ESD protection
Automotive

For In-Vehicle Networks and multimedia buses:

LIN, CAN, CAN FD, CAN XL, FlexRay, Automotive Ethernet (10BT1s, 100/1000BT1, MGBT1), SERDES, LVDS, USB, HDMI

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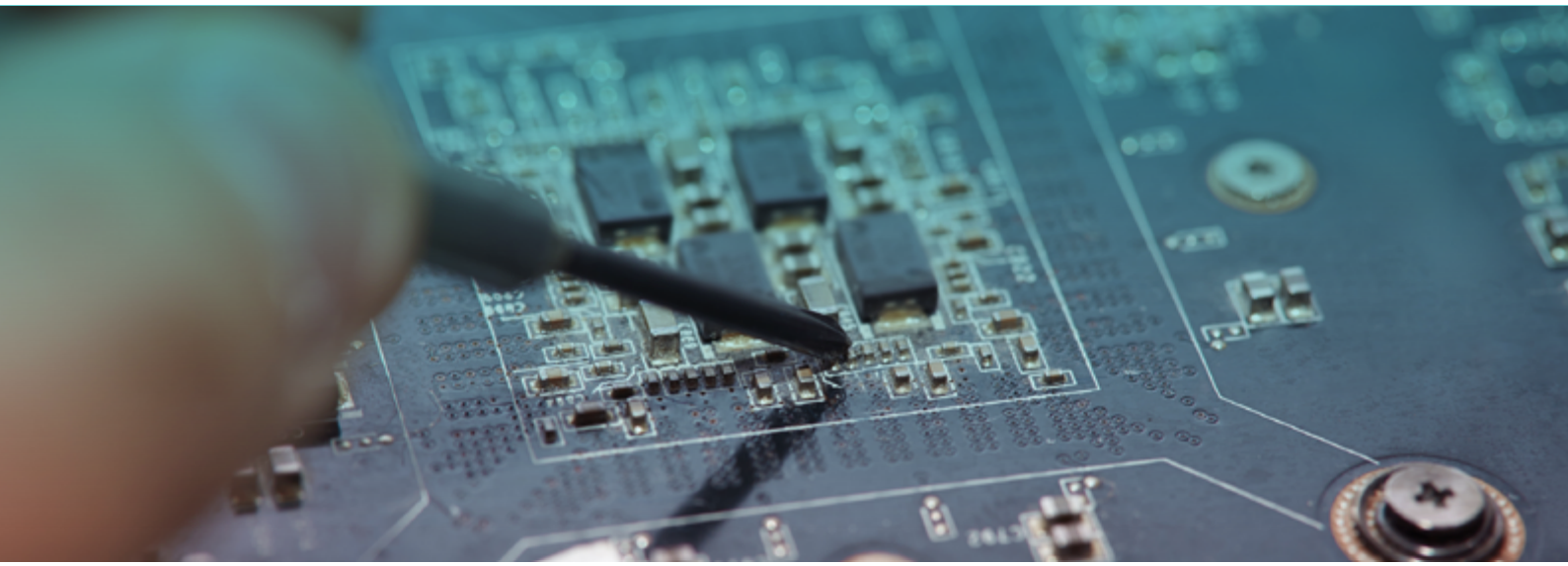
Contents

Introduction

Why protection against ESD events gets more important?

Also in the automotive domain ever-increasing data rates, greater calculation power of System-on-Chips, IC miniaturization and multiple power requirements in confined spaces are making components and systems more sensitive to ESD. Another factor increasing the risk of damage by ESD is the trend of smaller structures in semiconductors. This means even lower voltages can damage the thinner gate oxide.

The good news is that damages caused by ESD or EOS (Electrical Over Stress) can be avoided or at least massively reduced with an optimized ESD protection concept. Nexperia's ESD competence can help minimize the risk of ESD damage – supporting the engineering community in protecting applications and products against destructive ESD pulses.



What do you get with Nexperia's ESD protection?

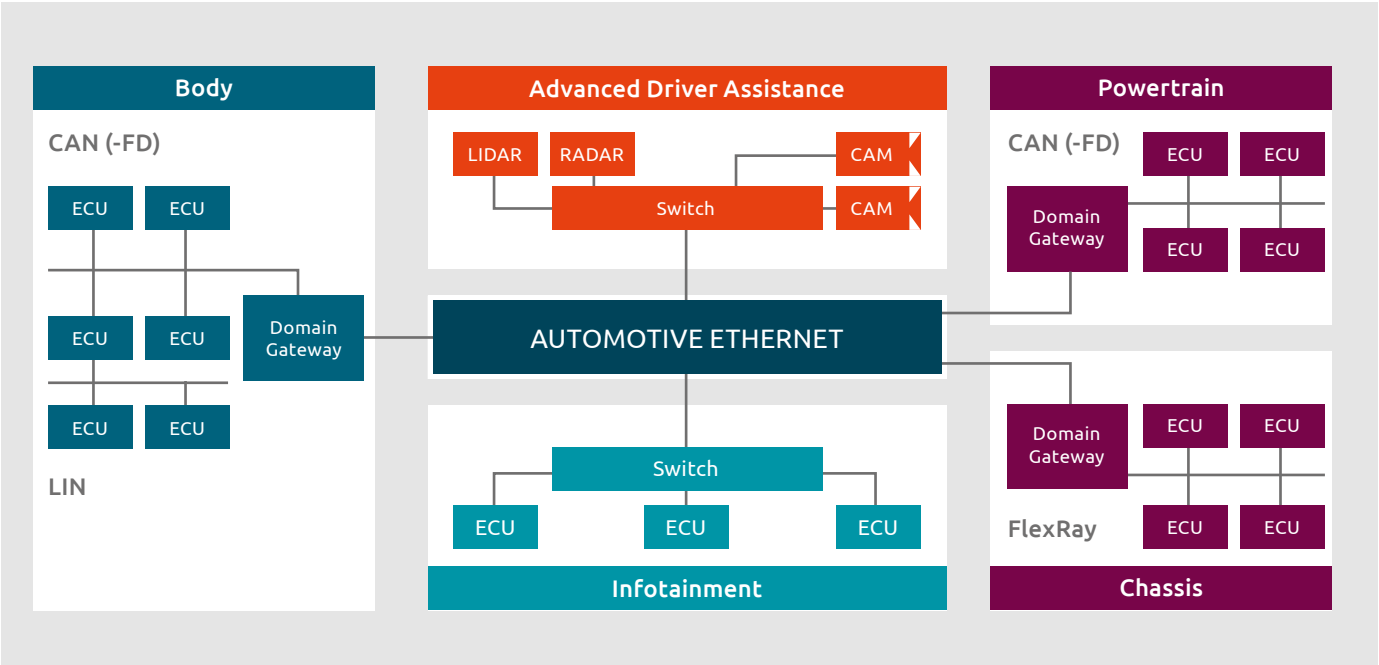
- Improved system-level robustness (based on IEC61000-4-2)
- Low clamping voltages safeguarding latest SoC technology
- Minimized impact on bus and interface signal integrity
- Arrays that combine multi-line protection in single packages
- Packages that simplify PCB design for optimized layouts
- AEC-Q101 qualification grade / PPAP capability

A growing and challenging market for ESD protection

Ever-increasing data rates, greater computing power of System-on-Chips, IC miniaturization, and multiple power requirements in confined spaces are making components and systems ever more sensitive to ESD. Furthermore, the trend to smaller structures of semiconductor processes goes in hand with the thinner gate oxides and increases the risk of damage by ESD at even lower voltages.

Despite all these challenges, the good news is that risk of failure due to ESD or EOS (Electrical Over Stress) can be avoided – or at least massively reduced – with an optimized ESD protection concept. To this end, Nexperia's ESD competence can help minimize the risk of ESD damage – supporting the design community in protecting applications and products against ESD issues.

To exchange all the data flowing between powertrain and body ECUs, a number of highly reliable In-Vehicle Networks (CAN/CAN-FD/CAN-XL, LIN, FlexRay, Ethernet) are needed. To ensure safe operation, solutions are required to pass emission and immunity tests, and guarantee signal integrity. Multimedia bus systems and infotainment networks generally use USB, Automotive Pixel Link (APIX), HDMI or Ethernet and will adopt USB Type-C. However, these interfaces also need to meet more stringent specifications than those commonly found in consumer markets.



