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# Application guide: ESD protection

**For automotive and industrial applications:**  
car infotainment, body control modules, video cameras,  
industrial computers, and test & measurement equipment

nexperia

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This document offers a lineup of commonly found interfaces along with suggested methods for protecting against ESD and/or surges. For each interface we show example circuits and present a lineup of recommended solutions from Nexperia. In all cases, the shown lineup is a subset of the total number of possible solutions Nexperia can offer. Please direct any questions or concern feel to your local Nexperia representative for further details and information.

# Introduction

## Nexperia – your partner for ESD protection

ESD protection has been an important part of electronic design for many years. Now, as integration levels continue to increase, and process geometries continue to shrink, the ESD-induced damage is a more present threat than ever before. Add this to the growing demand for portable electronics, and ESD protection has become an essential issue at the system level.

Adding comprehensive ESD protection to a system isn't just smart engineering, it's also a low-cost, easy way to prevent problems later in the product life cycle: An ESD problem that remains hidden in a system, poses an increased risk of field failures, reduced system life, and other quality-related problems that are difficult to manage and expensive to resolve. The after-market costs associated with field repair and product recalls can be crippling, and quality issues can do serious harm to the brand reputation.

Nexperia offers more than 400 protection devices, ranging from single-protection diodes to complete, highly integrated companion ICs. Our ESD solutions are offered in a wide package portfolio, ranging from leaded to leadless packages. Moreover, package innovations like solderable side pads enable visual inspection while a package innovation like pass-through routing assures an optimal board layout as well as enhanced ESD protection as the device can be positioned closed to the interface.

This application guide covers automotive and industrial applications. But what you see here is just the tip of the iceberg. For a full listing of our most up-to-date ESD protection solutions, visit [www.nexperia.com/protection](http://www.nexperia.com/protection).

## What you get when you choose Nexperia for ESD protection

- › Greater system-level immunity (IEC61000-4-2 level 4 standard and beyond)
- › Ultra-low clamping voltages, to safeguard even the latest, smallest geometries in SoC devices
- › Minimized impact on bus and interface signal integrity
- › Low leakage current, for maximum energy efficiency and minimum distortion on analog interfaces
- › Arrays that combine multiline protection in single devices
- › Packages that simplify PCB design for optimized layouts



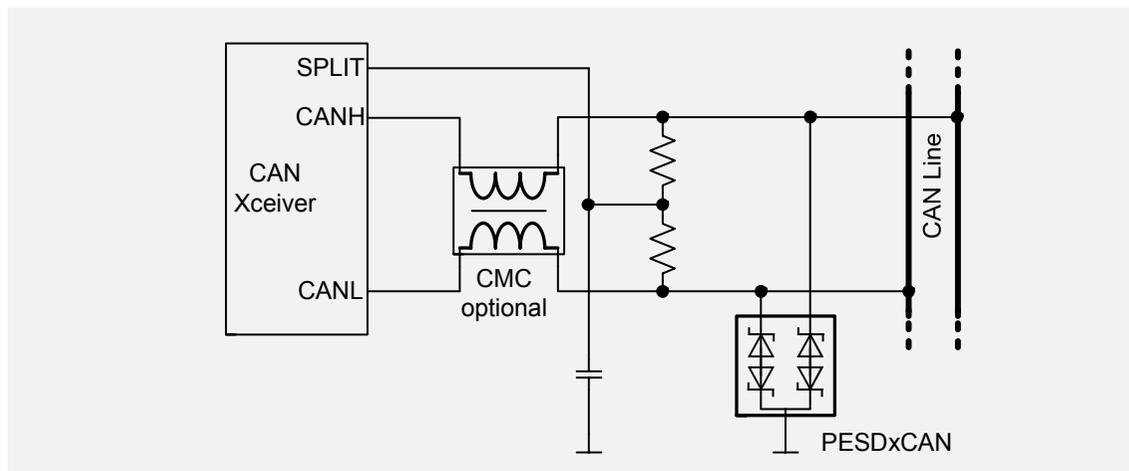
Automotive



Industrial

## 1.1 CAN

Nexperia's solutions protect two automotive Controller Area Network (CAN) bus lines from the damage caused by ESD and other transients. They can be used with high-speed and fault-tolerant CAN buses.



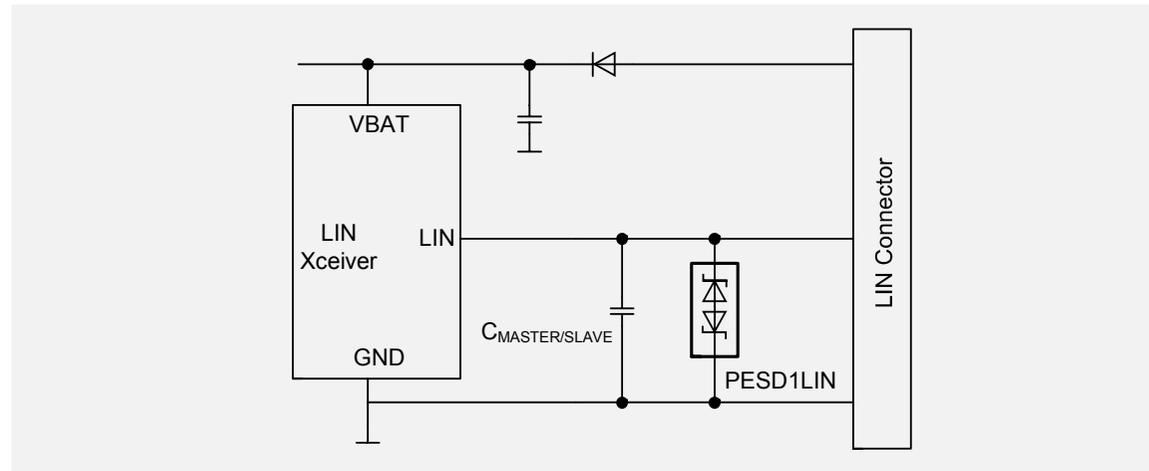
CAN system architecture with a single device to protect the CAN node

### Selection guide

Part	Package	Size (mm)	ESD robustness (IEC61000-4-2)	$C_d$ (max)	$P_{ppm}$ at $t_p = 8/20\mu s$	$V_{RWM}$	AEC-Q101
PESD2IVN-U	SOT323	2.0 x 1.25 x 0.95	23 kV	11 pF	150 W	26.5 V	Yes
PESD1CAN-U	SOT323	2.0 x 1.25 x 0.95	23 kV	12 pF	150 W	24 V	Yes
PESD1CAN	SOT23	2.9 x 1.3 x 1.0	23 kV	17 pF	200 W	24 V	Yes
PESD2CAN	SOT23	2.9 x 1.3 x 1.0	30 kV	30 pF	230 W	24 V	Yes

## 1.2 LIN

The PESD1LIN protects one automotive Local Interconnect Network (LIN) bus line from the damage caused by ESD and other transients. Its asymmetrical internal diode configuration ensures optimized electromagnetic immunity for the protected LIN ECU.



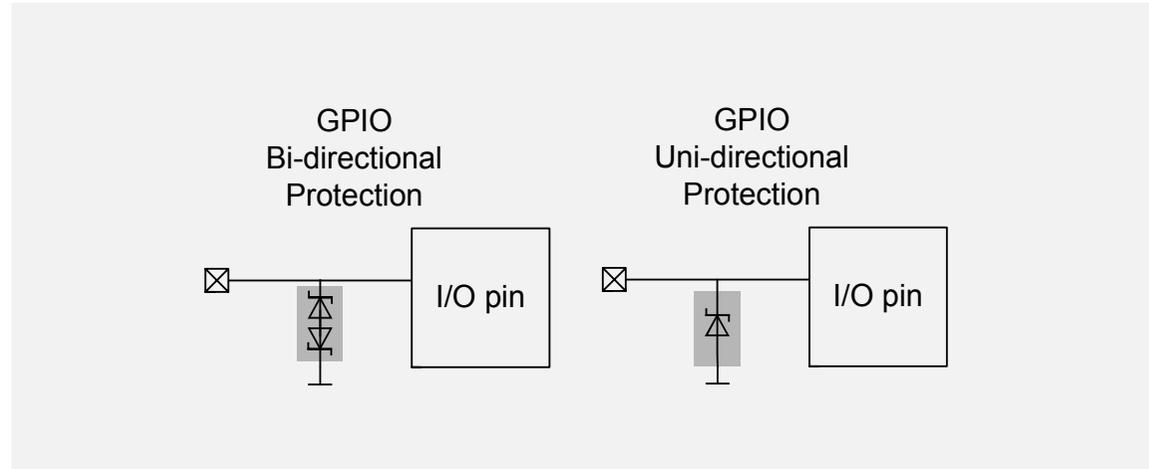
LIN system architecture with a single device to protect the LIN node

### Selection guide

Part	Package	Size (mm)	ESD robustness (IEC61000-4-2)	$C_d$ (max)	$P_{ppm}$ at $t_p = 8/20\mu s$	$V_{RWM}$	AEC-Q101
PESD1IVN-U	SOT323	2.0 x 1.25 x 0.95	23kV	11 pF	150 W	26.5 V	Yes
PESD1LIN	SOD323	1.7 x 1.25 x 0.95	23 kV	17 pF	160 W	15/24 V	Yes

## 1.3 FlexRay

The PESD1FLEX protects two automotive FlexRay data lines from the damage caused by ESD and other transients. It supports the FlexRay data rate of 10 Mbit/s and provides a surge capability of up to 200 W per line for an 8/20  $\mu$ s pulse.



