

# 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

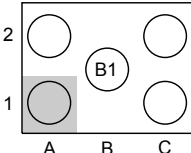
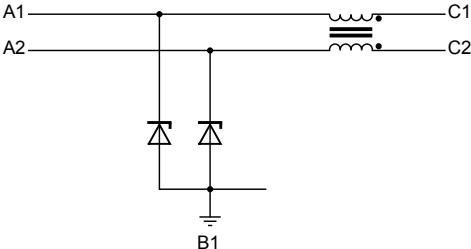
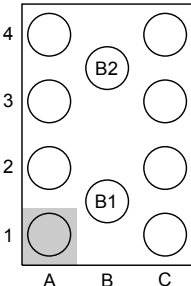
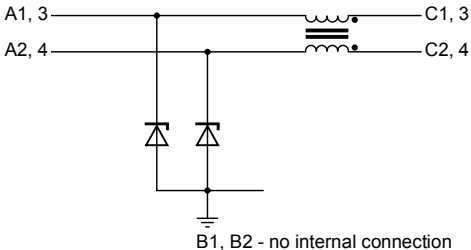
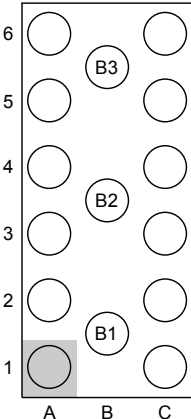
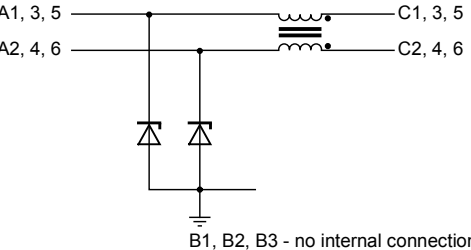
- One, two and three differential channels common-mode EMI filters with integrated ESD protection
- ESD protection up to  $\pm 15$  kV contact discharge according to IEC 61000-4-2
- Superior common-mode suppression over a wide frequency range
- Superior RF performance compared to other integrated filters 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                                                                                                                                 |
|----------------------------|----------|----------------------|------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------|
| PCMF1USB3S (WLCSP5_2-1-2)  |          |                      |                                                                                                                                          |                                                                                                                                                |
| A1                         | CH1_IN+  | channel 1+, external |  <p>Transparent top view<br/><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 |                                                                                                                                          |                                                                                                                                                |
| PCMF2USB3S (WLCSP10_4-2-4) |          |                      |                                                                                                                                          |                                                                                                                                                |
| A1                         | CH1_IN+  | channel 1+, external |  <p>Transparent top view<br/><b>WLCSP10_4-2-4</b></p>  |  <p>B1, B2 - no internal connection<br/>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 |                                                                                                                                          |                                                                                                                                                |
| PCMF3USB3S (WLCSP15_6-3-6) |          |                      |                                                                                                                                          |                                                                                                                                                |
| A1                         | CH1_IN+  | channel 1+, external |  <p>Transparent top view<br/><b>WLCSP15_6-3-6</b></p> |  <p>B1, B2, B3 - no internal connection<br/>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**

$T_{amb} = 25\text{ }^{\circ}\text{C}$  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;<br>$V_I = 5\text{ V}$           |     | -   | -    | 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  $\mu\text{s}$ ).

### 8.2. Frequency characteristics

**Table 7. Frequency characteristics**

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

| Symbol                               | Parameter         | Conditions  |     | Min | Typ | Max | Unit |
|--------------------------------------|-------------------|-------------|-----|-----|-----|-----|------|
| Common mode: S <sub>21cc</sub>       |                   |             |     |     |     |     |      |
| α <sub>il</sub>                      | insertion loss    | f = 800 MHz | [1] | -   | -12 | -   | dB   |
|                                      |                   | f = 2.6 GHz | [1] | -   | -38 | -   | dB   |
|                                      |                   | f = 5 GHz   | [1] | -   | -18 | -   | dB   |
| Differential mode: S <sub>21dd</sub> |                   |             |     |     |     |     |      |
| α <sub>il</sub>                      | insertion loss    | f = 1 MHz   | [1] | -   | 0.3 | -   | dB   |
| f <sub>-3dB</sub>                    | cut-off frequency |             | [1] | -   | 6   | -   | GHz  |

[1] Normalized to attenuation at 1 MHz.