Block diagram of a typical in-vehicle network

Common in-vehicle network technologies

Interface	Topology	data rate	Specifications standards
LIN	single wire, power train serves as return path	20 kbit/s	ISO17987: 2016 SAE J2602
CAN (low speed, fault tolerant)	differential two wires, twisted pair; in fault condition single wire	500 kbit/s	ISO11898 part 3 SAE J2411
CAN (high speed)	differential two wires, twisted pair	1 Mbit/s	ISO11898 part 2, 5, 6
CAN FD (flexible data rate)	differential two wires, twisted pair	2 and 5 Mbit/s	ISO11898-1:2015
CAN XL	differential two wires, twisted pair	up to 10 Mbit/s	Partly in ISO 11898-1
FlexRay	differential two wires, shielded twisted pair	10 Mbit/s	ISO17458-4:2013
100BASE-T1, 1000BASE-T1 (automotive Ethernet)	two wires, unshielded twisted pair cable	100/1000 Mbit/s	Open Alliance IEEE STD 802.3

LIN (Local Interconnected Network)

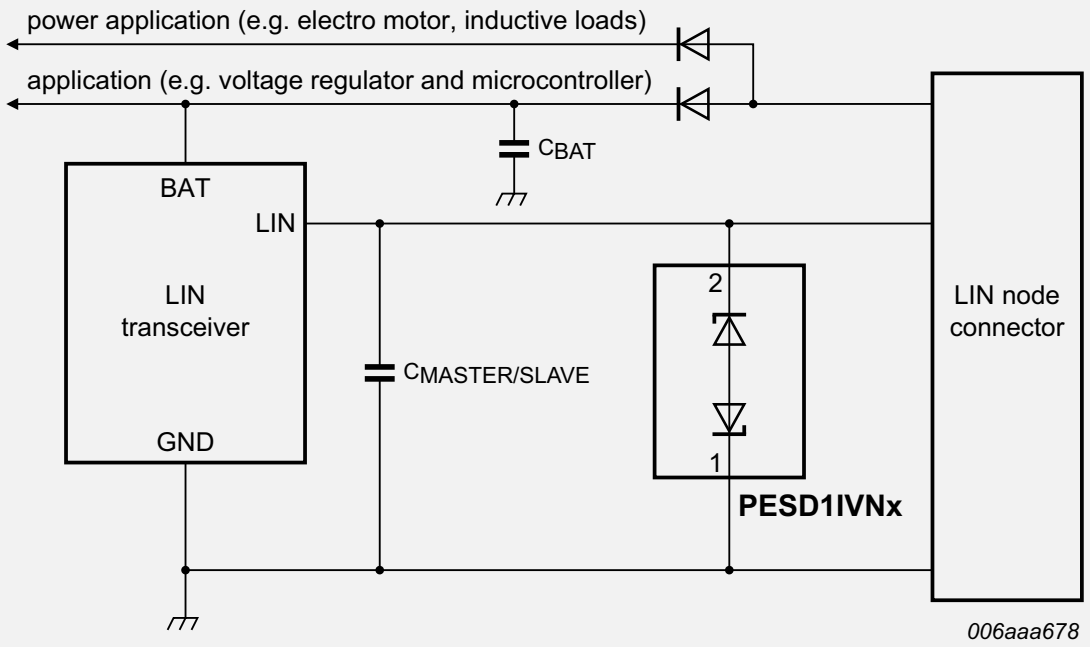
LIN is a concept for low-cost automotive networks. It is typically used where the higher data rates and versatility of the CAN network is not required. It connects modules into a sub-bus that is connected to the existing CAN network. Typical modules where LIN is used are seats, locks, mirrors, or as interface to sensors, for instance rain detectors. It uses a single wire, serial communication protocol and operates at low speed, with a maximum data rate of 20 kbit/s. The bus voltage level is approximately the supply voltage, in 12 V board net typically 14.4 V.

External ESD protection on the LIN bus connection is recommended by LIN transceiver suppliers for extending the ESD voltage level the module can withstand. In addition, ESD protection diodes should be chosen to withstand the maximum battery voltage without being damaged, in case the LIN bus line is shorted to the battery line. For a 12 V board net the maximum battery voltage is 16 V, but often also the jumpstart from a 24 V truck battery is considered. The operating voltage range for an ECU is defined between 8 V and 18 V, relative to the local ECU ground. From this range definition, V_{RWM} should be higher than 18 V. Typically, bi-directional ESD diodes are used for LIN bus application with a breakdown voltage higher than +/– 27 V because of the following aspects.

LIN bus uses single-ended transmission and during EMC tests the voltage levels of, e.g. capacitively coupled RF signals, can exceed the diode's breakdown voltage. With voltage exceeding the breakdown voltage of the ESD protection diode, the communication signal is clamped to the diode's clamping voltage V_{CL}. The higher the breakdown voltage, the later the EMC test levels will start to have an influence, i.e. disturbing the dominant and recessive voltage levels. The total system is more robust against inducted noise and EMI. With diodes having a $V_{BR} \geq 27$ V, modern transceiver modules pass typical EMC tests as required by the automotive industry.

To avoid impacting the module's EMC performance, it can be stated that the higher the breakdown voltage the better. On the other hand, sufficient clamping performance for ESD events must be achieved.

Moreover, diode capacitance Cd has to be lower than 100 pF to maintain signal integrity at the maximum data rate of 20 kbit/s. To minimize the total impact of the diode on the system however, Cd should be less than 30 pF.



ESD protection of one automotive LIN bus line with PESD1IVNx

Recommended protection devices for LIN bus

Part	Comment	Package	No. of channels	V_{RWM}	C_D max	ESD robustness (IEC61000-4-2)	I_{PPM} at t_p = 8/20µs	AEC-Q101 PPAP capable
PESD1IVN27-A	Preferred for LIN protection, single line	SOD323	1 x bi	27 V	17 pF	30 kV	3 .0 A	Yes
PESD1IVN24-A	Alternative V_{RWM} for LIN protection	SOD323	1 x bi	24 V	17 pF	30 kV	3 .5 A	Yes
PESD2IVN27-U	Preferred for LIN protection, two lines	SOT323	2 x bi	27 V	17 pF	30 kV	3 .0 A	Yes
PESD2IVN24-U	Alternative V_{RWM} for LIN protection, single line	SOT323	2 x bi	24 V	17 pF	30 kV	3 .5 A	Yes
PESD1IVN27LS-Q	Preferred DFN solution for LIN protection, single line	DFN1006BD-2	1 x bi	27 V	17 pF	30 kV	3 A	Yes
PESD1IVN24LS-Q	Alternative V_{RWM} for LIN protection in DFN, single line	DFN1006BD-2	1 x bi	24 V	17 pF	30 kV	3 .5 A	Yes
PESD2CANFD27L-U	Alternative for LIN protection, high ESD robustness	SOT323	2 x bi	27 V	10 pF	30kV	3 .9 A	Yes
PESD2CANFD27L-T	Alternative for LIN protection, high ESD robustness	SOT23	2 x bi	27 V	10 pF	30 kV	4 .0 A	Yes
PESD2CANFD27V-T	Alternative Cd for LIN protection, low capacitance	SOT23	2 x bi	27 V	6 pF	20 kV	2 .5 A	Yes
PESD2CANFD27V-U	Alternative Cd for LIN protection, low capacitance	SOT323	2 x bi	27 V	6 pF	20 kV	2 .5 A	Yes
PESD2CANFD27V-QB	Alternative Cd for LIN protection, low capacitance and DFN package	DFN1110D-3	2 x bi	27 V	6 pF	20 kV	2 .5 A	Yes
PESD2CANFD27V-QC	Alternative Cd for LIN protection, low capacitance and DFN package	DFN1412D-3	2 x bi	27 V	6 pF	20 kV	2 .5 A	Yes
PESD2CANFD27U-T	Alternative Cd for LIN protection, ultra-low capacitance	SOT23	2 x bi	27 V	3 .5 pF	14 kV	1 .5 A	Yes
PESD2CANFD27U-U	Alternative Cd for LIN protection, ultra-low capacitance	SOT323	2 x bi	27 V	3 .5 pF	14 kV	1 .5 A	Yes
PESD2CANFD27U-QB	Alternative Cd for LIN protection, ultra-low capacitance and DFN package	DFN1110D-3	2 x bi	27 V	3 .5 pF	15 kV	1 .5 A	Yes
PESD2CANFD27U-QC	Alternative Cd for LIN protection, ultra-low capacitance and DFN package	DFN1412D-3	2 x bi	27 V	3 .5 pF	15 kV	1 .5 A	Yes
PESD2CANFD24L-T	Alternative V_{RWM} for LIN protection, higher ESD robustness	SOT23	2 x bi	24 V	10 pF	30 kV	4 .0 A	Yes
PESD2CANFD24L-U	Alternative V_{RWM} for LIN protection, higher ESD robustness	SOT323	2 x bi	24 V	10 pF	30 kV	4 .0 A	Yes
PESD2CANFD24V-T	Alternative V_{RWM} for LIN protection, low capacitance	SOT23	2 x bi	24 V	6 pF	23 kV	2 .6 A	Yes
PESD2CANFD24V-U	Alternative V_{RWM} for LIN protection, low capacitance	SOT323	2 x bi	24 V	6 pF	23 kV	2 .6 A	Yes
PESD2CANFD24V-QB	Alternative V_{RWM} for LIN protection, low capacitance and DFN package	DFN1110D-3	2 x bi	24 V	6 pF	23 kV	2 .6 A	Yes
PESD2CANFD24V-QC	Alternative V_{RWM} for LIN protection, low capacitance and DFN package	DFN1412D-3	2 x bi	24 V	6 pF	23 kV	2 .6 A	Yes
PESD2CANFD24U-T	Alternative V_{RWM} for LIN protection, ultra-low capacitance	SOT23	2 x bi	24 V	3 .5 pF	14 kV	1 .5 A	Yes
PESD2CANFD24U-U	Alternative V_{RWM} for LIN protection, ultra-low capacitance	SOT323	2 x bi	24 V	3 .5 pF	14 kV	1 .5 A	Yes
PESD2CANFD24U-QB	Alternative V_{RWM} for LIN protection, ultra-low capacitance and DFN package	DFN1110D-3	2 x bi	24 V	3 .5 pF	14 kV	1 .5 A	Yes
PESD2CANFD24U-QC	Alternative V_{RWM} for LIN protection, ultra-low capacitance and DFN package	DFN1412D-3	2 x bi	24 V	3 .5 pF	14 kV	1 .5 A	Yes
PESDCANFD36UT-Q	Preferred for 24 V board net LIN protection, ultra-low capacitance	SOT23	2 x bi	36 V	4 .3 pF	15 kV	1 .5 A	Yes
PESD2CANFD36UU-Q	Preferred for 24 V board net LIN protection, ultra-low capacitance	SOT323	2 x bi	36 V	4 .3 pF	15 kV	1 .5 A	Yes
PESD2CANFD36VT-Q	Preferred for 24 V board net LIN protection, low capacitance	SOT23	2 x bi	36 V	6 pF	20 kV	2 A	Yes
PESD2CANFD36VU-Q	Preferred for 24 V board net LIN protection, low capacitance	SOT323	2 x bi	36 V	6 pF	20 kV	2 A	Yes
PESD2CANFD36LT-Q	Preferred for 24 V board net LIN protection, high ESD robustness	SOT23	2 x bi	36 V	10 pF	22 kV	3 .2 A	Yes
PESD2CANFD36LU-Q	Preferred for 24 V board net LIN protection, high ESD robustness	SOT323	2 x bi	36 V	10 pF	22 kV	3 .2 A	Yes
PESD2IVN48V-T-Q	Preferred for 48 V board net LIN protection	SOT23	2 x bi	48 V	7 .1 pF	30 kV	3 .5 A	Yes

