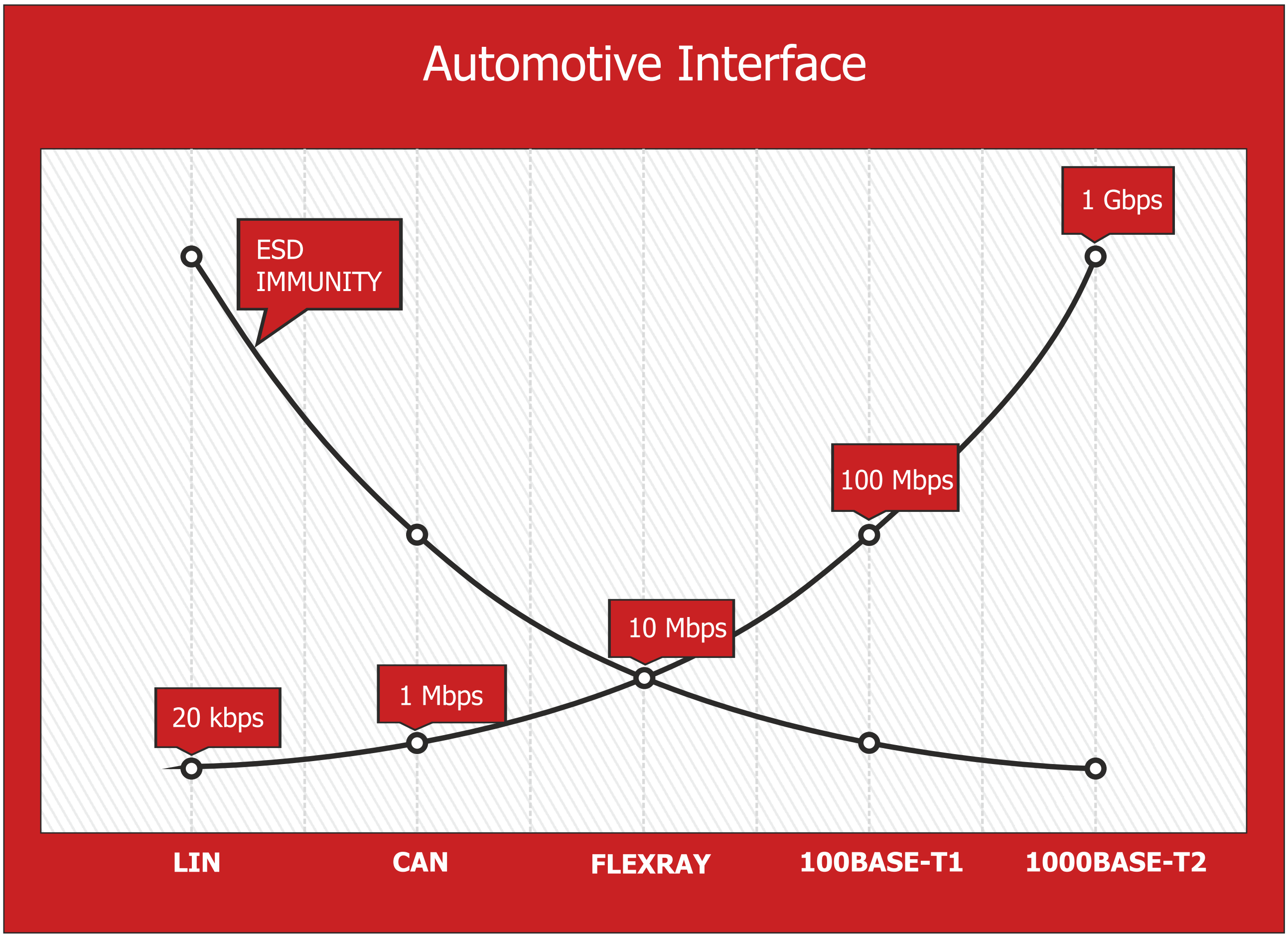


Fig. 3

transmission rates are associated with lower line capacitance, which implies smaller semiconductor structures - making them more vulnerable to ESD, as even lower voltages can damage thinner gate oxides.
The good news is that ESD or Electrical Overstress (EOS) damage can be significantly reduced - or even fully prevented - through a well-designed ESD protection strategy.

