

# PCMFxUSB3S series

Common-mode EMI filter for differential channels with integrated ESD protection

Rev. 3 — 7 March 2019

Product data sheet

## 1. General description

Common-mode ElectroMagnetic Interference (EMI) filters with integrated ElectroStatic Discharge (ESD) protection for one, two and three differential channels. The devices are designed to provide low insertion loss for differential high-speed signals on each channel while unwanted common-mode signals are attenuated.

Each differential channel incorporates two signal lines that are coupled by integrated coils. Diodes provide protection to downstream components from ESD voltages up to  $\pm 15$  kV on each signal line.

**Table 1. Product overview**

Type number	Number of channels	Package Name
PCMF1USB3S	1	WLCSP5
PCMF2USB3S	2	WLCSP10
PCMF3USB3S	3	WLCSP15

## 2. Features and benefits

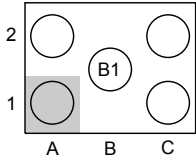
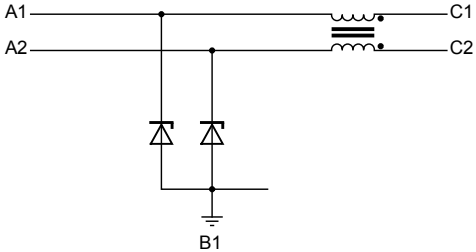
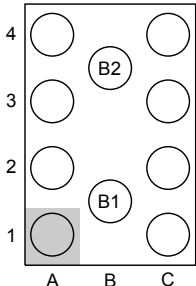
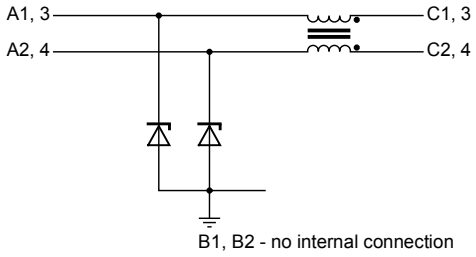
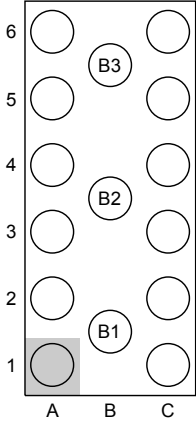
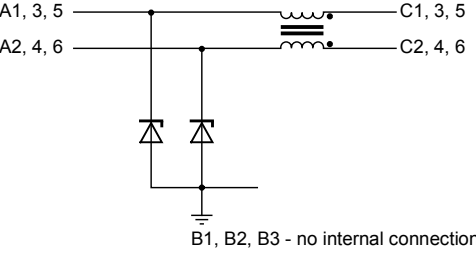
- One, two and three differential channels common-mode EMI filters with integrated ESD protection
- ESD protection up to  $\pm 15$  kV contact discharge according to IEC 61000-4-2
- Superior common-mode suppression over a wide frequency range
- Superior RF performance compared to other integrated filters or discrete filters with external ESD protection
- Extremely high symmetry between line pairs
- Industry-standard Wafer-Level Chip-Scale Packages: WLCSP5, 10 and 15 for smaller footprint

## 3. Applications

- Smartphone, cellular and cordless phone
- Tablet PC and Mobile Internet Device (MID)
- USB 3.2, USB 2.0, HDMI 2.0, HDMI 1.4
- MIPI M-PHY and D-PHY as used in Camera Serial Interface (CSI) and Display Serial Interface (DSI)
- General-purpose EMI and Radio-Frequency Interference (RFI) filter and downstream ESD protection

### 4. Pinning information

Table 2. Pinning

Pin	Symbol	Description	Simplified outline	Graphic symbol
<b>PCMF1USB3S (WLCSP5_2-1-2)</b>				
A1	CH1_IN+	channel 1+, external	 <p>Transparent top view <b>WLCSP5_2-1-2</b></p>	 <p>aaa-019784</p>
A2	CH1_IN-	channel 1-, external		
B1	GND_CH1	ground channel 1		
C1	CH1_OUT+	channel 1+, internal		
C2	CH1_OUT-	channel 1-, internal		
<b>PCMF2USB3S (WLCSP10_4-2-4)</b>				
A1	CH1_IN+	channel 1+, external	 <p>Transparent top view <b>WLCSP10_4-2-4</b></p>	 <p>B1, B2 - no internal connection aaa-019785</p>
A2	CH1_IN-	channel 1-, external		
A3	CH2_IN+	channel 2+, external		
A4	CH2_IN-	channel 2-, external		
B1	GND_CH1	ground channel 1		
B2	GND_CH2	ground channel 2		
C1	CH1_OUT+	channel 1+, internal		
C2	CH1_OUT-	channel 1-, internal		
C3	CH2_OUT+	channel 2+, internal		
C4	CH2_OUT-	channel 2-, internal		
<b>PCMF3USB3S (WLCSP15_6-3-6)</b>				
A1	CH1_IN+	channel 1+, external	 <p>Transparent top view <b>WLCSP15_6-3-6</b></p>	 <p>B1, B2, B3 - no internal connection aaa-019786</p>
A2	CH1_IN-	channel 1-, external		
A3	CH2_IN+	channel 2+, external		
A4	CH2_IN-	channel 2-, external		
A5	CH3_IN+	channel 3+, external		
A6	CH3_IN-	channel 3-, external		
B1	GND_CH1	ground channel 1		
B2	GND_CH2	ground channel 2		
B3	GND_CH3	ground channel 3		
C1	CH1_OUT+	channel 1+, internal		
C2	CH1_OUT-	channel 1-, internal		
C3	CH2_OUT+	channel 2+, internal		
C4	CH2_OUT-	channel 2-, internal		
C5	CH3_OUT+	channel 3+, internal		
C6	CH3_OUT-	channel 3-, internal		

## 5. Ordering information

Table 3. Ordering information

Type number	Package	
	Name	Description
PCMF1USB3S	WLCSP5	wafer level chip-size package; 5 bumps (2-1-2)
PCMF2USB3S	WLCSP10	wafer level chip-size package; 10 bumps (4-2-4)
PCMF3USB3S	WLCSP15	wafer level chip-size package; 15 bumps (6-3-6)

## 6. Marking

Table 4. Marking codes

Type number	Marking code
PCMF1USB3S	PF1S
PCMF2USB3S	PF2S
PCMF3USB3S	PF3S

## 7. Limiting values

Table 5. Limiting values

In accordance with the Absolute Maximum Rating System (IEC 60134).

Symbol	Parameter	Conditions	Min	Max	Unit
$V_I$	input voltage		-0.5	5	V
$V_{ESD}$	electrostatic discharge voltage	IEC 61000-4-2, level 4; all input pins to ground			
		contact discharge	-15	15	kV
		air discharge	-15	15	kV
		IEC 61000-4-2, level 4; all output pins to ground			
		contact discharge	-2	2	kV
		air discharge	-2	2	kV
$I_{PPM}$	rated peak-pulse current	$t_p = 8/20 \mu s$	-7	7	A
$T_{stg}$	storage temperature		-40	125	°C
$T_{amb}$	ambient temperature		-40	125	°C

## 8. Characteristics

### 8.1. Channel characteristics

**Table 6. Channel characteristics**

$T_{amb} = 25\text{ °C}$  unless otherwise specified.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$R_{s(ch)}$	channel series resistance	single line; input to output	-	3	-	$\Omega$
$C_d$	diode capacitance	$f = 1\text{ MHz}$ ; $V_I = 2.5\text{ V}$	[1]	0.25	-	pF
$I_{RM}$	reverse leakage current	per line; $V_I = 5\text{ V}$	-	-	100	nA
$V_{BR}$	breakdown voltage	$I_R = 1\text{ mA}$	6	9	-	V
$V_F$	forward voltage	$I_F = 10\text{ mA}$	-	0.8	-	V
$R_{dyn}$	dynamic resistance	TLP; positive transient	[2]	0.14	-	$\Omega$
		TLP; negative transient	[2]	0.14	-	$\Omega$
		surge; positive transient	[3]	0.22	-	$\Omega$
		surge; negative transient	[3]	0.22	-	$\Omega$

[1] This parameter is guaranteed by design.

[2] 100 ns Transmission Line Pulse (TLP); 50  $\Omega$ ; pulser at 70 ns to 90 ns.

