

# ESD protection – USB 3.2

Protected connection for mobile devices



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**This application guide covers:**  
Solutions for USB ESD protection  
(USB 3.2, 3.1, 2.0, Supply voltage configuration)

## Introducing USB

The Universal Serial Bus (USB), one of the industry's most widely used standard for data transfer.

Name	Protocol	Max. data rate
Enhanced SuperSpeed	USB 3.2	20 Gbit/s *
SuperSpeed+	USB 3.1	10 Gbit/s
SuperSpeed	USB 3.0	5 Gbit/s
Hi-Speed	USB 2.0	480 Mbit/s
Full Speed	USB 1.1	12 Mbit/s
Low Speed	USB 1.0	1,5 Mbit/s

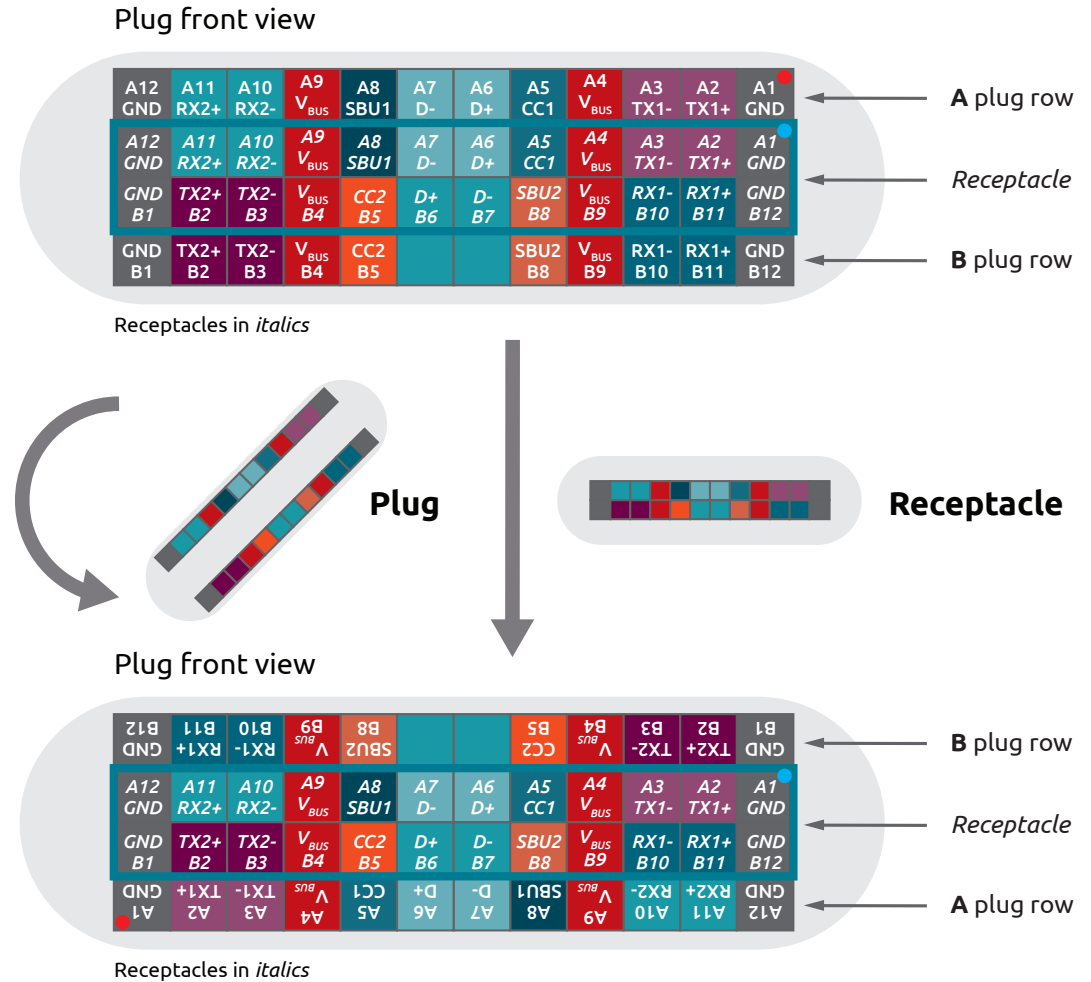
\* USB 3.2 is doubling the data rate by utilizing all Tx and Rx lines of USB Type-C

# The new Type-C connector

... was introduced as a part of the new USB 3.2 specification.

... will make USB 3.2 very attractive for portable devices:

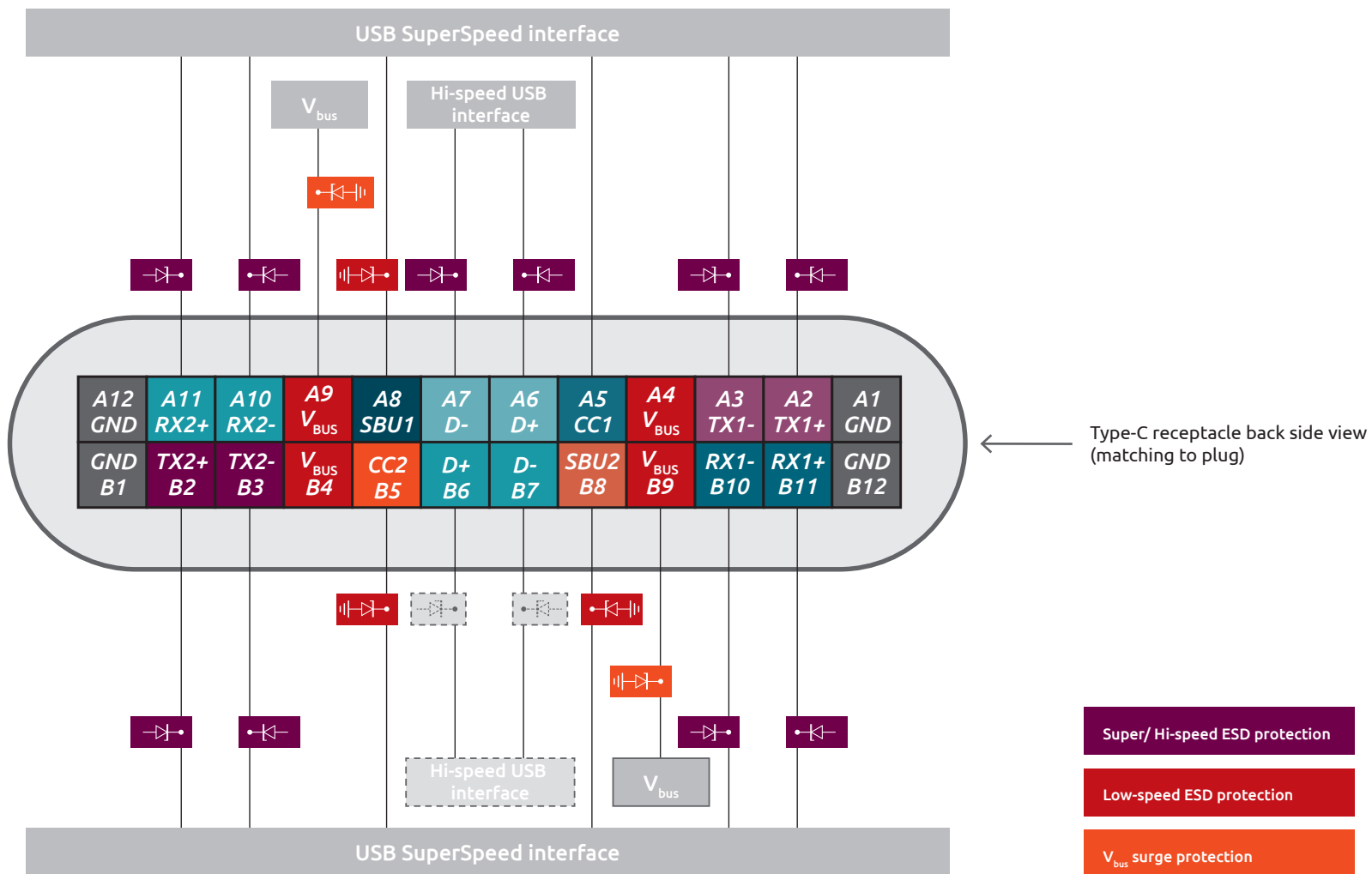
- › Very small outline
- › Connector can be plugged in using either orientation
- › Higher charging currents possible
- › Eliminates the need for a second data connector