Bidirectional and unidirectional ESD protection for GPIO

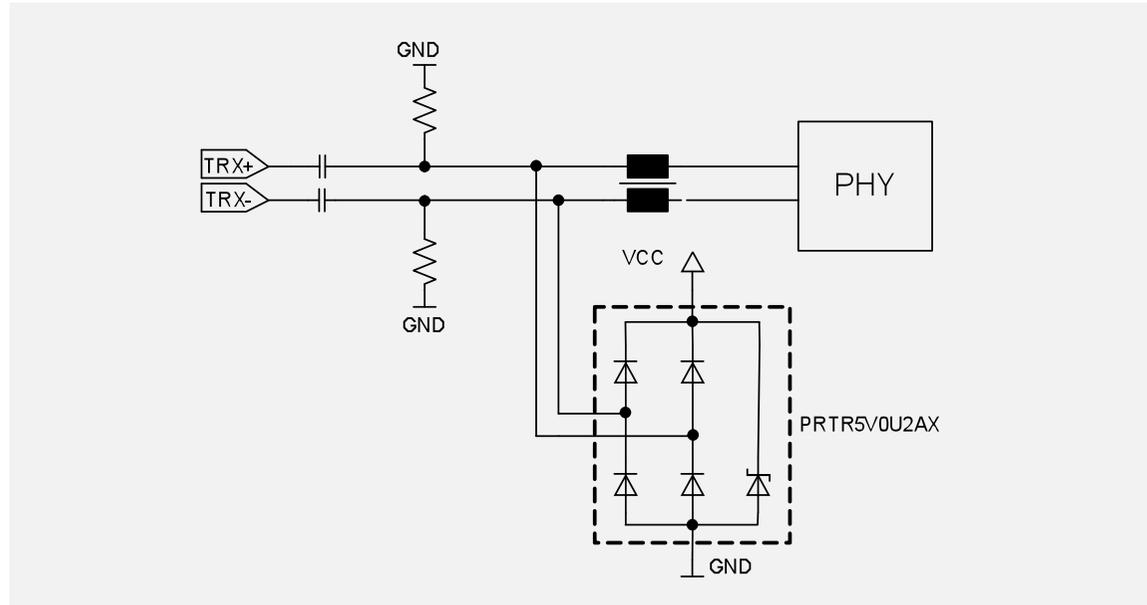
### Selection guide

Part	Package	Size (mm)	ESD robustness (IEC61000-4-2)	Cd (max)	$P_{ppm}$ at $t_p = 8/20\mu s$	$V_{RWM}$	AEC-Q101
PESD1FLEX	SOT23	2.9 x 1.3 x 1.0	23 kV	17 pF	200 W	24 V	YES
PESD3V3U1UL	SOT323	2.0 x 1.25 x 0.95	18 kV	11 pF	150 W	26.5 V	YES

## 1.4 BroadR-reach ESD protection

BroadR-Reach is a relatively new Ethernet standard mainly targeting automotive applications. One of the key advantages of this standard compared to the standard Ethernet specification is that no transformer is required. Today, the most commonly found speed is 100 Mbit per channel.

Typical applications are high-speed interfaces for infotainment or ADAS systems within a car. The figure on the right shows a typical ESD protection structure that can be used on a 100 Mbit BroadR-reach interface. The shown example implements a single channel. Multi-channel protection is possible with other devices as listed in the table below.



BroadR-reach protection, single channel

### Selection guide

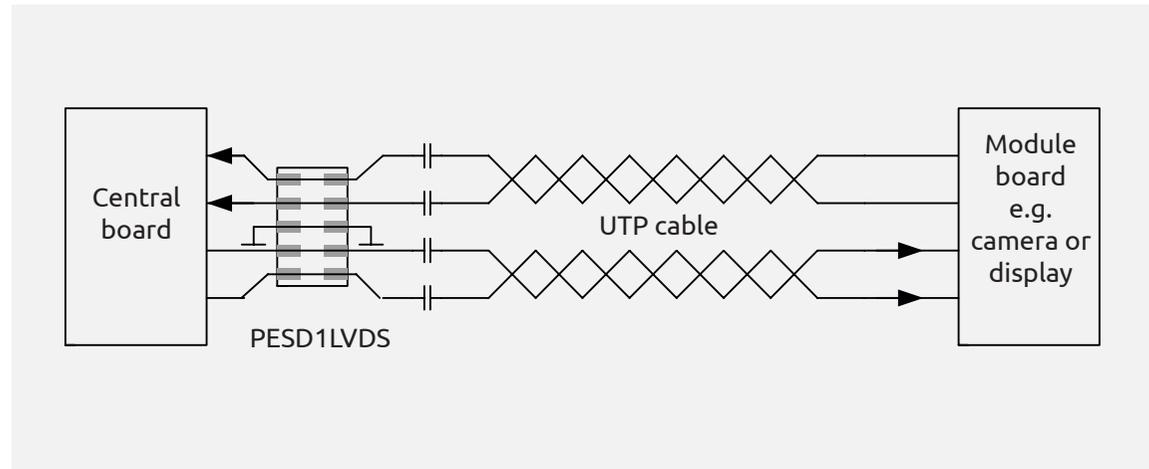
Part	Package	Size (mm)	$C_d$	Level	Note
PESD1LVDS	DFN2510-10	1.0 x 2.5 x 0.5	0.6 pF	8 kV	2-channel protection, AEC-Q101
PRTR5V0U4D	SOT457	2.9 x 1.5 x 1.0	1.0 pF	8 kV	2-channel protection, AEC-Q101
PRTR5V0U2AX	SOT143B	2.9 x 1.3 x 1.0	1.8 pF	12 kV	1-channel protection, AEC-Q101
PESD2ETH-X			1.0 pF	8 kV	1-channel protection, AEC-Q101
PESD2ETH-AX			1.8 pF	12 kV	1-channel-protection, AEC-Q101

## 1.5 Car infotainment

The PESD1LVDS is specifically designed to provide ESD protection for the ultra high-speed interfaces used for in-vehicle networking, such as Low-Voltage Differential Signaling (LVDS), High-Definition Multimedia Interface (HDMI) and DisplayPort.

The device enables pass-through routing for the TMDS lines which supports ease of design and the minimization of parasitic influences.

The PESD1LVDS is AEC-Q101 qualified and hence an ideal choice for high speed interfaces in the automotive market.



In LVDS systems, the PESD1LVDS provides ultra high-speed ESD protection that is fully AEC-Q101 compliant

### Selection guide

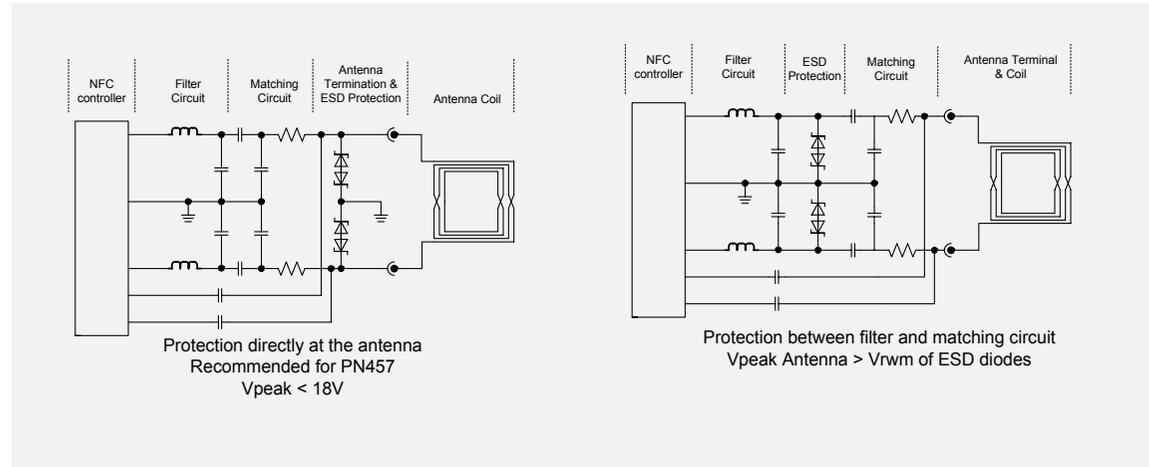
Part	Package	Size (mm)	ESD robustness (IEC61000-4-2)	$C_d$ (max)	$C_d$ Matching	$V_{RWM}$	AEC-Q101
PESD1LVDS	DFN2510-10 (XSON10)	1.0 x 2.5 x 0.5	8 kV	0.6 pF	< 0.05 pF	5.5 V	Yes

## 2. NFC antennas

Near Field Communication (NFC) is a standard that supports user-friendly contactless ID functions. Typical applications include contactless payment, ticketing in public transport, and easy contactless data transfer.

In most NFC designs, the NFC antenna is connected to the NFC controller IC via small contacts. These contacts are an easy entry point for ESD strikes that can damage the NFC controller IC. For this reason, external ESD protection is highly recommended in systems that use NFC.

Nexperia co-created the NFC standard and founded the NFC Forum. The PESD18VF1Bx and PESD24VF1Bx devices are specifically designed to provide optimal protection against ESD strikes in NFC systems, while minimizing the impact that loading and/or impedance mismatch can have on the sensitive antenna portion of the design.