[3] According to IEC 61000-4-5 (8/20  $\mu$ s).

### 8.2. Frequency characteristics

**Table 7. Frequency characteristics**

$T_{amb} = 25\text{ °C}$  unless otherwise specified.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
<b>Common mode: <math>S_{21cc}</math></b>						
$\alpha_{il}$	insertion loss	$f = 800\text{ MHz}$	[1]	-12	-	dB
		$f = 2.6\text{ GHz}$	[1]	-38	-	dB
		$f = 5\text{ GHz}$	[1]	-18	-	dB
<b>Differential mode: <math>S_{21dd}</math></b>						
$\alpha_{il}$	insertion loss	$f = 1\text{ MHz}$	[1]	0.3	-	dB
$f_{-3dB}$	cut-off frequency		[1]	6	-	GHz

[1] Normalized to attenuation at 1 MHz.

Common-mode EMI filter for differential channels with integrated ESD protection

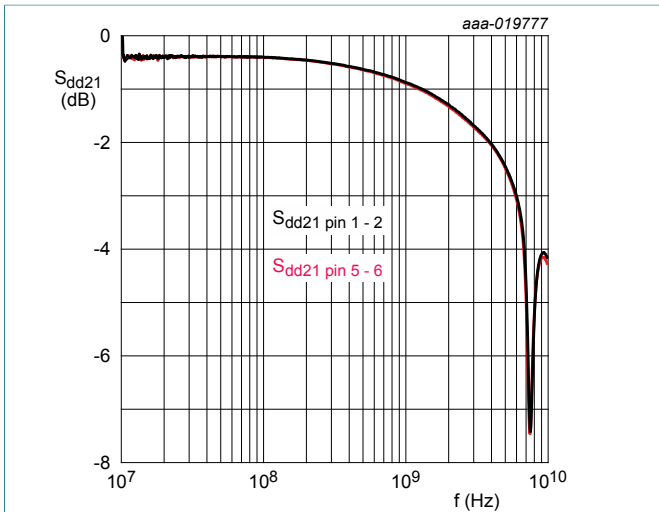


Fig. 1. Differential-mode insertion loss; typical values

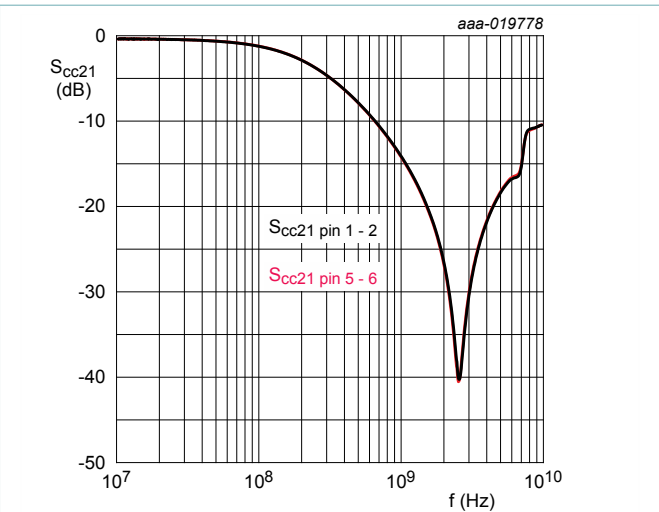
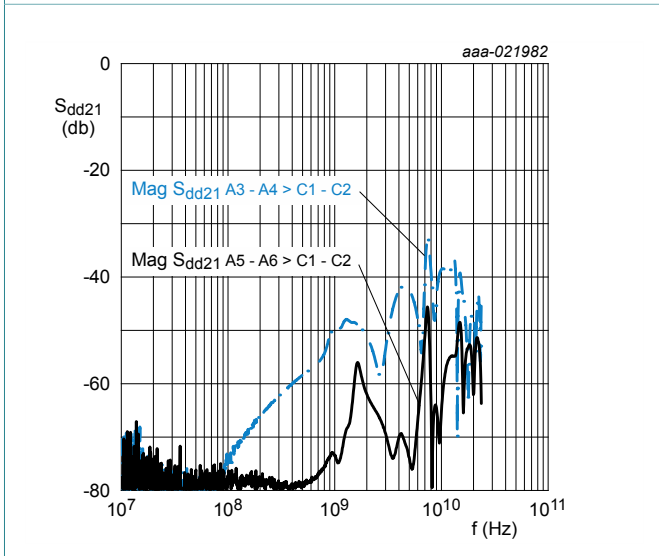
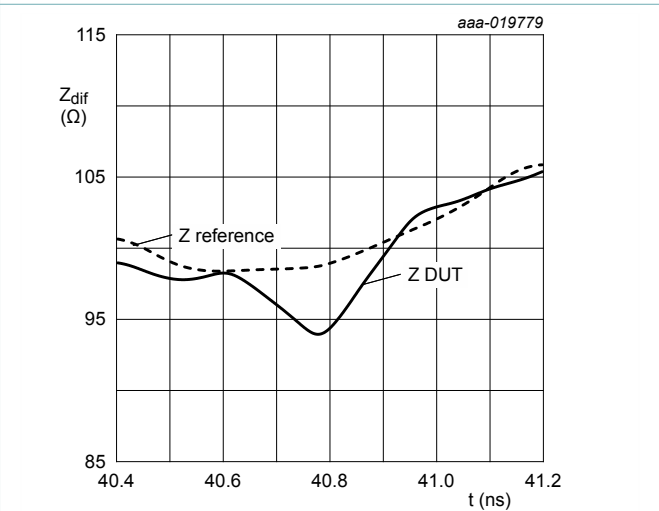


Fig. 2. Common-mode insertion loss; typical values



CH1 to CH2

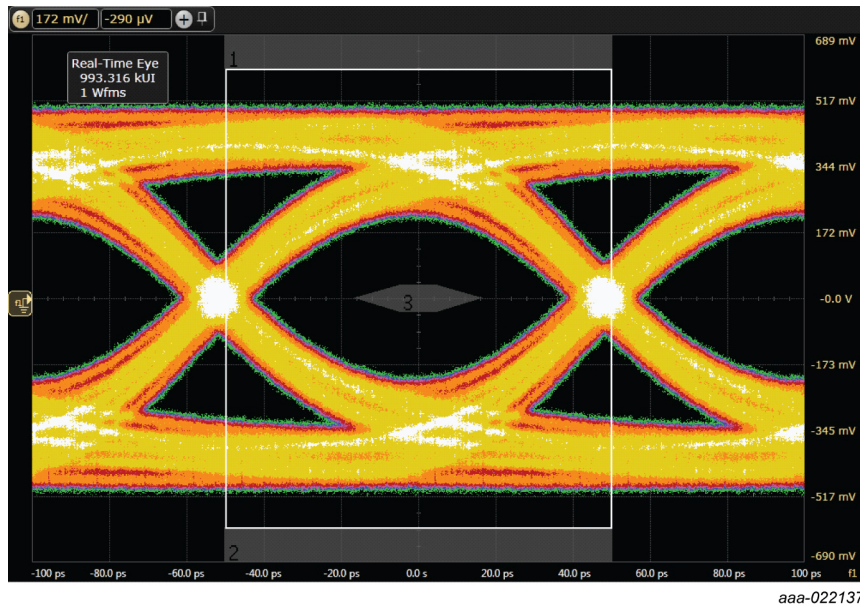
Fig. 3. Differential crosstalk; typical values



$t_r = 200$  ps

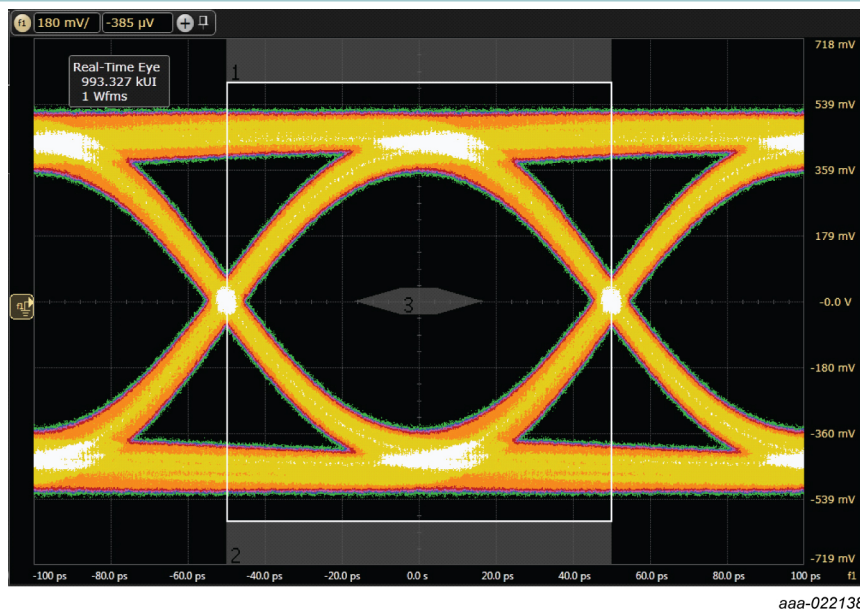
Fig. 4. Differential Time Domain Reflectometer (TDR) plot; typical values