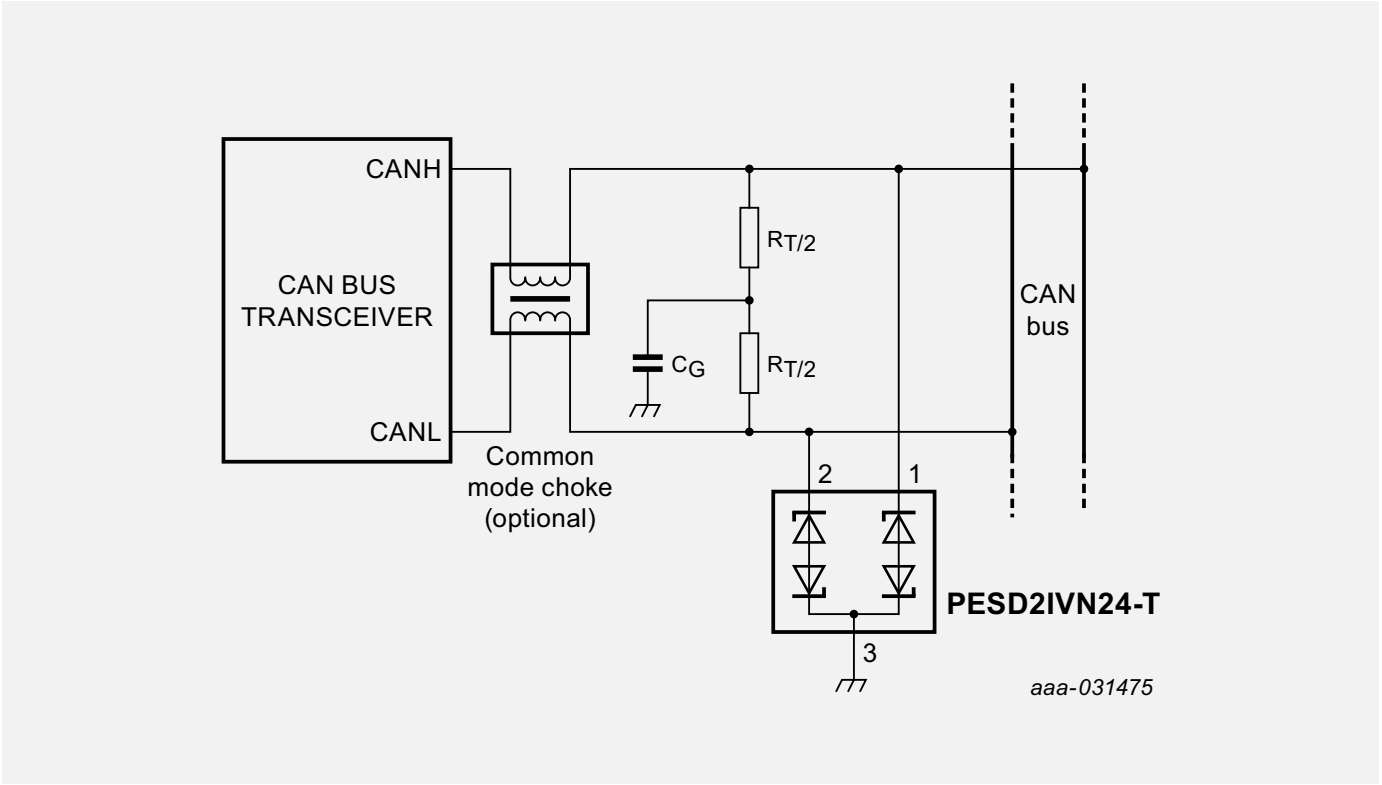
CAN (Controller Area Network)

CAN is a very well-established network for automotive and is considered more flexible, but more expensive, than LIN. A CAN network typically uses a two wire, twisted pair cable to transmit and receive serial data. High-speed CAN (parts 2, 5, and 6 of the ISO 11898), specifies transmission rates up to 1 Mbit/s. Low-speed, fault-tolerant CAN (part 3 of the ISO 11898), specifies up to 500 kilobits per second. Fault tolerant often means that the transceiver can switch from a differential receive and transmit capability to a single-wire transmitter and/or receiver in error conditions. This means a maximum single ended (fault tolerant) +12 V bus voltage, and a differential –12 V bus voltage.

A CAN transceiver provides the physical link between the protocol controller and the physical bus wires in a network. CANL is the LOW-level CAN bus line. In normal operating mode, the value of dominant state is about 1.4 V and the value of recessive state is 5 V. In low-power modes, the voltage of CANL is equal to the battery voltage. CANH is the HIGH-level CAN bus line. In a typical operating mode, the value of dominant state is about 3.6 V and the value of recessive state as well as in low-power modes is 0 V.

External clamping circuits can be applied to the CANH and CANL line to extend the ESD robustness of the network, protect the CAN transceivers and ensure communication. Nexperia offers devices specifically designed to protect two CAN bus lines from damage caused by ESD and other transients.

As CAN networks may be shorted to voltage sources, e.g. the car battery, ESD protection devices at the CANL and CANH lines must be able to withstand the higher voltage levels. In jump-start conditions, or two 12 V batteries in series, this means that a minimum of 2 × 12 V = 24 V is required as stand-off voltage $V_{RWM.}$ Maximum data rate for CAN is 1Mbit/s.