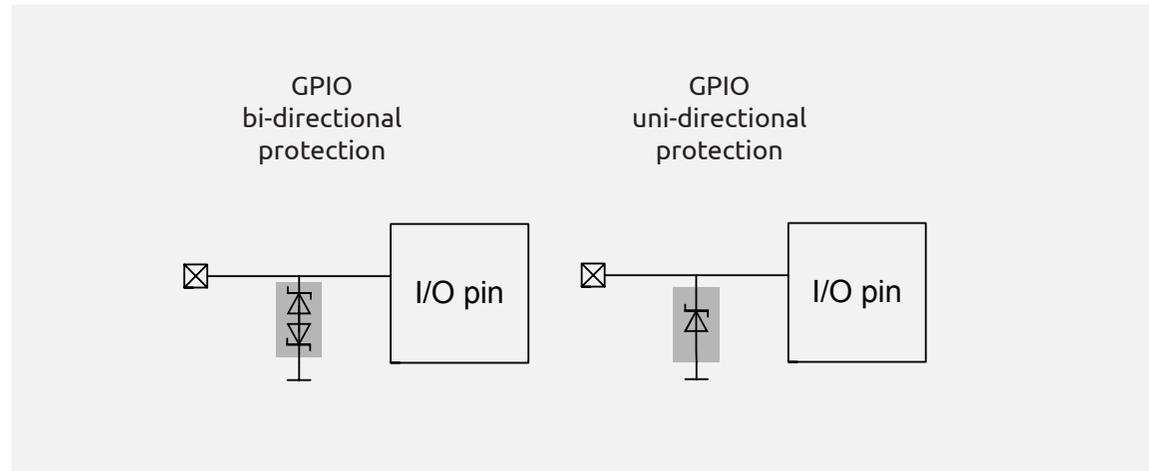
NFC protection can reside at the antenna or between the filter and the matching circuit

### Selection guide

Part	Package	Size (mm)	ESD robustness (IEC61000-4-2)	$C_d$ (max)	$I_{PPM}$	$V_{RWM}$	$R_{dyn}$		
PESD18VF1BSF	DSN0603-2	0.6 x 0.3 x 0.3	10 kV	0.45 pF	1 A	18 V	0.6 $\Omega$		
PESD1NFC-SF									
PESD18VF1BL	DFN1006-2	1.0 x 0.6 x 0.48				0.5 pF		24 V	0.8 $\Omega$
PESD24VF1BL									
PESD1NFC-L						0.5 pF	18 V		
PESD2NFC-L	DSN0603-2	0.6 x 0.3 x 0.3				0.45 pF	24 V	0.6 $\Omega$	
PESD24VF1BSF									
PESD2NFC-SF				0.4 pF					

#### 3.1 Digital I/O

There are many ways to protect general-purpose digital I/O (GPIO). High-frequency signaling is not typically applicable for these kind of interfaces, so there's no need to optimize for low capacitive loading. The three key elements to select upon are unidirectional vs. bidirectional, one vs. multi channel device and last but not least the package variant. As shown in the table, there are many standard devices that meet these various requirements.



Bidirectional and unidirectional ESD protection for GPIO

#### Selection guide

Part	Package	Size (mm)	ESD robustness (IEC61000-4-2)	Configuration
PESD5Z6.0	SOD523	1.2 x 0.8 x 0.6	30 kV	1 channel unidirectional
PESD3V3U1UL	DFN1006-2	1.0 x 0.6 x 0.48	9 kV	1 channel unidirectional
PESD5V0S1BL	DFN1006-2	1.0 x 0.6 x 0.48	30 kV	1 channel bidirectional
PESD5V0S1BA	SOD323	1.7 x 1.25 x 0.95	30 kV	1 channel bidirectional
PESD5V2S2UT	SOT23	2.9 x 1.3 x 1.0	30 kV	2 channel unidirectional/ 1 channel bidirectional
BZA456A	SOT457	2.9 x 1.5 x 1.0	8 kV	4 channel unidirectional
PESD3V3S4UD	SOT457	2.9 x 1.5 x 1.0	30 kV	4 channel unidirectional
PESD5V0V1BL	DFN1006-2	1.0 x 0.6 x 0.48	30 kV	1 channel bidirectional
PESD5V0X1UALD	DFN1006D-2	1.0 x 0.6 x 0.37	15 kV	1 channel unidirectional
PESD5V0V1BDSF	DSN0603-2	0.6 x 0.3 x 0.3	30 KV	1 channel bidirectional

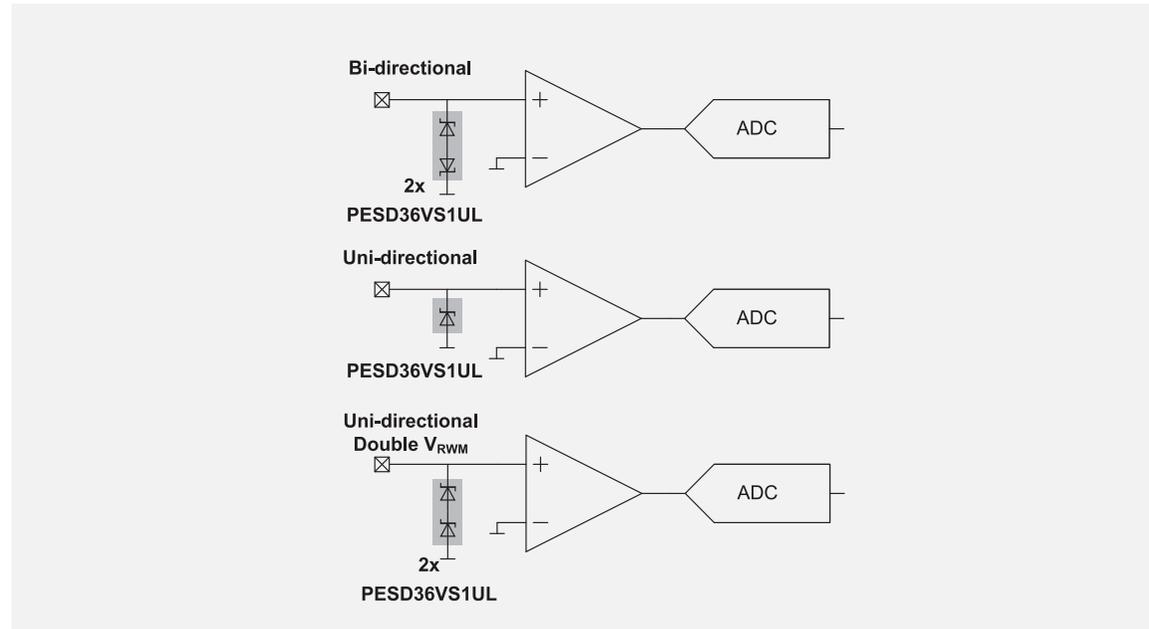
### 3. General I/O protection

#### 3.2 Analog I/O

Although the operating voltages for analog I/O are often limited, most devices can tolerate relatively high voltages for prolonged period without sustaining damage. For ESD protection, this means the required reverse blocking voltage ( $V_{RWM}$ ) must be sufficiently high to not conduct at higher voltages.

Low leakage is another requirement for many analog I/O systems. When implementing a fairly accurate analog input, it's recommended to limit any externally induced leakage that loads the analog input. The protection structure must minimize leakage currents.

Nexperia offers several devices that are ideal for industrial analog I/O port protection, offering higher-than-standard  $V_{RWM}$ , lower leakage, and a small footprint to enable high-density analog front-end designs.



Analog I/O protection using the PESD36VS1UL with single or multiple devices

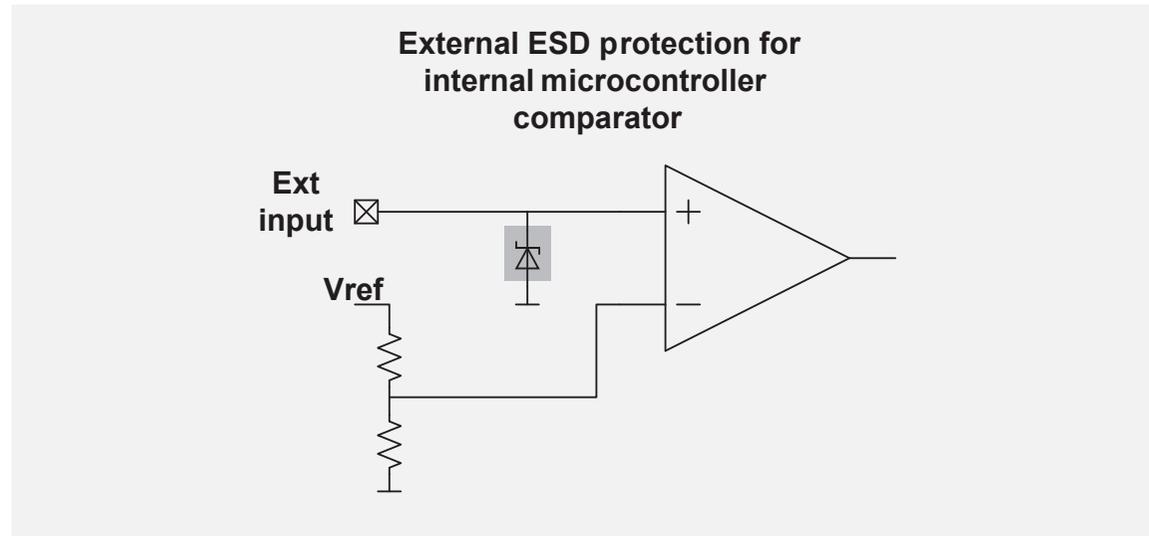
#### Selection guide

Part	Package	Size (mm)	$V_{RWM}$	ESD robustness (IEC61000-4-2)	Configuration
PESD36VS1UL	DFN1006-2	1.0 x 0.6 x 0.48	36 V	30 kV	1 channel unidirectional
PESD24VU1UT	SOT23	2.9 x 1.3 x 1.0	24 V	30 kV	1 channel unidirectional
PESD24VS1UB	SOD523	1.2 x 0.8 x 0.6	24 V	23 kV	1 channel unidirectional
PESD36VS2UT	SOT23	2.9 x 1.3 x 1.0	36 V	30 kV	2 channel unidirectional
PESD24VS2UT	SOT23	2.9 x 1.3 x 1.0	24 V	23 kV	2 channel unidirectional
PESD12VV1BL	DFN1006-2	1.0 x 0.6 x 0.48	12 V	30 kV	1 channel bidirectional
PESD36VS1UJ	SOD323F	1.7 x 1.25 x 0.8	36 V	30 kV	1 channel unidirectional
PESD18VF1BL	DFN1006-2	1.0 x 0.6 x 0.48	18 V	10 kV	1 channel unidirectional

#### 3.3 Low-voltage comparator

Many microcontrollers today integrate analog functions such as a comparator. Depending on the connection to the comparator input(s), ESD protection may be required.