Diotec's expertise in ESD protection helps engineers minimize the risk of ESD-related failures, supporting the development of robust and reliable automotive applications. Among the various communication protocols, the Controller Area Network (CAN) stands out as one of the most widely used in modern vehicles. Given its ubiquity in new vehicle platforms, ESD protection for the CAN bus has become a critical focus in ensuring long-term system reliability.

The CAN bus has become the standard communication protocol in modern vehicles due to its robustness, reliability and cost-effectiveness. CAN was designed to handle the increasing complexity of automotive electronics while reducing wiring. It enables real-time communication between various electronic control units (ECUs) using a simple two-wire system, significantly lowering system complexity and weight. Its built-in error detection, fault tolerance and ability to operate in electrically noisy environments make it ideal for automotive applications. As a result, CAN is now widely adopted across virtually all vehicle platforms, managing everything from powertrain control and braking systems to lighting, climate control and infotainment.

4. CAN bus overview

So, what exactly is CAN? The Controller Area Network (CAN) is a differential two-wire communication standard - using CAN_H and CAN_L. It allows various electronic control units (ECUs) and modules within a vehicle to communicate over a shared communication bus. This enables data and commands to travel efficiently between systems, allowing seamless coordination across numerous functions.

CAN manages communication between systems such as the Powertrain Control Module (PCM), anti-lock braking, traction and stability control, electronic steering, suspension systems, automatic climate control, keyless entry, lighting modules and many others.

CAN systems began appearing in production vehicles around 2003. By 2008, virtually all passenger cars and light trucks sold in the U.S. were equipped with CAN-based networks. Originally developed in 1984 by Robert Bosch GmbH, the CAN protocol was designed to meet the growing need for robust, reliable communication between increasingly sophisticated onboard electronic systems.

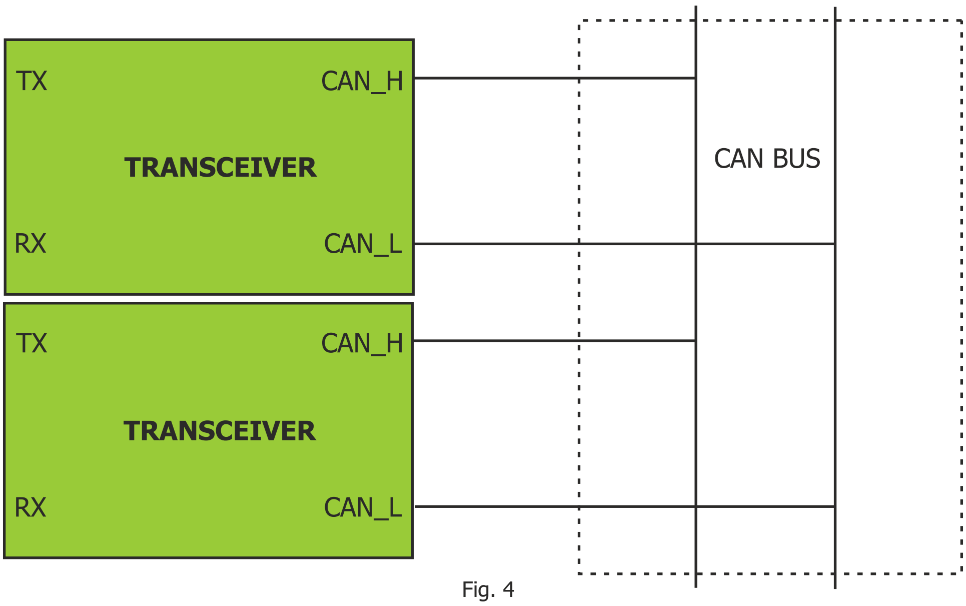
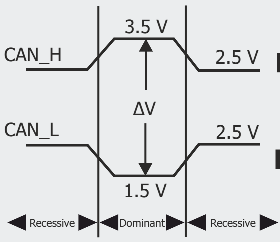
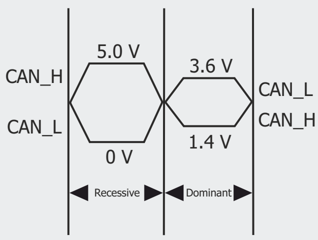