ESD protection of one automotive LIN bus line with PESD1IVN24-T

Recommended protection devices for CAN bus

Part	Comment	Package	No. of channels	V_{RWM}	C_D max	ESD robustness (IEC61000-4-2)	I_{PPM} at t_p = 8/20µs	AEC-Q101 PPAP capable
PESD2CANFD24LT-Q	Preferred for CAN protection	SOT23	2 x bi	24 V	10	30 kV	1 A	Yes
PESD2CANFD24L-U	Preferred for CAN protection	SOT323	2 x bi	24 V	10 pF	30 kV	4 .0 A	Yes
PESD2CANFD24VQB-Q	Preferred DFN alternative for CAN protection	DFN1110D-3	2 x bi	24 V	6	23 kV	2 .6 A	Yes
PESD2CANFD24VQC-Q	Preferred DFN alternative for CAN protection	DFN1412D-3	2 x bi	24 V	6	23 kV	2 .6 A	Yes
PESD2IVN24-T	Alternative for CAN protection	SOT23	2 x bi	24 V	17 pF	30 kV	3 .5 A	Yes
PESD2IVN24-U	Alternative for CAN protection	SOT323	2 x bi	24 V	17 pF	30 kV	3 .5 A	Yes
PESD2IVN27-T	Alternative V_{RWM} for CAN protection	SOT23	2 x bi	27 V	17 pF	30 kV	3 .0 A	Yes
PESD2IVN27-U	Alternative V_{RWM} for CAN protection	SOT323	2 x bi	27 V	17 pF	30 kV	3 .0 A	Yes
MMBZ27VAL	High surge robustness/ Common anode configuration	SOT23	1 x bi, 2 x uni	22 V	60 pF	30 kV	1 A (10/1000µs)	Yes
PESD2CANFD24V-T	Alternative for CAN protection, low capacitance	SOT23	2 x bi	24 V	6 pF	23 kV	2 .6 A	Yes
PESD2CANFD24V-U	Alternative for CAN protection, low capacitance	SOT323	2 x bi	24 V	6 pF	23 kV	2 .6 A	Yes
PESD2CANFD24V-QB	Alternative for CAN protection, low capacitance and DFN package	DFN1110D-3	2 x bi	24 V	6 pF	23 kV	2 .6 A	Yes
PESD2CANFD24V-QC	Alternative for CAN protection, low capacitance and DFN package	DFN1412D-3	2 x bi	24 V	6 pF	23 kV	2 .6 A	Yes
PESD2CANFD24U-T	Alternative for CAN protection, ultra-low capacitance	SOT23	2 x bi	24 V	3 .5 pF	14 kV	1 .5 A	Yes
PESD2CANFD24U-U	Alternative for CAN protection, ultra-low capacitance	SOT323	2 x bi	24 V	3 .5 pF	14 kV	1 .5 A	Yes
PESD2CANFD24U-QB	Alternative for CAN protection, ultra-low capacitance and DFN package	DFN1110D-3	2 x bi	24 V	3 .5 pF	14 kV	1 .5 A	Yes
PESD2CANFD24U-QC	Alternative for CAN protection, ultra-low capacitance and DFN package	DFN1412D-3	2 x bi	24 V	3 .5 pF	14 kV	1 .5 A	Yes
PESD2CANFD27L-U	Alternative V_{RWM} for CAN protection	SOT323	2 x bi	27 V	10 pF	30 kV	3 .9 A	Yes
PESD2CANFD27L-T	Alternative V_{RWM} for CAN protection	SOT23	2 x bi	27 V	10 pF	30 kV	4 .0 A	Yes
PESD2CANFD27V-T	Alternative V_{RWM} for CAN protection, low capacitance	SOT23	2 x bi	27 V	6 pF	20 kV	2 .5 A	Yes
PESD2CANFD27V-U	Alternative V_{RWM} for CAN protection, low capacitance	SOT323	2 x bi	27 V	6 pF	20 kV	2 .5 A	Yes
PESD2CANFD27V-QB	Alternative V_{RWM} for CAN protection, low capacitance and DFN package	DFN1110D-3	2 x bi	27 V	6 pF	20 kV	2 .5 A	Yes
PESD2CANFD27V-QC	Alternative V_{RWM} for CAN protection, low capacitance and DFN package	DFN1412D-3	2 x bi	27 V	6 pF	20 kV	2 .5 A	Yes
PESD2CANFD27U-T	Alternative V_{RWM} for CAN protection, ultra-low capacitance	SOT23	2 x bi	27 V	3 .5 pF	14 kV	1 .5 A	Yes
PESD2CANFD27U-U	Alternative V_{RWM} for CAN protection, ultra-low capacitance	SOT323	2 x bi	27 V	3 .5 pF	14 kV	1 .5 A	Yes
PESD2CANFD27U-QB	Alternative V_{RWM} for CAN protection, ultra-low capacitance and DFN package	DFN1110D-3	2 x bi	27 V	3 .5 pF	15 kV	1 .5 A	Yes
PESD2CANFD27U-QC	Alternative V_{RWM} for CAN protection, ultra-low capacitance and DFN package	DFN1412D-3	2 x bi	27 V	3 .5 pF	15 kV	1 .5 A	Yes
PESD2CANFD36VT-Q	Preferred for 24 V board net CAN protection, low capacitance	SOT23	2 x bi	36 V	6 pF	20 kV	2 A	Yes
PESD2CANFD36VU-Q	Preferred for 24 V board net CAN protection, low capacitance	SOT323	2 x bi	36 V	6 pF	20 kV	2 A	Yes
PESDCANFD36UT-Q	Preferred for 24 V board net CAN protection, ultra-low capacitance	SOT23	2 x bi	36 V	4 .3 pF	15 kV	1 .5 A	Yes
PESD2CANFD36UU-Q	Preferred for 24 V board net CAN protection, ultra-low capacitance	SOT323	2 x bi	36 V	4 .3 pF	15 kV	1 .5 A	Yes
PESD2CANFD36LT-Q	Preferred for 24 V board net CAN protection, high ESD robustness	SOT23	2 x bi	36 V	10 pF	22 kV	3 .2 A	Yes
PESD2CANFD36LU-Q	Preferred for 24 V board net CAN protection, high ESD robustness	SOT323	2 x bi	36 V	10 pF	22 kV	3 .2 A	Yes
PESD2ETH100-T*	For VW 80121-3 specification	SOT23	2 x bi	24 V	3 pF	> 30 kV	3 .2 A	Yes

* To fulfill the VW 80121-3 specificaiton, higher trigger voltage devices are required to ensure system robustness.

CAN FD (CAN Flexible Data rate)

Because more and more ECUs are used in an automotive network with the requirement to transmit and receive more data, the classical CAN network with its limitation to 1 Mbit/s is considered insufficient for future needs. CAN FD is an update of the physical layer of CAN.

A major difference is a flexible data rate, that is defined up to 10 Mbit/s. 2 Mbit/s is the typical implementation limit suitable for many applications that do not require higher data rates.

Nexperia offers arrange of protection solutions for CAN FD

- Improved system-level robustness (IEC61000-4-2)
- Low clamping voltages safeguarding latest SoC technology
- Minimized impact on bus and interface signal integrity
- Arrays that combine multi-line protection in single packages
- Packages that simplify PCB design for optimized layouts
- AEC-Q101 qualification grade / PPAP capability