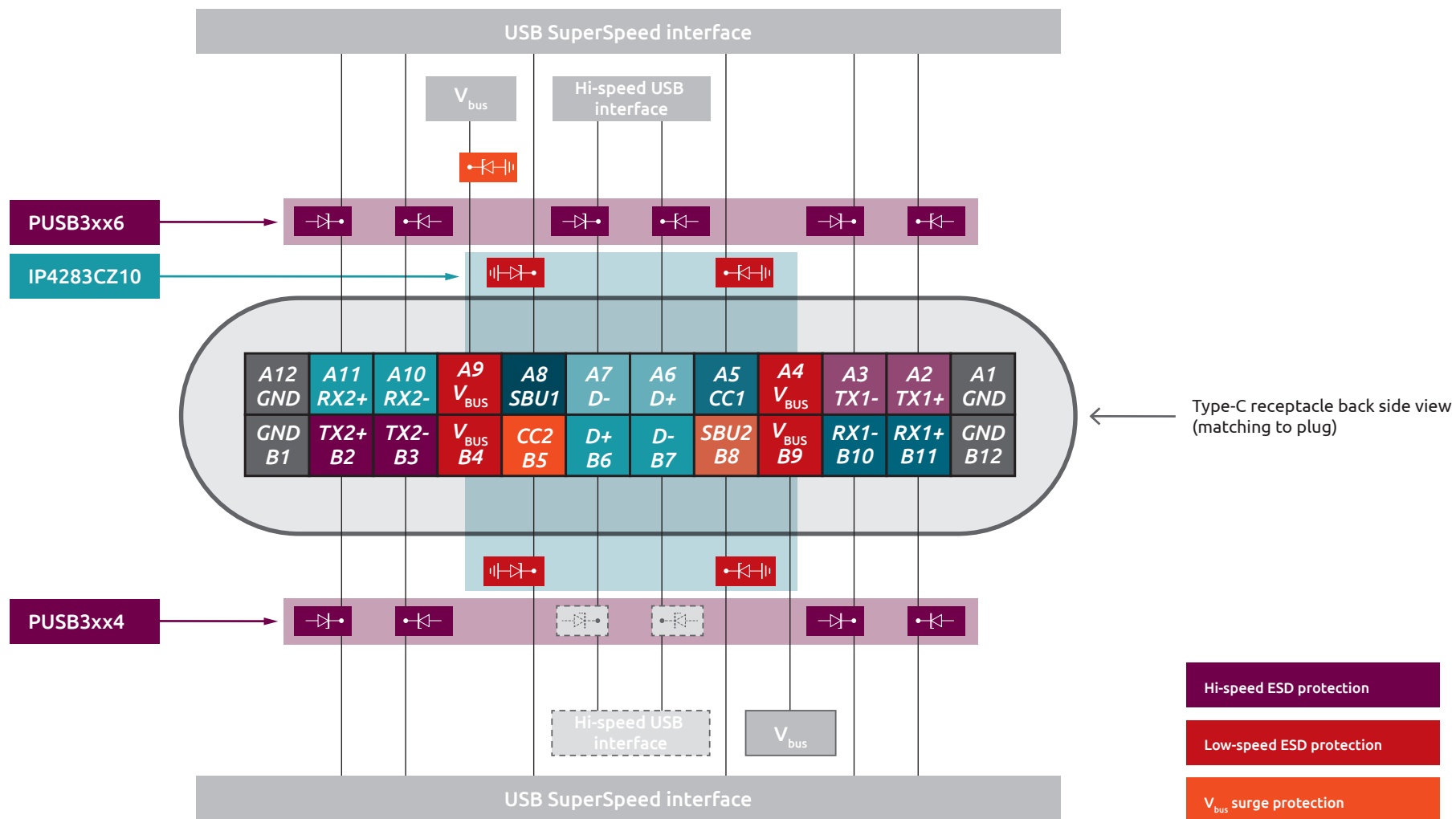
## Categories of USB data lines to protect

	Trends in system-level ESD protection	USB data lines of this category	System-level ESD requirements	Data rate	Data rate requirements
High-speed ESD protection with optional common mode filters	- Extremely sensitive SoCs	- Tx +/-, Rx +/-, D +/-	- Extremely low clamping - SCRs - Low dynamic resistance - High surge robustness	- 480 Mbit/s to 20 Gbit/s and increasing	- RF-friendly routing mandatory - Integrated concept for target data rate
Low-speed ESD protection	- Very sensitive SoCs	- SBU, CC	- Very low clamping (protection with low $V_{cl}$ and low $R_{dyn}$ ) - Very high surge robustness	- Low	- RF friendly routing advisable to minimize influence on high-speed lines
$V_{bus}$ surge protection	- Increasing energies of possible surge pulses - Type-C allows higher energies	- $V_{bus}$	- Extremely high surge robustness	- DC	- None

