AN5878

Application note

How to design a robust automotive CAN system

Introduction

Controller area network (CAN) communication bus is extremely popular in the automotive industry. On top of standalone CAN transceivers, many ASICs or SBCs embed one or several CAN transceivers.

To comply with the high-level of reliability required by the automotive industry and the various surges and standards applicable on CAN links, the CAN transceivers and the electronics components part of the CAN physical layer must be protected by an external TVS.

This application note will:

- Describe the CAN bus electrical parameters.
- Detail the applicable surges to a CAN node.
- Explain the main characteristics of a CAN protection device and how to select the right ESDCAN part number.

1 CAN bus overview

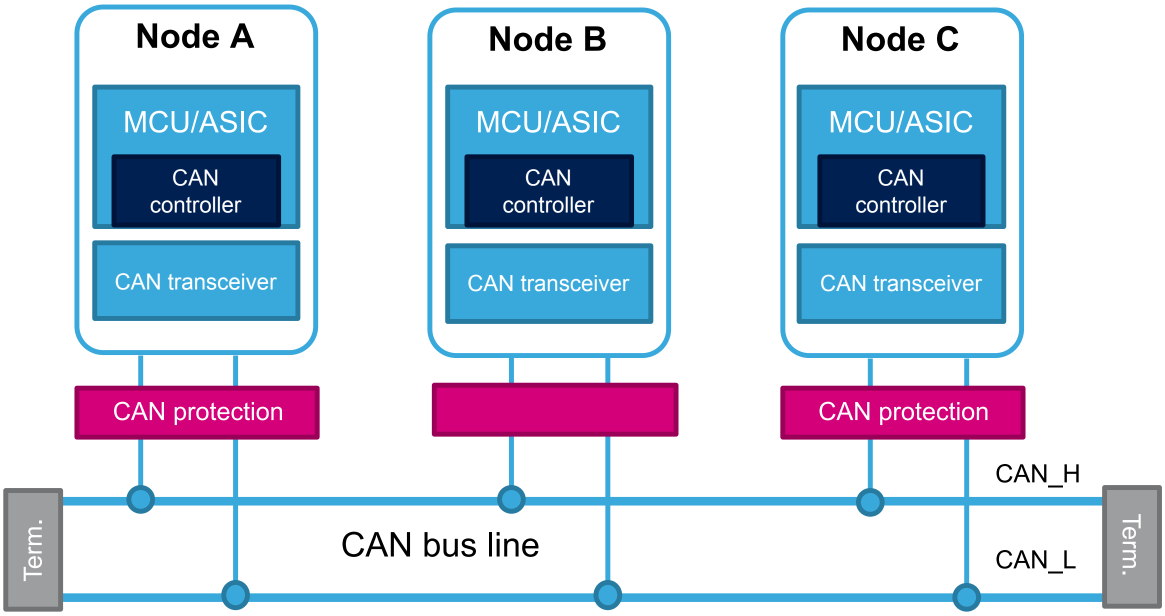
1.1 Topology

This protocol has been developed by Bosch in the 1980’s and is now widely used, not only in the automotive industry, but also in the industrial segment.

CAN, controller area network, protocol allows serial half-duplex multimaster communication between various ECUs through a multiplexed bus. It therefore limits the number of wires.

Each node can send and receive messages, but not simultaneously (half-duplex data transmission).

Figure 1. **CAN bus topology**



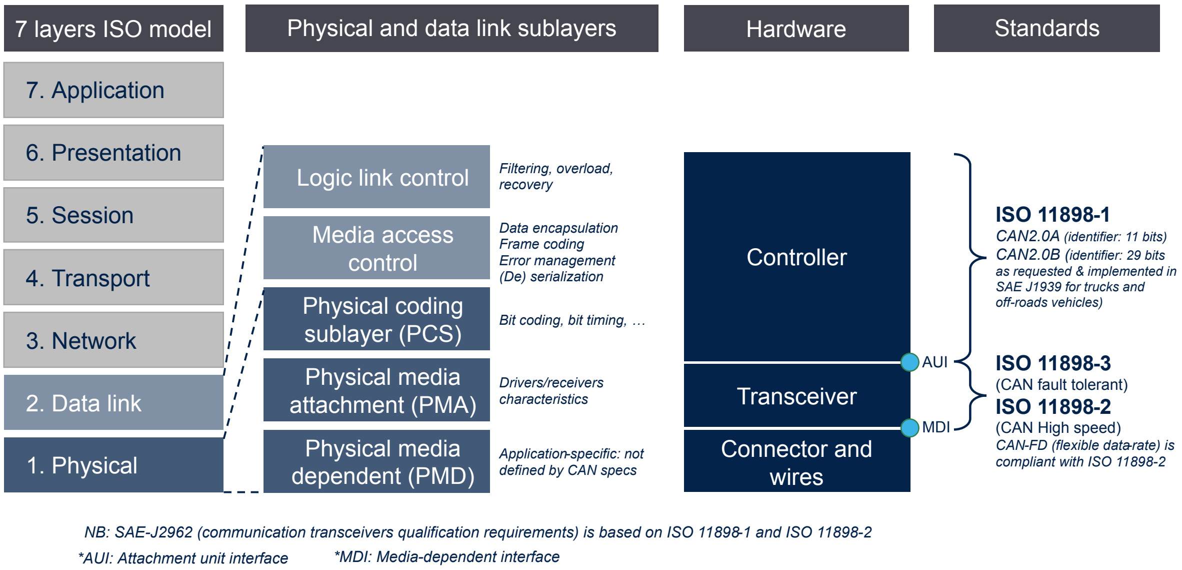
CAN communication uses a differential signal through CAN_H (CAN HIGH) and CAN_L (CAN LOW) and can reach several data speeds that will be detailed in the following sections.

1.2 CAN standards

As many network protocols, the CAN protocol can be described using the 7-layer open system interconnection (OSI) model.

To properly understand the scope of CAN standards from the hardware point of view, only the physical layer and the data link layer are interesting.

Figure 2. **CAN standards ecosystem**



As shown in the figure above, the physical layer itself is divided into three sublayers.

The first sublayer called physical media dependent or PMD corresponds to the connector and wires. The CAN standards do not define this part which is highly specific to the application. The connector can be a DB9, an OBD-II or any other connectors and the pins assignment for these connectors are not fixed.

The second sublayer called physical media attachment or PMA is the one defining the CAN transceiver (also called CAN PHY) characteristics at the hardware level.

Two standards exist at this level:

- ISO 11898-2 for CAN high-speed (CAN high-speed medium access unit).
- ISO 11898-3 for CAN fault tolerant (CAN low-speed, fault tolerant, medium-dependent interface).

The CAN-FD or flexible data rate is compliant with the ISO 11898-2 CAN high-speed standard.

Between the CAN transceiver and the CAN connector, various electronic components ensure a proper conditioning of the CAN signals and are part of the media dependent interface (MDI). See next figure.

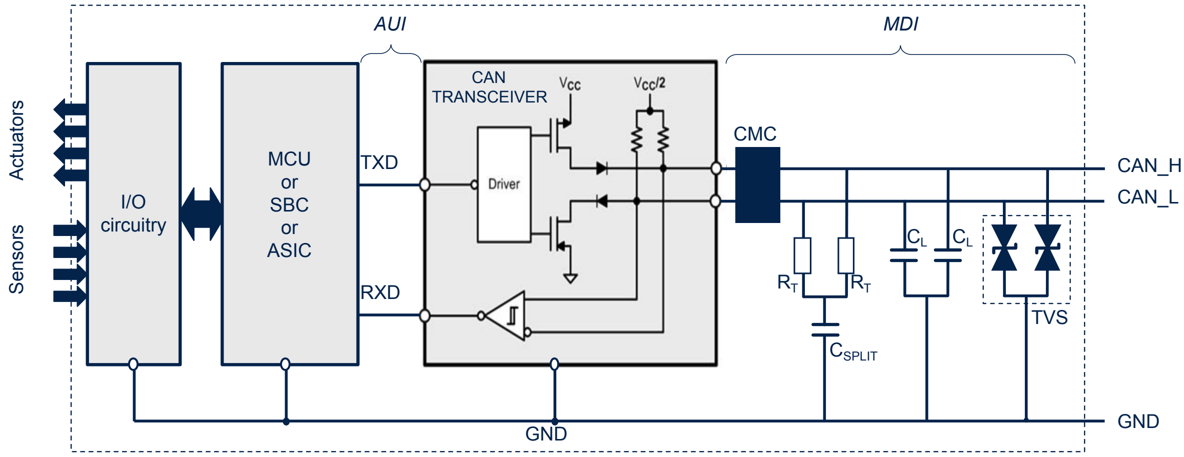
The last sublayer physical coding sublayer (PCS) as well as the media control access (MAC) and logic link control (LLC) sub layers of the data link layer are covered by the ISO 11898-1 (CAN data link layer and physical signaling).