Common-mode EMI filter for differential channels with integrated ESD protection



Data rate: 10 Gbit/s  
 Vertical scale 172 mV/div  
 Horizontal scale: 20 ps/div

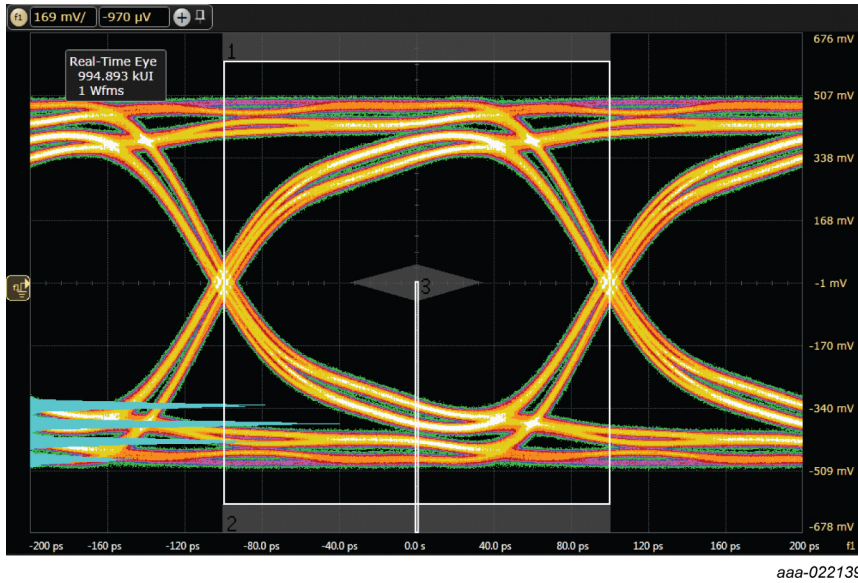
Fig. 5. USB 3.2 eye diagram 10 Gbps, test board with PCMF2USB3S; typical values



Data rate: 10 Gbit/s  
 Vertical scale 180 mV/div  
 Horizontal scale: 20 ps/div

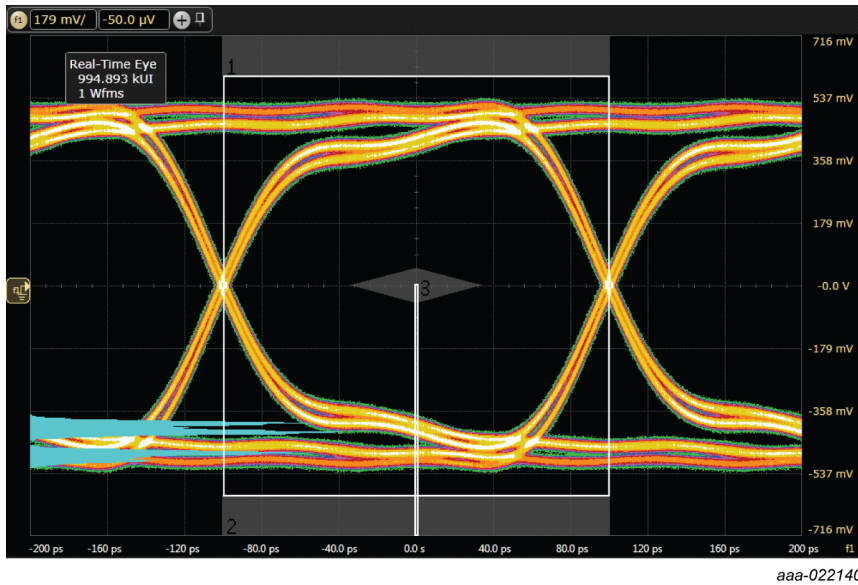
Fig. 6. USB 3.2 eye diagram 10 Gbps, test board without device; typical values

Common-mode EMI filter for differential channels with integrated ESD protection



Data rate: 5 Gbit/s  
 Vertical scale 169 mV/div  
 Horizontal scale: 40 ps/div

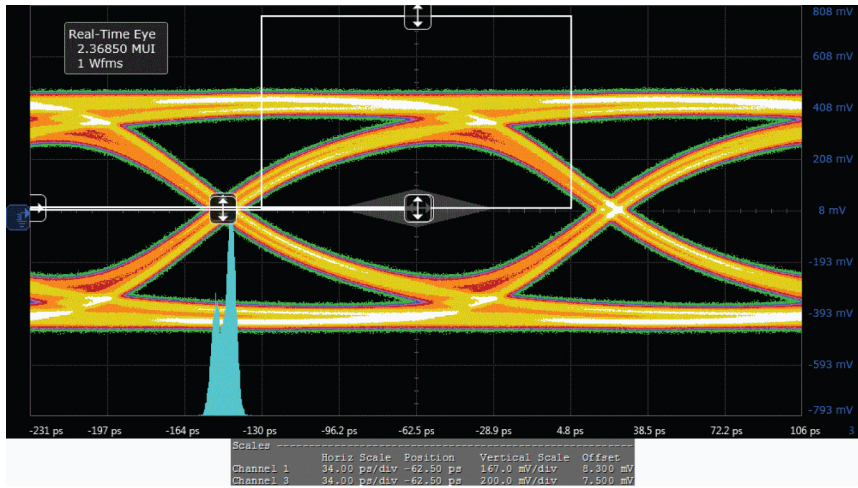
Fig. 7. USB 3.2 eye diagram 5 Gbps, test board with PCMF2USB3S; typical values



Data rate: 5 Gbit/s  
 Vertical scale 179 mV/div  
 Horizontal scale: 40 ps/div

Fig. 8. USB 3.2 eye diagram 5 Gbps, test board without device; typical values

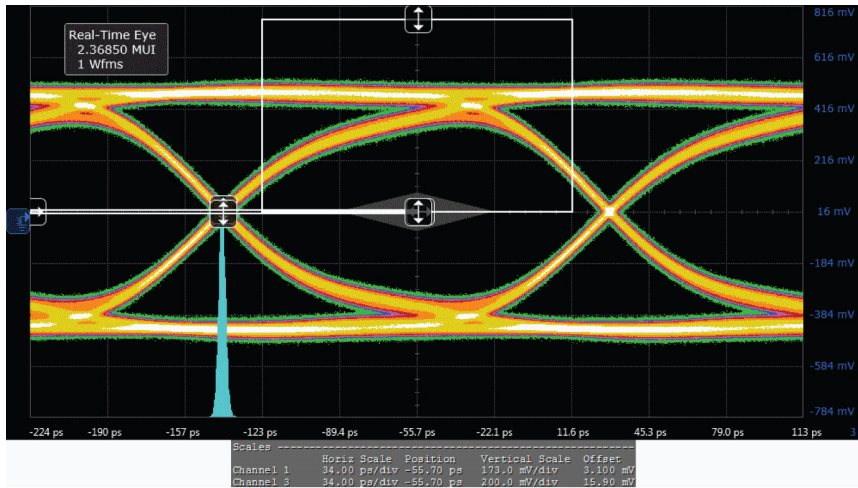
Common-mode EMI filter for differential channels with integrated ESD protection



aaa-022141

Test frequency: 148.5 MHz  
 Differential swing voltage: 861 mV  
 Horizontal scale: 34 ps/div