Fig. 4

5. Why does a CAN bus need protection?

- Noisy, harsh environment operation
- Nodes must sustain high energy transients
  - Load dump
  - Inductive switching
  - Relay noise
  - Ignition system noise
- Automotive systems require a high level of robustness and must be extremely reliable, especially when they control safety devices.

Parameter	High Speed CAN	Low Speed CAN
Physical layer	ISO 11898-2	ISO 11898-3
Speed	1 Mbit/s @ 40 m 5 Mbit/s (CAN FD)	125 kbit/s @ 500 m
Min/Max supply voltage	12 V System: -3/16 V 24 V System: -3/32 V	
Min/Max common mode voltage	CAN_L: -2 - 2.5 V CAN_H: 2.5 V - 7 V	
Termination Resistance	120 Ω resistors at each node	2.2 kΩ serial on each side
Signal Waveform	 **High Speed CAN (ISO11898-2)** **Bus Logic States** Recessive: ΔV ≤ 0.5 V Dominant: ΔV ≥ 0.9 V	 **Fault Tolerant CAN (ISO11898-3)** **Bus Logic States** Recessive: CAN_H > 0.5 V Dominant: CAN_H < 0.9 V

6. CAN ESD compliant standards:

Standards	Hazards	Description	CAN protection specifics
ISO 10605	ESD protection	Simulation of voltage spikes due to electro-static discharge, based on IEC61000-4-2	ESD robustness up to 15 kV contact (R=330 Ω, C= 330 pF) and low ESD clamping voltage
ISO 7637-3, pulse 3a/3b	Surge protection	Fast transient test pulses are generated when relays open or close on the battery bus, and these pulses can couple onto the data line	Must pass the surge and clamp the generated overvoltage. 12 V system = -110 V – 75 V 24 V system = -150 V – 150 V Repetitive pulses with a short duration of 150 ns and a very fast rise time of 5 ns for 10 mins.
ISO16750-2	Jump start	Wrong connection of battery in series with a flat battery, in this case, 24 V is applied on the entire system for 1 min without failure	Reverse breakdown voltage V_{BR} > 24 V
ISO16750	Reverse battery	Application of -14 V for 12 V battery system and -28 V for 24 V battery over 60 s to simulate reversed battery connection when using an auxiliary starting device	Forward breakdown voltage V_{BR} < -14 V for 12 V battery Forward breakdown voltage V_{BR} < -28 V for 24 V battery
ISO16750-2	Short to battery	This test simulates a failure on the regulator device, leading to an overvoltage to the battery power line.	Applicable voltage = 18 V (12 V System) Applicable voltage = 36 V (24 V System)

7. ESD protection device selection:

1. Maximum supply voltage

   A ESD diode is designed to clamp transient voltages, but it is not intended to operate in avalanche mode under continuous DC conditions. Therefore, when the CAN bus is exposed to sustained overvoltage events - such as a short to battery, jump start, or reverse battery connection - where the current is not limited and the test duration can last from one minute to an hour, the EDS diode must avoid entering avalanche mode. Based on these requirements, a breakdown voltage greater than 24 V is recommended for 12 V systems, and 36 V for 24 V systems.