As long as the comparator does not operate at a very high speed, the protection device can be a standard device with a standard capacitance.



Unidirectional, low-voltage comparator ESD protection

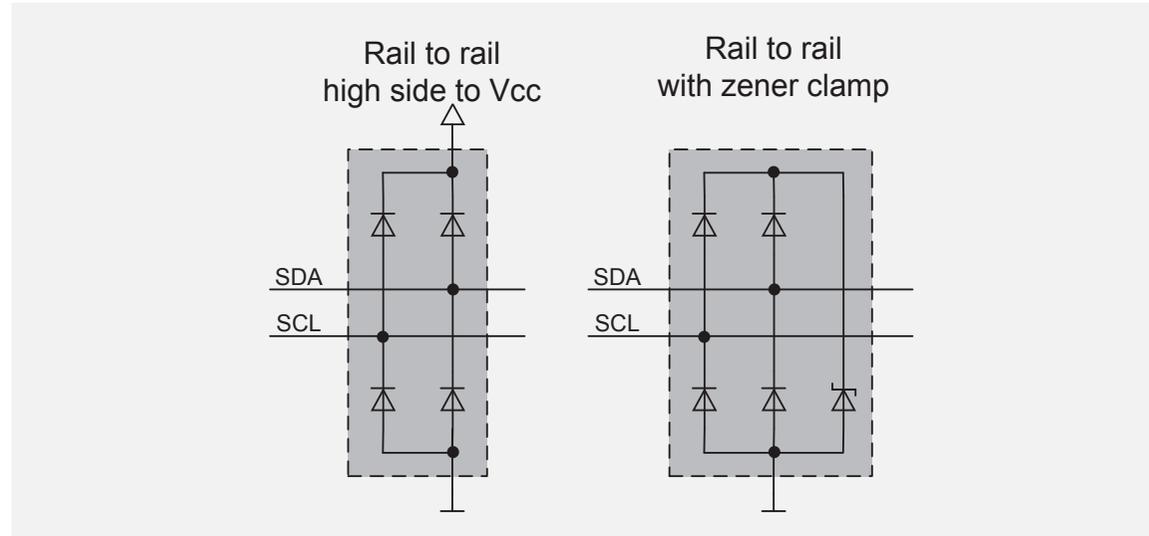
#### Selection guide

Part	Package	Size (mm)	ESD robustness (IEC61000-4-2)	Configuration
PESD5Z6.0	SOD523	1.2 x 0.8 x 0.6	30 kV	1 channel unidirectional
PESD3V3U1UL	DFN1006-2	1.0 x 0.6 x 0.48	9 kV	1 channel unidirectional
PESD5V0S1BL	DFN1006-2	1.0 x 0.6 x 0.48	30 kV	1 channel bidirectional
PESD5V0S1BA	SOD323	1.7 x 1.25 x 0.95	30 kV	1 channel bidirectional
PESD5V2S2UT	SOT23	2.9 x 1.3 x 1.0	30 kV	2 channel unidirectional / 1 channel bidirectional
PESD3V3S4UD	SOT457	2.9 x 1.5 x 1.0	30 kV	4 channel unidirectional
PESD5V0V1BL	DFN1006-2	1.0 x 0.6 x 0.48	30 kV	1 channel bidirectional
PESD5V0X1UALD	DFN1006D-2	1.0 x 0.6 x 0.37	15 kV	1 channel unidirectional

### 4.1 Legacy: I<sup>2</sup>C

I<sup>2</sup>C speeds range from the original 100 KHz up to 5 MHz in Ultra Fast mode. The solutions shown here are more tailored for I<sup>2</sup>C solutions running at speeds of 100 kHz (standard) to 400 kHz (Fast Mode).

The figure represents two types of rail-to-rail protection, which tends to offer better performance for high-speed interfacing.



I<sup>2</sup>C protection two rail-to-rail configurations that minimize capacitive line loading

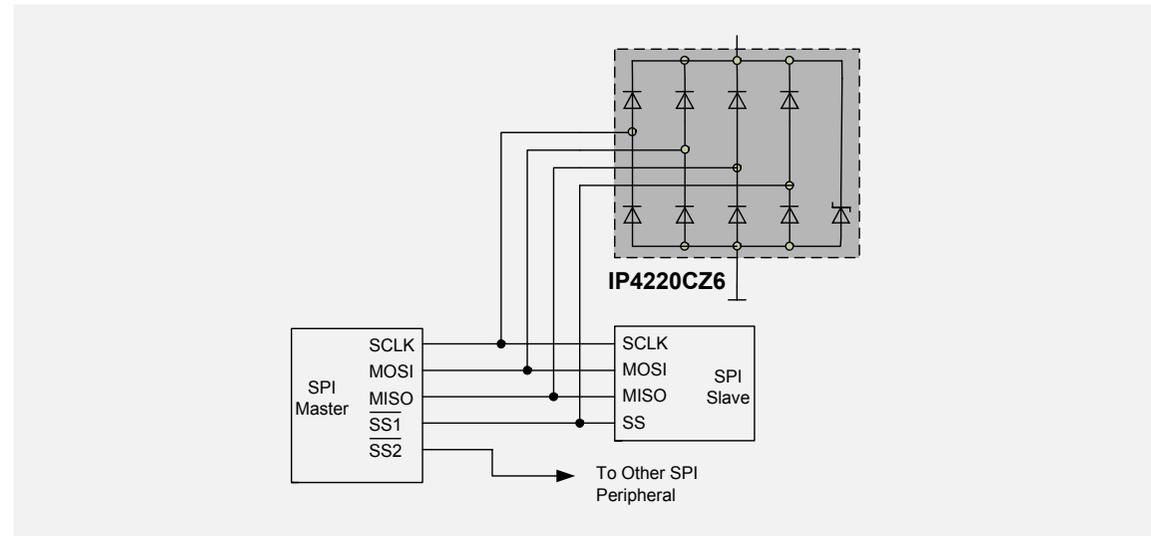
#### Selection guide

Part	Package	Size (mm)	No. of Lines	C <sub>d</sub>	ESD robustness (IEC61000-4-2)
NUP1301	SOT23	2.9 x 1.3 x 1.0	1	0.75 pF	30 kV
NUP1301U	SOT323	2.0 x 1.25 x 0.95	1	0.75 pF	30 kV
IP4220CZ6	SOT457	2.9 x 1.5 x 1.0	4	1 pF	8 kV
IP4221CZ6-S	DFN1410-6	1.45 x 1.0 x 0.48	4	1 pF	8 kV
PRTR5V0U4Y	SOT363	2.0 x 1.25 x 0.95	4	1 pF	8 kV
PRTR5V0U2X	SOT143B	2.9 x 1.3 x 1.0	2	1 pF	8 kV
PRTR5V0U2F	DFN1410-6	1.45 x 1.0 x 0.48	2	1 pF	8 kV
PRTR5V0U2AX	SOT143B	2.9 x 1.3 x 1.0	2	1.8 pF	12 kV

### 4.2 Legacy: SPI/SSI

The Serial Peripheral Interface (SPI), also known as the Synchronous Serial Interface (SSI), is a synchronous serial data link that has devices communicate in master/slave mode. Common clock frequencies are in the range of 10 kHz to 100 MHz.

SPI protection might be required if a connection goes off-board or is routed through a connector. For low-frequency operation, basic single-ended protection schemes may suffice, but, given the upper limit of bus frequencies, rail-to-rail implementations are a better match for universal protection.