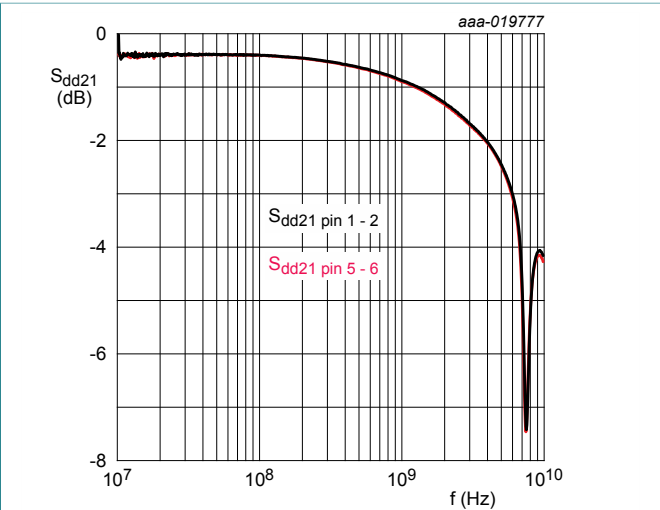


Fig. 1. Differential-mode insertion loss; typical values

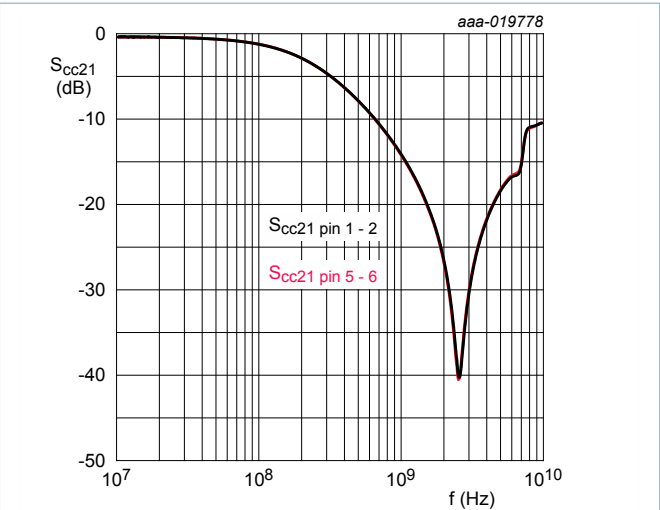
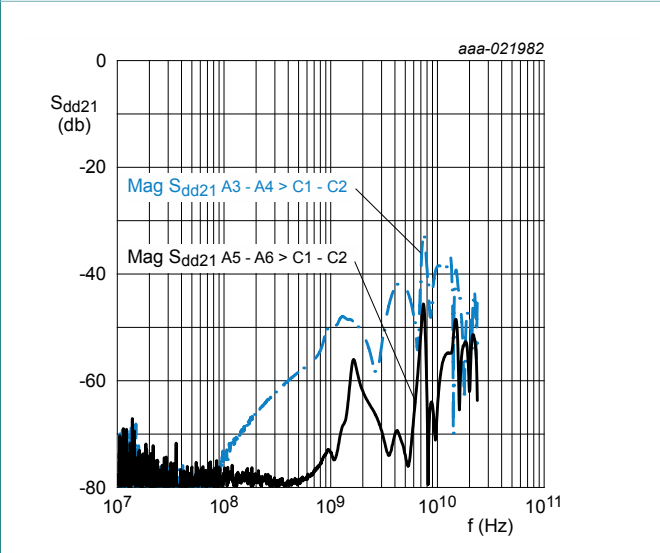
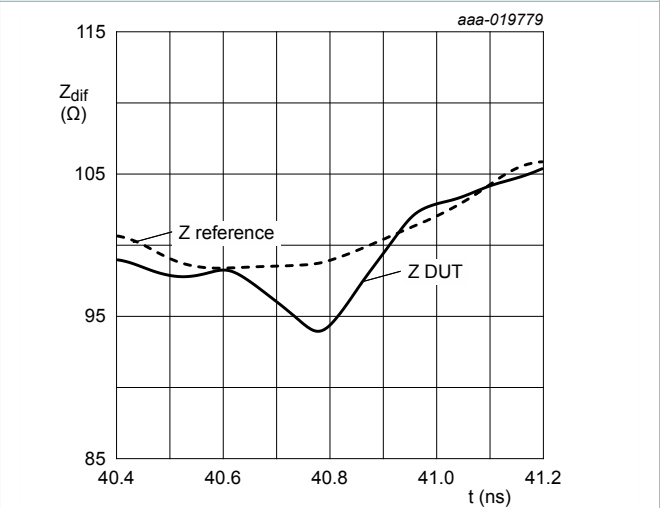


Fig. 2. Common-mode insertion loss; typical values



CH1 to CH2

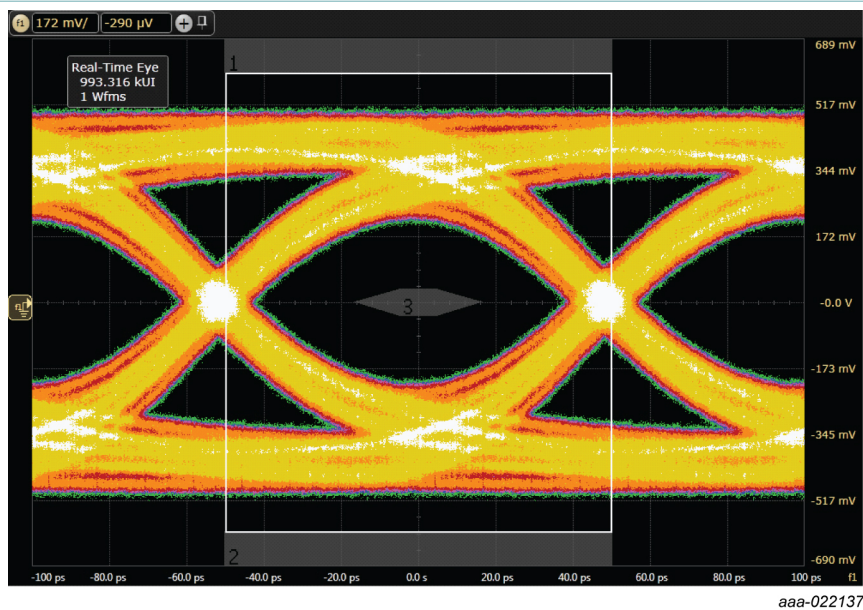
Fig. 3. Differential crosstalk; typical values