2. Common mode voltage

   Common mode voltage arises when there is a significant voltage potential difference between the ground references of the transmitting and receiving nodes. According to ISO 11898, the voltage on the data lines may shift by up to ±2.0 V from their nominal levels. Therefore, the maximum working voltage of the EDS diode must accommodate this potential offset.

3. Maximum transmission speed

   The transmission speed of CAN data signals imposes a limit on the maximum allowable capacitance of the data lines. Minor signal distortion is acceptable as long as the capacitance on the CAN_H and CAN_L lines is well balanced. However, due to inherent tolerances, it is difficult to precisely match the discrete capacitance of an ESD diode. Therefore, the capacitance introduced by the ESD diode should be kept as low as possible.

4. ESD rating

   An ESD event can occur when a charged object - such as a person - touches or approaches the connector pins or cable. To ensure robust protection, it is recommended that the CAN bus supports a contact discharge rating of at least ±15 kV, as outlined by IEC61000-4-2, IEC61000-4-5.

8. ESD testing standard IEC61000-4-2

Indicated voltage	I_{peak} (±15%) A	t_r (±25%) A	I @ 30 ns (±30%) A	I @ 60 ns (±30%) A
2 kV	7.5	0.8	4.0	2.0
4 kV	15.0	0.8	8.0	4.0
6 kV	22.5	0.8	12.0	6.0
8 kV	30.0	0.8	16.0	8.0