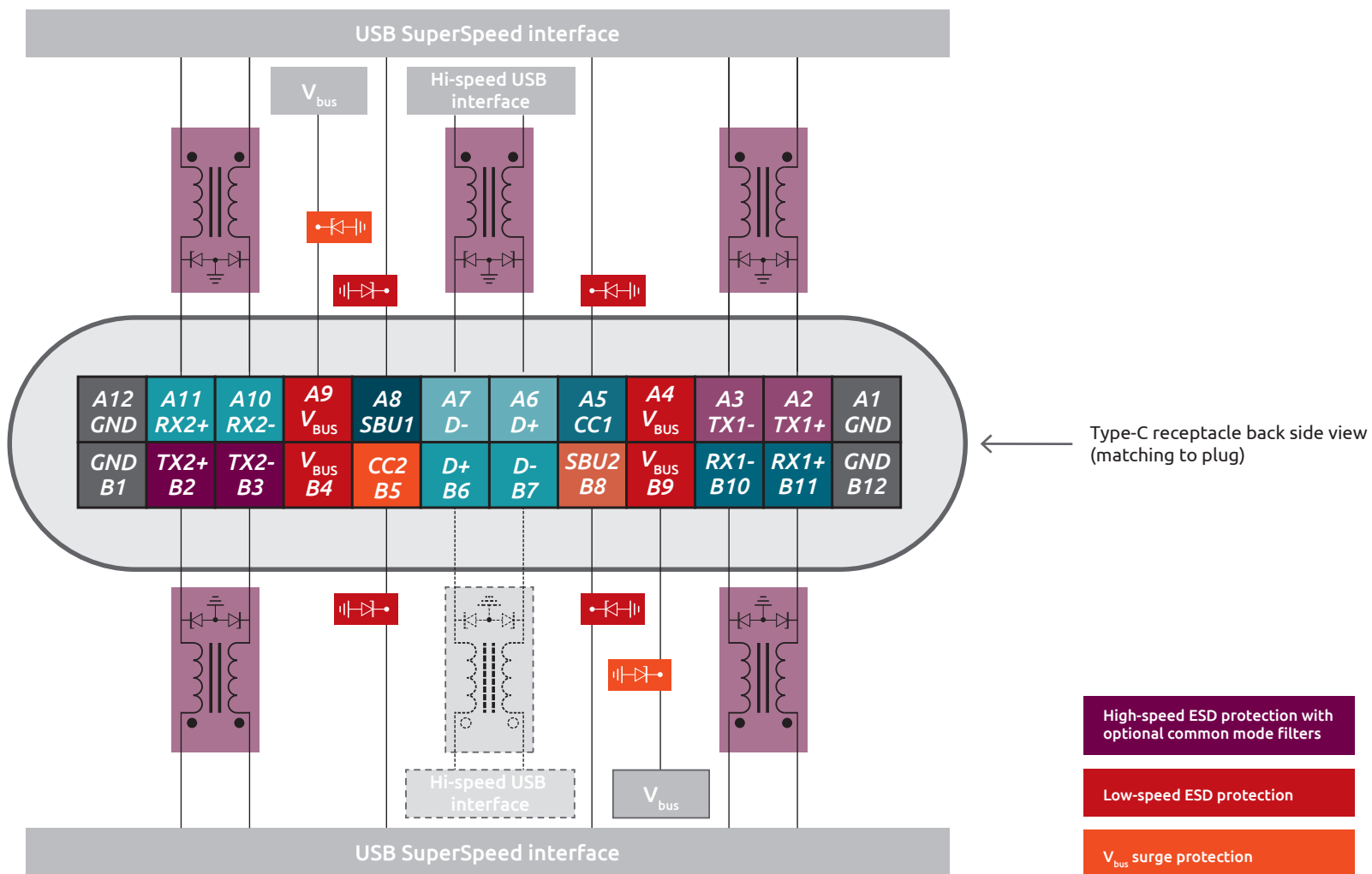
# Single-line protection concept



# Multi-line protection concept

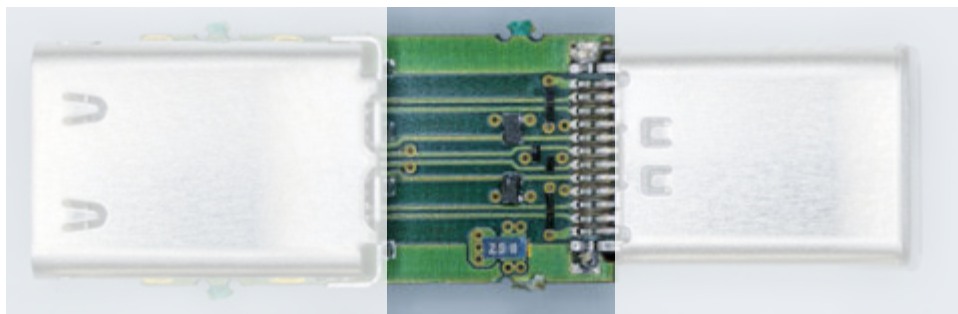


# Common mode filter with ESD protection concept

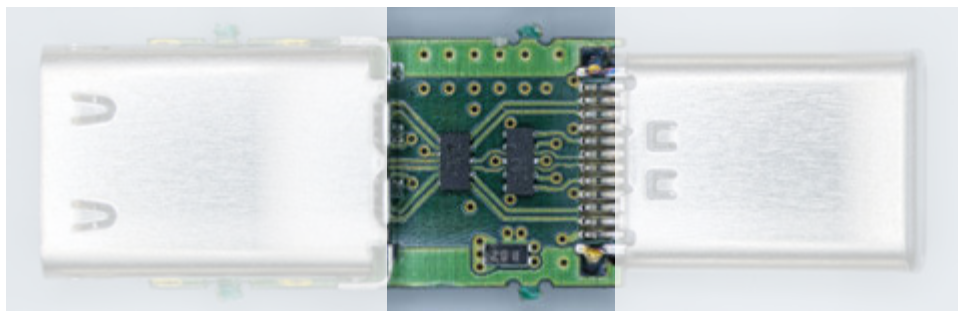


# Application of the USB Type-C connector

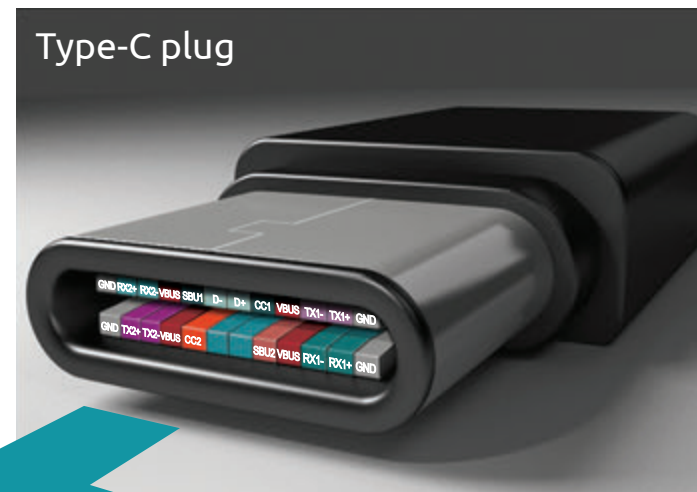
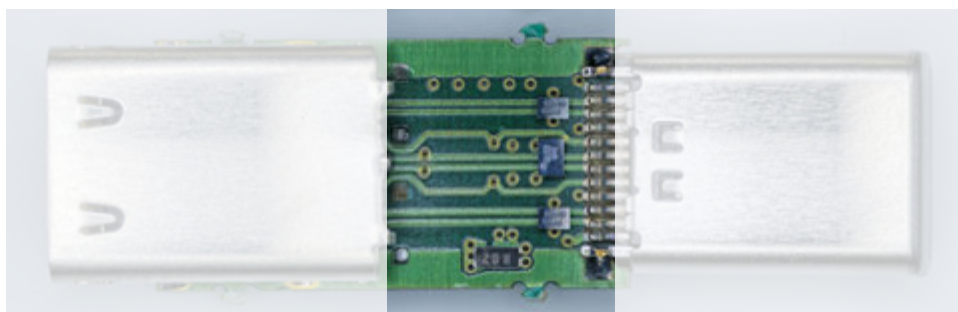
Single-line



Multi-line



Common mode filter



Plug front view

## Type-C receptacle back side view (matching to plug)

### USB Type-C test dongles

Nexperia has designed Type-C test dongles, which are using protection and filtering solutions. They can be used for a quick check of device suitability. They can also be used by RF board-designers for inspiration.