SPI protection showing a single device with a four-line, rail-to-rail diode

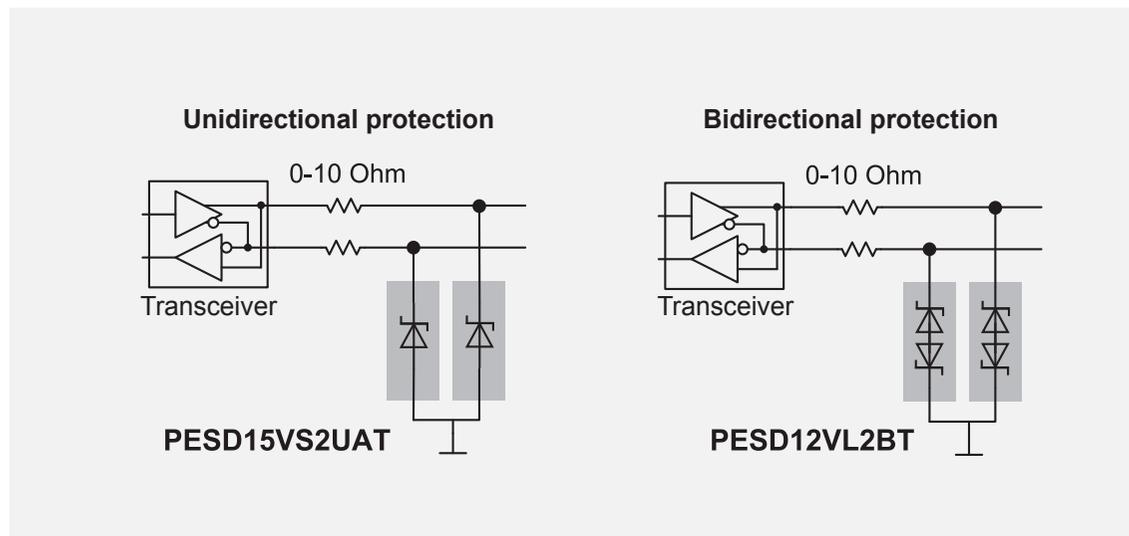
#### Selection guide

Part	Package	Size (mm)	No. of Lines	$C_d$	ESD robustness (IEC61000-4-2)
NUP1301	SOT23	2.9 x 1.3 x 1.0	1	0.75 pF	30 kV
NUP1301U	SOT323	2.0 x 1.25 x 0.95	1	0.75 pF	30 kV
IP4220CZ6	SOT457	2.9 x 1.5 x 1.0	4	1 pF	8 kV
IP4221CZ6-S	DFN1410-6	1.45 x 1.0 x 0.48	4	1 pF	8 kV
PRTR5V0U4Y	SOT363	2.0 x 1.25 x 0.95	4	1 pF	8 kV
PRTR5V0U2X	SOT143B	2.9 x 1.3 x 1.0	2	1 pF	8 kV
PRTR5V0U2F	DFN1410-6	1.45 x 1.0 x 0.48	2	1 pF	8 kV
PRTR5V0U2AX	SOT143B	2.9 x 1.3 x 1.0	2	1.8 pF	12 kV

### 4.3 Legacy: RS-232 and RS-485

Nexperia offers several devices that are well suited for protection of RS-485 or RS-232 interfaces.

The figure shows unidirectional protection with the PESD15VS2UT, and bidirectional protection with the PESD12VL2BT. An additional serial resistor can be used to further limit currents entering the transceiver.



Standard serial port, RS-485, or RS-232 protection can be either unidirectional or bidirectional

#### Selection guide

Part	Package	Size (mm)	No. of Lines	$V_{RWM}$	ESD robustness (IEC61000-4-2)
PESD15VS2UT	SOT23	2.9 x 1.3 x 1.0	2 unidirectional / 1 bidirectional	15 V	30 kV
PESD12VL2BT	SOT23	2.9 x 1.3 x 1.0	2 bidirectional	12 V	30 kV

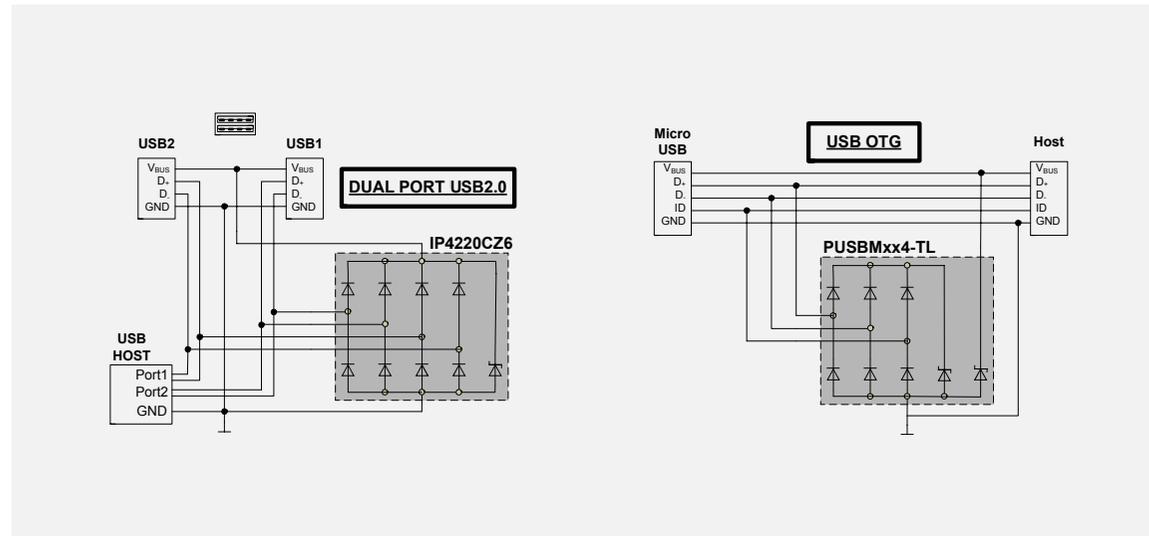
### 4.4 USB2.0 and USB OTG

The USB 2.0 standard features a maximum signaling rate of 480 Mbit/s with an effective throughput of up to 35 MByte/s or 280 Mbit/s. USB 2.0 is a mainstream interface in today's electronic systems and is one of the most common interfaces used in microcontrollers.

The figure shows two basic protection setups, one for USB 2.0, and another optimized for USB On-The-Go (OTG).

Dual-port implementations are commonly found in (embedded) computing designs. Devices with protection optimized specifically for USB 2.0, such as the IP4220CZ6 and PUSB2X4Y, are perfect fits for protecting dual-port implementations.

Since OTG implementations are often portable, they tend to be smaller, so a single-chip solution for protecting the  $V_{bus}$ , such as the PUSBMxx4-TL, is an ideal choice.



USB 2.0 and USB OTG ESD protection

#### Selection guide

Part	Package	Size (mm)	$C_d$	ESD robustness (IEC61000-4-2)	Note
PUSB2X4Y	SOT363	2.0 x 1.25 x 0.95	0.55 pF	12 kV	4 lines, ultra-low clamping
PUSB2X4D	SOT457	2.9 x 1.5 x 1.0	0.55 pF	12 kV	4 lines, ultra-low clamping
PUSBMxxVX4-TL	DFN1616-6	1.6 x 1.6 x 0.5	0.8 pF	8 kV	Add $V_{bus}$ protection for USB OTG & charging
PESD5V0X1ULD	DFN1006D-2	1.0 x 0.6 x 0.37	0.95 pF	8 kV	1 line, unidirectional
IP4220CZ6	SOT457	2.9 x 1.5 x 1.0	1 pF	8 kV	4 lines
IP4221CZ6-S	DFN1410-6	1.45 x 1.0 x 0.48	1 pF	8 kV	IP4220 with smaller package
PRTR5V0U4D	SOT457	2.9 x 1.5 x 1.0	1 pF	8 kV	4 lines, AEC-Q101 qualified
IP3319CX6	WLCSP6	1.35 x 0.95 x 0.57	1.5 pF	15 kV	Common mode filter + ESD protection (1 line pair CMF + 1 line pair ESD protection)
PESD5V0X2UAM	SOT883	1.0 x 0.6 x 0.48	0.8 pF	15 kV	2 lines, unidirectional



# TrEOS Protection

## ESD protection without compromise

TrEOS  
Protection



A new technology delivering the ideal combination of low capacitance, high ESD robustness and low clamping voltage. Supporting high-speed data lines including USB3.1 at 10 Gbps. Protecting very sensitive system chips.

Safeguard your system now and in the future with TrEOS Protection devices – from Nexperia, the global leader in ESD protection.

More information on the following pages and [www.nexperia.com/protection](http://www.nexperia.com/protection)

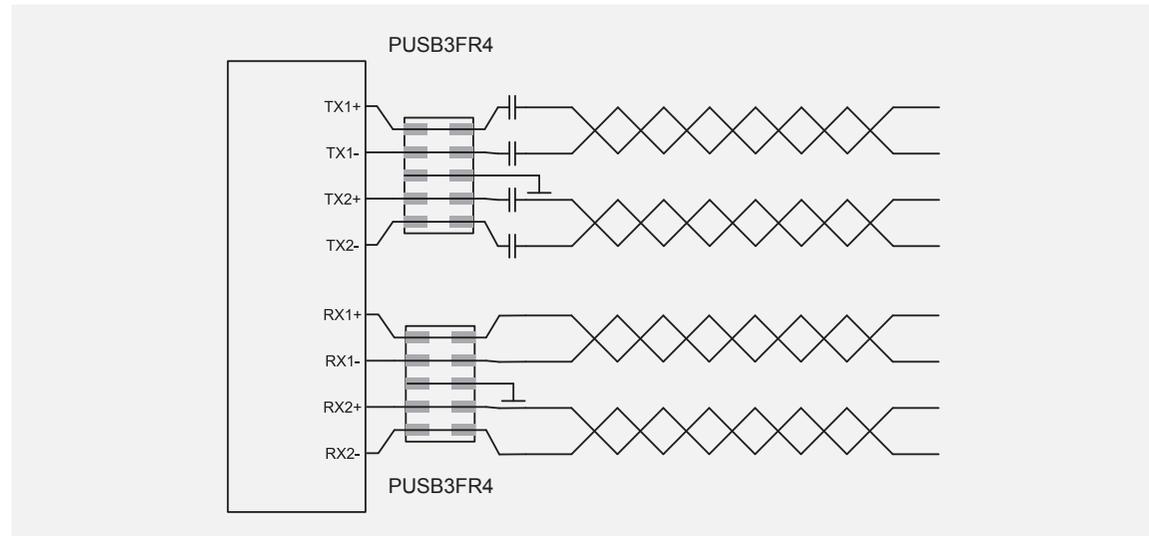
nexperia

### 4.5 High data-rate: USB 3.1

The USB 3.1 standard features a signaling speed of up to 10 Gbit/s. Communication is full-duplex.

The ultra-high speed, combined with controlled impedance routing, makes it a challenge to implement decent ESD protection without significantly impacting overall signal integrity.