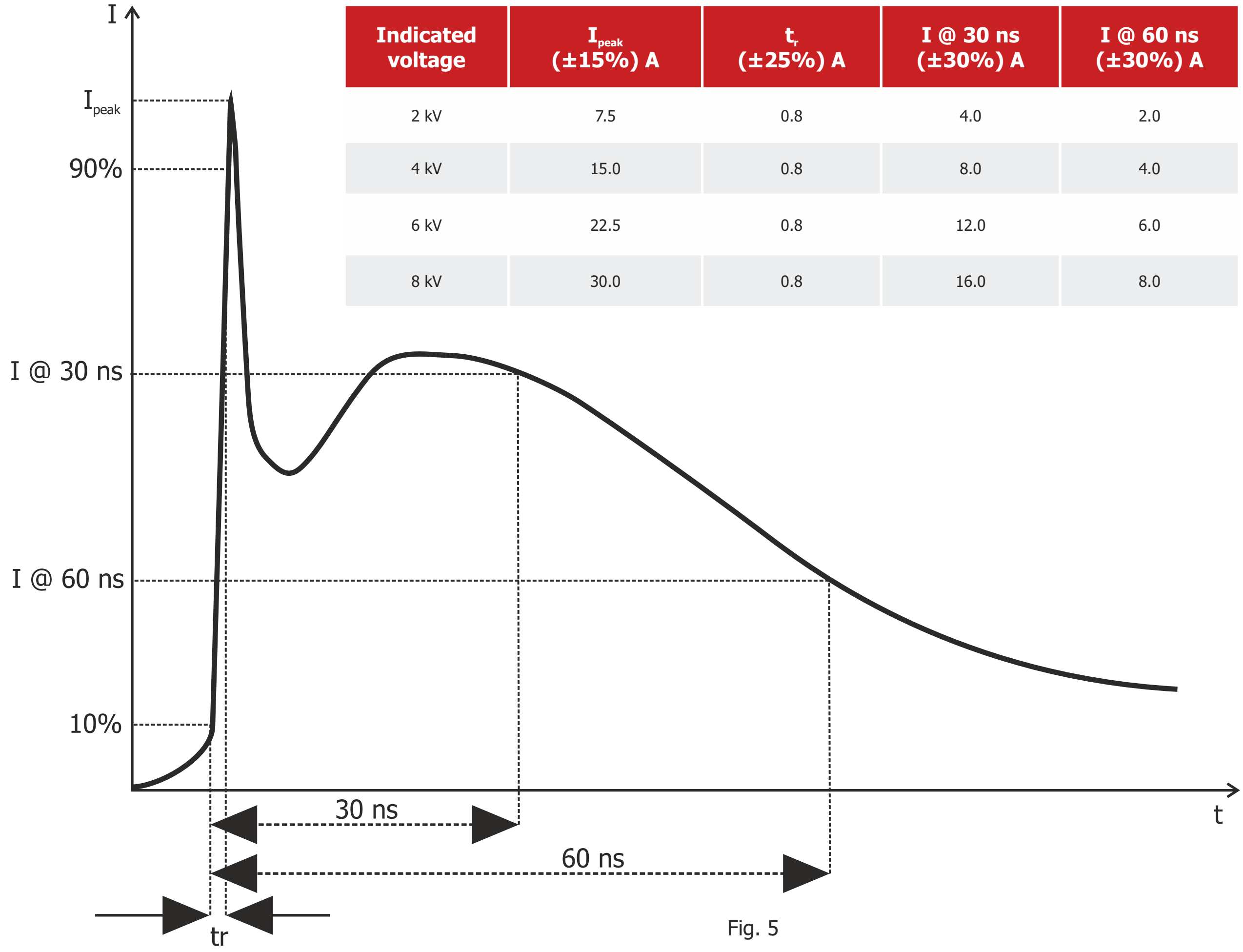


Fig. 5

- IEC 61000-4-2 defines test methods and configuration environment for ESD robustness testing
- The pulse rises within 0.7 to 1 ns
- The first spike reaches its peak current with the peak value I_{peak}
- The pulse then declines within about 80 ns including a shoulder-shape curve
- Most of the surge pulse energy is carried by the shoulder
- The first spike stresses the target with voltage and high current, but with less energy because the duration is short.

9. ESD testing standard IEC61000-4-5

9.1. Waveform of open-circuit voltage (1.2/50 µs) at the output of the generator with no CDN connected (waveform definition according to IEC 60060-1)