$t_r = 200$  ps

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

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

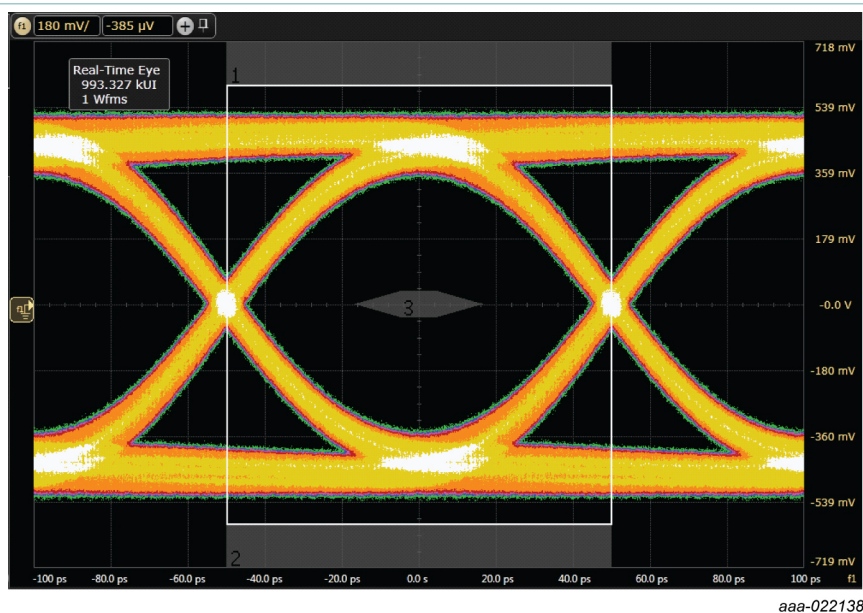


Data rate: 10 Gbit/s

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**



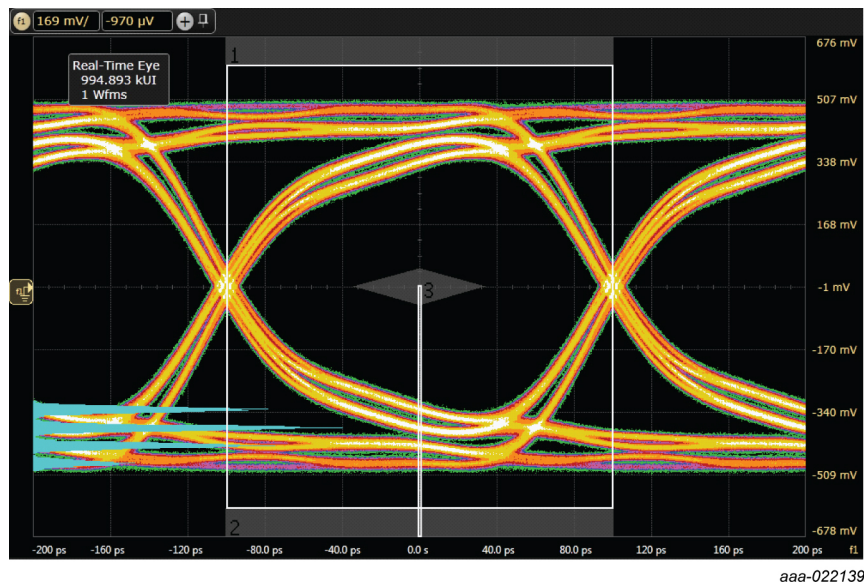
Data rate: 10 Gbit/s

Vertical scale 180 mV/div

Horizontal scale: 20 ps/div

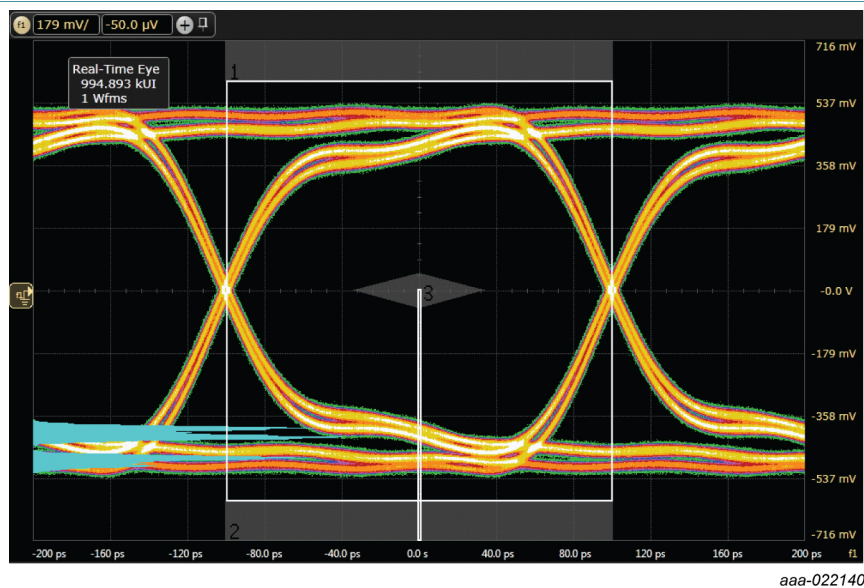
**Fig. 6. USB 3.2 eye diagram 10 Gbps, test board without device; typical values**