Nexperia offers a variety of protection devices specifically designed for ultra high-speed interfaces. For USB 3.1, Nexperia's latest offer is based on the PUSB3FR4. Its excellent clamping performance, combined with ultra-low and well-matched capacitance, makes it an ideal fit for USB 3.1 protection.



USB 3.1 ESD protection

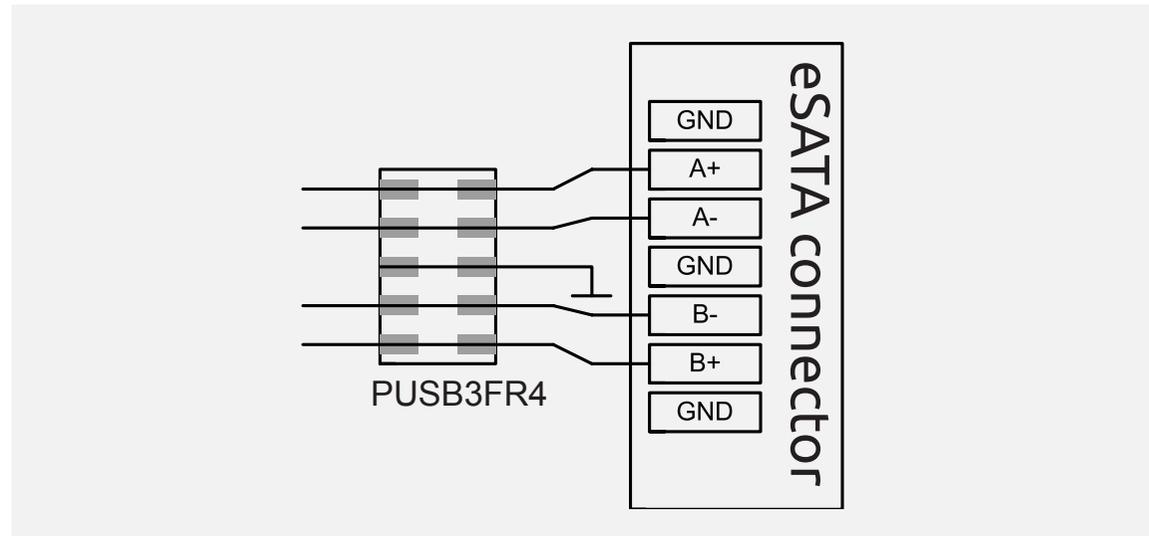
#### Selection guide

Part	Package	Size (mm)	$C_d$	ESD robustness (IEC61000-4-2)	Note
PUSB3AB4	DFN2510A-10	2.5 x 1.0 x 0.5	<0.2 pF	15 kV	2 channels / 4 lines TrEOS Protection
PUSB3AB6	DFN2111-7	2.1 x 1.1 x 0.5	0.15 pF	15 kV	3 channels / 6 lines TrEOS Protection
PUSB3FR4	DFN2510A-10	2.5 x 1.0 x 0.5	0.29 pF	15 kV	2 channels / 4 lines TrEOS Protection
PUSB3FR6	DFN2111-7	2.1 x 1.1 x 0.5	0.35 pF	15 kV	3 channels / 6 lines TrEOS Protection
PUSB3F96	DFN2510A-10	2.5 x 1.0 x 0.5	0.5 pF	10 kV	2 channels / 4 lines
PESD5V0R1BSF	DSN0603-2	0.6 x 0.3 x 0.3	0.1 pF	10 kV	Single line bidirectional TrEOS Protection
PESD5V0H1BSF	DSN0603-2	0.6 x 0.3 x 0.3	0.15 pF	15 kV	Single line bidirectional TrEOS Protection
PESD5V0C1BSF	DSN0603-2	0.6 x 0.3 x 0.3	0.2 pF	20 kV	Single line bidirectional TrEOS Protection
PESD3V3Z1BSF	DSN0603-2	0.6 x 0.3 x 0.3	0.28 pF	20 kV	Single line bidirectional TrEOS Protection
PESD5V0C1USF	DSN0603-2	0.6 x 0.3 x 0.3	0.45 pF	20 kV	Single line unidirectional TrEOS Protection
PCMF1USB3	WLCSP5	0.8 x 1.2 x 0.5	0.3 pF	15 kV	Single channel CMF + ESD TrEOS Protection
PCMF2USB3	WLCSP10	1.6 x 1.2 x 0.5	0.3 pF	15 kV	Dual channel CMF + ESD TrEOS Protection
PCMF3USB3	WLCSP15	2.4 x 1.2 x 0.5	0.3 pF	15 kV	Triple channel CMF + ESD TrEOS Protection

### 4.6 High data-rate: eSATA

The eSATA standard is a variant of SATA, meant for external connectivity. Having the ability to connect to the outside world means ESD protection is strongly recommended for eSATA.

With its ultra-low capacitance, pass through routing package, and excellent clamping performance, the PUSB3FR4 is ideally suited for eSATA protection.



eSATA ESD protection using PUSB3FR4

#### Selection guide

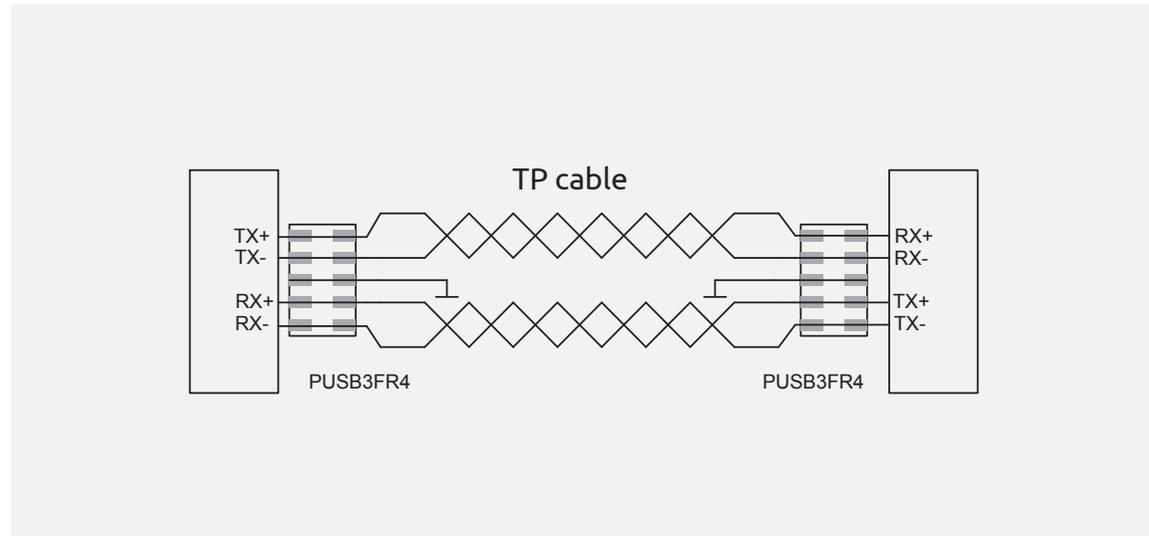
Part	Package	Size (mm)	$C_d$	ESD robustness (IEC61000-4-2)	Note
PUSB3AB4	DFN2510A-10	2.5 x 1.0 x 0.5	<0.2 pF	15 kV	2 channels/ 4 lines, 0.5 mm pitch package TrEOS Protection
PUSB3FR4	DFN2510A-10	2.5 x 1.0 x 0.5	0.29 pF	15 kV	2 channels/ 4 lines, 0.5 mm pitch package TrEOS Protection
PUSB3F96	DFN2510A-10	2.5 x 1.0 x 0.5	0.5 pF	10 kV	2 channels/ 4 lines, 0.5 mm pitch package
IP4285CZ10-TBB	DFN2110-9	2.1 x 1.0 x 0.5	0.8 pF	12 kV	2 channels/ 4 lines, 0.4 mm pitch package

### 4.7 High-speed differential mode signaling (LVDS, CML, TMDS, etc.)

Our highly integrated companion ICs for HDMI offer protection, level shift, LDO, buffering, and more. A single device provides essentially all the interfacing needs for HDMI. Our portfolio comprise dedicated solutions for HDMI transmitters (IP4787CZ32) and HDMI receivers (IP4786CZ32). The figure shows these devices with their basic connections. With the exception of a small capacitor, no other external device is needed.

Nexperia also offers solutions for specific HDMI protection subsets, such as applications where level shifting is already implemented elsewhere. A dedicated protection solution can be implemented using two PHDMI2F4 and a single PUSB2X4Y.

Some systems require enhanced filtering or noise removal. For this, Nexperia offers common mode filters with built-in ESD protection. Using two single PCMF2DFN2 devices, the HDMI TMDS channels can be protected against common-mode noise as well as ESD.