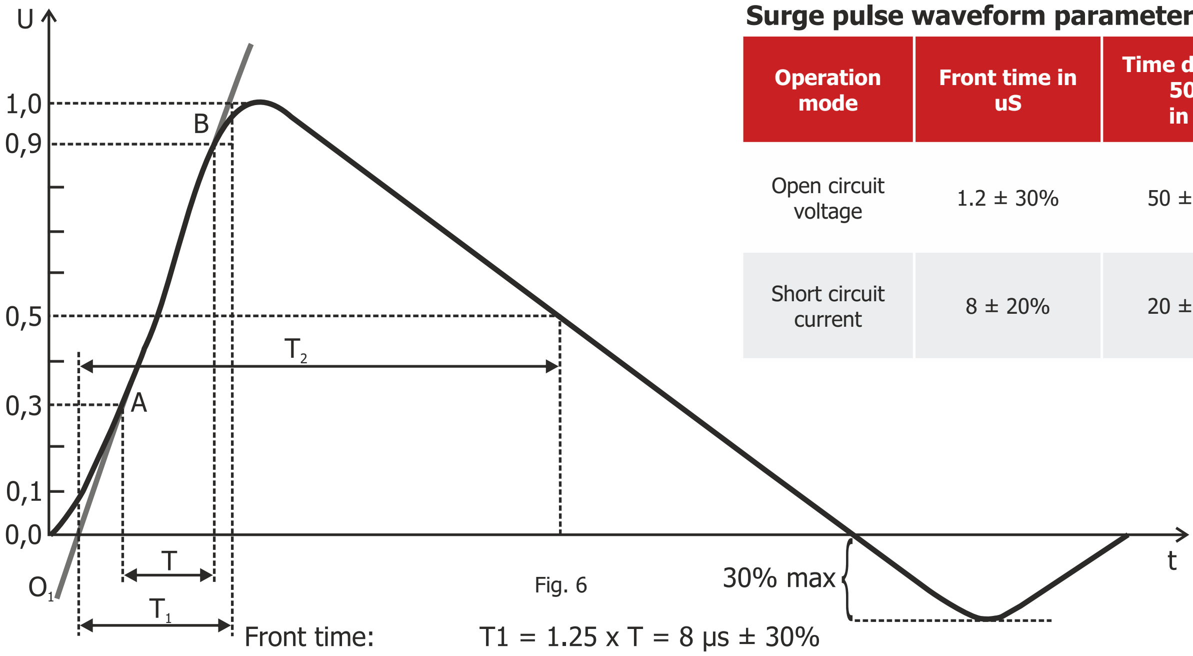


Fig. 6

Front time: T1 = 1.25 x T = 8 µs ± 30%
Time to half-value: T2 = 50 µs ± 20%

Surge pulse waveform parameters

Operation mode	Front time in uS	Time down to 50% in uS
Open circuit voltage	1.2 ± 30%	50 ± 20%
Short circuit current	8 ± 20%	20 ± 20%

Note: The open circuit voltage waveform at the output of the coupling/decoupling network may have a considerable undershoot, Fig. 6

9.2. Waveform of short-circuit current (8/20 µs) at the output of the generator with no CDN connected (waveform definition according to IEC 60060-1)

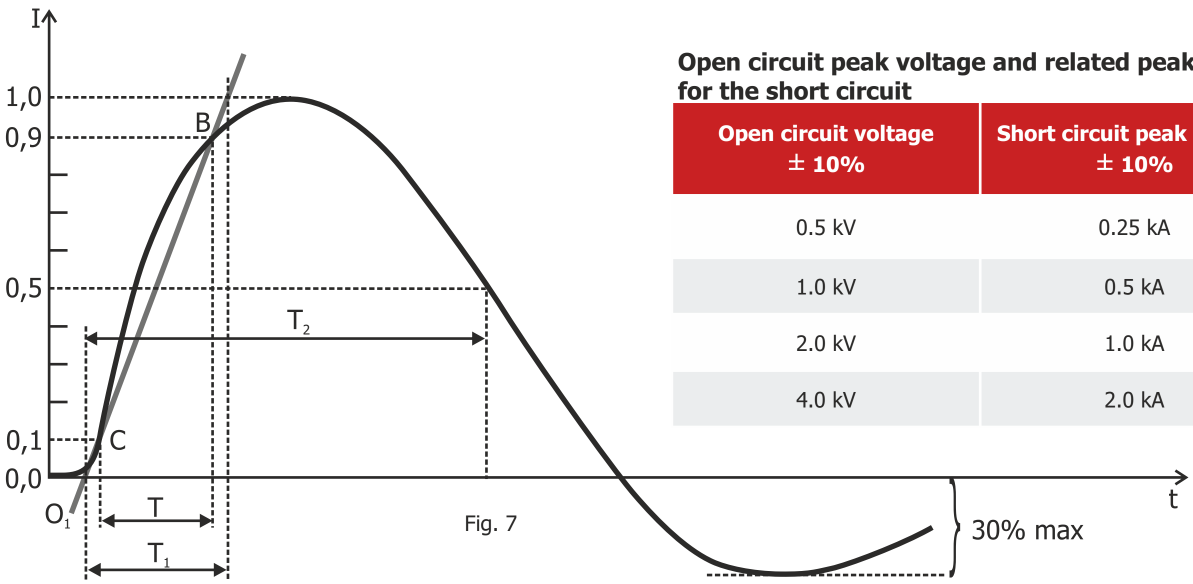


Fig. 7

Front time: T1 = 1.25 x T = 8 µs ± 20%
Time to half-value: T2 = 20 µs ± 20%

Open circuit peak voltage and related peak current for the short circuit

Open circuit voltage ± 10%	Short circuit peak current ± 10%
0.5 kV	0.25 kA
1.0 kV	0.5 kA
2.0 kV	1.0 kA
4.0 kV	2.0 kA