Fig. 9. HDMI 2.0 eye diagram TP1, test board with PCMF2USB3S; typical values



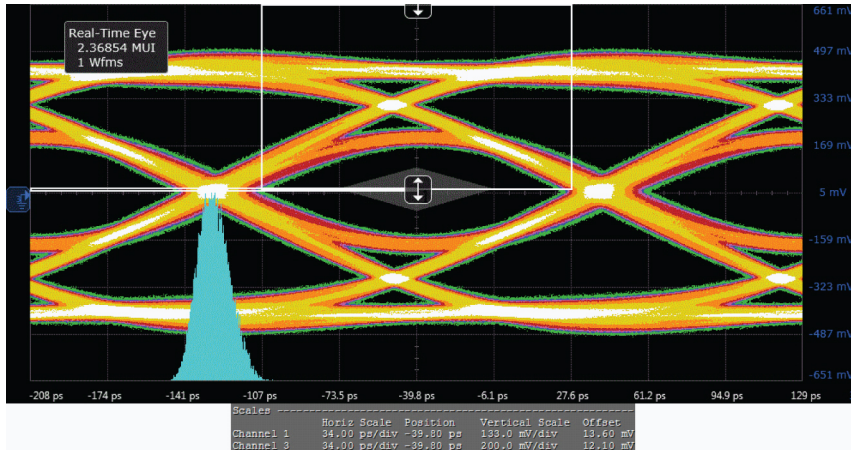
aaa-022142

Test frequency: 148.5 MHz  
 Differential swing voltage: 917 mV  
 Horizontal scale: 34 ps/div

Fig. 10. HDMI 2.0 eye diagram TP1, test board without device; typical values



Common-mode EMI filter for differential channels with integrated ESD protection



aaa-022143

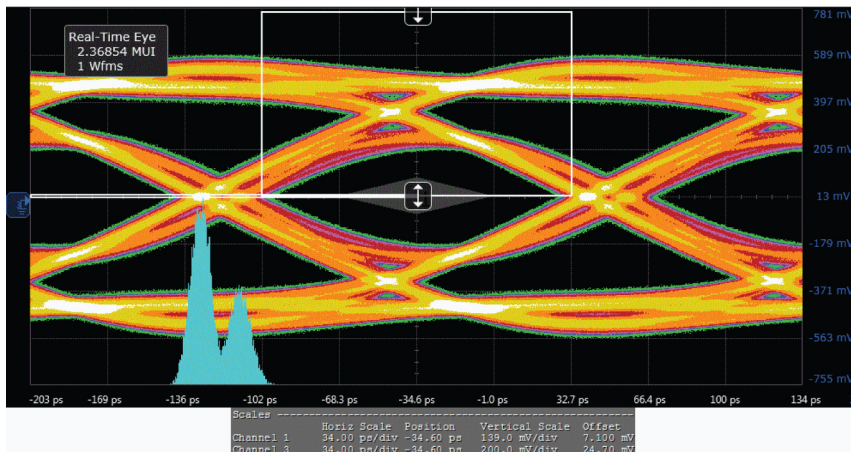
Test frequency: 148.5 MHz

Differential swing voltage: 849 mV

Horizontal scale: 34 ps/div

**Remark:** Measured at Test Point 2 (TP2) worst cable emulator, reference cable equalizer and worst case positive skew.

Fig. 11. HDMI 2.0 eye diagram TP2, test board with PCMF2USB3S; typical values



aaa-022144

Test frequency: 148.5 MHz

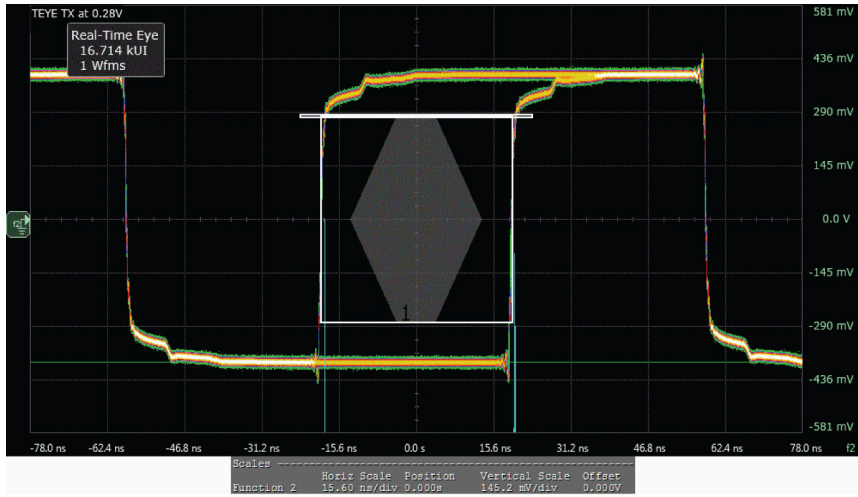
Differential swing voltage: 909 mV

Horizontal scale: 34 ps/div

**Remark:** Measured at Test Point 2 (TP2) worst cable emulator, reference cable equalizer and worst case positive skew.

Fig. 12. HDMI 2.0 eye diagram TP2, test board without device; typical values

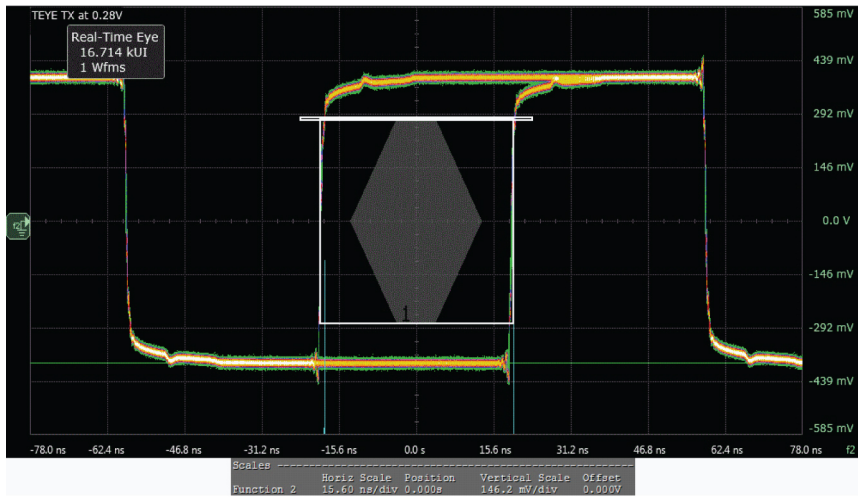
Common-mode EMI filter for differential channels with integrated ESD protection



aaa-022146

Vertical scale: 145 mV/div  
 Horizontal scale: 15.6 ns/div

Fig. 13. MIPI M-PHY PWM-TX transmitter eye opening at 140 mV, test board with PCMF2USB3S; typical value

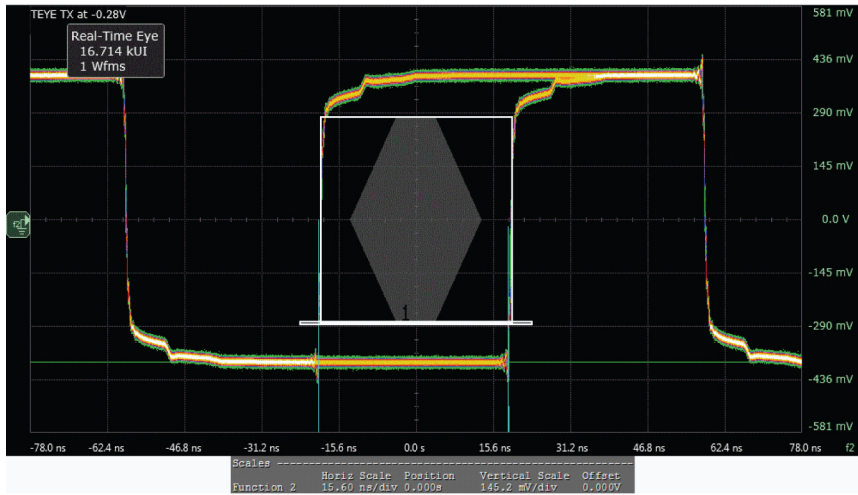


aaa-022148

Vertical scale: 146 mV/div  
 Horizontal scale: 15.6 ns/div

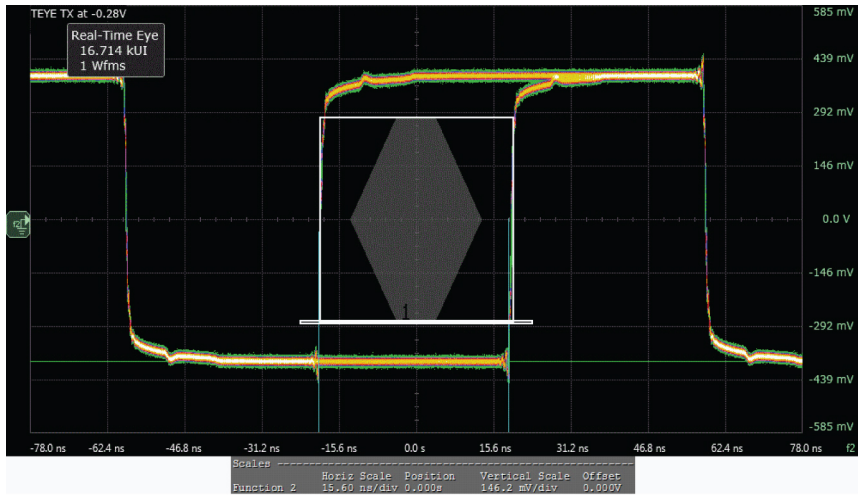
Fig. 14. MIPI M-PHY PWM-TX transmitter eye opening at 140 mV, test board without device; typical value