DFN1110D-3
(SOT8015)
1.1 x 1 x 0.48

DFN1412D-3
(SOT8009)
1.4 x 1.2 x 0.47

SOT323
(SC-70)
2 x 1.25 x 0.95

SOT23
2.9 x 1.3 x 1

Leadless DFN and leaded SMD package options for protection devices

Recommended protection devices for CAN FD bus

Part	Comment	Package	No. of channels	V_{RWM}	C_D max	ESD robustness (IEC61000-4-2)	I_{PPM} at t_p = 8/20µs	AEC-Q101 PPAP capable
PESD2CANFD24V-T	Preferred for CAN FD protection	SOT23	2 x bi	24 V	6 pF	23 kV	2 .6 A	Yes
PESD2CANFD24V-U	Preferred for CAN FD protection	SOT323	2 x bi	24 V	6 pF	23 kV	2 .6 A	Yes
PESD2CANFD24V-QB	Preferred DFN alternative for CAN FD protection	DFN1110D-3	2 x bi	24 V	6 pF	23 kV	2 .6 A	Yes
PESD2CANFD24V-QC	Preferred DFN alternative for CAN FD protection	DFN1412D-3	2 x bi	24 V	6 pF	23 kV	2 .6 A	Yes
PESD2CANFD24U-T	Preferred for high-speed CAN FD protection, lower capacitance	SOT23	2 x bi	24 V	3 .5 pF	14 kV	1 .5 A	Yes
PESD2CANFD24U-U	Preferred for high-speed CAN FD protection, lower capacitance	SOT323	2 x bi	24 V	3 .5 pF	14 kV	1 .5 A	Yes
PESD2CANFD24U-QB	Preferred DFN alternative for high-speed CAN FD protection, lower capacitance	DFN1110D-3	2 x bi	24 V	3 .5 pF	14 kV	1 .5 A	Yes
PESD2CANFD24U-QC	Preferred DFN alternative for high-speed CAN FD protection, lower capacitance	DFN1412D-3	2 x bi	24 V	3 .5 pF	14 kV	1 .5 A	Yes
PESD2CANFD24L-T	Alternative for CAN FD protection, higher ESD robustness	SOT23	2 x bi	24 V	10 pF	30 kV	4 .0 A	Yes
PESD2CANFD24L-U	Alternative for CAN FD protection, higher ESD robustness	SOT323	2 x bi	24 V	10 pF	30 kV	4 .0 A	Yes
PESD2CANFD27V-T	Alternative V_{RWM} for CAN FD protection	SOT23	2 x bi	27 V	6 pF	20 kV	2 .5 A	Yes
PESD2CANFD27V-U	Alternative V_{RWM} for CAN FD protection	SOT323	2 x bi	27 V	6 pF	20 kV	2 .5 A	Yes
PESD2CANFD27V-QB	Alternative V_{RWM} for CAN FD protection, DFN package	DFN1110D-3	2 x bi	27 V	6 pF	20 kV	2 .5 A	Yes
PESD2CANFD27V-QC	Alternative V_{RWM} for CAN FD protection, DFN package	DFN1412D-3	2 x bi	27 V	6 pF	20 kV	2 .5 A	Yes
PESD2CANFD27L-T	Alternative V_{RWM} for CAN FD protection, higher ESD robustness	SOT23	2 x bi	27 V	10 pF	30 kV	4 .0 A	Yes
PESD2CANFD27L-U	Alternative V_{RWM} for CAN FD protection, higher ESD robustness	SOT323	2 x bi	27 V	10 pF	30 kV	4 .0 A	Yes
PESD2CANFD27U-T	Alternative V_{RWM} for CAN FD protection, lower capacitance	SOT23	2 x bi	27 V	3 .5 pF	14 kV	1 .5 A	Yes
PESD2CANFD27U-U	Alternative V_{RWM} for CAN FD protection, lower capacitance	SOT323	2 x bi	27 V	3 .5 pF	14 kV	1 .5 A	Yes
PESD2CANFD27U-QB	Alternative V_{RWM} for CAN FD protection, lower capacitance and DNF package	DFN1110D-3	2 x bi	27 V	3 .5 pF	14 kV	1 .5 A	Yes
PESD2CANFD27U-QC	Alternative V_{RWM} for CAN FD protection, lower capacitance and DFN package	DFN1412D-3	2 x bi	27 V	3 .5 pF	14 kV	1 .5 A	Yes
PESD2CANFD36VT-Q	Preferred for 24 V board net CAN FD protection	SOT23	2 x bi	36 V	6 pF	20 kV	2 A	Yes
PESD2CANFD36VU-Q	Preferred for 24 V board net CAN FD protection	SOT323	2 x bi	36 V	6 pF	20 kV	2 A	Yes
PESDCANFD36UT-Q	Preferred for high-speed 24 V board net CAN FD protection, lower capacitance	SOT23	2 x bi	36 V	4 .3 pF	15 kV	1 .5 A	Yes
PESD2CANFD36UU-Q	Preferred for high-speed 24 V board net CAN FD protection, lower capacitance	SOT323	2 x bi	36 V	4 .3 pF	15 kV	1 .5 A	Yes
PESD2CANFD36LT-Q	Alternative for 24 V board net CAN FD protection, higher ESD robustness	SOT23	2 x bi	36 V	10 pF	22 kV	3 .2 A	Yes
PESD2CANFD36LU-Q	Alternative for 24 V board net CAN FD protection, higher ESD robustness	SOT323	2 x bi	36 V	10 pF	22 kV	3 .2 A	Yes
PESD2ETH100-T *	For VW 80121-3 specification	SOT23	2 x bi	24 V	3 pF	> 30 kV	3 .2 A	Yes

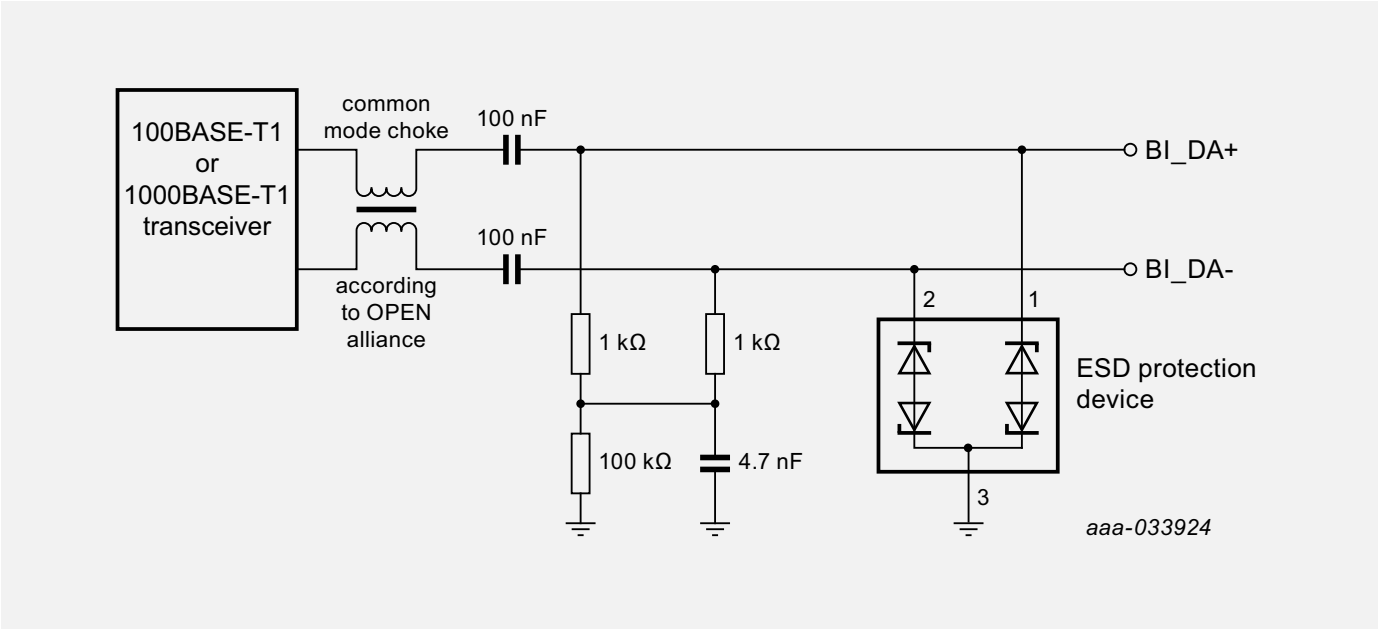
* To fulfill the VW 80121-3 specificaiton, higher trigger voltage devices are required to ensure system robustness.

Automotive Ethernet 100BASE-T1 and 1000BASE-T1

Ethernet is seen as a universal and flexible alternative to CAN or FlexRay networks. It is used for modules that need to process more data, and need higher data rates, like camera, driver assistance and back-bone networks. Automotive Ethernet IEEE 100/1000 BASE-T1 (IEEE 802.3bw) provides 100 or 1000 Mbit/s respectively and transmit and receive capability over a single unshielded twisted pair cable. The standard basics were developed by Broadcom (BroadR-Reach™) and completed by the IEEE 802.3 working group. Today the deployment of automotive Ethernet is driven by the OPEN (One Pair Ethernet) Alliance SIG (Special Interest Group). OPEN Alliance SIG is a is a non-profit, open industry organization to encourage wide scale adoption of Ethernet- based networks as the standard in automotive networking applications. For future car generations, there are several directions planed. The one is to have automotive multi- Gigabit Ethernet to cover high data rate ethernet in the range of 2.5/5.0/10Gbps. The other is to have a low cost ethernet topology in 10 Mbps rang, 10BASE-T1s.

Due to topology of the 10 Base T1s and 100/1000 Base T1 systems having UTP cables and a mandatory common mode choke (CMC), the resulting trigger voltage of the ESD device is specified above 100V. Here, we strongly recommend to place the ESD protection device close to the connector, as shown in figure below. Thus, the energy of the ESD event will be immediately directed to the ground. Not only the PHY but also the passive components like CMC, resistors and capacitors are protected.

At this exposed position the ESD diode has to withstand the harsh environment of automotive cabling like high energy common mode noise or overvoltage due to short to battery condition. The ESD protection devices are designed for a trigger voltage ≥ 100 V and – in addition to IEC61000-4-2 level 4 – must withstand a minimum of 1000 discharges. To guarantee the signal integrity a low parasitic capacitance of < 3.5 pF is required. More signal integrity testing results in terms of S-parameters are available for all ethernet devices and can be provided.