There are three test dongles:

- › Single-line ESD protection
- › Multi-line ESD protection
- › Common mode filters with integrated ESD protection



# Product selection for data lines

High-speed ESD protection with optional common mode filters

Low-speed ESD protection

Type number	Application	No. of protected lines	SuperSpeed Tx/Rx +/-	HighSpeed D+/-	CC, SBU	Configuration	C <sub>d</sub> [typ] (pF)	Package version	Package name	Size (mm)	V <sub>ESD</sub> IEC61000-4-2 (kV)	I <sub>PPM</sub> @8/20μs [max] (A)	Remarks
PESD5V0C1BSF	ESD protection	1	yes	yes		Bidirectional	0,2	SOD962-2	DSN0603-2	0.6 x 0.3 x 0.3	20	9	Very high robustness for single data lines
PESD5V0C1USF	ESD protection	1	yes	yes		Unidirectional	0,45	SOD962-2	DSN0603-2	0.6 x 0.3 x 0.3	20	9	Extremely low clamping and high robustness for single data-lines
PESD3V3Z1BSF	ESD protection	1	yes	yes		Bidirectional	0,28	SOD962-2	DSN0603-2	0.6 x 0.3 x 0.3	20	9,5	Extremely low clamping and high robustness for single data-lines
PESD3V3W1BSF	ESD protection	1	yes	yes		Bidirectional	0,45	SOD962-2	DSN0603-2	0.6 x 0.3 x 0.3	30	> 15	Extremely low clamping and high robustness for single data-lines
PESD5V0H1BSF	ESD protection	1	yes	yes		Bidirectional	0,15	SOD962-2	DSN0603-2	0.6 x 0.3 x 0.3	15	7	First offer for single data-lines
PESD5V0R1BSF	ESD protection	1	yes	yes		Bidirectional	0,1	SOD962-2	DSN0603-2	0.6 x 0.3 x 0.3	10	4,5	Extremely low capacitance for single data lines
PESD5V0S1USF	ESD protection	1			yes	Unidirectional	35	SOD962	DSN0603-2	0.6 x 0.3 x 0.3	30	3,5	
PESD5V0S1BSF	ESD protection	1			yes	Bidirectional	35	SOD962-2	DSN0603-2	0.6 x 0.3 x 0.3	30	8	
IP3319CX6	Common mode filter + ESD	2+1 *		yes		Unidirectional	0,3	OL-IP3319CX6	WLCSP6	0.95 x 1.34 x 0.6	15	6	
IP4283CZ10-TBR	ESD protection	4		yes	yes	Unidirectional	0,6	SOT1176-1	DFN2510A-10	2.5 x 1.0 x 0.5	8	> 3	Allows a combination of CC/SBU protection
PCMF1USB3S	Common mode filter + ESD	2	yes	yes		Unidirectional	0,3	WLCSP5_2-1-2	WLCSP5	0.77 x 1.17 x 0.57	15	7	Very easy routing for USB Type-C connector
PCMF2USB3S	Common mode filter + ESD	4	yes	yes		Unidirectional	0,3	WLCSP10_4-2-4	WLCSP10	1.57 x 1.17 x 0.57	15	7	Two line pairs
PCMF3USB3S	Common mode filter + ESD	6	yes	yes		Unidirectional	0,3	WLCSP15_6-3-6	WLCSP15	2.37 x 1.17 x 0.57	15	7	Three line pairs
PESD5V0V2BM	ESD protection	2			yes	Bidirectional	18	SOT883	DFN1006-3	1.0 x 0.6 x 0.48	30	9	Extremely low clamping and robustness for two data-lines
PESD5V0V2BMB	ESD protection	2			yes	Bidirectional	18	SOT883B	DFN1006B-3	1.0 x 0.6 x 0.37	30	9	Extremely low clamping and robustness for two data-lines
PESD5V0X1BCAL	ESD protection	1		yes	yes	Bidirectional	0,85	SOD882	DFN1006-2	1.0 x 0.6 x 0.5	15	1,8	
PESD5V0X2UAM	ESD protection	2		yes	yes	Unidirectional	0,8	SOT883	DFN1006-3	1.0 x 0.6 x 0.48	15	2,5	0.37 thickness: ...UAMB
PESD1USB3S	ESD protection	2	yes	yes		Unidirectional	0,3	WLCSP5_2-1-2	WLCSP5	0.77 x 1.17 x 0.57	15	7	Allows changing between ESD and filter
PESD2USB3S	ESD protection	4	yes	yes		Unidirectional	0,3	WLCSP10_4-2-4	WLCSP10	1.57 x 1.17 x 0.57	15	7	Allows changing between ESD and filter
PESD3USB3S	ESD protection	6	yes	yes		Unidirectional	0,5	WLCSP15_6-3-6	WLCSP15	2.37 x 1.17 x 0.57	15	7	Allows changing between ESD and filter
PUSB3AB6	ESD protection	6	yes	yes		Bidirectional	0,15	SOT1358-1	XSON7	1.1 x 2.1 x 0.5	15	7	
PUSB3FR4	ESD protection	4	yes	yes		Unidirectional	0,29	SOT1176-1	DFN2510A-10	2.5 x 1.0 x 0.5	15	7	First offer for 4 data lines
PUSB3FR6	ESD protection	6	yes	yes		Unidirectional	0,35	SOT1358-1	XSON7	1.1 x 2.1 x 0.5	15	7	First offer for 6 data lines

\* On The Go

# Product selection for $V_{bus}$ / $V_{bat}$ protection

Type	$V_{RWM}$ (V)	8/20 $\mu$ s pulse		10/1000 $\mu$ s pulse	
		$I_{ppm}$ 8/20 $\mu$ s (A)	$V_{cl}$ @ $I_{ppm}$ 8/20 $\mu$ s (V) max	$I_{ppm}$ 10/1000 $\mu$ s (A)	$V_{cl}$ @ $I_{ppm}$ 10/1000 $\mu$ s (V) max
PTVS5V0Z1USKP	5	100	20.4	23	11.4
PTVS5V0Z1USK	5	80	18	20	12
PTVS7V5Z1USK	7.5	100	22	17	13.5
PTVS10VZ1USK	10	75	27	12.5	18.2
PTVS12VZ1USK	12	65	29	10.5	21.8
PTVS15VZ1USK	15	52	36	7.5	27.4
PTVS18VZ1USK	18	41	44	6.4	32.8
PTVS20VZ1USK	20	41	48.3	6	36.9
PTVS22VZ1USK	22	41	39.5	5	40
PTVS26VZ1USK	26	32	57.5	4.5	46

Type	$V_{RWM}$ (V)	8/20 $\mu$ s pulse		10/1000 $\mu$ s pulse	
		$I_{PPM}$ [max] (A)	$V_{cl}$ @ $I_{PPM}$ [max] (V)	$I_{PPM}$ [max] (A)	$V_{cl}$ @ $I_{PPM}$ [max] (V)
PTVS7V5U1UPA	7.5	178	19.7	23.3	12.9
PTVS10VU1UPA	10	148	23	17.6	17
PTVS12VU1UPA	12	131	25.2	15.1	19.9
PTVS15VU1UPA	15	111	28.8	12.3	24.4
PTVS18VU1UPA	18	97	32	10.3	29.2
PTVS20VU1UPA	20	98.5	38.7	9.2	32.5
PTVS22VU1UPA	22	88.5	41	8.4	35.5
PTVS24VU1UPA	24	79	44.2	7.7	38.8
PTVS26VU1UPA	26	69	43.5	7	42.1

$V_{bus}$  surge protection

All devices offer 30 kV ESD ruggedness.