Note: The open circuit voltage waveform at the output of the coupling/decoupling network may have a considerable undershoot, Fig. 7

10. Common protection methods

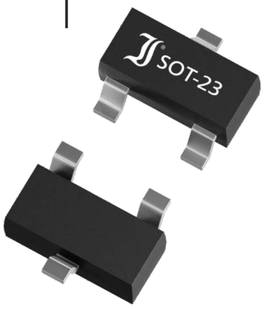
The NUP2105L-AQ ESD diode is designed to protect high speed communication lines from ESD events. Ultra−low capacitance and high level of ESD protection make these devices well suited for use in CAN applications.

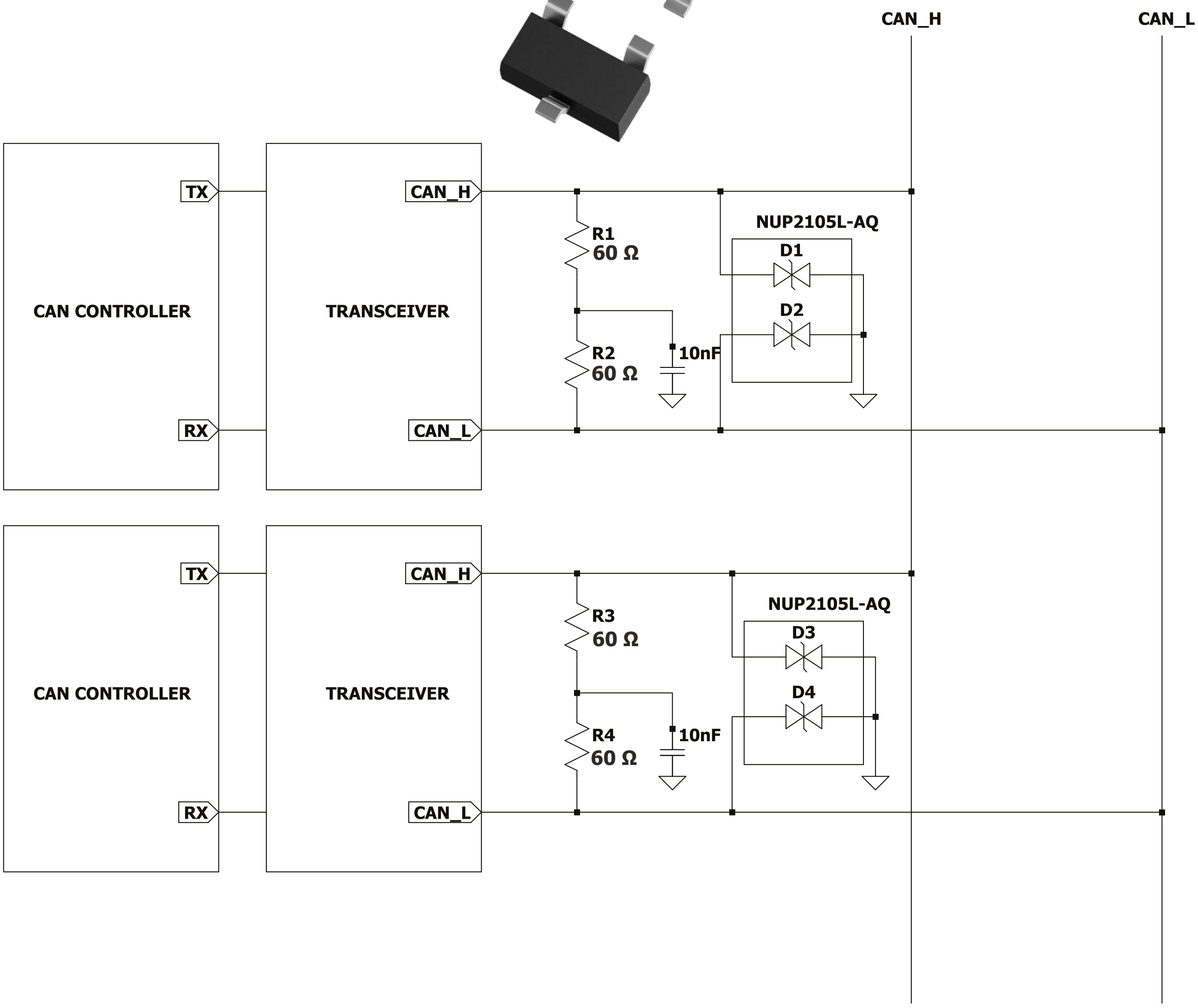
Features

- Dual bi-directional ESD diode in SOT-23
- Breakdown voltage > 24 V
- Low capacitance < 30 µF
- Low leakage current
- IEC61000-4-2 ± 30 kV
- Qualified to AEC-Q101 for high reliability

Typical applications

- High speed data line and power line protection
- Can bus protection
- Monitors and flat panel displays
- Notebook computers





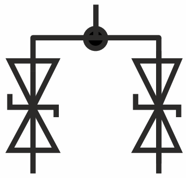
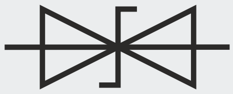
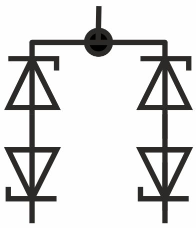
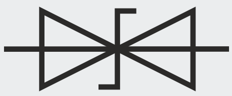
11. Reliable CAN bus protection with Diotec's NUP2105L-AQ

Automotive networks demand a higher standard of ESD protection than typical consumer electronics. Diotec's **NUP2105L-AQ** is purpose-built for the CAN bus, offering robust protection for transceiver lines against ESD events — without compromising signal integrity.

Designed for harsh automotive environments, this diode withstands short-to-battery conditions and maintains stable performance during EMI testing. With optimized capacitance values, the NUP2105L-AQ ensures minimal signal distortion, making it ideal for differential communication systems like CAN. Its precise capacitance matching helps prevent unwanted signal skew and jitter, ensuring smooth and reliable data transmission across the vehicle network.