## 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

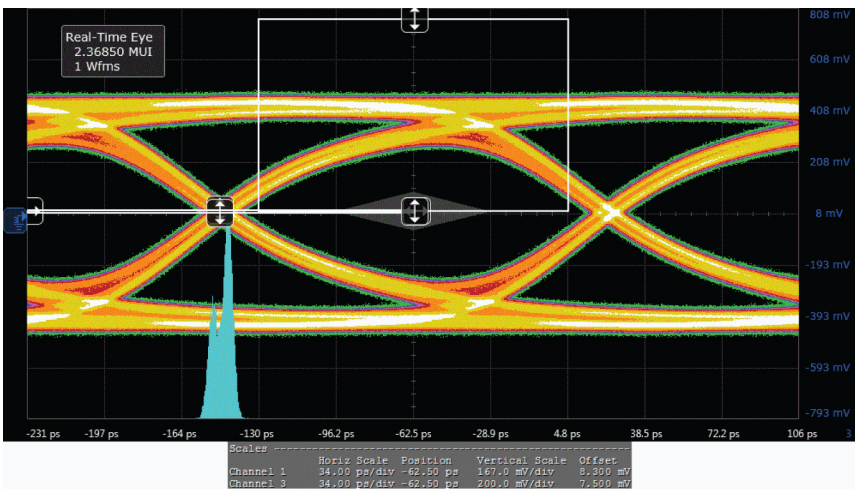
**Fig. 7. USB 3.2 eye diagram 5 Gbps, test board with PCMF2USB3S; typical values**



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**

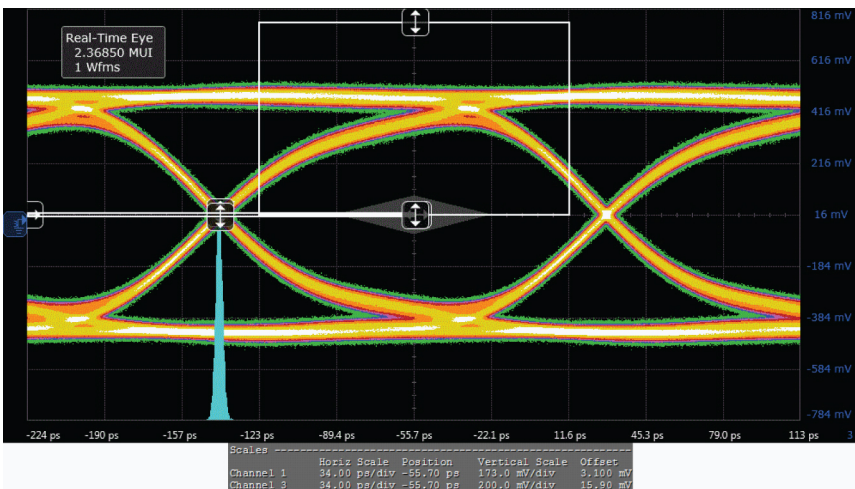
Common-mode EMI filter for differential channels with integrated ESD protection



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

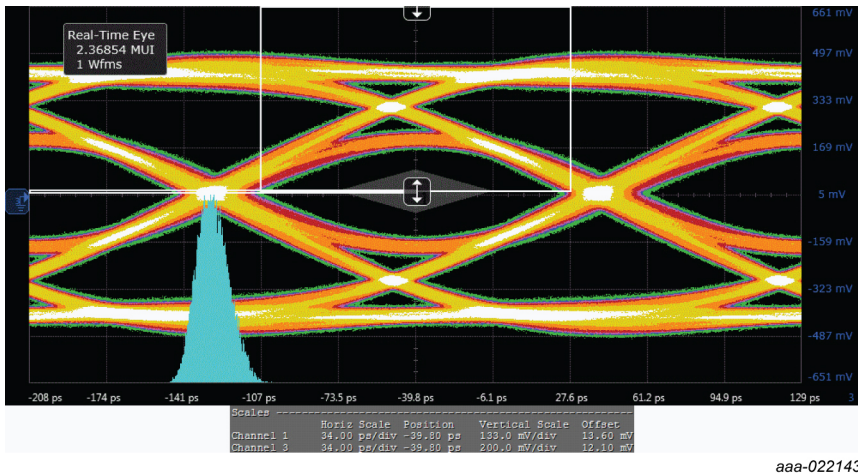


aaa-022142

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

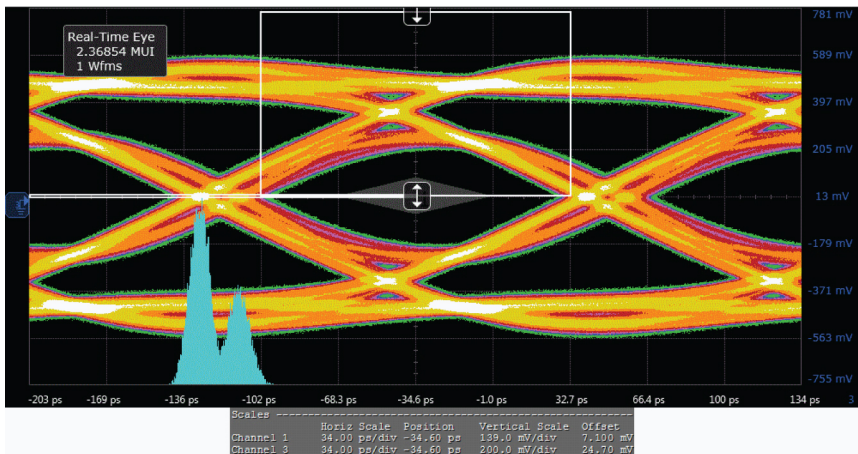
Common-mode EMI filter for differential channels with integrated ESD protection