General high-speed differential mode signaling line ESD protection (actual data rate influences device choice)

#### Selection guide

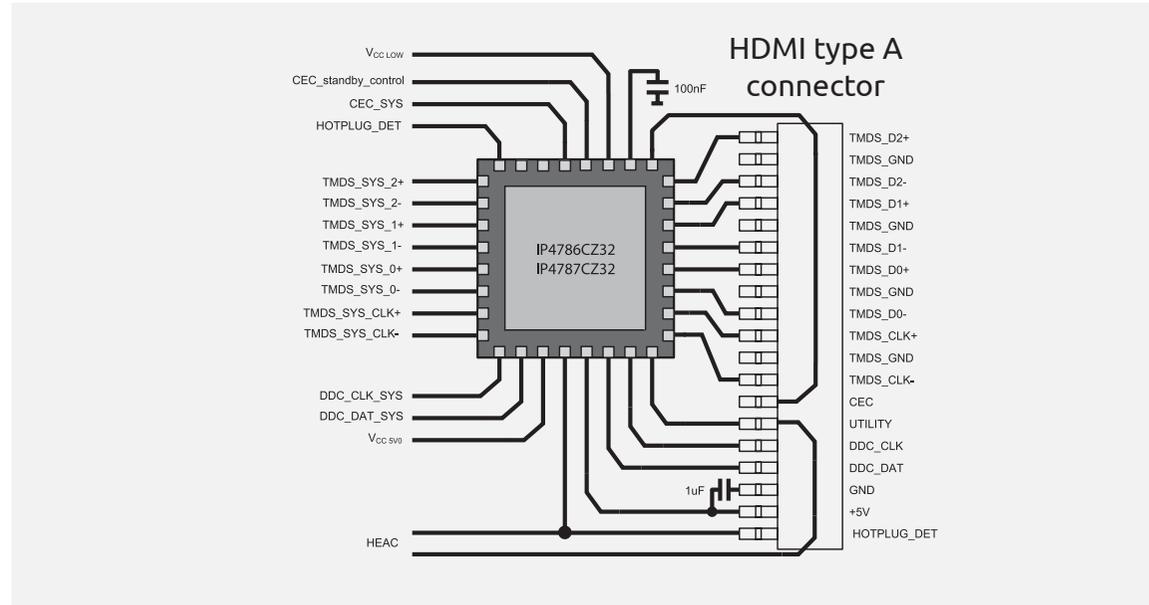
Part	Package	Size (mm)	C <sub>d</sub>	ESD robustness (IEC61000-4-2)	Note
PUSB3AB4	DFN2510A-10	2.5 x 1.0 x 0.5	<0.2 pF	15 kV	2 channels/ 4 lines, 0.5 mm pitch package TrEOS Protection
PUSB3FR4	DFN2510A-10	2.5 x 1.0 x 0.5	0.29 pF	15 kV	2 channels/ 4 lines, 0.5 mm pitch package TrEOS Protection
PUSB3F96	DFN2510A-10	2.5 x 1.0 x 0.5	0.5 pF	10 kV	2 channels/ 4 lines
PESD1LVDS	DFN2510-10	2.5 x 1.0 x 0.5	0.6 pF	8 kV	0.6 pF Ch/Ch matching, AEC-Q101 qualified
IP4285CZ10-TBB	DFN2110-9	2.1 x 1.0 x 0.5	0.8 pF	12 kV	2 channels/ 4 lines

### 5.1 HDMI

Our highly integrated companion ICs for HDMI offer protection, level shift, LDO, buffering, and more. A single device provides essentially all the interfacing needs for HDMI. Our portfolio comprise dedicated solutions for HDMI transmitters (IP4787CZ32) and HDMI receivers (IP4786CZ32). The figure shows these devices with their basic connections. With the exception of a small capacitor, no other external device is needed.

Nexperia also offers solutions for specific HDMI protection subsets, such as applications where level shifting is already implemented elsewhere. A dedicated protection solution can be implemented using two PHDMI2F4 and a single PUSB2X4Y.

Some systems require enhanced filtering or noise removal. For this, Nexperia offers common mode filters with built-in ESD protection. Using two single PCMF2DFN2 devices, the HDMI TMDS channels can be protected against common mode noise as well as ESD.



HDMI single-device ESD protection with level shift, showing IP4787CZ32 for receiver and IP4786CZ32 for transmitter applications.

#### Selection guide

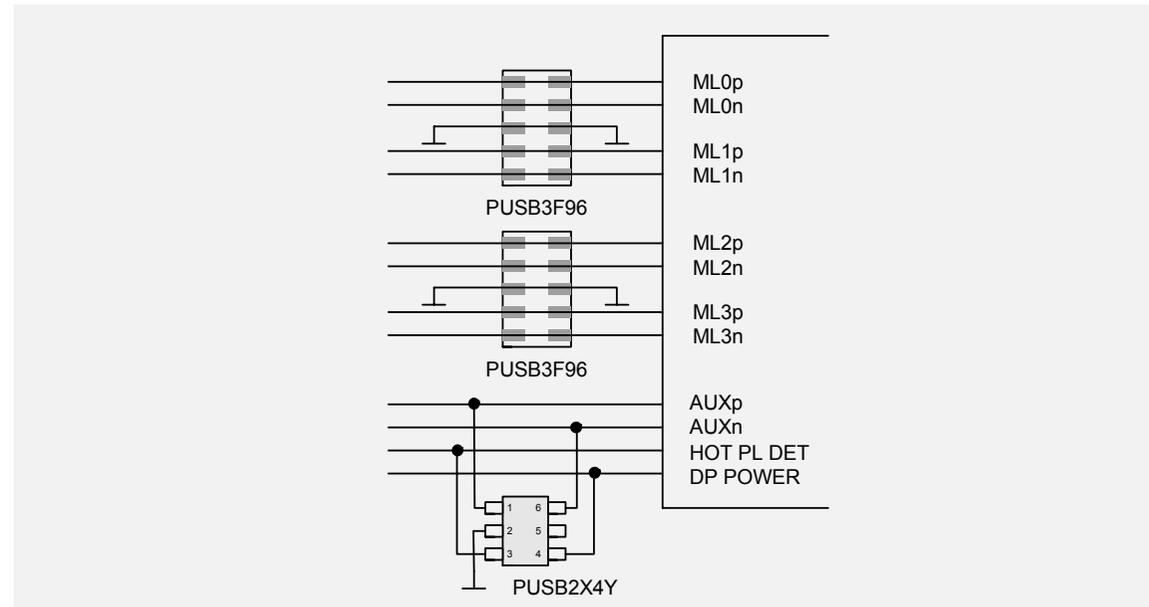
Part	Package	Size (mm)	C <sub>d</sub>	ESD robustness (IEC61000-4-2)	Note
PHDMI2F4	DFN2510A-10	2.5 x 1.0 x 0.5	0.5 pF	10 kV	2 channel high-speed TMDS line protection, 0.5 pF
PCMF2DFN2	DFN2520-9	2.5 x 2.0 x 0.5	0.6 pF	15 kV	2 channel common mode filter + ESD
IP4786CZ32	DFN5050-32	5.0 x 5.0 x 0.85	0.6 pF	8 kV	TX, single-chip HDMI companion
IP4788CZ32	DFN5050-32	5.0 x 5.0 x 0.85	0.6 pF	12 kV	TX, single chip HDMI companion, lower clamping
IP4786CZ32S	DFN4040-32 (HXQFN32)	4.0 x 4.0 x 0.5	0.6 pF	8 kV	TX, single chip HDMI companion, smaller package
IP4787CZ32	DFN5050-32	5.0 x 5.0 x 0.85	0.6 pF	8 kV	RX, single-chip HDMI companion
PUSB2X4Y	SOT363	2.0 x 1.25 x 0.95	0.8 pF	8 kV	DDC/ CEC/HPD protection, 0.8 pF
IP4285CZ10-TBB	DFN2110-9	2.1 x 1.0 x 0.5	0.8 pF	12 kV	2 channel high-speed TMDS line protection

### 5.2 DisplayPort

With DisplayPort, the main link can have one, two, or four differential data pairs or lanes. Each link has a raw bit rate of 1.62, 2.7, or 5.4 Gbit/s per lane, with the self-clock running at 162, 270, or 540 MHz. Using 8b/10b coding, the effective data rate can reach a maximum of 4.32 Gbit/s per lane.

DisplayPort protection can be split between the high-speed differential lanes and the much slower AUX channels. The figure shows a straightforward implementation using the PUSB3F96 and PUSB2X4Y.

The PUSB3F96, with its ultra-low capacitance, excellent  $C_d$  matching, and pass-through routing package layout, is a good choice for implementing ESD protection on the high-speed differential lines of DisplayPort.



DisplayPort ESD protection with high-speed lines protected with PUSB3F96 and low-speed lines with PUSB2X4Y