SOD964  
DSN1608-2  
1.6 x 0.8 x 0.29 mm



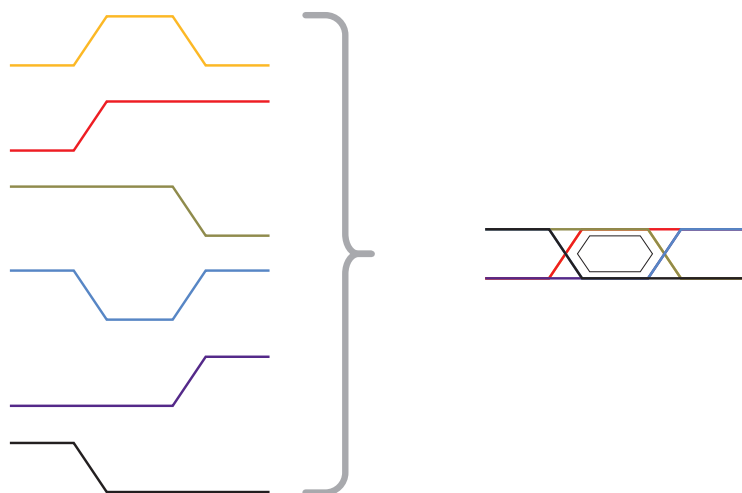
SOT1061  
DFN2020-3  
2.0 x 2.0 x 0.65 mm

# ESD protection for USB 3.2: signal integrity

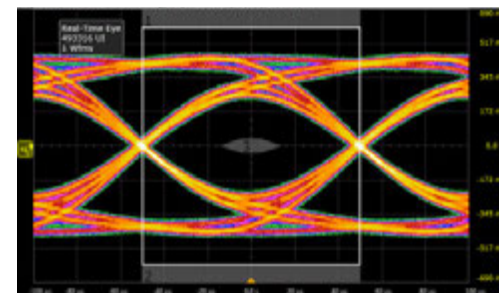
## Eye diagrams

Differential signals are applied to the Device-Under-Test (DUT). An overlay of sweeps of different 0-1 and 1-0 transitions is shown in the eye diagram:

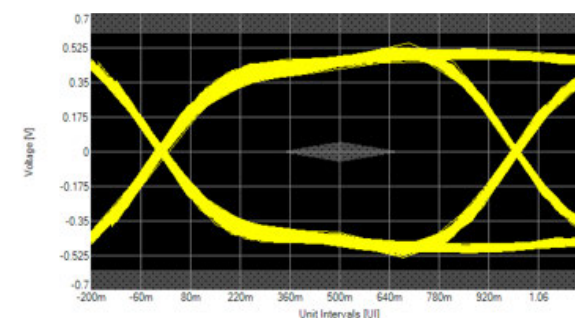
- › Due to imperfections and suppression of higher harmonics, the signal after a system looks like an eye – hence the name of the measurement
- › A mask, that surrounds the eye but is not touched by it, defines the maximum allowed signal degradation that is acceptable to all receivers
- › Differential signals are measured after a comparator



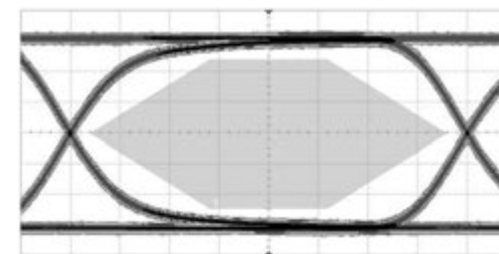
USB 3.1 / 3.2  
10 Gbps



USB 3.1 / 3.2  
5 Gbps



USB 2.0



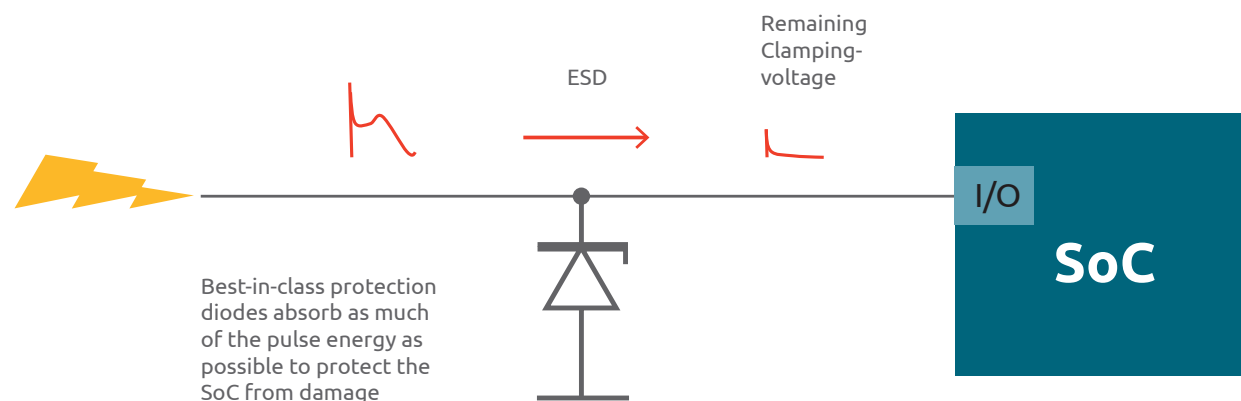
# System-level ESD protection for USB 3.2

## Protection of the SoC

With system-level ESD protection, the greater part of an ESD pulse is kept away from the protected System-on-Chip (SoC) and signal integrity is maintained for all frequencies used in the application. System-level protection can be improved by providing fast diode reaction time, low dynamic resistance, deep snap-back and low inductance package concepts. An eye diagram for the highest frequency used by the application will show the signal integrity Walso with onboard.

## System-level test

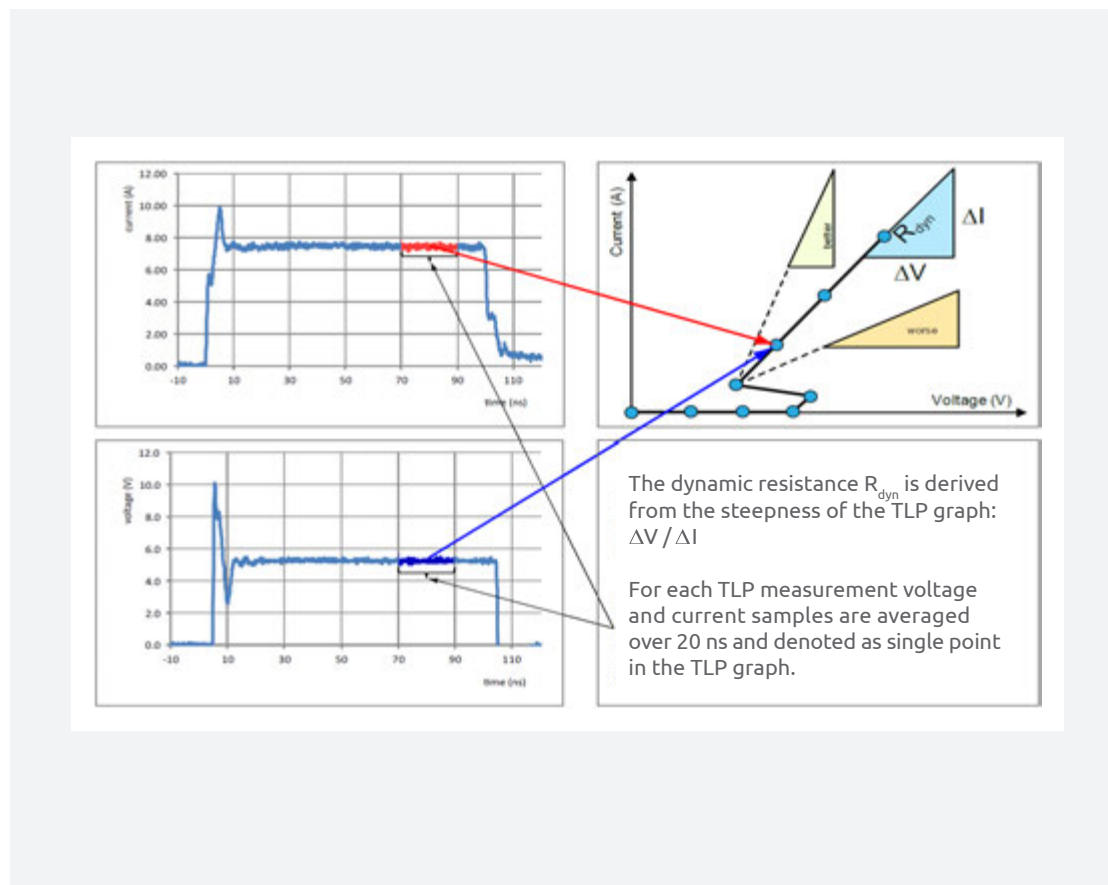
- › Stresses the pins with an ESD gun until an increase in leakage current shows signs of failure which is the most straight forward way to measure system-level robustness
- › In Nexperia tests on commonly available USB applications, the USB system chip failed but the ESD protection remained undamaged
- › System level protection is achieved by reducing the ESD stress on the system:
  - Deep snap-back
  - Low dynamic resistance
  - Fast diode switching time
  - Low inductance package concept