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

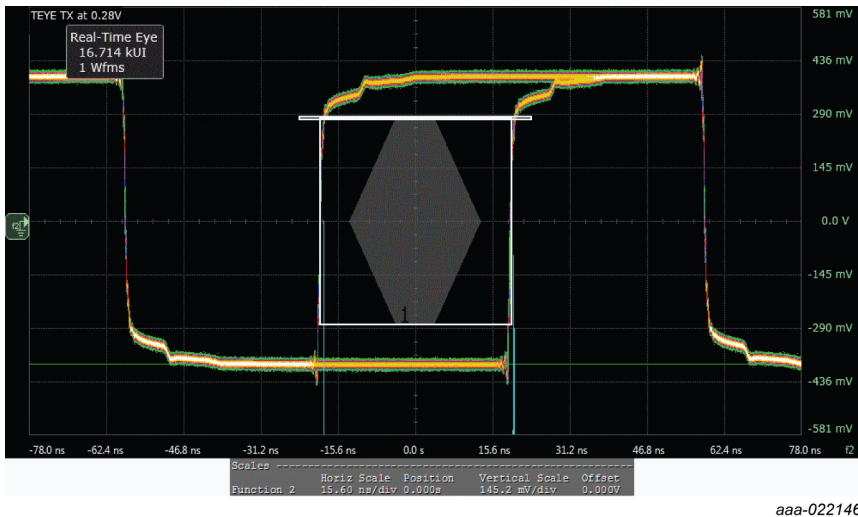


aaa-022144

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.

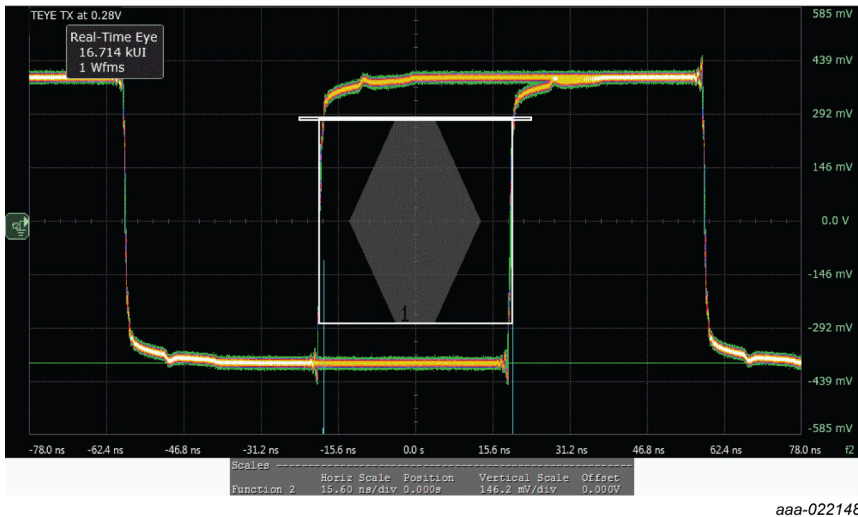
Fig. 12. HDMI 2.0 eye diagram TP2, test board without device; typical values

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



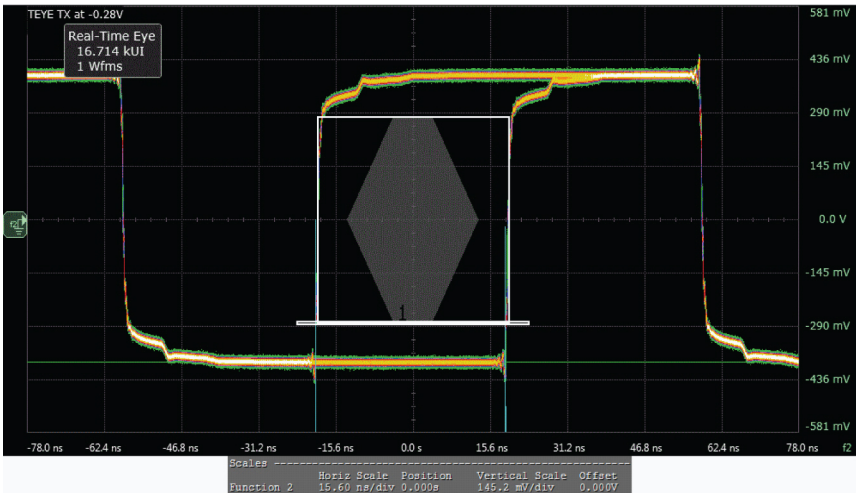
Vertical scale: 145 mV/div  
Horizontal scale: 15.6 ns/div