Common-mode EMI filter for differential channels with integrated ESD protection



Vertical scale: 145 mV/div  
Horizontal scale: 15.6 ns/div

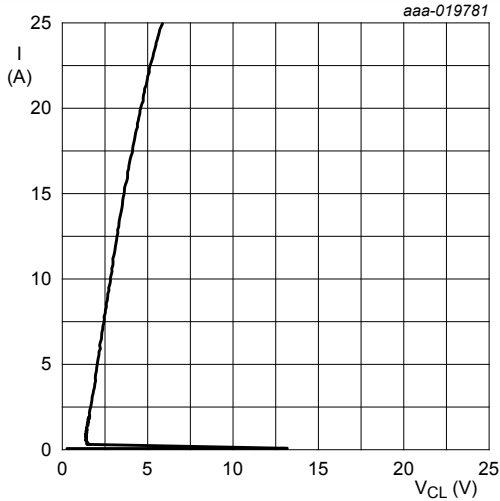
Fig. 15. MIPI M-PHY PWM-TX transmitter eye opening at -140 mV, test board with PCMF2USB3S; typical value



Vertical scale: 145 mV/div  
Horizontal scale: 15.6 ns/div

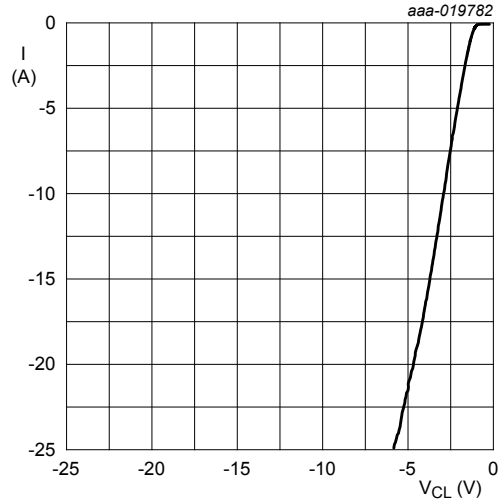
Fig. 16. MIPI M-PHY PWM-TX transmitter eye opening at -140 mV, test board without device; typical value

Common-mode EMI filter for differential channels with integrated ESD protection



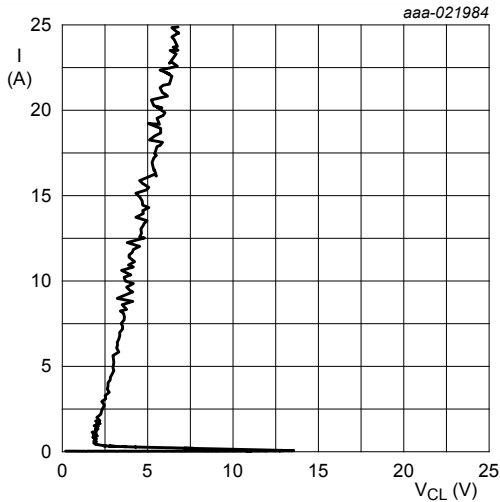
Transmission Line Pulse (TLP) = 100 ns;  
 $t_r = 1$  ns

**Fig. 17. Dynamic resistance with positive clamping; typical values**



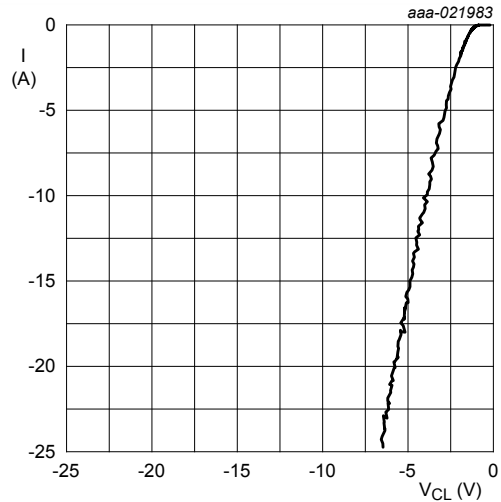
Transmission Line Pulse (TLP) = 100 ns;  
 $t_r = 1$  ns

**Fig. 18. Dynamic resistance with negative clamping; typical values**



Very-Fast Transmission Line Pulse (VF-TLP) = 5 ns;  
 $t_r = 600$  ps

**Fig. 19. Dynamic resistance with positive clamping; typical values**

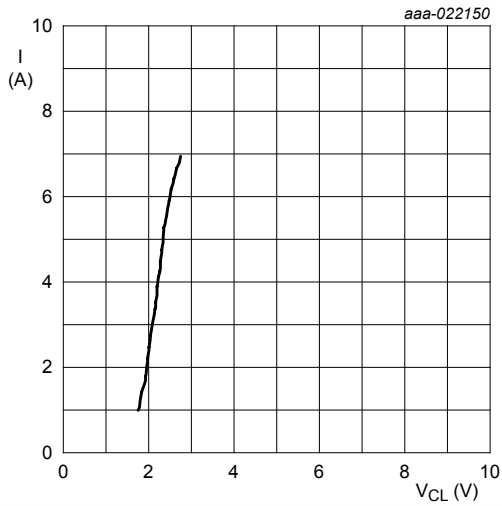


Very-Fast Transmission Line Pulse (VF-TLP) = 5 ns;  
 $t_r = 600$  ps

**Fig. 20. Dynamic resistance with negative clamping; typical values**

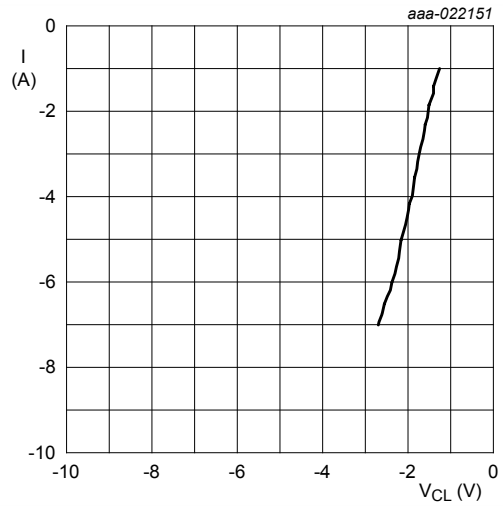
The device uses an advanced clamping structure showing a negative dynamic resistance. This snap-back behavior strongly reduces the clamping voltage to the system behind the ESD protection during an ESD event. Do not connect unlimited DC current sources to the data lines to avoid keeping the ESD protection device in snap-back state after exceeding breakdown voltage (due to an ESD pulse for instance).