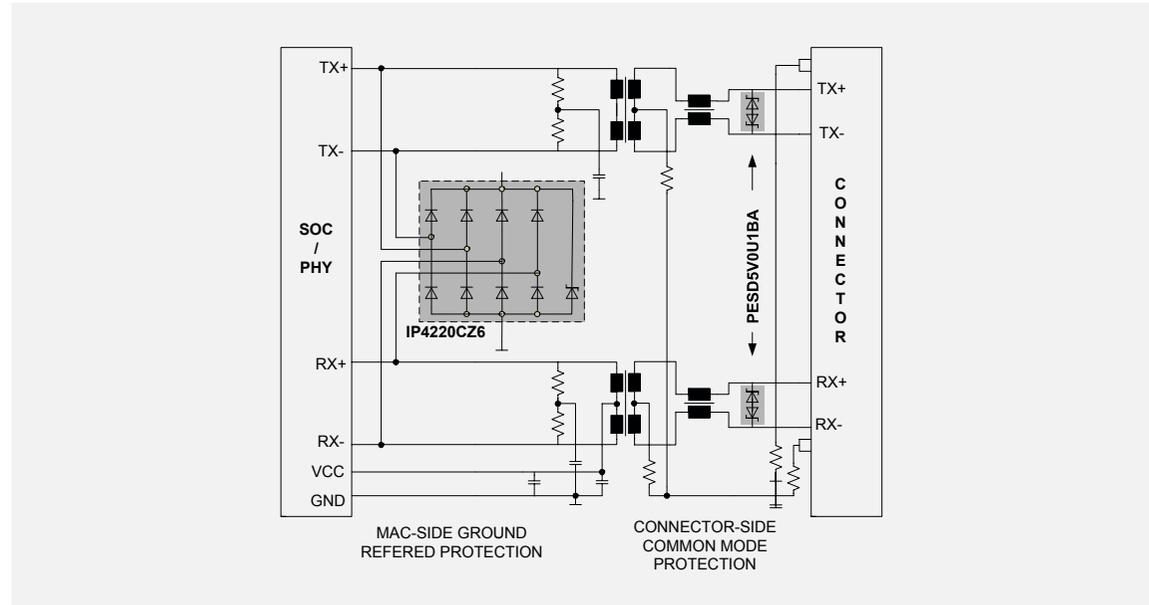
#### Selection guide

Part	Package	Size (mm)	$C_d$	ESD robustness (IEC61000-4-2)	Note
PUSB3FR4	DFN2510A-10	2.5 x 1.0 x 0.5	0.29 pF	15 kV	2 channels / 4 lines TrEOS Protection
IP4292CZ10	DFN2510A-10	2.5 x 1.0 x 0.5	0.45 pF	8 kV	2 channels / 4 lines
PHDMI2F4	DFN2510A-10	2.5 x 1.0 x 0.5	0.5 pF	10 kV	2 channels / 4 lines
PUSB3F96	DFN2510A-10	2.5 x 1.0 x 0.5	0.5 pF	10 kV	2 channels / 4 lines
PESD1LVDS	DFN2510-10	2.5 x 1.0 x 0.5	0.6 pF	8 kV	0.6 pF Ch/Ch matching, AEC-Q101 qualified
IP4285CZ10-TBB	DFN2110-9	2.1 x 1.0 x 0.5	0.8 pF	12 kV	2 channels / 4 lines

## 6.1 Ethernet ESD protection

ESD protection for Ethernet can typically be done in two ways. Protection can be placed on the MAC/PHY side of the interface or line-to-line protection can be added to the connector side. For optimal protection, a design may implement both schemes, as shown in the figure.

The figure at right shows a 100 Mbit interface that uses two pairs. A similar solution can be created for Gbit Ethernet, using four pairs.



10/100 ESD protection, with ground-referred protection on the MAC side and Common mode protection on the connector side

### Selection guide

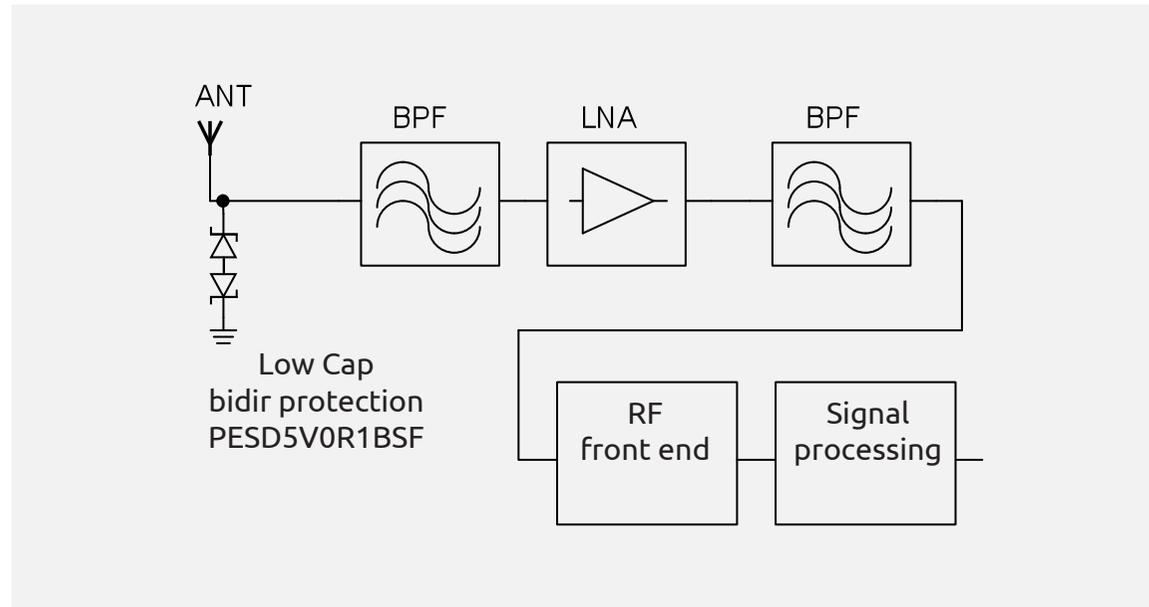
Part	Package	Size (mm)	C <sub>d</sub>	ESD robustness (IEC61000-4-2)	Note
IP4233CZ6	SOT363	2.0 x 1.25 x 0.95	0.9 pF	8 kV	Common mode protection
IP4220CZ6	SOT457	2.9 x 1.5 x 1.0	1 pF	8 kV	1 port protection
IP4221CZ6-S	DFN1410-6	1.45 x 1.0 x 0.48	1 pF	8 kV	IP4220 with smaller package
IP4221CZ6-XS	DFN1010-6 (XSON6)	1.0 x 1.0 x 0.48			
PRTR5V0U4D	SOT457	2.9 x 1.5 x 1.0	1 pF	8 kV	1 port protection, AEC-Q101 qualified
PESD5V0U1BA	SOD323	1.7 x 1.25 x 0.95	2.9 pF	10 kV	Common mode protection

## 7.1 GPS / GNSS

GPS applications are commonplace today. ESD can enter the system via the antenna. Protection of the sensitive receiver circuitry is often required.

Requirements for this type of protection are extremely low capacitance and high linearity. Low clamping and high maximum peak surge capability remain a key need as well.

The figure on the right shows a typical protection scheme using the new, ultra-low-capacitance, bidirectional PESD5V0R1BSF. This device comes in an ultra-small DSN0603 package that further minimizes any resistive and inductive impedance.



GPS ESD protection using PESD5V0R1BSF

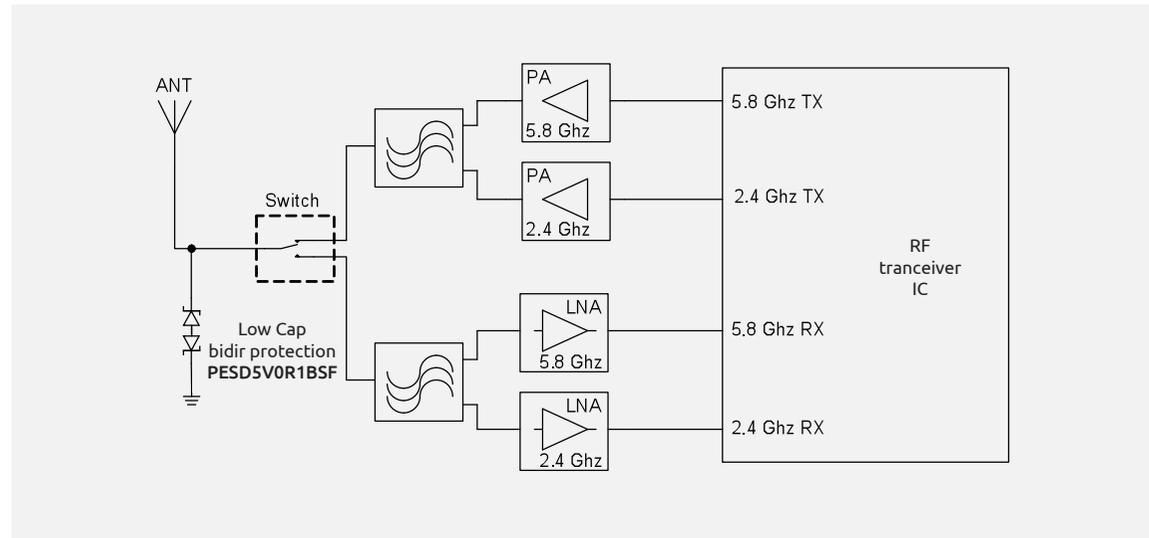
### Selection guide

Part	Package	Size (mm)	$C_d$	ESD robustness (IEC61000-4-2)	Note
PESD5V0R1BSF	DSN0603-2	0.6 x 0.3 x 0.3	0.1 pF	10 kV	Single-line bidirectional TrEOS Protection
PESD5V0H1BSF	DSN0603-2	0.6 x 0.3 x 0.3	0.15 pF	15 kV	Single-line bidirectional TrEOS Protection
PESD5V0C1BSF	DSN0603-2	0.6 x 0.3 x 0.3	0.2 pF	20 kV	Single-line bidirectional TrEOS Protection

## 7.2 WLAN

WLAN is today's de facto standard for wireless connectivity in a multitude of applications. Dual-band is the most commonly found implementation. The figure on the right shows a sample implementation with an ESD protection device (PESD5V0R1BSF) to protect the sensitive RF circuitry against ESD strikes entering via the antenna.

To maintain optimal RF performance, extremely low capacitance and linearity for the ESD protection device are an absolute must. The table below shows a number of the latest ultra-low-capacitance and clamping devices.



Dual-band WLAN ESD protection using PESD5V0R1BSF

### Selection guide

Part	Package	Size (mm)	$C_d$	ESD robustness (IEC61000-4-2)	Note
PESD5V0R1BSF	DSN0603-2	0.6 x 0.3 x 0.3	0.1 pF	10 kV	Single-line bidirectional TrEOS Protection
PESD5V0H1BSF	DSN0603-2	0.6 x 0.3 x 0.3	0.15 pF	15 kV	Single-line bidirectional TrEOS Protection
PESD5V0C1BSF	DSN0603-2	0.6 x 0.3 x 0.3	0.2 pF	20 kV	Single-line bidirectional TrEOS Protection



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**Date of release:**

February 2017

**Printed:**

In the Netherlands