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



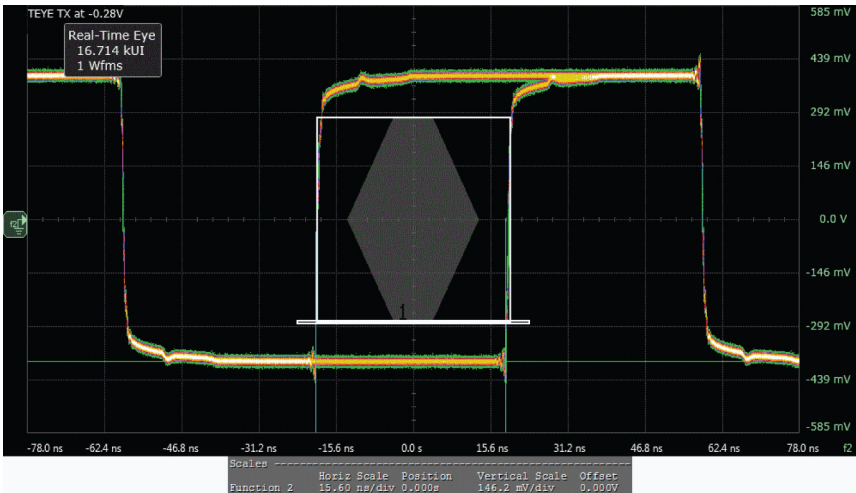
Vertical scale: 146 mV/div  
Horizontal scale: 15.6 ns/div

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



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

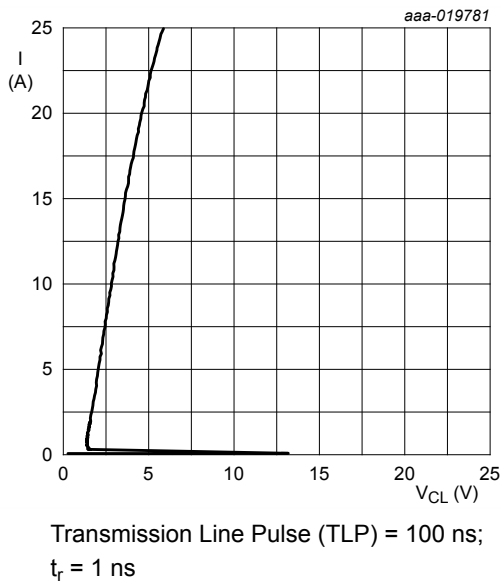


Fig. 17. Dynamic resistance with positive clamping; typical values

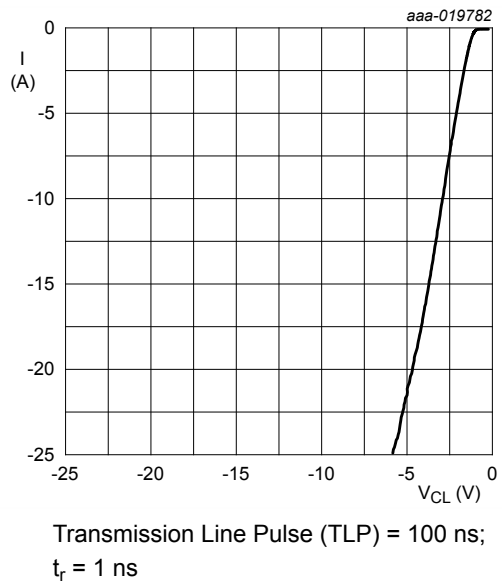


Fig. 18. Dynamic resistance with negative clamping; typical values

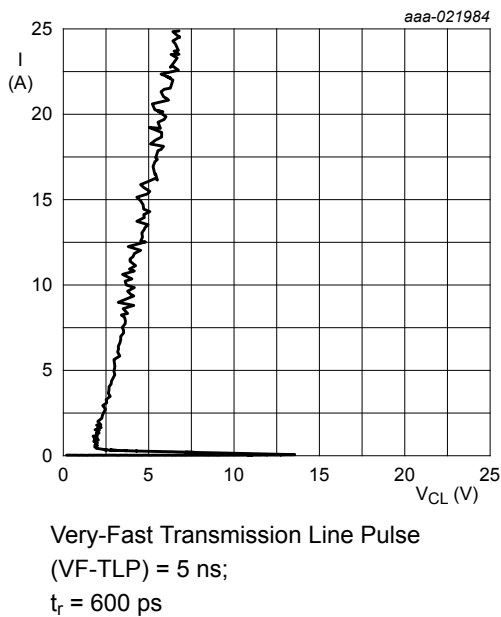


Fig. 19. Dynamic resistance with positive clamping; typical values

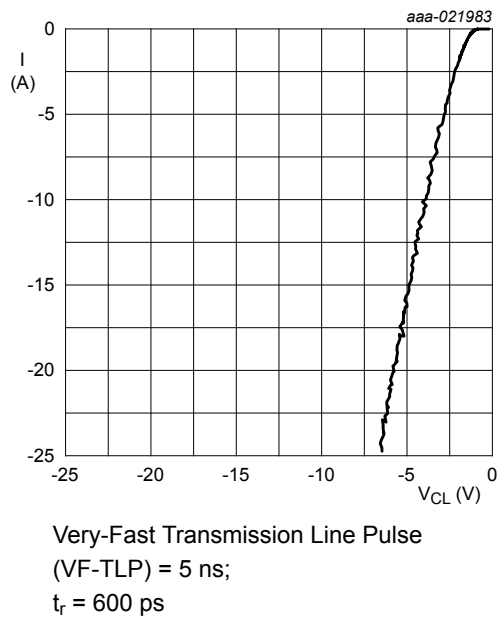
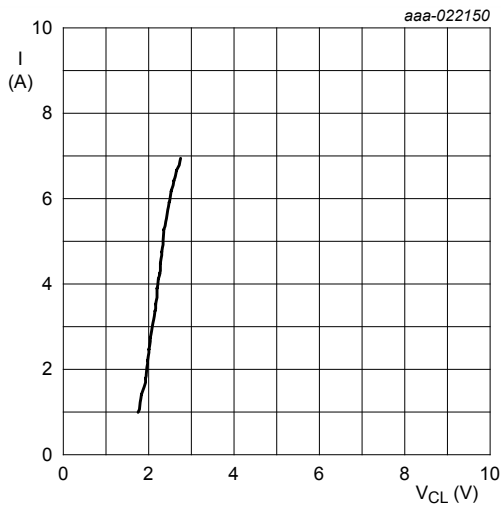