Within ISO 11898-1, two formats of frames can coexist on the same network and are defined by:

- CAN 2.0 A, implementing an identifier field of 11-bits. This allows to theoretically 2048 different message types. Practically slightly less: 2032.
- CAN 2.0 B, implementing an identifier field of 29 bits. This allows more than 500 million of different messages. The SAE J1939 (recommended practice for a serial control and communications vehicle network) standard is based on CAN 2.0B. The 29-bit length for this field enables a more structured identifier needed for heavy-duty vehicles like trucks, bus, agricultural vehicles.

The attachment unit interface (AUI) is the physical link between the CAN controller (MCU, ASIC, SBC, …) and the CAN transceiver. Most of the time it is made of one line for reception (RXD) and one line for Transmission (TXD) as shown in the following figure.

Figure 3. **CAN physical layer**



Between the CAN transceiver and the connector, a common mode choke (CMC) is often used to reject the common mode signal.

Since the CAN bus is bidirectional, the termination resistors R_T is needed to suppress or deeply attenuate the reflection caused by the impedance mismatch of the cable ends. It is particularly required on extended CAN bus with long wires. To preserve the symmetry between CAN_H and CAN_L signals, R_T must have the same value with a small tolerance.

Adding a split capacitor C_{SPLIT} combined with the termination resistors R_T makes a low pass filter for common-mode noise between CAN_H and CAN_L lines and will improve the EMC.

To even reinforce the noise filtering, two optional data line capacitors C_L can be used as well between the CAN data line and the ground.

Finally, the TVS, placed close to the connector, will protect all the components downstream against ESD events and surges. The line capacitance of the TVS may play the same role as C_L capacitors and provides an additional low pass filter.

1.3 CAN data rates and electrical specifications

The ISO 11898-2 for the high-speed CAN and ISO 11898-3 for the low-speed CAN provide the electrical characteristics of the CAN bus.

Table 1. **CAN bus characteristics**

Parameters	High-speed CAN	Low-speed CAN
Physical layer standard	ISO 11898-2	ISO 11898-3
Maximum length	30 m	500 m
Termination	120 Ω shunt	2.2 kΩ serial on each line
Recessive voltage level	$V_{CAN\_H} = V_{CAN\_L} = 2.5$ V	$V_{CAN\_H} \sim 0$ V $V_{CAN\_L} \sim 5$ V
Dominant voltage level	$V_{CAN\_H} = 3.6$ V $V_{CAN\_L} = 1.4$ V	$V_{CAN\_H} = 4$ V $V_{CAN\_L} = 1$ V
Signal waveforms	See Figure 4. High-speed CAN signal waveform	See Figure 5. Low-speed CAN signal waveform

Figure 4. **High-speed CAN signal waveform**

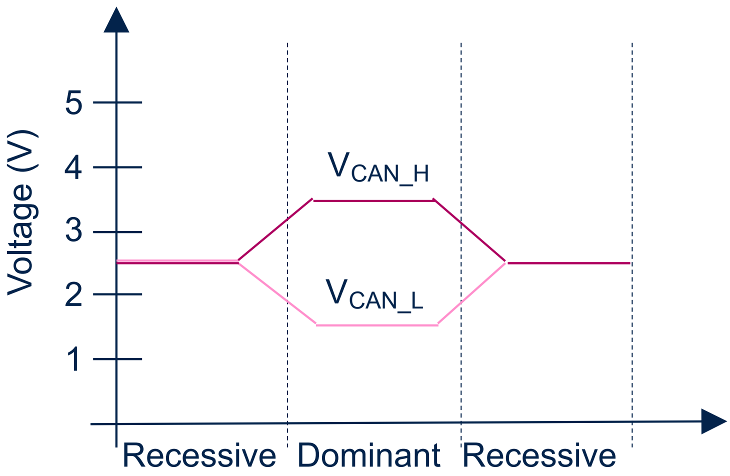
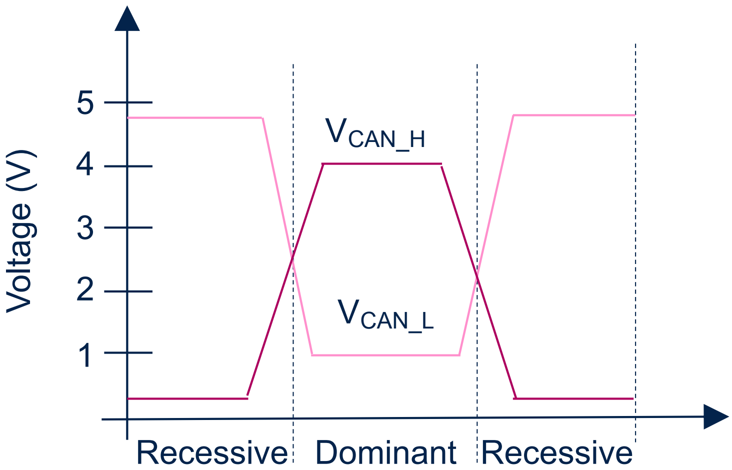


Figure 5. **Low-speed CAN signal waveform**



The data rate of the CAN bus depends on the CAN version and the selected CAN transceiver like shown in the following table.

Table 2. **CAN data rates**

CAN version	Data rate
CAN low-speed, Fault Tolerant	125 kbps
CAN high-speed	1 Mbps
CAN FD (flexible data rate)	2 Mbps (5 Mbps on simple network)
CAN FD SIC (signal improvement capability)	5 Mbps (8 Mbps on simple network)
CAN SIC XL (FAST mode)	10 Mbps (20 Mbps on simple network)

CAN high-speed, CAN FD, CAN SIC and CAN SIC XL are using the same physical layer described in ISO 11898-2.

2 Surges and applicable standards for automotive applications

When implemented in a vehicle, the CAN bus can be subject to many surges, hazards and mistakes during servicing or repairing.

2.1 ESD events – ISO 10605

ESD events can be caused by manual handling of CAN connector during mounting or repairing and sometimes by indirect coupling depending on the location of the CAN bus lines inside the vehicle.

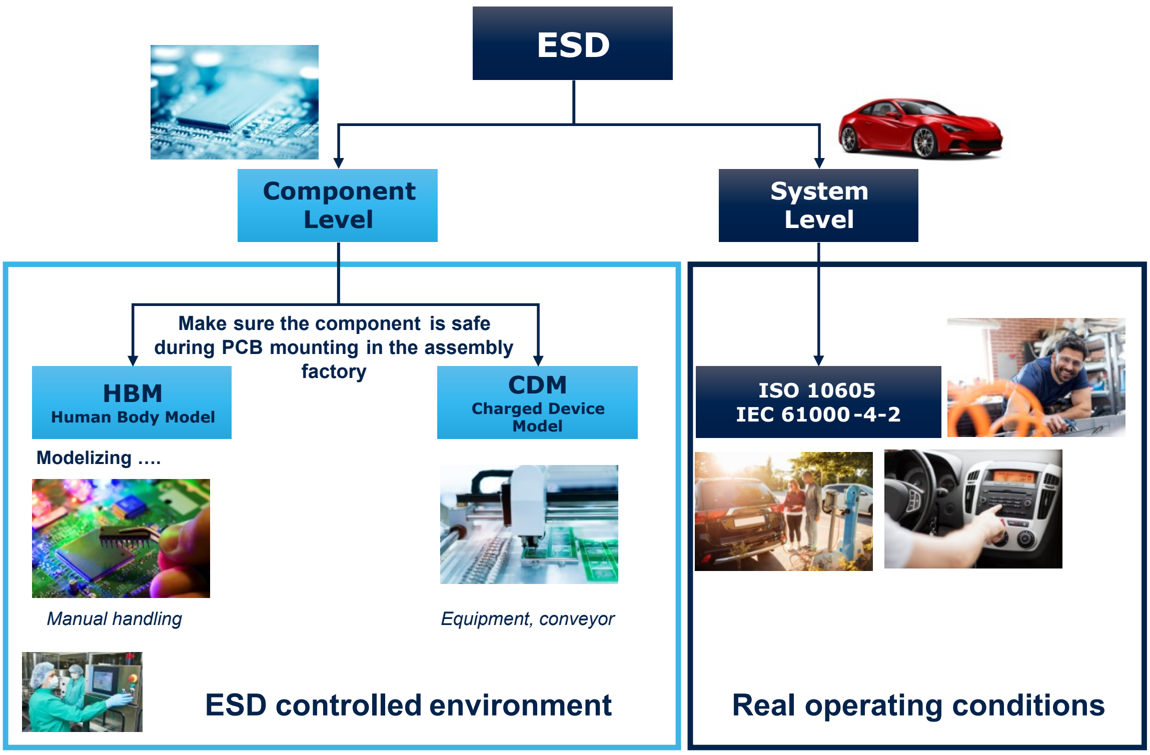
The ISO 10605 describes the test set-up and the expected level of robustness for ESD in the automotive environment.