# System-level ESD protection for USB 3.2

## TLP measurements

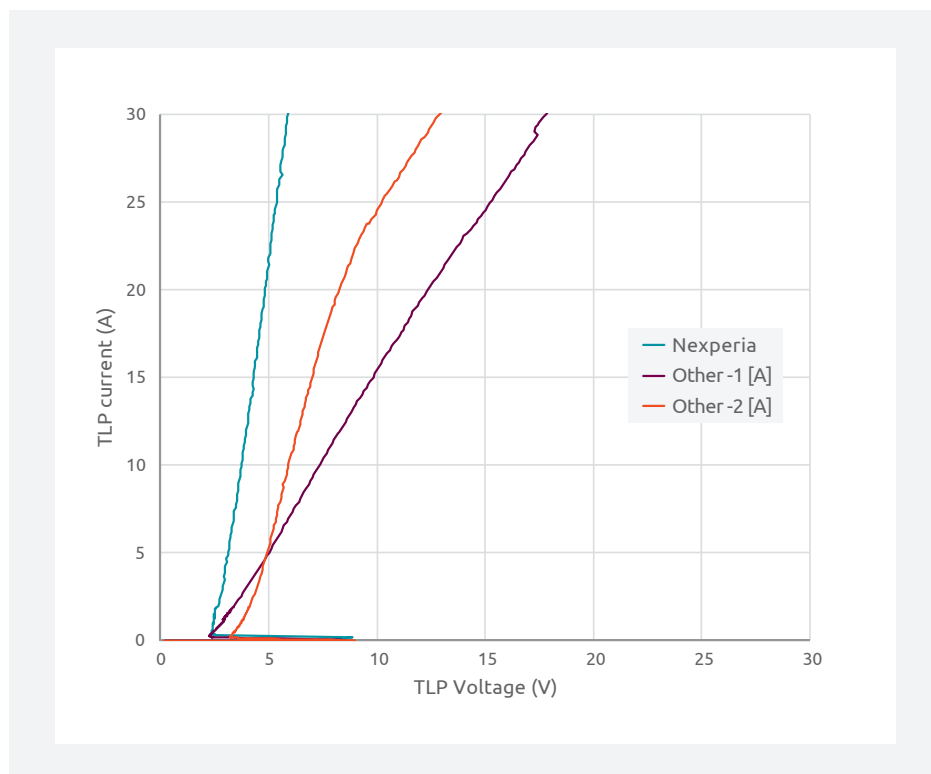
Transmission Line Pulse (TLP) measurements are a way to characterize the I(V) behaviour of ESD protection devices without overstressing them. First, a defined transmission-line is charged. Next, this line is discharged over the Device Under Test (DUT), which can be a single component or a complete system. Current and clamping voltage are recorded, with a pair of single current (voltage) measurements forming one point in the TLP diagram. The leakage current is measured after each discharge to establish any signs of damage to the DUT.



## System-level ESD protection for USB 3.2

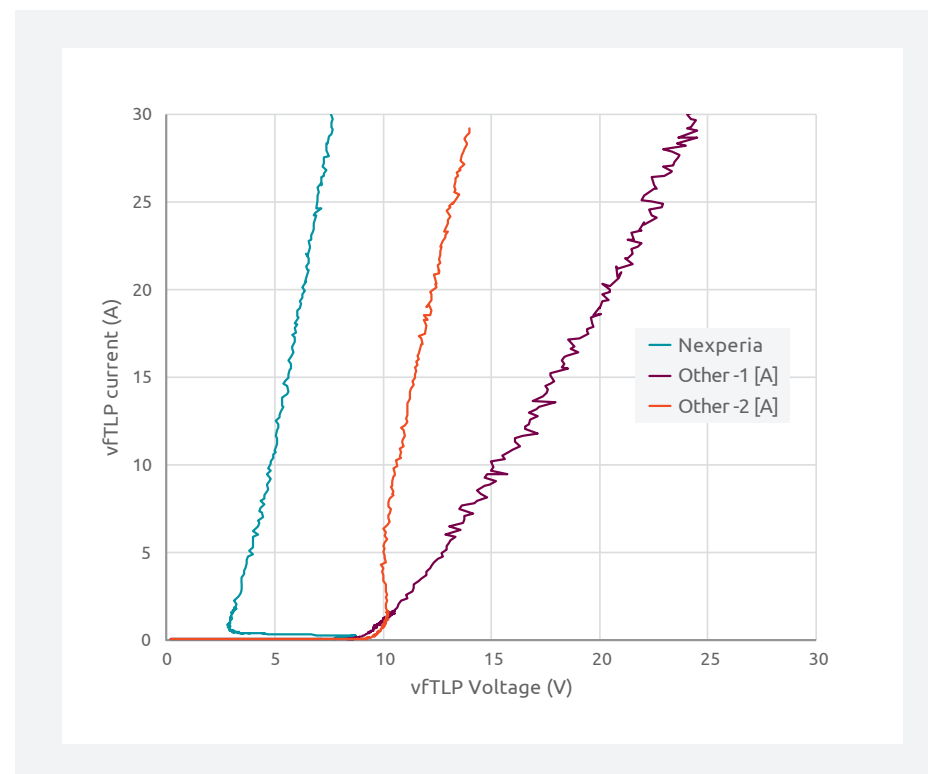
### Transmission Line Pulse (TLP) measurements (100 ns pulse)

Comparing the TLP I(V) behaviour of three bi-directional ESD protection devices with SCR for USB 3.2. Nexperia offers the lowest clamping voltages, leading to the best system-level protection.