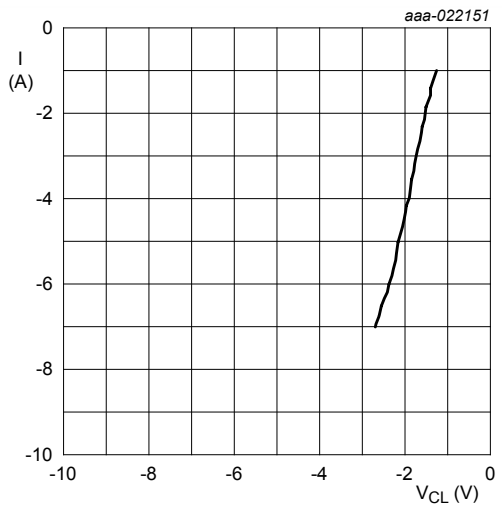
Fig. 20. Dynamic resistance with negative clamping; typical values

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).



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

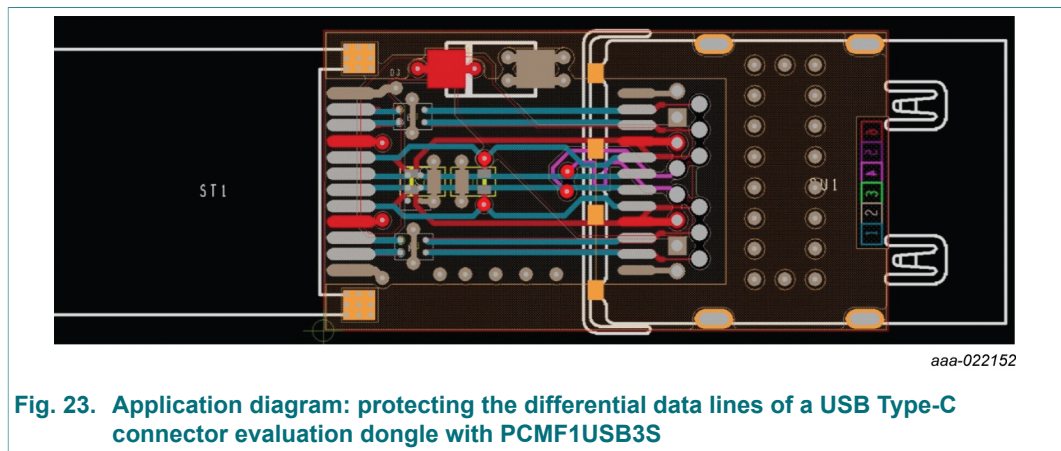
Fig. 22. Dynamic resistance with negative clamping; typical values