Even if IEC 61000-4-2 is covering all other industries but automotive, it remains a reference for automotive players.

Both ISO 10605 and IEC 61000-4-2 are system-level standards and are much more stringent than HBM (human body model) or CDM (charge device model) stress specified in ICs datasheets. HBM and CDM ESD stresses are intended to provide a minimum level of ESD robustness to enable a proper mounting of this IC on the PCB in an ESD-controlled environment (ionizer, grounded equipment) with trained people.

System levels ESD standards (ISO 10605 and IEC 61000-4-2) guarantee the ESD robustness in the real world as shown in the following figure.

Figure 6. ESD standards

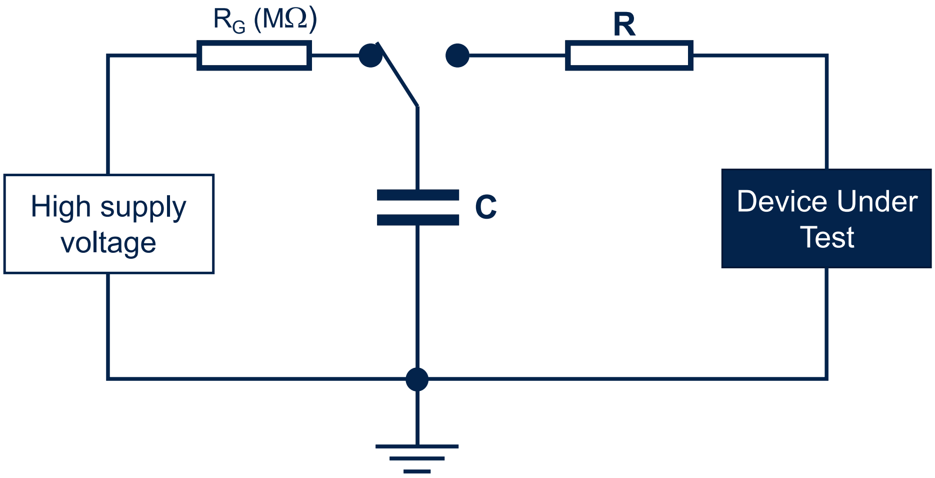


ESD testing shall consist of direct or indirect application of discharges to the DUT using an ESD gun. Two distinct types of discharges can be applied:

- Contact discharge: the ESD gun is directly in contact with the device under test (DUT). Conductive surfaces must be tested using contact discharges.
- Air discharge: the ESD gun is being approached at a constant speed to the DUT. Non-conductive surfaces shall be tested using air mode discharges. Air discharge may also be applied to conductive surfaces, if required in the test plan.

The ESD gun can be modelized as shown in the following figure.

Figure 7. ESD gun model



The severity of the ESD spike applied obviously depends on the RC network. The standards define these RC networks that must be selected according to the use case in the vehicle.

In the following table, the RC networks are ranked by severity (the upper, the more stressful).

Table 3. ESD RC network defined by the standards

RC network	Use cases	Standards
R = 330 Ω, C = 330 pF	Powered-up electronics module easily accessible from inside the vehicle (human body discharge through a metallic part)	ISO 10605
R = 330 Ω, C = 150 pF	Powered-up electronics module only accessible from outside the vehicle (human body discharge through a metallic part) Unpowered electronics module	ISO 10605 IEC 61000-4-2
R = 2 kΩ, C = 330 pF	Powered-up electronics module easily accessible from inside the vehicle (human body discharge through the skin)	ISO 10605
R = 2 kΩ, C = 150 pF	Powered-up electronics module only accessible from outside the vehicle (human body discharge through the skin) Unpowered electronics module	ISO 10605

2.2 Fast transients - ISO 7637-3 pulse 3a/3b

Fast transient test pulses a and b simulate transients which occur because of the switching processes due to bounces of relays opening or closing on the battery bus as instance and that are coupled on the data line.

Two different methods can be used to simulate the coupled voltage for fast transients:

1. Capacitive coupling clamp (CCC) method: harness is placed inside the metallic clamp and transient pulses defined in a standard are applied on this metallic clamp.
2. Direct capacitive coupling (DCC) method consists in applying transient pulses to the capacitor in series with the DUT. For fast transients, the value of this capacitor is 100 pF.

After the tests, the DUT must be operational.

These transients and the test set-up are defined in ISO 7637-3 standard, and they are also called fast 3a pulse (for negative) and fast 3b pulse (for positive).

They are repetitive pulses with a short duration of 150 ns and a very fast rise time of 5 ns. These repetitive pulses are applied during 10 minutes on the DUT.

The following table defines the more stressful peak pulse voltages (corresponding to the level IV of ISO 7637-3).

Table 4. **Fast transients maximum peak pulse voltages**

Transient pulses test	12 V electrical system	24 V electrical system
Fast 3a	-110 V	-150 V
Fast 3b	+75 V	+150 V

2.3 Slow transients - ISO 7637-3 negative and positive pulses 2a

Slow transient test pulses simulate transients which occur because of interrupting the current in a circuit with large inductive load (such as a radiator fan motor, air conditioning compressor clutch, …) and that are coupled on data lines.

Two different methods can be used to simulate the coupled voltages for slow transients:

- Direct capacitive coupling (DCC) method consists in applying transient pulses to the capacitor in series with the DUT. For slow transient, the capacitor value is 100 nF.
- Inductive coupling clamp (ICC) method: harness is placed inside the injection probe and transient pulses defined in the standard are applied on this injection probe.

After the tests, the DUT must be operational.

These transients are defined in ISO 7637-3 standard, and they are also called slow positive and negative pulses 2a.

These transients are repetitive with a pulse duration of approximately 50 µs and a rise time of 1 µs. These repetitive pulses are applied during 5 minutes on the DUT.

The following table defines the most stressful peak pulse voltages (corresponding to level IV of ISO 7637-3).

Table 5. **Slow transients maximum peak pulse voltages**

Transient pulses test	12 V electrical system	24 V electrical system
Slow DCC +	+ 30 V	+ 45 V
Slow DCC -	- 30 V	- 45 V
Slow ICC +	+ 6 V	+ 10 V
Slow ICC -	- 6 V	- 10 V

2.4 Regulator failure – ISO 16750-2

This test simulates a failure on the regulator device, leading to an overvoltage to the battery power line (V_{BAT}).

The ISO 16750-2 standard describes this test and the voltage to be applied on all the relevant inputs of the electronics module depends on the electrical system type as shown in the following table.