ESD protection of one pair automotive Gigabit Ethernet (OPEN Alliance) with PESD2ETH1G-T

Portfolio OPEN Alliance compliant with protection at the connector

Part	Comment	Package	No. of channels	V_{RWM}	C_D max	ESD robustness (IEC61000-4-2)	I_{PPM} at t_p = 8/20µs	AEC-Q101 PPAP capable
PESD2ETH1G-T	For 100/1000BASE-T1 OPEN Alliance Ethernet	SOT23	2 x bi	24 V	2 pF	> 30 kV	2 .3 A	Yes
PESD2ETH1GXT-Q	For 100/1000BASE-T1 OPEN Alliance Ethernet	SOT23	2 x bi	24 V	< 1 pF	> 15 kV	2 A	Yes
PESD2ETH100-T	For 100BASE-T1 OPEN Alliance Ethernet	SOT23	2 x bi	24 V	3 pF	> 30 kV	3 .2 A	Yes
PESD1ETH1GLS-Q	For 100/1000BASE-T1 OPEN Alliance Ethernet	SOD882BD	1 x bi	24 V	< 2 pF	> 15 kV	2 A	Yes
PESD1ETH1GXLS-Q	For 100/1000BASE-T1 OPEN Alliance Ethernet	SOT23	2 x bi	24 V	< 1 .3 pF	> 15 kV	2 .3 A	Yes
PESD1ETH1GXLS-Q	For 100/1000BASE-T1 OPEN Alliance Ethernet	SOD882BD	1 x bi	24 V	< 1 .2 pF	>15 kV	2 .3 A	Yes

Portfolio for classic protection approach at the PHY

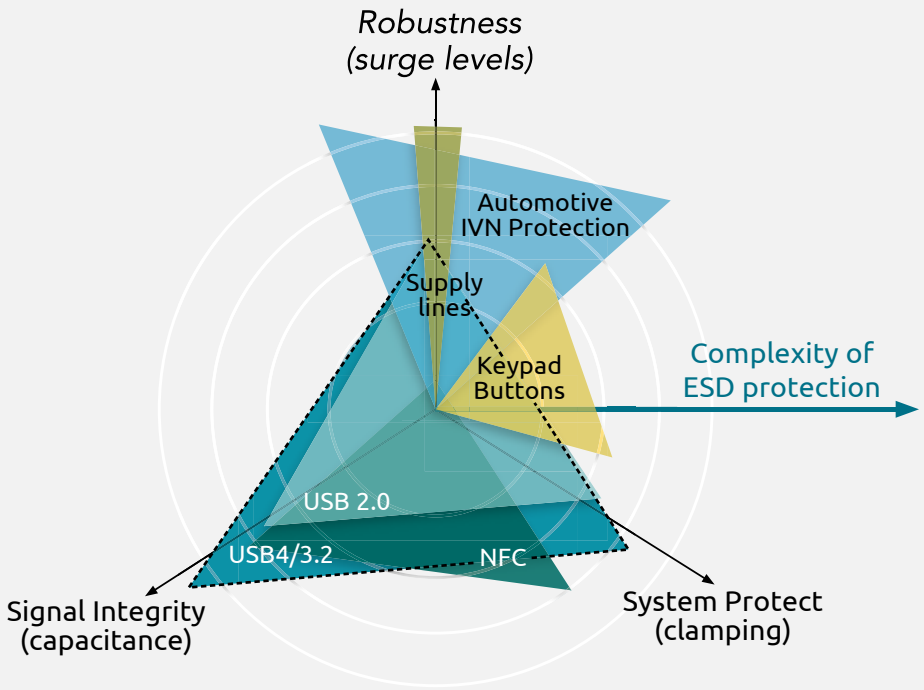
Part	Comment	Package	No. of channels	V_{RWM}	C_D max	ESD robustness (IEC61000-4-2)	I_{PPM} at tp = 8/20µs	AEC-Q101 PPAP capable
PESD2ETH-X	Lower capacitance	SOT143B	1	5 .5 V	1 .5 pF	8 kV	–	Yes
PESD2ETH-AX	Higher ESD robustnesss	SOT143B	1	5 .5 V	1 .8 pF (typ)	12 kV	–	Yes
PESD2ETH-D	Dual channel protection, Lower capacitance	SOT457	2	5 .5 V	1 .8 pF	8 kV	2 .5 A	Yes
PESD2ETH-AD	Dual channel protection, Higher ESD robustness	SOT457	2	5 .5 V	2 .3 pF	12 kV	3 .5 A	Yes
PESD5V0F1BL(D)	Ultra-low capacitance, DFN1006D-2 with side wettable flanks (SWF) for automated optical inspection (AOI)	DFN1006(D)-2 (SOD882(D))	1	5 .5 V	0 .55 pF	10 kV	2 .5 A	Yes
PESD18VF1BL-Q	Ultra-low capacitance, increased signal integrity performance, DFN1006-2	DFN1006-2	1	18	0 .5 pF	10 kV	1 A	Yes
PESD24VF1BL-Q	Ultra-low capacitance, increased signal integrity performance, DFN1006-2	DFN1006-2	1	24	0 .45 pF	10 kV	1 A	Yes
PESD30VF1BL-Q	Ultra-low capacitance, increased signal integrity performance, DFN1006-2	DFN1006-2	1	30	0 .4 pF	12 kV	1 A	Yes
PESD18VF1BLS-Q	Ultra-low capacitance, increased signal integrity performance, DFN1006BD-2	DFN1006BD-2	1	18	0 .5 pF	10 kV	–	Yes
PESD24VF1BLS-Q	Ultra-low capacitance, increased signal integrity performance, DFN1006BD-2	DFN1006BD-2	1	24	0 .45 pF	10 kV	–	Yes
PESD30VF1BLS-Q	Ultra-low capacitance, increased signal integrity performance, DFN1006BD-2	DFN1006BD-2	1	30	0 .4 pF	10 kV	–	Yes
PESD32VF1BLS-Q	Ultra-low capacitance, increased signal integrity performance, DFN1006BD-2	DFN1006BD-2	1	32	0 .4 pF	10 kV	–	Yes

Multimedia / infotainment HDMI, USB

Despite dedicated IVN technologies designed for the reliable connection of electromechanical devices and modules in the car, bus and point-to-point connections are also used in the multimedia systems of modern cars. When using high-speed buses known from consumer, communication and computing in the automotive environment, individual components need to meet higher quality standards. Furthermore functional requirements occasionally change, like short-to-battery scenarios.

Usually buses that are known to computing interfaces are used in automotive applications within the multimedia environment. As this is a non-safety related application the same protection strategies can be used. In order to match the high standards which are common in automotive applications Nexperia qualified it's cutting edge TrEOS protection technology according to AEC-Q101. Nexperia's TrEOS technology allows to balance the performance between:

- Low capacitance for highest signal integrity
- Low clamping and trigger voltage for best system protection
- High device robustness against surge current and ESD voltage.