Choose Diotec's NUP2105L-AQ for your next automotive design — where safety, signal integrity and performance matter most.

12. Common automotive communication bus protection

Type	Description		Circuit	Applications
NUP2105L-AQ NUP2405L-AQ	24 V 240 W - 350 W SOT-23			Automotive CAN
ESD3B24WS-AQ	24 V 350 W SOD-323			Low speed CAN CAN/Switches Buttons/IO ports
ESDB24C-AQ	24 V 200 W SOT-23			Automotive CAN
ESDB24D-AQ	24 V 67 W DFN0603			Automotive LIN Bus

13. PCB layout recommandations for ESD protection devices

- Place ESD diodes close to the connector

  As ESD events typically enter through connectors, mount the ESD diode as close as physically possible to the CAN connector (e.g., DB9, M12). This prevents the ESD pulse from reaching sensitive transceiver inputs.

- Use short and wide traces

  Keep traces between the ESD diode, CAN bus and ground as short and wide as possible to minimize parasitic inductance and resistance to ensure fast clamping.

- Ground path is key

  Ensure the ESD diode has a low-inductance path to ground, use a dedicated via to the ground plane preferably one via per ESD diode pad and avoid routing ground traces with loops or unnecessary bends.

- Symmetric placement for differential lines

  For CAN_H and CAN_L, use matched trace length and place symmetrical protection to maintain signal balance, if using a dual-channel diode, center it between the lines.

Datasheets of all mentioned products can be found at www.diotec.com

Do not hesitate to contact us for further questions and schematics:
technicalsupport@diotec.com