Table 6. **Regulator failure – applicable voltage**

12 V electrical system	24 V electrical system
+ 18 V	+ 36 V

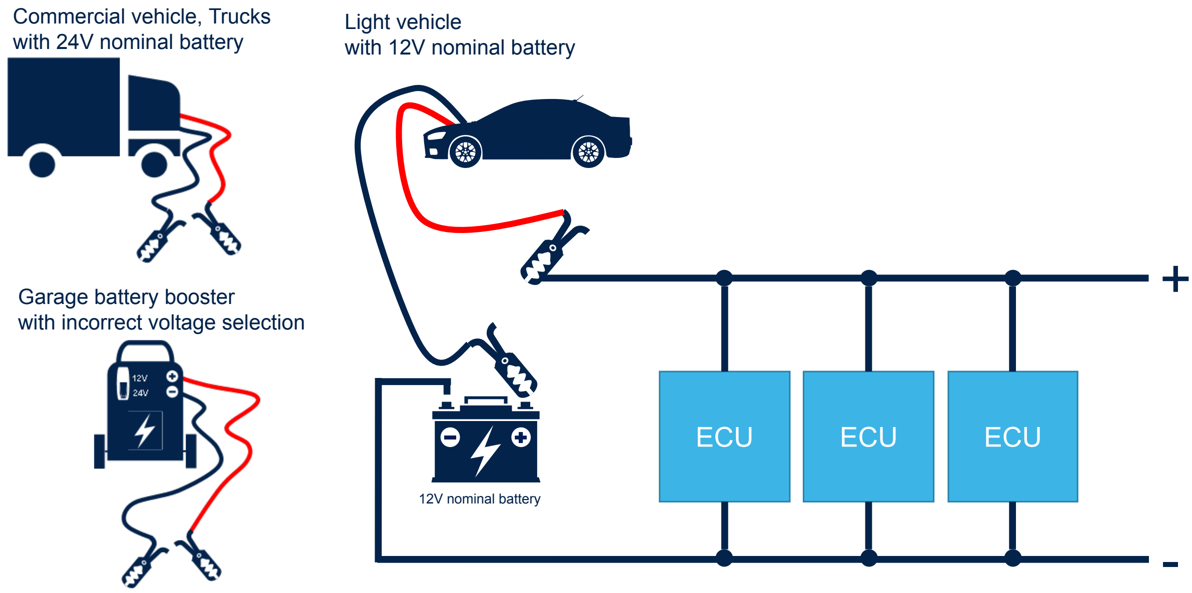
This test is applied for 60 min.

2.5 Jump start - ISO 16750-2

As shown in the following figure, the jump start test corresponds to the application of 24 V on all inputs to simulate for examples:

- Wrong connection of an auxiliary battery in series with a flat battery of a passenger car.
- A garage battery booster with a wrong voltage selection connected to power a passenger car with no battery.
- A truck battery connected to power a passenger car to start the engine.

Figure 8. **Jump start wrong connection**



In these different cases, 24 V is applied on the entire system. Not only the ECUs and all the circuits have to withstand the overvoltage but also the TVS.

The ISO 16750-2 standard describes this test which is applicable only for 12 V electrical systems.

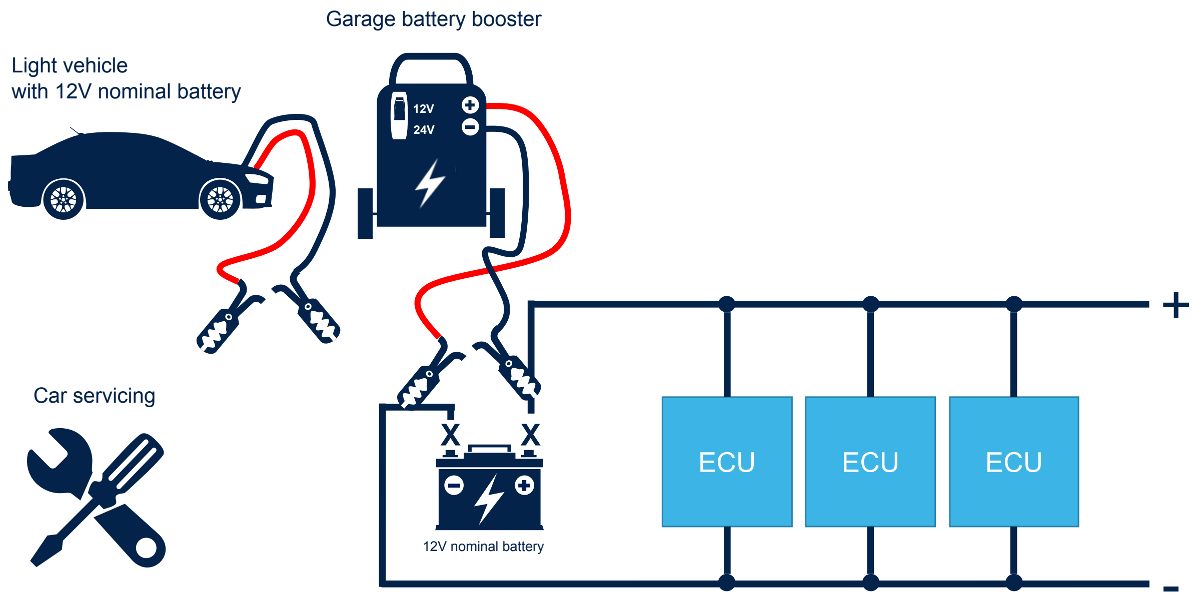
A voltage of 24 V must be applied on all relevant points for 1 minute ±10%.

2.6 ISO 16750 – reverse battery

As shown in the following figure, the reverse battery test corresponds to the application of -14 V for 12 V battery nominal voltage over 60 s to simulate a reversed battery connection for example when:

- Using an auxiliary battery (from another passenger car, a battery booster, …).
- Reconnecting a battery to the car power net.
- Repairing the car power net (junction boxes, …).

Figure 9. **Reverse battery wrong connection**



The ISO 16750 standard describes this test.

The reverse voltage must be applied for 1 minute ±10% and the voltage level depends on the electrical system type as shown in the next table.

Table 7. Reverse battery – applicable voltage

12 V electrical system	24 V electrical system
- 14 V	- 28 V

3 Requirements on CAN protection

As we have seen on the previous sections, on top of the normal operating conditions, the CAN links must withstand many types of surges, transients and survive wrong connections. The CAN TVS protection, as part of the MDI must comply with all the standards and must protect all the CAN bus components against these surges.

In this section, we will detail the impact of the previously described standards constraints on the CAN protection devices and we will review how the ST ESDCAN series can match them.

3.1 Breakdown voltage

A TVS is meant to clamp transient voltages, but it is not supposed to operate in the avalanche mode in DC mode, sinking a high current.

So when the CAN bus is submitted to overvoltage due to regulator failure, jump start or reverse battery, as the current is not limited and the test duration is very long (from one minute to one hour), the CAN protection TVS must not enter in avalanche mode.

Therefore, one should select a CAN protection TVS with a reverse breakdown voltage adapted to the regulator overvoltage, jump start or reverse battery applicable to the electrical system of the vehicle as described in the following table.

Table 8. Constraints on directionality and V_{BR} of CAN TVS protection

	Regulator failure	Jump start	Reverse battery	Impact on CAN TVS protection
12 V electrical system	+18 V	+ 24 V	-14 V	Bidirectional V_{BR}> 24 V
24 V electrical system	+ 36 V	Not applicable	-28 V	Bidirectional V_{BR} > 36 V

As one can see in the extract of the datasheet of the SOT323-3L ESDCAN series in the following figure, several part numbers with various V_{BR} are available.

Figure 10. SOT323-3L ESDCAN series breakdown voltages at 25 °C

Order code	I_{RM} max. at V_{RM}		V_{BR} at I_R		
			Min.	Max.	
	µA	V	V		mA
ESDCAN02-2BWY	0.01	26.5	28.5	31.7	1
ESDCAN03-2BWY	0.01	24	26.5	29.7	1
ESDCAN04-2BWY	0.05	25.5	27.5	30.7	1
ESDCAN05-2BWY	0.1	36	39	43.3	1
ESDCAN06-2BWY	0.1	35	38	42.2	1

12 V electrical systems

24 V electrical systems

ST offers several values of V_{BR} even within the 12 V or 24 V electrical systems series, to address all the customers' specific requirements. Indeed, some OEMs may want to be more stressful than ISO 16750-2 with the jump start voltages that they apply on their vehicle models, by adding a safety margin of a few Volts.

This variety of V_{BR} allows to answer all the specific requirements with an optimized maximum clamping voltage V_{CL} / maximum jump start voltage ratio.

It is important to consider the maximum ambient temperature of the application when checking the V_{BR} values.