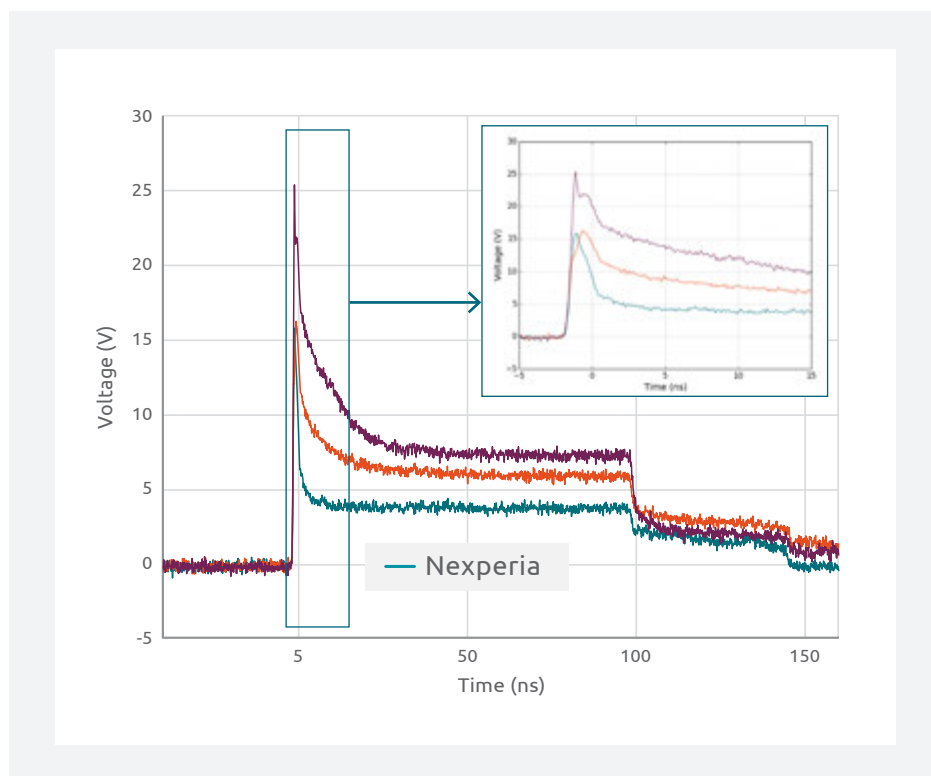
### Very-fast TLP (vFTLP) measurements (5 ns pulse)

Comparing three bi-directional SCR ESD protection devices for USB 3.2 in their vFTLP behaviour. Nexperia's SCR is the only device, which triggers for vFTLP pulses. Untriggered, the system-level protection is reduced to the level of a standard device.

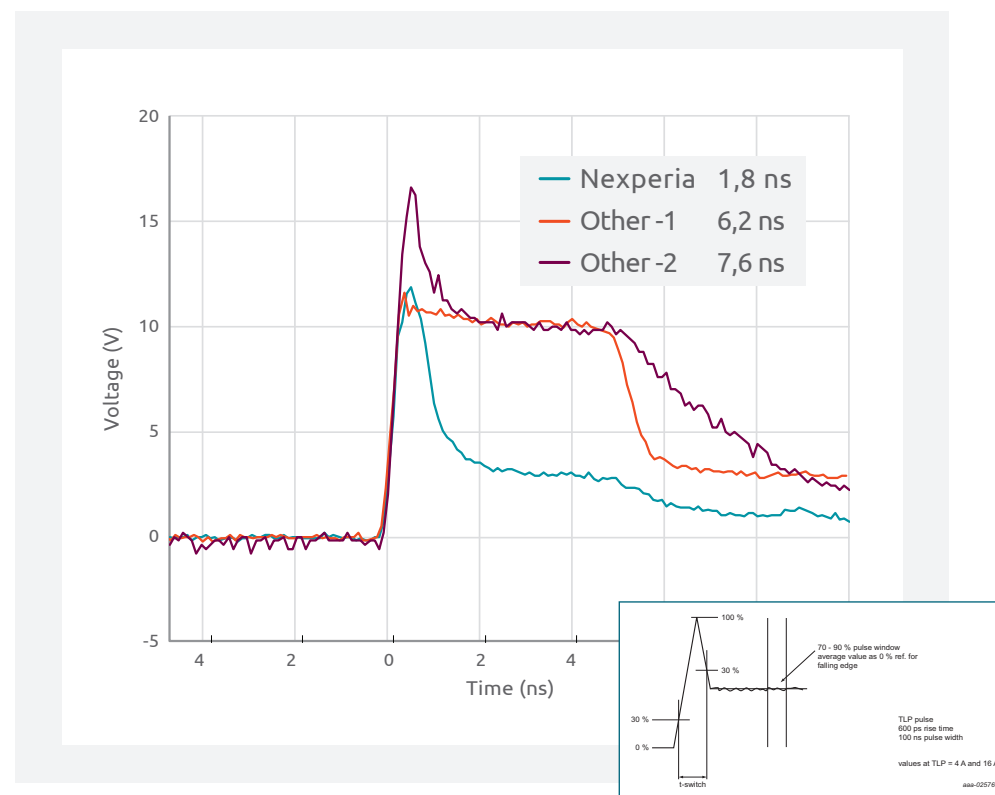


## System-level ESD protection for USB 3.2

Comparing switching speeds for 100 ns TLP measurements @ 10 A TLP  
Nexperia offers the shortest switching times to the lowest clamping  
voltage compared to the next best devices on the market.



Comparing switching speeds of three SCR devices for 5 ns very-fast  
TLP (vTLP) measurements @ 1 A vTLP. Nexperia offers the only SCR  
in this comparison, which triggers for very fast pulses.