Common-mode EMI filter for differential channels with integrated ESD protection



IEC61000-4-5;  $t_p = 8/20 \mu s$ ; positive pulse

**Fig. 21. Dynamic resistance with positive clamping; typical values**



IEC61000-4-5;  $t_p = 8/20 \mu s$ ; negative pulse

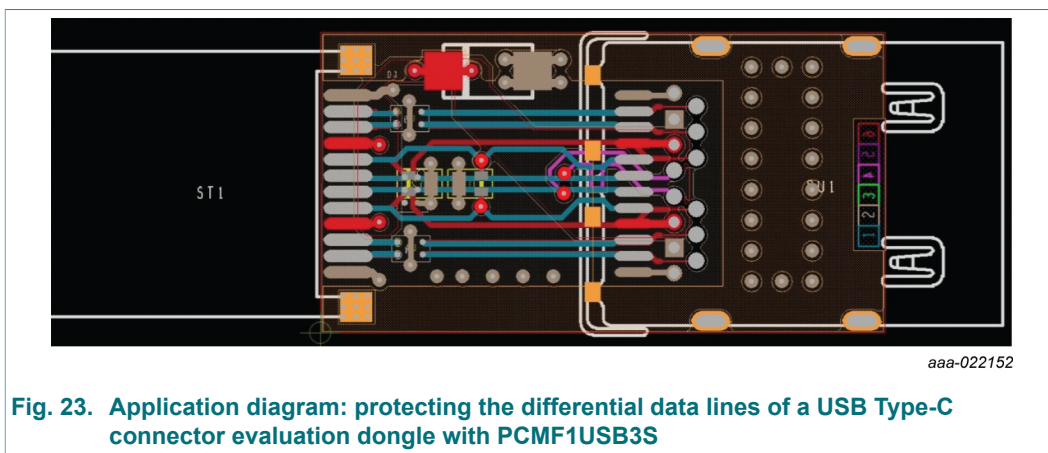
**Fig. 22. Dynamic resistance with negative clamping; typical values**

## 9. Application information

The device is designed to provide high-level ESD protection for differential high-speed data line pairs such as:

- USB 3.2
- HDMI 2.0
- Transition-Minimized Differential Signaling (TMDS)
- DisplayPort
- external Serial Advanced Technology Attachment (eSATA)
- Low Voltage Differential Signaling (LVDS)

When designing the Printed-Circuit Board (PCB), give careful consideration to impedance matching and signal coupling. Do not connect the protected signal lines to unlimited current sources like, for example, a battery.



**Fig. 23. Application diagram: protecting the differential data lines of a USB Type-C connector evaluation dongle with PCMF1USB3S**

Since the SuperSpeed TX/RX lines are separated by GND or VBUS from the Hi-Speed lines, PCMF1USB3S makes it easy to achieve same signal lengths, straight routing, and optimal positioning for ESD protection directly at the connector.

10. Package outline

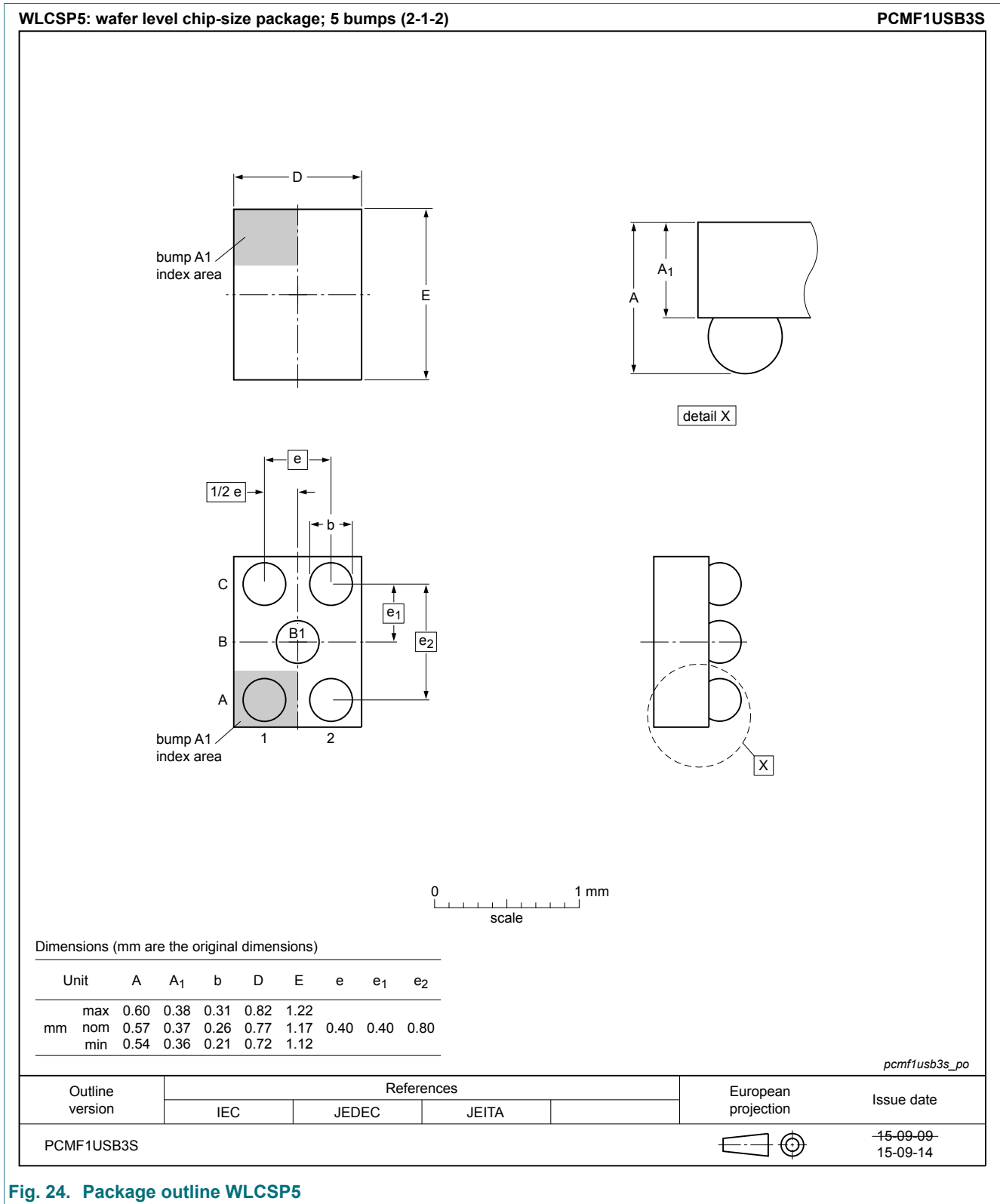
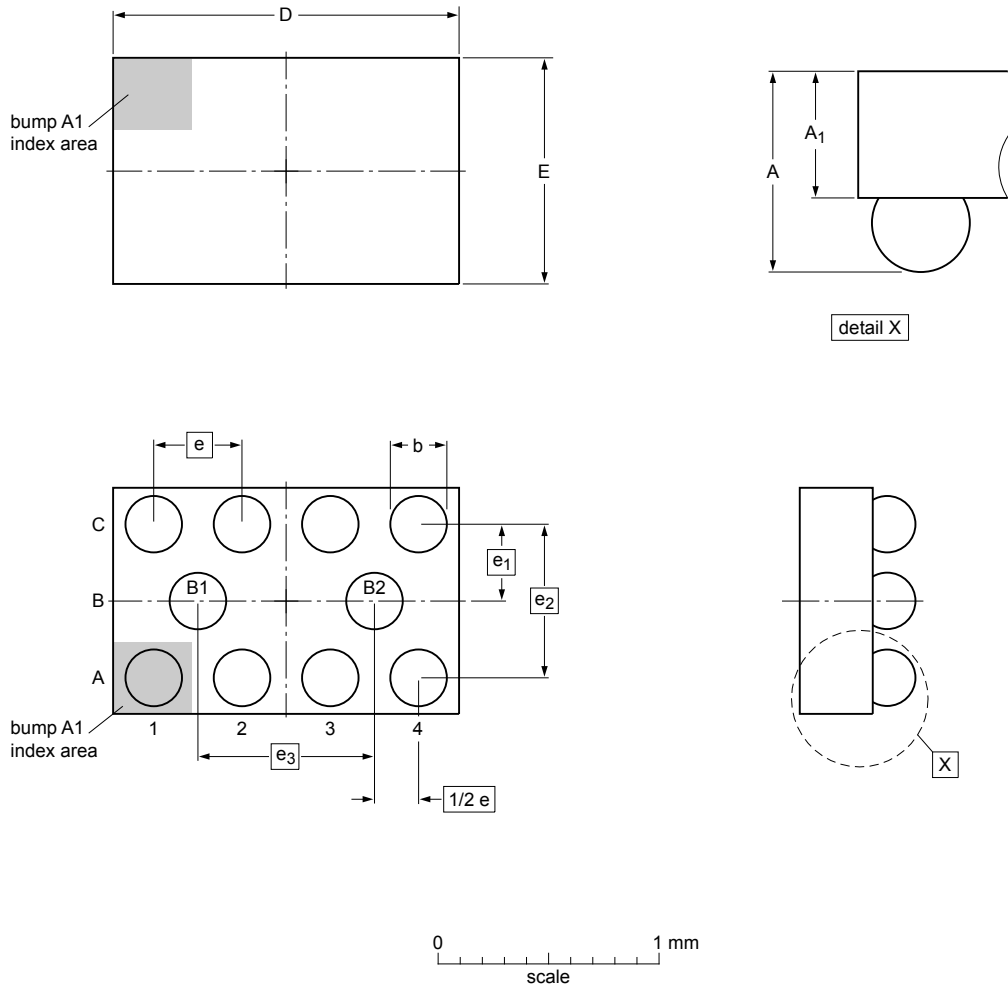