The regulator failure test is supposed to be applied at 20 °C below the maximum operating temperature.

The variation of breakdown voltage (and thus clamping voltage) versus the temperature can be calculated thanks to the αT of the devices (see next figure) and the following equation:

$$VBR@Tj = VBR@25°C \times (1 + \alpha\mathrm{T} \times (\mathrm{Tj} - 25°\mathrm{C}))$$

Figure 11. **SOT323-3L ESDCAN series αT values**

αT values

Order code	I_{RM} max. at V_{RM}		V_{BR} at I_R			V_{CL} Pulse ISO7637-3		V_{CL} at I_{PP} (8/20 µs)		C		ΔC[1]	αT[2]
			Min.	Max.		3a at -150 V min.	3b at +150 V max.	Max.		Typ.	Max.	Typ.	Typ.
	µA	V	V		mA	V		V	A	pF		pF	10^{-4}/°C
ESDCAN02-2BWY	0.01	26.5	28.5	31.7	1	-36	36	44	3	3	3.5	0.01	9
ESDCAN03-2BWY	0.01	24	26.5	29.7	1	-34	34	41	3	3	3.5	0.01	9
ESDCAN04-2BWY	0.05	25.5	27.5	30.7	1	-35	35	43	3	17	19	0.1	9
ESDCAN05-2BWY	0.1	36	39	43.3	1	-45	45	61	3	3	3.5	0.01	9
ESDCAN06-2BWY	0.1	35	38	42.2	1	-44	44	59	3	13	15	0.1	9

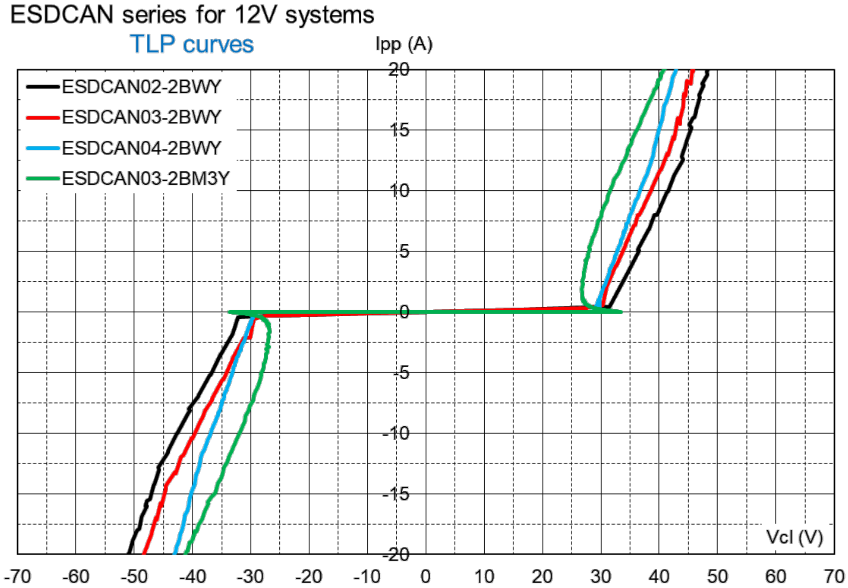
1. *ΔC : capacitance variation between IO1 and IO2 versus GND*
2. *to calculate V_{BR} versus T_j: V_{BR} at T_j = V_{BR} at 25 °C x (1 + αT x (T_j - 25))*

$V_{BR}@T_J$ formula

Thanks to the last generation of protection technology with snapback effect, the need to offer various V_{BR} values tends to disappear.

As shown in the next figure, the ESDCAN03-2BM3Y features a trigger voltage V_{TRIG} at 28 V (covering all jump start specifics) avoiding compromising the clamping voltage V_{CL}.

Figure 12. ESDCAN03-2BM3Y – snapback effect



ESDCAN03-2BM3Y datasheet extract

Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
V_{Trig}	Trigger voltage, higher voltage than V_{TRIG} guarantees the protection turn-on		28			V
V_H	Holding voltage, lower voltage than V_H guarantees the protection turn-off		24			V

Related links

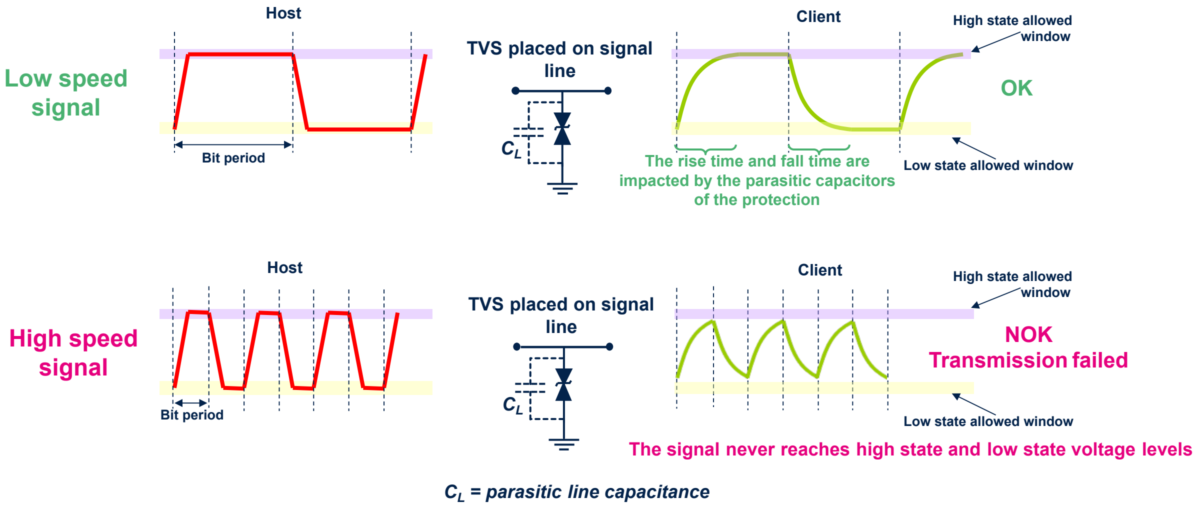
2.4 Regulator failure – ISO 16750-2 on page 8
2.5 Jump start - ISO 16750-2 on page 8
2.6 ISO 16750 – reverse battery on page 9
ESDCAN03-2BW3Y datasheet

3.2 Line capacitance

The parasitic line capacitance of a TVS is critical regarding the data rate of the signal. If the line capacitance is too high, the signal integrity may be degraded, and the bits can be lost.

As shown in the following figure, the line capacitance impacts both rise and fall times.

Figure 13. Impact of the line capacitance of a TVS on the signal integrity



Obviously, the parasitic capacitances of the whole components and wires between the emitter and the receiver can impact the rise times and fall times of the CAN signals.

The SAE J2962-2 requests a maximum total line-to-ground capacitance of 100 pF on each CAN line (CAN_H and CAN_L) on their test set-up for high-speed CAN transceivers qualification requirements.

The lower the capacitance of the TVS, the more margin for the rest of the circuit.

ESDCAN series offers part number with 3 pF parasitic capacitance to save as much as possible on the CAN lines capacitance budgets.

Figure 14. Line capacitance of SOT323-3L ESDCAN series

Order code	I_{RM} max. at V_{RM}		V_{BR} at I_R			V_{CL} Pulse ISO7637-3		V_{CL} at I_{PP} (8/20 µs)		C		ΔC(1)
			Min.	Max.		3a at -150 V min.	3b at +150 V max.	Max.		Typ.	Max.	Typ.
	µA	V	V		mA	V		V	A	pF		pF
ESDCAN02-2BWY	0.01	26.5	28.5	31.7	1	-36	36	44	3	3	3.5	0.01
ESDCAN03-2BWY	0.01	24	26.5	29.7	1	-34	34	41	3	3	3.5	0.01
ESDCAN04-2BWY	0.05	25.5	27.5	30.7	1	-35	35	43	3	17	19	0.1
ESDCAN05-2BWY	0.1	36	39	43.3	1	-45	45	61	3	3	3.5	0.01
ESDCAN06-2BWY	0.1	35	38	42.2	1	-44	44	59	3	13	15	0.1

As the CAN communication is a differential link, the matching between both TVS embedded in the same package is key. On low capacitance ESDCAN (ESDCAN02, 03 and 05) the difference of the line capacitance between the two TVS in the same package is as low as 10 fF which guarantees an excellent matching.