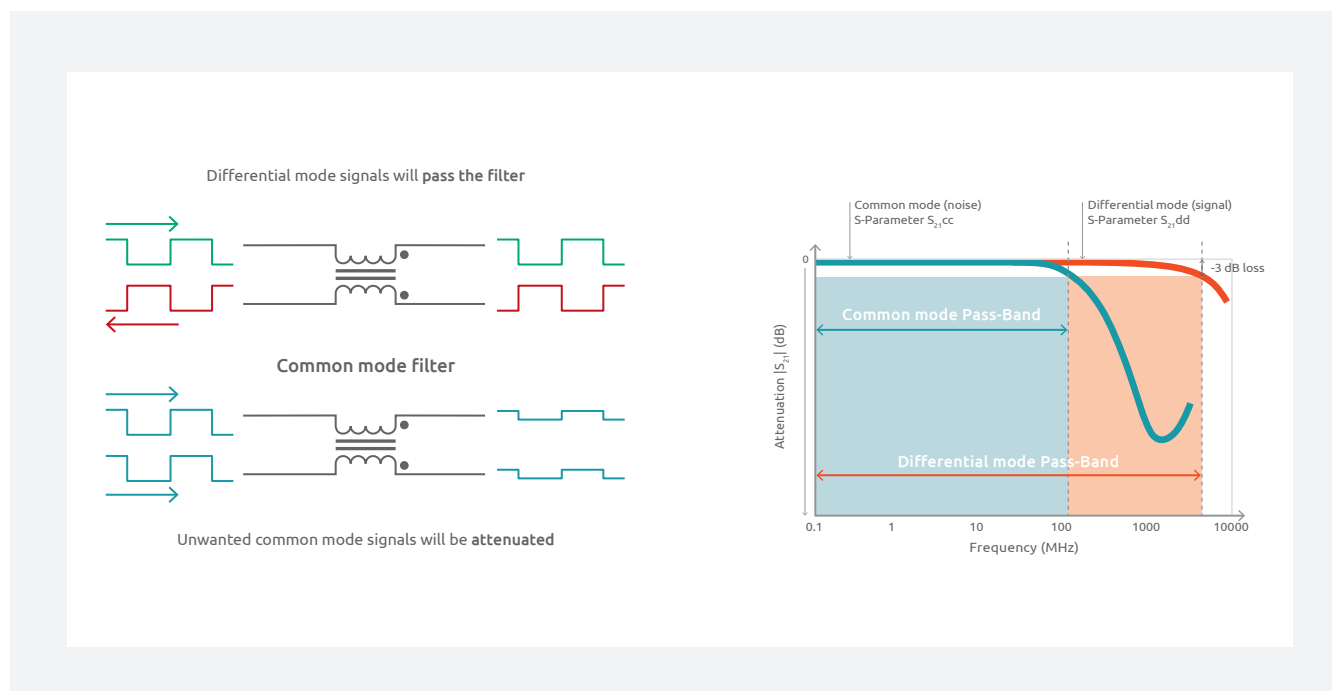


Measurement of switching time  
(turn-on time) based on vTLP test pulse

# Common mode filters for USB 2.0 and USB 3.2

## Common mode filters for USB

- › Increased integration, in portable devices, of different signals in the Gigahertz range has led to higher demands for EMI suppression
- › Nexperia offers a selection of common mode filters with integrated ESD protection to protect and filter USB 2.0 and 3.x interfaces
- › Details are in our dedicated application guide for common mode filters



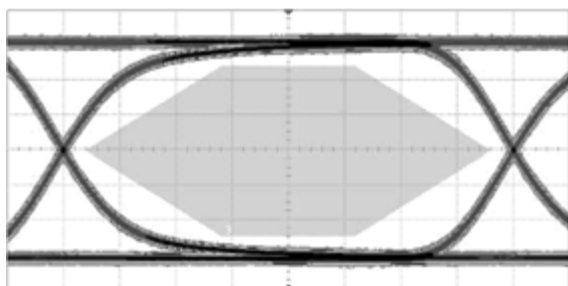


# Common mode filters for USB 2.0 and USB 3.2

## IP3319CX6 for USB 2.0 OTG (On-The-Go)

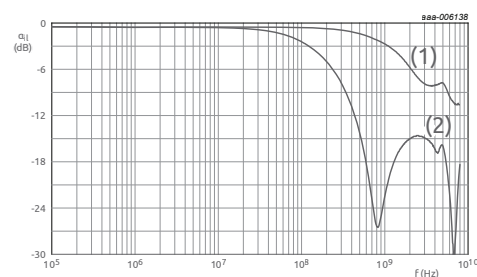
### Key features:

- › Common mode filter for one differential line pair
- › 3-line ESD protection for one line pair plus one pin (ID for OTG)
- › Best common mode protection in this footprint
- › Best-in-class ESD protection due to deep snap-back and very low  $R_{dyn}$
- › Very compact WLCSP6 package:
- › 0.95 x 1.34 x 0.57 mm

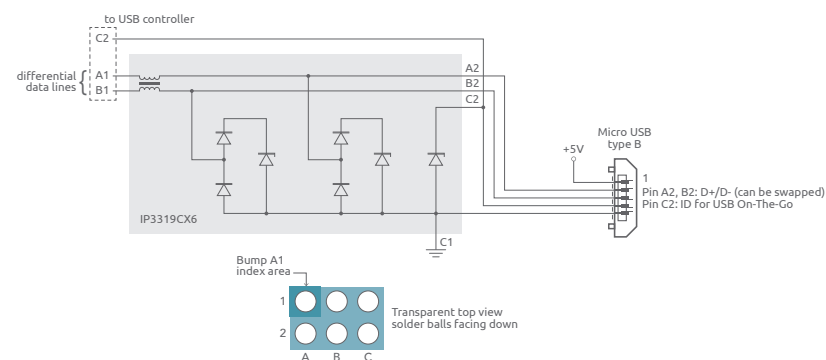


USB 2.0 eye diagram with IP3319CX6 on test board

IP3319CX6 insertion losses for differential and common modes



Typical IP3319CX6 application using Micro USB connector Type B

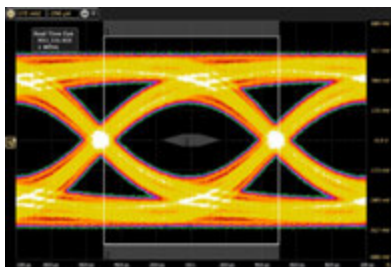


# Common mode filters for USB 2.0 and USB 3.2

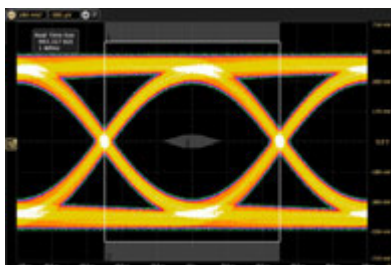
## PCMFxUSB3y for USB 3

### Key features:

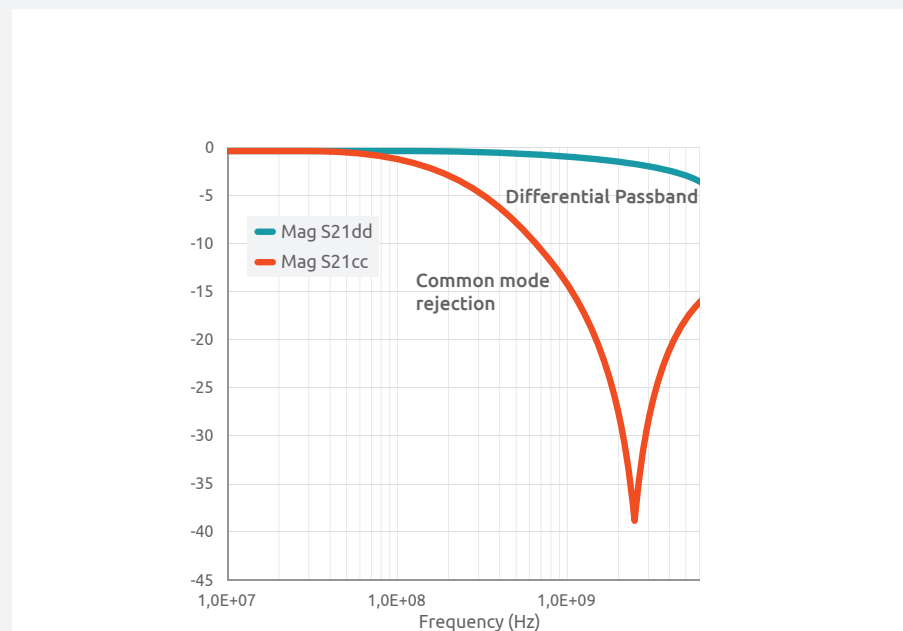
- › Common mode filter with ESD protection for one, two and three differential line-pairs
- › Extremely wide differential pass band of 6.5 GHz
- › Very wideband common mode suppression between 0.7 to 10 GHz
- › Excellent system-level ESD protection due to
  - Very fast ESD diode switching speeds
  - Very deep snap-back
  - Very low dynamic resistance
  - Low inductance WLCSP package
- › Extremely strong common mode suppression for the 5 Gbps USB3 fundamental @ 2.5 GHz



USB 3.1 / 3.2 eye @  
5 Gbps PCMFxUSB3y



USB 3.1 / 3.2 eye @  
10 Gbps PCMFxUSB3y



5-Ball CSP, 1 channel



0.8 x 1.2 mm

10-Ball CSP, 2 channels



1.6 x 1.2 mm

15-Ball CSP, 3 channels



2.4 x 1.2 mm

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## Notes

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**Date of release:**  
November 2017

**Printed:**  
In the Netherlands