Fig. 24. Package outline WLCSP5

WLCSP10: wafer level chip-size package; 10 bumps (4-2-4)

PCMF2USB3S



Dimensions (mm are the original dimensions)

Unit	A	A <sub>1</sub>	b	D	E	e	e <sub>1</sub>	e <sub>2</sub>	e <sub>3</sub>
mm	max 0.60	0.38	0.31	1.62	1.22				
	nom 0.57	0.37	0.26	1.57	1.17	0.40	0.40	0.80	0.80
	min 0.54	0.36	0.21	1.52	1.12				

pcmf2usb3s\_po

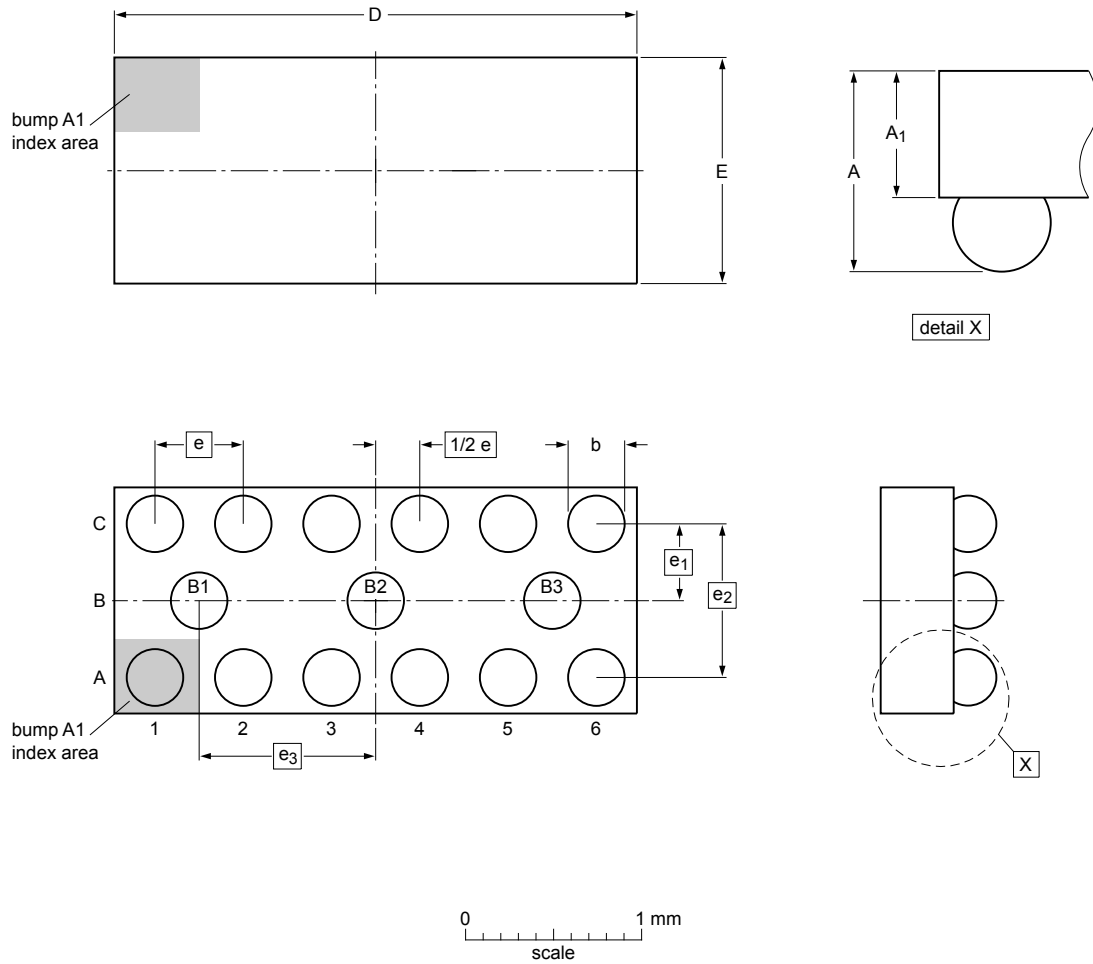
Outline version	References				European projection	Issue date
	IEC	JEDEC	JEITA			
PCMF2USB3S						15-09-09 15-09-14

Fig. 25. Package outline WLCSP10



WLCSP15: wafer level chip-size package; 15 bumps (6-3-6)

PCMF3USB3S



Dimensions (mm are the original dimensions)

Unit	A	A <sub>1</sub>	b	D	E	e	e <sub>1</sub>	e <sub>2</sub>	e <sub>3</sub>
mm	max 0.60	0.38	0.31	2.42	1.22				
	nom 0.57	0.37	0.26	2.37	1.17	0.40	0.40	0.80	0.80
	min 0.54	0.36	0.21	2.32	1.12				

pcmf3usb3s\_po

Outline version	References			European projection	Issue date
	IEC	JEDEC	JEITA		
PCMF3USB3S					15-09-09 15-09-14

Fig. 26. Package outline WLCSP15

### 11. Soldering

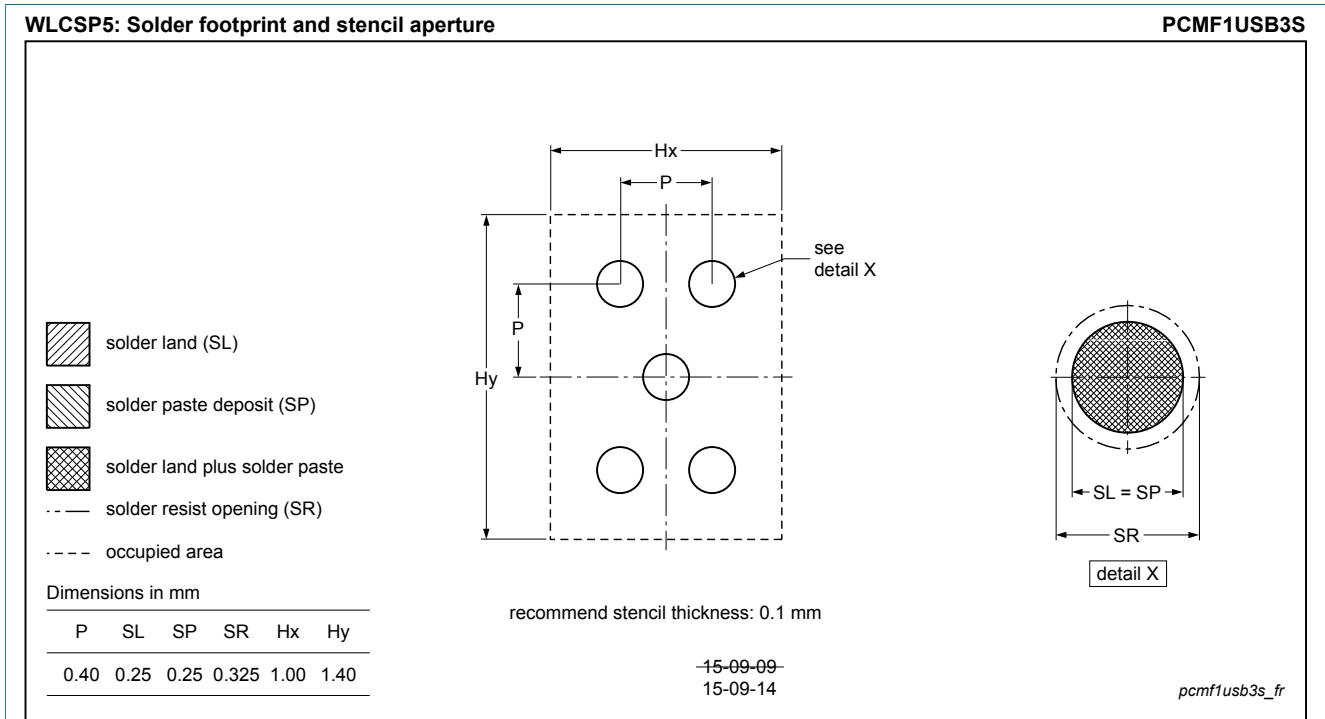


Fig. 27. Soldering footprint WLCSP5 (PCMF1USB3S)