Related links

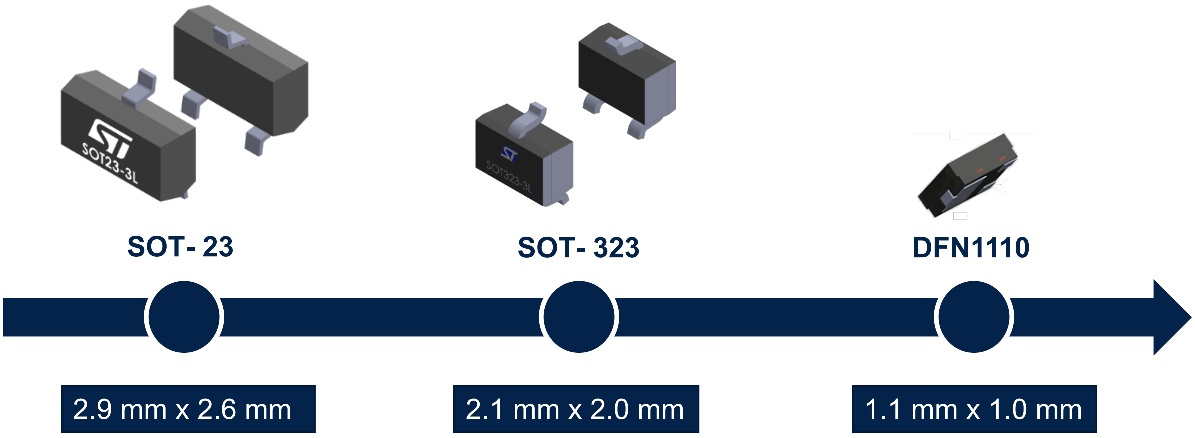
ESDCAN03-2BW3Y datasheet

3.3 Package

The digitalization of the car leads to an increasing number of ECUs (electronic control unit). Moreover, these ECUs are more complex, connected to many sensors, with a high-level of computation. Many comfort and safety devices are also added in the new cars.

All these trends create heavy space constraints in the car and therefore on the electronics boards. To address this new need for miniaturization, the ESDCAN series offer three different packages as shown in the following figure.

Figure 15. **ESDCAN series–packages offer**



The SOT-23 and the SOT-323 are very popular and mature leaded packages. It is easy to implement an automated optical inspection (AOI) with one or several camera modules during the PCB mounting to control the soldering process.

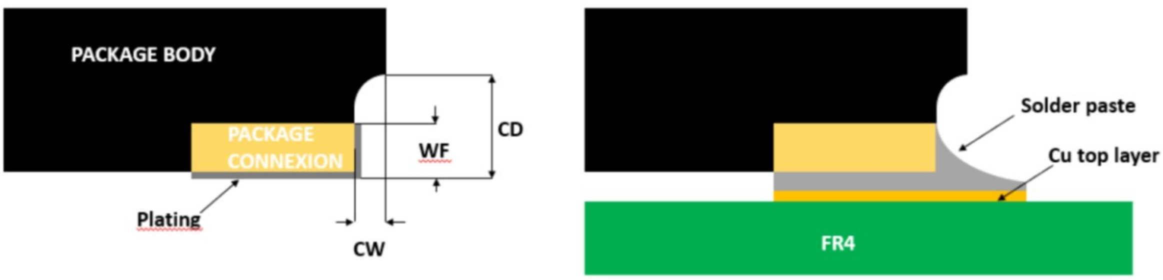
To move forward in the package miniaturization, the DFN packages are the most appropriate. However, standard DFN packages used in other non-automotive industry (personal electronics, factory automation, consumer goods, ...) do not allow to implement an AOI during PCB mounting. The solder pads being located in the bottom of the package, the solder joints are not visible and impose to implement an automated X-ray inspection (AXI).

The AXI usually requires a longer programming time, a higher capital investment and generates additional constraints on the PCB layout (two-side PCB cannot be easily inspected for example).

So, to adapt the DFN packages to the AOI, it was necessary to add wettable flanks on DFN packages. As shown in the following figure, the side of the pads are exposed and wettable so solder menisci are visible and can be optically inspected.

If the CW dimension (see next figure) is short enough (50 µm maximum on ESDCAN03-2BM3Y), the shadow on the solder fillet is minimized and even 2D AOI can be sufficient in some cases to inspect the solder joints of this DFN package (no need for 3D AOI).

Figure 16. **Wettable flank profile on ESDCAN03-2BM3Y**



3.4 Robustness

If the CAN protection TVS must not degrade the signal nor complicate the PCB layout and mounting, the primary role is to efficiently protect the CAN transceivers and the components of the MDI.

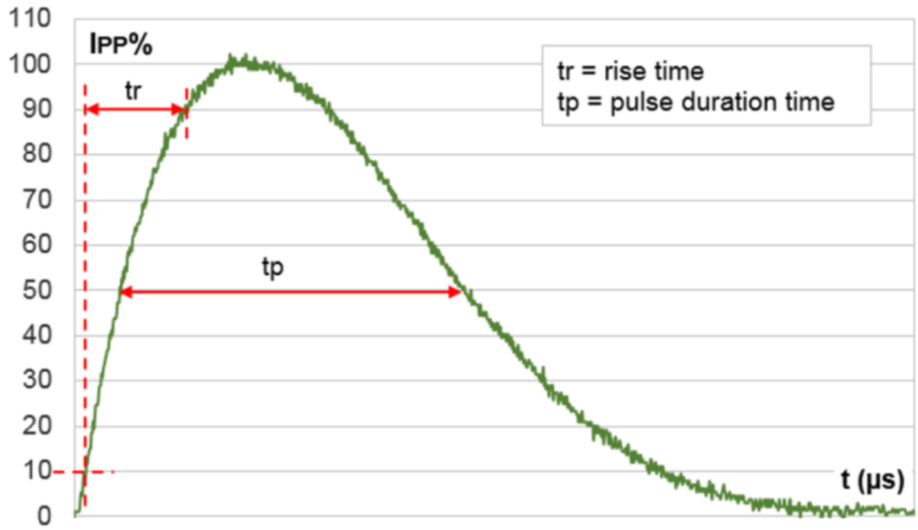
On one hand, the robustness will characterize the severity of the surges (in terms of voltage, current, power, …) that the TVS can withstand.

On the other hand, the quality of protection will be characterized, most of the time, by the clamping performances of the TVS that is, the residual voltage and the residual current that will actually hit the CAN transceivers and the components of the MDI.

On top of all the surges and hazards described in the section 2, a way to quantify the robustness of a TVS versus pulses longer than ESD is to measure the destructive peak pulse current I_{PP} against 8/20 µs current waveform.

This test consists in applying an exponential current waveform as shown in the following figure with a rise time (10% - 90%) of 8 µs and a pulse time (tp) corresponding to 20 µs (time difference between rise time to $I_{PP}/2$ and fall time to $I_{PP}/2$).

Figure 17. **Exponential current waveform**



It is quite easy to summarize the robustness of a STMicroelectronics CAN protection TVS versus all the previous surges described above. All the data are available in the datasheet. Let us take the example of ESDCAN03-2BWY.

The performances regarding ISO 7637-3 and ISO 10605 are given on the cover page (see the next figure) but also in the absolute ratings table in page 2 (see Figure 19. ESDCAN03-2BWY absolute ratings table).