The ideal balance of performance for each use case

Recommended protection devices for multimedia & infotainment connections

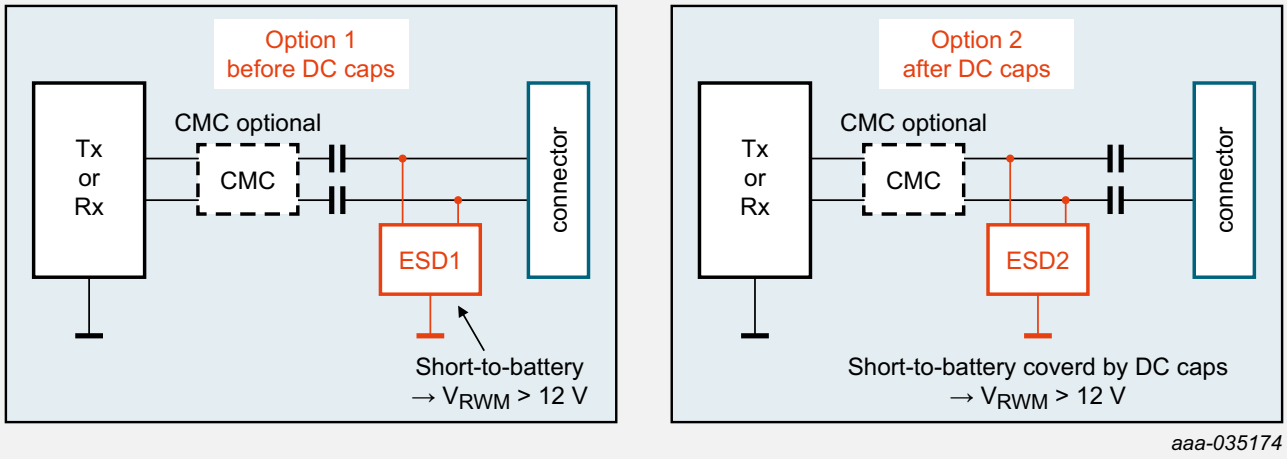
Part	Comment	Package	No. of channels	V_{RWM}	C_D max	ESD robustness (IEC61000-4-2)	I_{PPM} at t_p = 8/20µs	AEC-Q101 PPAP capable
PESD2USB3UV-T	automotive TrEOS for USB2.0, HDMI, LVDS, SerDes	SOT23	2	3 .3 V	1 pF	18 kV	8 A	Yes
PESD2USB3UX-T	automotive TrEOS for USB2.0, HDMI, LVDS, SerDes	SOT23	2	3 .3 V	0 .7 pF	8 kV	4 A	Yes
PESD2USB5UV-T	automotive TrEOS for USB2.0, HDMI, LVDS, SerDes	SOT23	2	5 V	0 .9 pF	22 kV	10 A	Yes
PESD2USB5UX-T	automotive TrEOS for USB2.0, HDMI, LVDS, SerDes	SOT23	2	5 V	0 .6 pF	8 kV	4 A	Yes
PESD4USB3U-TBR	automotive TrEOS for USB2.0, HDMI, LVDS, SerDes	DFN2510A-10 (SOT1176-1)	4	3 .3 V	0 .34 pF	15 kV	7 A	Yes
PESD4USB5U-TBR	automotive TrEOS for USB2.0, HDMI, LVDS, SerDes	DFN2510A-10 (SOT1176-1)	4	5 .5 V	0 .34 pF	15 kV	7 A	Yes
PESD4USB3B-TBR	automotive TrEOS for USB3.2, HDMI, LVDS, SerDes	DFN2510A-10 (SOT1176-1)	4	3 .3 V	0 .25 pF	15 kV	7 A	Yes
PESD4USB5B-TBR	automotive TrEOS for USB3.2, HDMI, LVDS, SerDes	DFN2510A-10 (SOT1176-1)	4	5 .5 V	0 .25 pF	15 kV	7 A	Yes
PESD4USB3U-TBS	automotive TrEOS for USB2.0, HDMI, LVDS, SerDes	DFN2510D (SOT1176D)	4	3 .3 V	0 .34 pF	15 kV	7 A	Yes
PESD4USB5U-TBS	automotive TrEOS for USB2.0, HDMI, LVDS, SerDes	DFN2510D (SOT1176D)	4	5 .5 V	0 .34 pF	15 kV	7 A	Yes
PESD4USB3B-TBS	automotive TrEOS for USB3.2, HDMI, LVDS, SerDes	DFN2510D (SOT1176D)	4	3 .3 V	0 .25 pF	15 kV	7 A	Yes
PESD4USB5B-TBS	automotive TrEOS for USB3.2, HDMI, LVDS, SerDes	DFN2510D (SOT1176D)	4	5 .5 V	0 .25 pF	15 kV	7 A	Yes
PESD4USB3U-TTS	automotive TrEOS for USB2.0, HDMI, LVDS, SerDes	DFN2510D (SOT1165D)	4	3 .3 V	0 .34 pF	15 kV	7 A	Yes
PESD4USB5U-TTS	automotive TrEOS for USB2.0, HDMI, LVDS, SerDes	DFN2510D (SOT1165D)	4	5 .5 V	0 .34 pF	15 kV	7 A	Yes
PESD4USB3B-TTS	automotive TrEOS for USB3.2, HDMI, LVDS, SerDes	DFN2510D (SOT1165D)	4	3 .3 V	0 .25 pF	15 kV	7 A	Yes
PESD4USB5B-TTS	automotive TrEOS for USB3.2, HDMI, LVDS, SerDes	DFN2510D (SOT1165D)	4	5 .5 V	0 .25 pF	15 kV	7 A	Yes
PESD1LVDS	LVDS, HDMI, DisplayPort, dual channel protection with capacitance matching or USB lines plus CC1, CC2	DFN2510-10 (SOT1165)	2	5 .5 V	0 .6 pF (typ)	8 kV	-	Yes
PESD18VF1BL	Audio Interface, Charger Port, Antenna, (NFC, WiFi), LVDS	DFN1006-2 (SOD882)	1	18 V	0 .5 pF	10 kV	1 A	Yes
PESD24VF1BL	Audio Interface, Charger Port, Antenna, (NFC, WiFi), LVDS	DFN1006-2 (SOD882)	1	24 V	0 .45 pF	10 kV	1 A	Yes
PESD30VF1BL	Audio Interface, Charger Port, Antenna, (NFC, WiFi), LVDS	DFN1006-2 (SOD882)	1	30 V	0 .4 pF	12 kV	1 A	Yes
PESD5V0F1BL(D)	Ultra low capacitance, DFN1006D-2 with side wettable flanks (SWF) for automated optical inspection (AOI)	DFN1006(D)-2 (SOD882(D))	1	5 .5 V	0 .55 pF	10 kV	2 .5 A	Yes
PESD5V0X1BCAL	USB2 .0 lines only	DFN1006D-2 (SOD882)	1	5 .5 V	0 .95 pF	15 kV	1 .8 A	Yes
PESD5V0X1UALD	USB2.0 lines only, side wettable flanks (SWF) for auto- mated optical inspection (AOI)	DFN1006D-2 (SOD882D)	1	5 .5V	1 .75 pF	15 kV	2 A	Yes
PESD5V0C1BLS-Q	Bi-directional single line automotive ESD protection for high speed interfaces such as USB 3.2, HDMI 2.0, LVDS, A/V monitors, displays and cameras.	DFN1006BD-2	1	5 V	0 .3 pF	15 kV	6 .5 A	Yes
PESD5VC1ULS-Q	Uni-directional single line automotive ESD protection for high speed interfaces such as USB 3.2, HDMI 2.0, LVDS, A/V monitors, displays and cameras.	DFN1006BD-2	1	5 V	0 .6 pF	15 kV	6 .5 A	Yes
PESD5V0C2UM-Q	Uni-directional dual line automotive ESD protection for high speed interfaces such as USB 3.0, HDMI 2.0, LVDS, A/V monitors, displays and cameras.	DFN1006-3	1	5 V	0 .6 pF	15 kV	6 .5 A	Yes
PESD5V5C1BL-Q	Bi-directional single line automotive ESD protection for high speed interfaces such as USB 3.2, HDMI 2.0, LVDS, A/V monitors, displays and cameras.	DFN1006-2	1	5 .5 V	0 .3 pF	15 kV	6 .5 A	Yes
PESD5V5C1UL-Q	Uni-directional single line automotive ESD protection for high speed interfaces such as USB 3.2, HDMI 2.0, LVDS, A/V monitors, displays and cameras.	DFN1006-2	1	5 .5 V	0 .6 pF	15 kV	6 .5 A	Yes

ADAS and video interfaces LVDS, APIX, GMSL, FPD-link

Currently several competing technologies emerge for automotive high-speed data transmission. Main application is the transmission of raw video data for ADAS, HMI, displays or control devices. Depending on the OEM and supplier one or the other of these technologies will be used.

- LVDS: Low-voltage differential signaling: ANSI/TIA/ EIA-644-A, technical standard for differential, serial communications protocol
- APIX: Automotive Pixel Link, serial high speed multichannel link
- GMSL2: Gigabit Multimedia Serial Link
- FPD-link: Flat Panel Display Link, high speed digital video interface
- SerDes: Serializer/ De-Serializer, underlying technology, device to convert a parallel data stream in a serial one and vice-versa

Nexperia automotive qualified TrEOS protection technology is the first choice to protect the sensitive system chips. There is a vast collection of protection devices available to meet the diverse application needs like space constraints, different voltage or transmission speed levels.



Typical LVDS configuration showing two different possibilities placing the ESD device. The option 1 considers the short to battery and therefore needs to have V_{RWM} > 12V Option 2 can consider lower values of V_{RWM} in the range of 5 or even 3.3V.