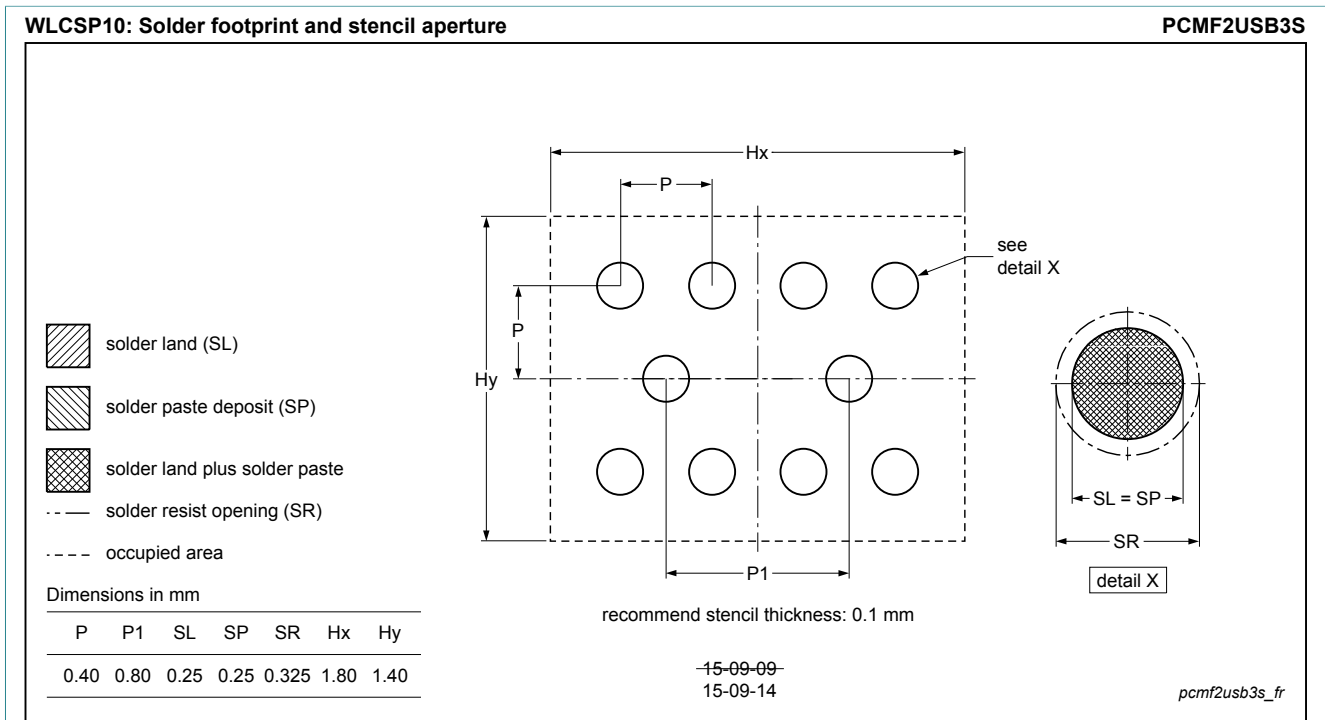
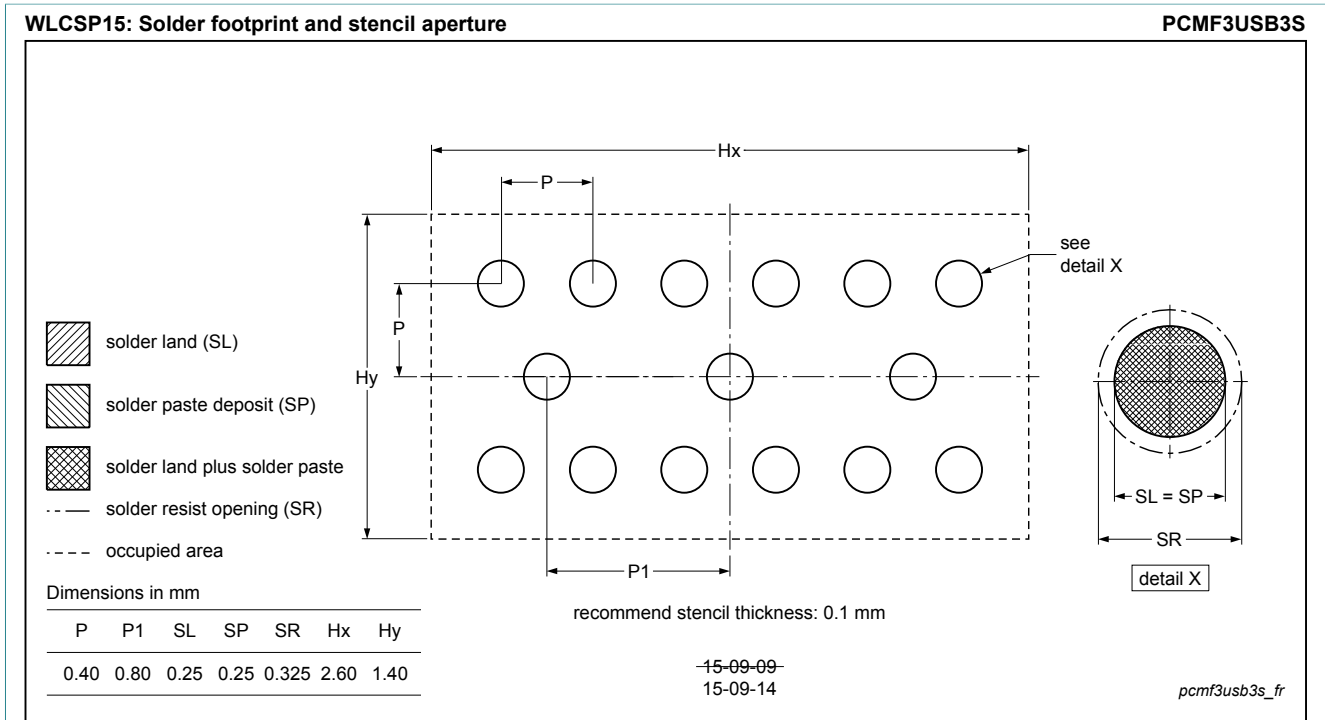


Fig. 28. Soldering footprint WLCSP10 (PCMF2USB3S)



**Fig. 29. Soldering footprint WLCSP15 (PCMF3USB3S)**

## 12. Revision history

Table 8. Revision history

Data sheet ID	Release date	Data sheet status	Change notice	Supersedes
PCMFxUSB3S_SER v.3	20190307	Product data sheet	-	PCMFxUSB3S_SER v.2
Modifications:	<ul style="list-style-type: none"> <li>Limiting values: <math>T_{amb}</math> maximum values updated.</li> <li>Frequency characteristics: corrected typos in Figures 1, 2, 3 and 5.</li> </ul>			
PCMFxUSB3S_SER v.2	20160307	Product data sheet	-	PCMFxUSB3S_SER v.1
PCMFxUSB3S_SER v.1	20151007	Preliminary data sheet	-	-

## 13. Legal information

### Data sheet status

Document status [1][2]	Product status [3]	Definition
Objective [short] data sheet	Development	This document contains data from the objective specification for product development.
Preliminary [short] data sheet	Qualification	This document contains data from the preliminary specification.
Product [short] data sheet	Production	This document contains the product specification.

- [1] Please consult the most recently issued document before initiating or completing a design.
- [2] The term 'short data sheet' is explained in section "Definitions".
- [3] The product status of device(s) described in this document may have changed since this document was published and may differ in case of multiple devices. The latest product status information is available on the internet at <https://www.nexperia.com>.

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