Figure 18. **ESDCAN03-2BWY cover page**

ESDCANxx-2BWY

Datasheet

Automotive dual-line TVS in SOT323-3L for CAN bus

SOT323-3L
(Jedec SC-70)

Product status link	
ESDCANxx-2BWY	ESDCAN02-2BWY, ESDCAN03-2BWY, ESDCAN04-2BWY, ESDCAN05-2BWY, ESDCAN06-2BWY

Features

- AEC-Q101 qualified
- Dual-line ESD and EOS protection
- Breakdown voltage, V_{BR}:
  - ESDCAN02-2BWY: 28.5 V
  - ESDCAN03-2BWY: 26.5 V
  - ESDCAN04-2BWY: 27.5 V
  - ESDCAN05-2BWY: 39 V
  - ESDCAN06-2BWY: 38 V
- Bidirectional device
- Max pulse power up to 170 W (8/20 µs)
- Low clamping factor V_{CL} / V_{BR}
- Low leakage current
- ECOPACK®2 ROHS compliant component

Complies with the following standards

- UL94, V0
- J-STD-020 MSL level 1
- IPC7531 footprint and JEDEC registered package
- ISO 16750-2 (Jump start and reversed battery tests)
- ISO 10605 - C = 150 pF, R = 330 Ω, exceeds level 4:
  - ±30 kV (air discharge)
  - ±30 kV (contact discharge)
- ISO 10605 - C = 330 pF, R = 330 Ω exceeds level 4:
  - ±30 kV (air discharge)
  - ±30 kV (contact discharge)
- ISO 7637-3:
  - Pulse 3a: -150 V
  - Pulse 3b: +150 V
  - Pulse 2a: +/- 85 V

Applications

Automotive controller area network (CAN) bus lines where electrostatic discharges and other transients must be suppressed. These product are compliant with most of automotive interfaces.

Description

These devices are dual-line transient voltage suppressor (TVS) specifically designed for the protection of automotive CAN bus lines against electrostatic discharge (ESD).

Their improved parameters make them compliant with all key drivers in automotive: CAN-FD, LIN, FlexRay, MOST, SENT, USB, etc.

Figure 19. **ESDCAN03-2BWY absolute ratings table**

Table 1. **Absolute ratings (T_{amb} = 25 °C)**

Symbol	Parameter			Value	Unit
V_{PP}	Peak pulse voltage	ISO 10605 - C = 150 pF, R = 330 Ω: Contact discharge Air discharge		30 30	kV
		ISO 10605 - C = 330 pF, R = 330 Ω: Contact discharge Air discharge	ESDCAN02-2BWY ESDCAN03-2BWY ESDCAN04-2BWY	30 30	
		ISO 10605 - C = 330 pF, R = 330 Ω: Contact discharge Air discharge	ESDCAN05-2BWY ESDCAN06-2BWY	22 22	
I_{PP}	Peak pulse current (8/20 µs)		ESDCAN02-2BWY ESDCAN03-2BWY ESDCAN04-2BWY	3.7	A
			ESDCAN05-2BWY ESDCAN06-2BWY	3	

Finally, the Table 9. ESDCAN03-2BWY robustness summary gives a summary of the robustness of the ESDCAN03-2BWY versus the standards.

Table 9. **ESDCAN03-2BWY robustness summary**

Standard	Most severe standard requirement	ESDCAN03-2BWY robustness	PASS/FAIL status
ISO 10605 (R= 330 Ω, C= 330 pF) Contact discharge	Component test direct discharge Category 3 / Level 4i: **± 15 kV**	± 30 kV	PASS
ISO 10605 (R= 330 Ω, C= 330 pF) Air discharge	Component test direct discharge Category 3 / Level 4i: **± 25 kV**	± 30 kV	PASS
ISO 10605 (R= 330 Ω, C= 150 pF) Contact discharge	Vehicle test (DUT accessible from outside) Category 3 / Level 4i: **± 8 kV**	± 30 kV	PASS
ISO 10605 (R= 330 Ω, C= 150 pF) Air discharge	Vehicle test (DUT accessible from outside) Category 3 / Level 4i: **± 25 kV**	± 30 kV	PASS
ISO 10605 (R= 2 kΩ, C= 330 pF) Contact discharge	Vehicle test (DUT accessible from inside) Category 3 / Level 4i: **± 8 kV**	± 30 kV	PASS
ISO 10605 (R= 2 kΩ, C= 330 pF) Air discharge	Vehicle test (DUT accessible from inside) Category 3 / Level 4i: **± 15 kV**	± 30 kV	PASS
ISO 10605 (R= 2 kΩ, C= 150 pF) Contact discharge	Component test direct contact discharge Category 3 / Level 4i: **± 15 kV**	± 30 kV	PASS
ISO 10605 (R= 2 kΩ, C= 150 pF) Air discharge	Component test direct discharge Category 3 / Level 4i: ± 25 kV or Vehicle test (DUT accessible from outside) Category 3 / Level 4i: **± 25 kV**	± 30 kV	PASS
Fast transients ISO 7637-3 pulse 3a	Test level IV (DCC / CCC): **-110 V** (12 V electrical system)	-150 V	PASS
Fast transients ISO 7637-3 pulse 3b	Test level IV (DCC / CCC): **+75 V** (12 V electrical system)	+150 V	PASS
Slow transients ISO 7637-3 positive	Test level IV (DCC): +**30 V** (12 V electrical system)	+ 85 V	PASS
Slow transients ISO 7637-3 negative	Test level IV (DCC): -**30 V** (12 V electrical system)	- 85 V	PASS
Regulator failure ISO 16750-2	18 V for 60 min	$V_{BR} \geq 26.5$ V	PASS
Jump start ISO 16750-2	24 V for 1 min	$V_{BR} \geq 26.5$ V	PASS
Reverse battery ISO 16750-2	-14 V for 1 min	$-26.5 \text{ V} \leq V_{BR}$	PASS

Related links

ESDCAN03-2BW3Y datasheet

3.5 Clamping voltage

As mentioned above, the clamping voltage is related to the quality of protection of the CAN protection TVS.

The clamping voltage is the residual voltage seen by the components (CAN transceivers, termination resistors, capacitors, …) when a surge is applied.

The role of the CAN protection TVS is to sink as much as possible of the pulse current to the ground and limits the voltage increase on the line. So, we understand that the main electrical characteristics of a CAN protection TVS is the dynamic resistance. As a first approach, the lower the dynamic resistance, the better the quality of protection.

Decreasing the dynamic resistance of a TVS can be easily done by increasing the active area of the PN junction of the TVS diode (to increase its current capability). But increasing the active area will obviously increase:

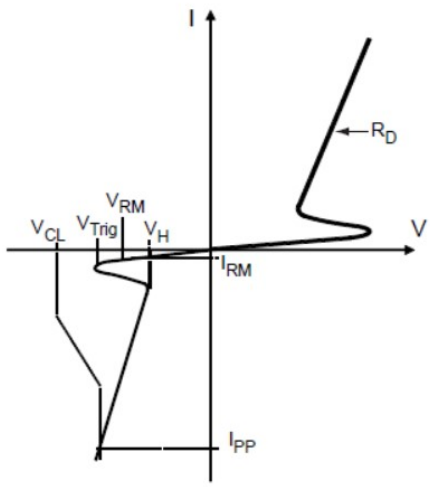
- the die size and then limits the package miniaturization.
- the parasitic capacitance of the diode and then limits the bandwidth of the TVS and its ability to address high data rate or save the capacitance budget of the CAN lines.

So, an efficient CAN protection TVS is a trade-off between all these electrical characteristics.

As shown in Figure 12. ESDCAN03-2BM3Y – snapback effect for ESDCAN03-2BM3Y, another way to significantly decrease the clamping voltage is to use technologies with snapback. When the voltage applied on the TVS exceeds the “trigger” voltage, V_{TRIG}, its voltage suddenly decreases to the holding voltage V_H and then it acts like a standard clamping voltage (see the following figure). This helps to decrease the clamping voltage by 10% to 20% without compromising the other electrical characteristics.