Recommended protection devices for ADAS interfaces

Part	Comment	Package	No. of channels	V_{RWM}	C_D max	ESD robustness (IEC61000-4-2)	I_{PPM} at t_p = 8/20µs	AEC-Q101 PPAP capable
PESD2USB3UV-T	automotive TrEOS for USB2.0, HDMI, LVDS, SerDes	SOT23	2	3 .3 V	1 pF	18 kV	8 A	Yes
PESD2USB3UX-T	automotive TrEOS for USB2.0, HDMI, LVDS, SerDes	SOT23	2	3 .3 V	0 .7 pF	8 kV	4 A	Yes
PESD2USB5UV-T	automotive TrEOS for USB2.0, HDMI, LVDS, SerDes	SOT23	2	5 V	0 .9 pF	22 kV	10 A	Yes
PESD2USB5UX-T	automotive TrEOS for USB2.0, HDMI, LVDS, SerDes	SOT23	2	5 V	0 .6 pF	8 kV	4 A	Yes
PESD4USB3U-TBR	automotive TrEOS for USB2.0, HDMI, LVDS, SerDes	DFN2510A-10 (SOT1176-1)	4	3 .3 V	0 .34 pF	15 kV	7 A	Yes
PESD4USB5U-TBR	automotive TrEOS for USB2.0, HDMI, LVDS, SerDes	DFN2510A-10 (SOT1176-1)	4	5 .5 V	0 .34 pF	15 kV	7 A	Yes
PESD4USB3B-TBR	automotive TrEOS for USB3.2, HDMI, LVDS, SerDes	DFN2510A-10 (SOT1176-1)	4	3 .3 V	0 .25 pF	15 kV	7 A	Yes
PESD4USB5B-TBR	automotive TrEOS for USB3.2, HDMI, LVDS, SerDes	DFN2510A-10 (SOT1176-1)	4	5 .5 V	0 .25 pF	15 kV	7 A	Yes
PESD1LVDS	LVDS, HDMI, DisplayPort, dual channel protection with capacitance matching or USB lines plus CC1, CC2	DFN2510-10 (SOT1165)	2	5 .5 V	0 .6 pF (typ)	8 kV	-	Yes
PESD18VF1BL	Audio Interface, Charger Port, Antenna, (NFC, WiFi), LVDS, SerDes	DFN1006-2 (SOD882)	1	18 V	0 .5 pF	10 kV	1 A	Yes
PESD24VF1BL	Audio Interface, Charger Port, Antenna, (NFC, WiFi), LVDS, SerDes	DFN1006-2 (SOD882)	1	24 V	0 .45 pF	10 kV	1 A	Yes
PESD30VF1BL	Audio Interface, Charger Port, Antenna, (NFC, WiFi), LVDS, SerDes	DFN1006-2 (SOD882)	1	30 V	0 .4 pF	12 kV	1 A	Yes
PESD5V0F1BL(D)	Ultra low capacitance, DFN1006D-2 with side wettable flanks (SWF) for automated optical inspection (AOI)	DFN1006(D)-2 (SOD882(D))	1	5 .5 V	0 .55 pF	10 kV	2 .5 A	Yes
PESD5V0X1BCAL	USB2 .0 lines only	DFN1006D-2 (SOD882)	1	5 .5 V	0 .95 pF	15 kV	1 .8 A	Yes
PESD5V0X1UALD	USB2.0 lines only, side wettable flanks (SWF) for auto- mated optical inspection (AOI)	DFN1006D-2 (SOD882D)	1	5 .5V	1 .75 pF	15 kV	2 A	Yes
PESD5V0C1BLS-Q	Bi-directional single line automotive ESD protection for high speed interfaces such as USB 3.2, HDMI 2.0, LVDS, A/V monitors, displays and cameras.	DFN1006BD-2	2	5 V	0 .3 pF	15 kV	6 .5 A	Yes
PESD5VC1ULS-Q	Uni-directional single line automotive ESD protection for high speed interfaces such as USB 3.2, HDMI 2.0, LVDS, A/V monitors, displays and cameras.	DFN1006BD-2	1	5 V	0 .6 pF	15 kV	6 .5 A	Yes
PESD5V0C2UM-Q	Uni-directional dual line automotive ESD protection for high speed interfaces such as USB 3.0, HDMI 2.0, LVDS, A/V monitors, displays and cameras.	DFN1006-3	2	5 V	0 .6 pF	15 kV	6 .5 A	Yes
PESD5V5C1BL-Q	Bi-directional single line automotive ESD protection for high speed interfaces such as USB 3.2, HDMI 2.0, LVDS, A/V monitors, displays and cameras.	DFN1006-2	2	5 .5 V	0 .3 pF	15 kV	6 .5 A	Yes
PESD5V5C1UL-Q	Uni-directional single line automotive ESD protection for high speed interfaces such as USB 3.2, HDMI 2.0, LVDS, A/V monitors, displays and cameras.	DFN1006-2	1	5 .5 V	0 .6 pF	15 kV	6 .5 A	Yes

Transient voltage suppressors (TVS)

Introduction to supply line protection

Transient voltage suppressors (TVS) protect supply lines against high current surge pulses. Sources of high current surge pulses can be external or internal. External surge events can originate from, e.g. a wall box or a discharge event from a charged cable. Internal surge events can originate from sources such as switching events or load changes.
The Nexperia terminology differentiate between ESD protection products and TVS products. Namely TVS protection devices (PTVS or MMBZ) can withstand significantly higher energy originating from high current surge pulses and are meant to be placed on supply lines. In some literature and by some protection device suppliers both protection devices are classified as TVS.

Pulse standards

Depending on the source of the pulse it may have different pulse shapes (i.e. pulse length and rise/fall times) and energy. Although standards like IEC 61000-4-5 are intended to describe the direct or indirect effect of lightning strikes to power lines, devices that are tested to this standard are not subject to these events. The test methods are used to characterize device robustness against other events that contain a similar amount of energy and have similar pulse shape.

TVS operation

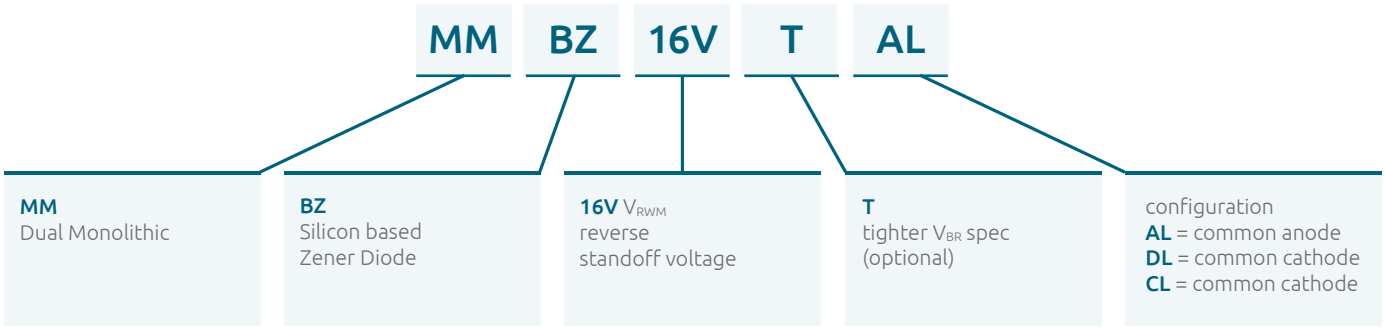
As long as the voltage on the protected line stays below the breakdown voltage of the TVS diode the protection device does not react. Once the voltage on the line reaches the protection device's breakdown voltage, it will start conducting current to ground resulting in the voltage to be clamped to $V_{CL.}$

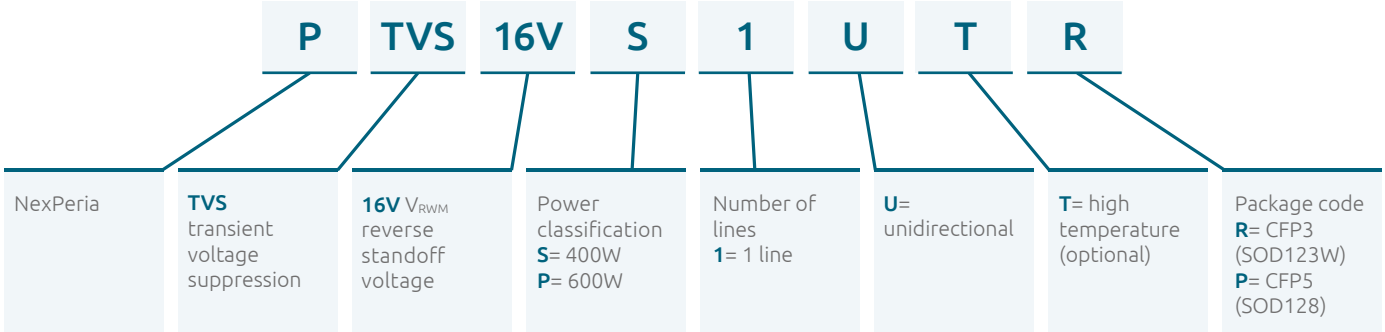
Portfolio

For the use in the automotive domain Nexperia offers two quite different series of TVS diodes:

- MMBZ – Legacy industry standard, Dual, Monolithic, Silicon based, Zener diodes with a P_{tot} of 24 or 40W in common anode or common cathode configuration in a SOT23 plastic SMD package
- PTVS – the more powerful unidirectional, single TVS diodes in a two-pin clip bonded CFP3 (P_{tot}=400W) or CFP5 (P_{tot}=600W) package.

Naming convention for TVS diodes at Nexperia





ESD protection design

The golden rules of ESD design:

1. Place the device as close to the input terminal or connector as possible and increase the distance to the PHY.
2. Minimize the path length between the device and the protected line.
3. Keep parallel signal paths to a minimum.
4. Avoid running protected conductors in parallel with unprotected conductors.
5. Minimize all Printed-Circuit-Board (PCB) conductive loops including power and ground loops.
6. Minimize the length of the transient return path to ground.
7. Avoid using shared transient return paths to a common ground point.
8. Use ground planes whenever possible. For multilayer PCBs, use ground vias.

Fore more information about Nexperia's automotive ESD and TVS products refer to: https://www.nexperia.com/esdprotection

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