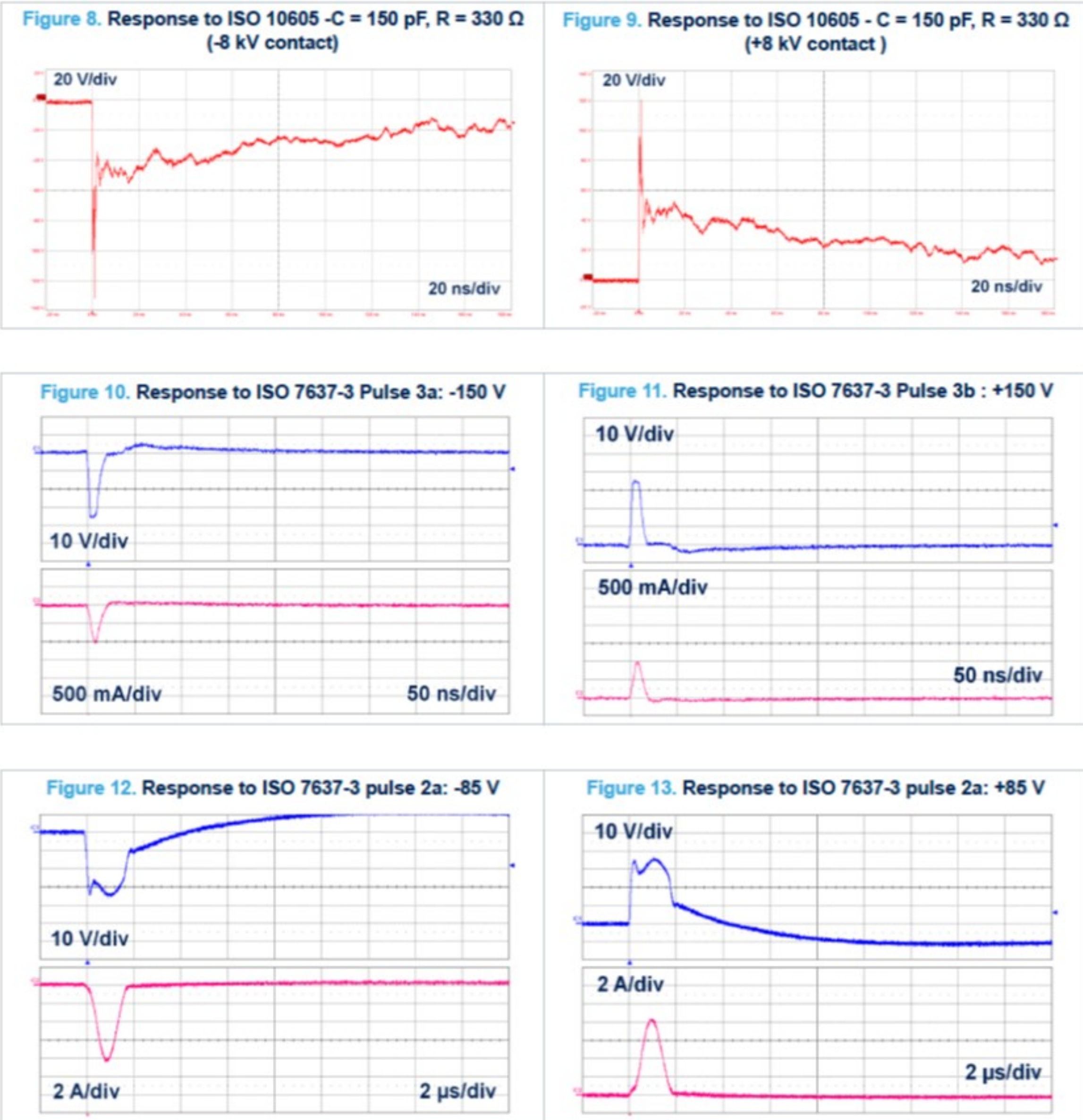
Figure 20. ESDCAN03-2BM3Y – electrical characteristics with snapback

Symbol		Parameter
V_{Trig}	=	Trigger voltage
V_{CL}	=	Clamping voltage
I_{RM}	=	Leakage current @ V_{RM}
V_{RM}	=	Stand-off voltage
I_{PP}	=	Peak pulse current
R_D	=	Dynamic resistance
V_H	=	Holding voltage
C_{LINE}	=	Input capacitance per line



All the clamping voltages versus the various automotive pulses are given in the ESDCAN datasheets. The surges are directly applied on the ESDCAN part, so without any other circuit or component limiting the surges. It is the most stressful condition and so the worst case for the protection device. A datasheet extract of ESDCAN03-2BM3Y is given as example in the following figure.

Figure 21. **ESDCAN03-2BM3Y – responses to automotive surges**



Note: DCC (direct capacitive coupling) for Figure 10, Figure 11, Figure 12 and Figure 13.

In the final application, on the real PCB embedding all the MDI components, the value of the clamping voltage will be different (most of the time lower) when applying a surge. It is particularly important to perform the test on the final design to make sure that the CAN protection TVS will clamp enough energy not to degrade any downstream components.

The layout and the placement of the TVS plays a critical role in maximizing the protection efficiency. Thorough recommendations are given in AN5686 : PCB layout tips to maximize ESD protection efficiency.

Related links

ESDCAN03-2BM3Y datasheet

AN5686: PCB layout tips to maximize ESD protection efficiency

3.6 Junction temperature

Finally, the last important parameter when selecting a CAN protection TVS is the “Operating junction temperature range”. In normal operation, the CAN protection TVS is quiet and is not supposed to sink any current so there is no self-heating phenomenon.

So, the operating junction temperature range, is the temperature range at which the device can operate without drastically impacting its lifetime. The reliability tests of the ESDCAN series (H3TRB, thermal cycling, …) are always performed at the worst conditions so meaning at 175 °C for example for ESDCAN series in SOT323-3L and DFN1110.

4 How to select the right ESDCAN

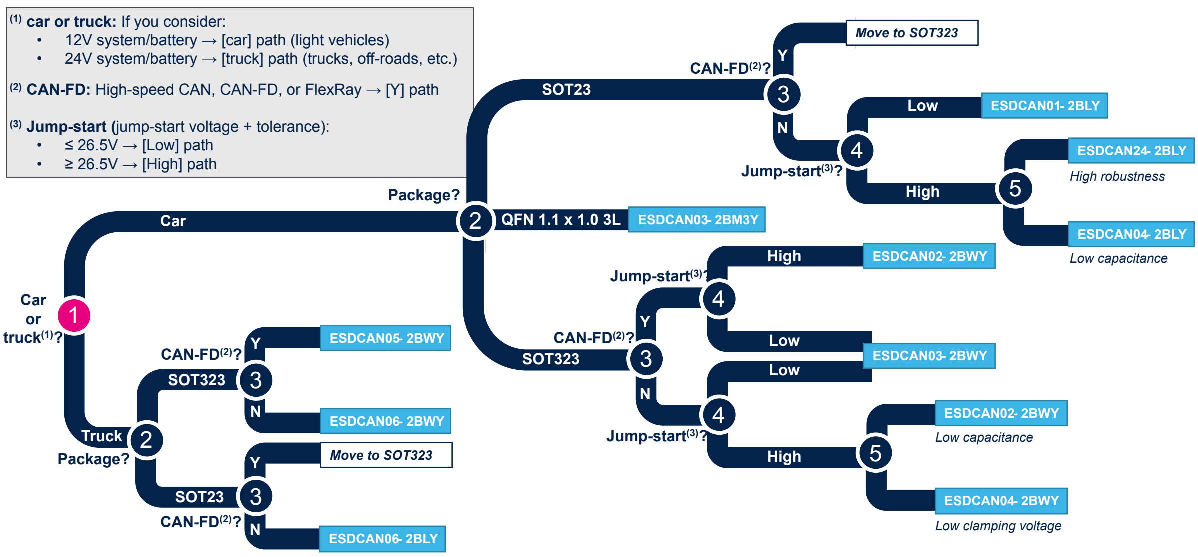
All the parameters and characteristics presented above allow to select the right CAN protection TVS in most of the cases.

However, to make it even faster, we developed a tool for the ESDCAN series as shown in the following figure.

By answering five simple questions, one can get the right part number:

1. Is it for cars or trucks?
2. Which package is needed?
3. Which kind of CAN: low speed CAN or high speed CAN?
4. Is a jump start voltage value higher than 28 V necessary?
5. Which item is the most critical in the design or project?
   – the surge level so high robustness is preferred.
   – the capacitance budget so low capacitance is preferred.
   – the CAN transceiver vulnerability so low clamping voltage is preferred.

Figure 22. Five steps to select the right ESDCAN



5 Conclusion

This application note describes the CAN communication link from the physical layer point of view as well as the automotive surges that CAN transceivers and components part of the MDI must survive. Based on this information, the requirements on the electrical characteristics on CAN protection TVS are listed and explained.

Ultimately, this document shows how to select the proper CAN protection TVS using the ESDCAN series example.

It is mandatory to confirm with measurements and tests, that the ESDCAN device selected based on these criteria is suitable in the final design and layout.

Revision history

Table 10. **Document revision history**

Date	Revision	Changes
21-Nov-2022	1	Initial release.
22-Nov-2022	2	Minor document structure changes to improve readability.

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