## 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.



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

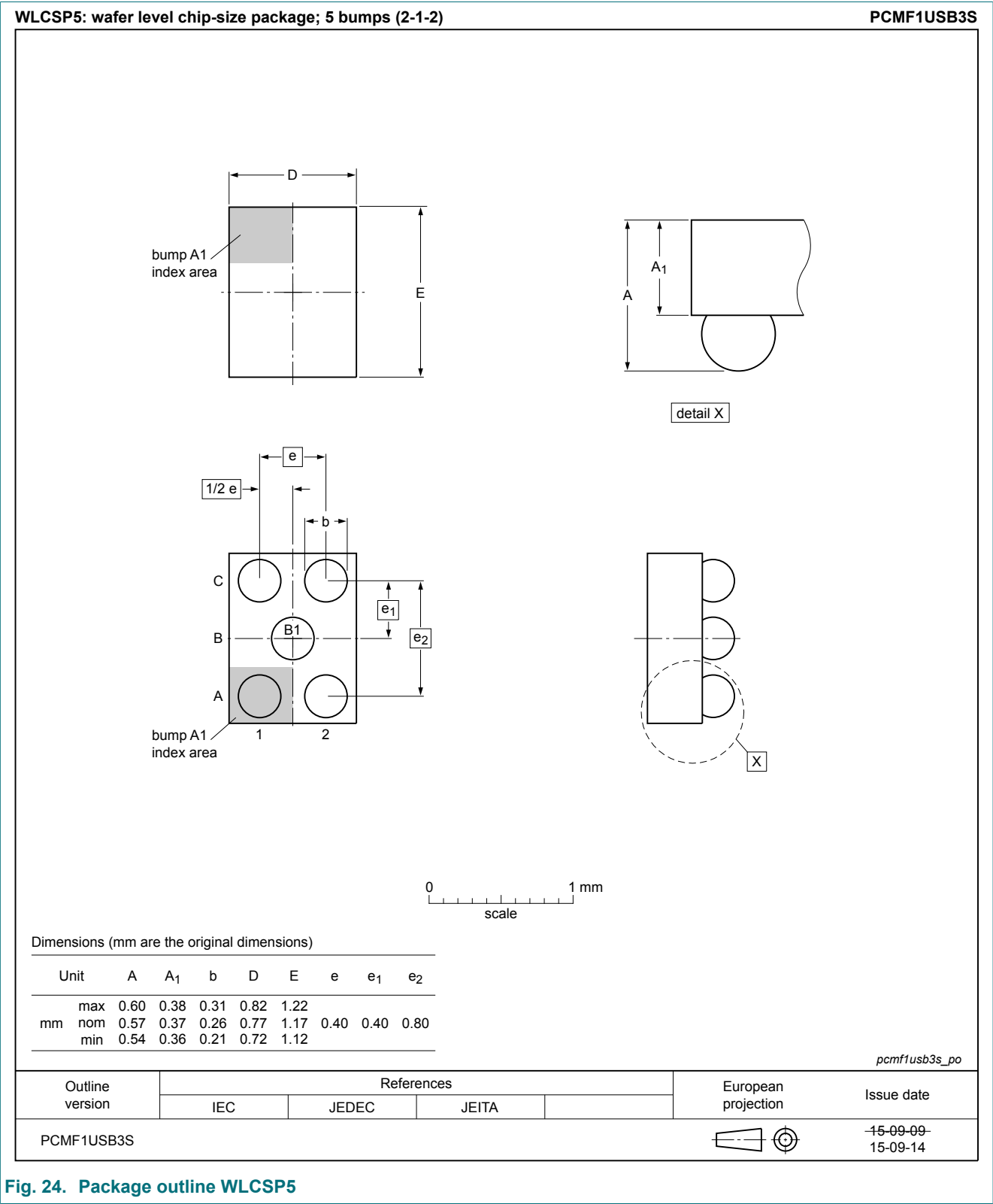


Fig. 24. Package outline WLCSP5

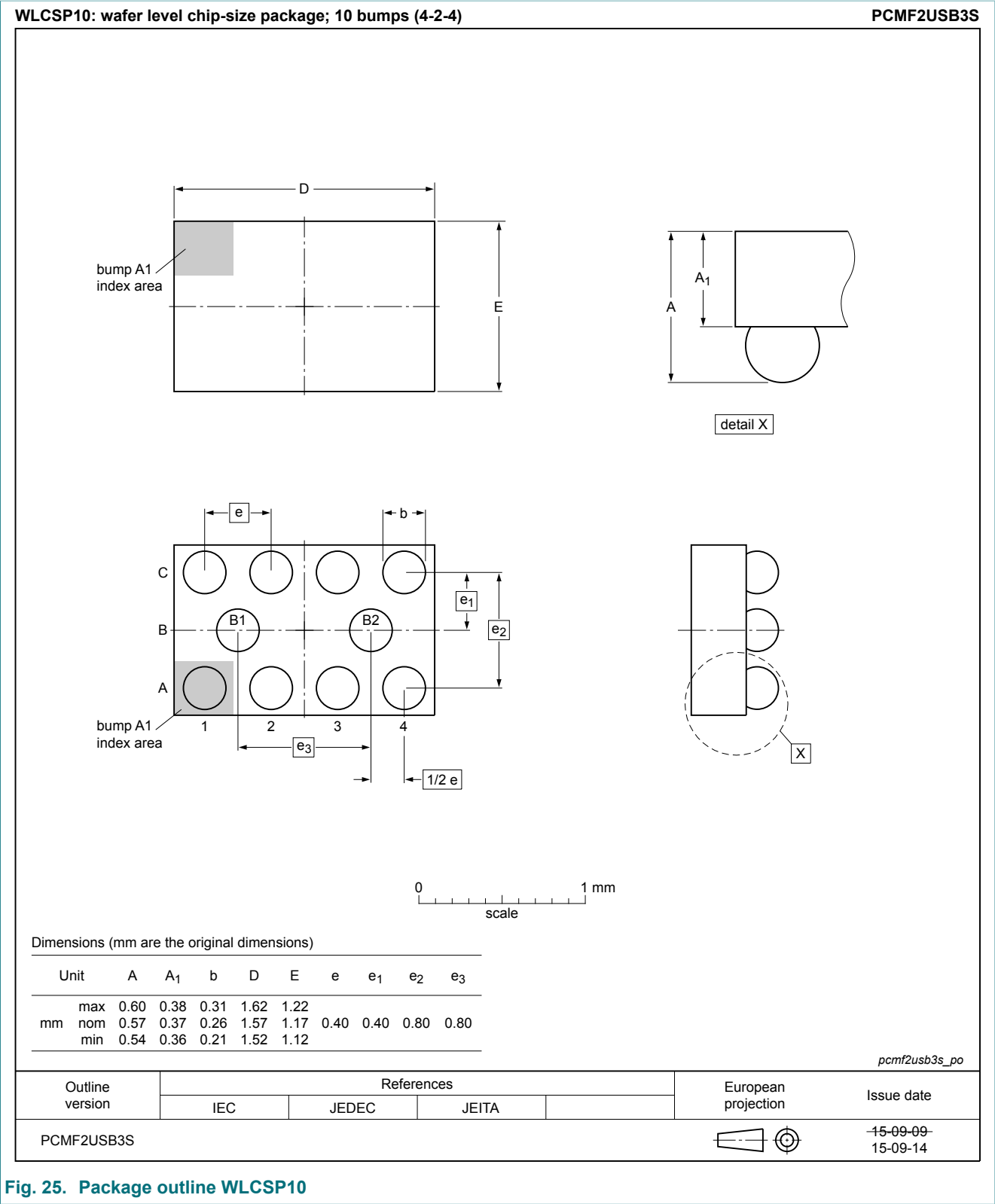
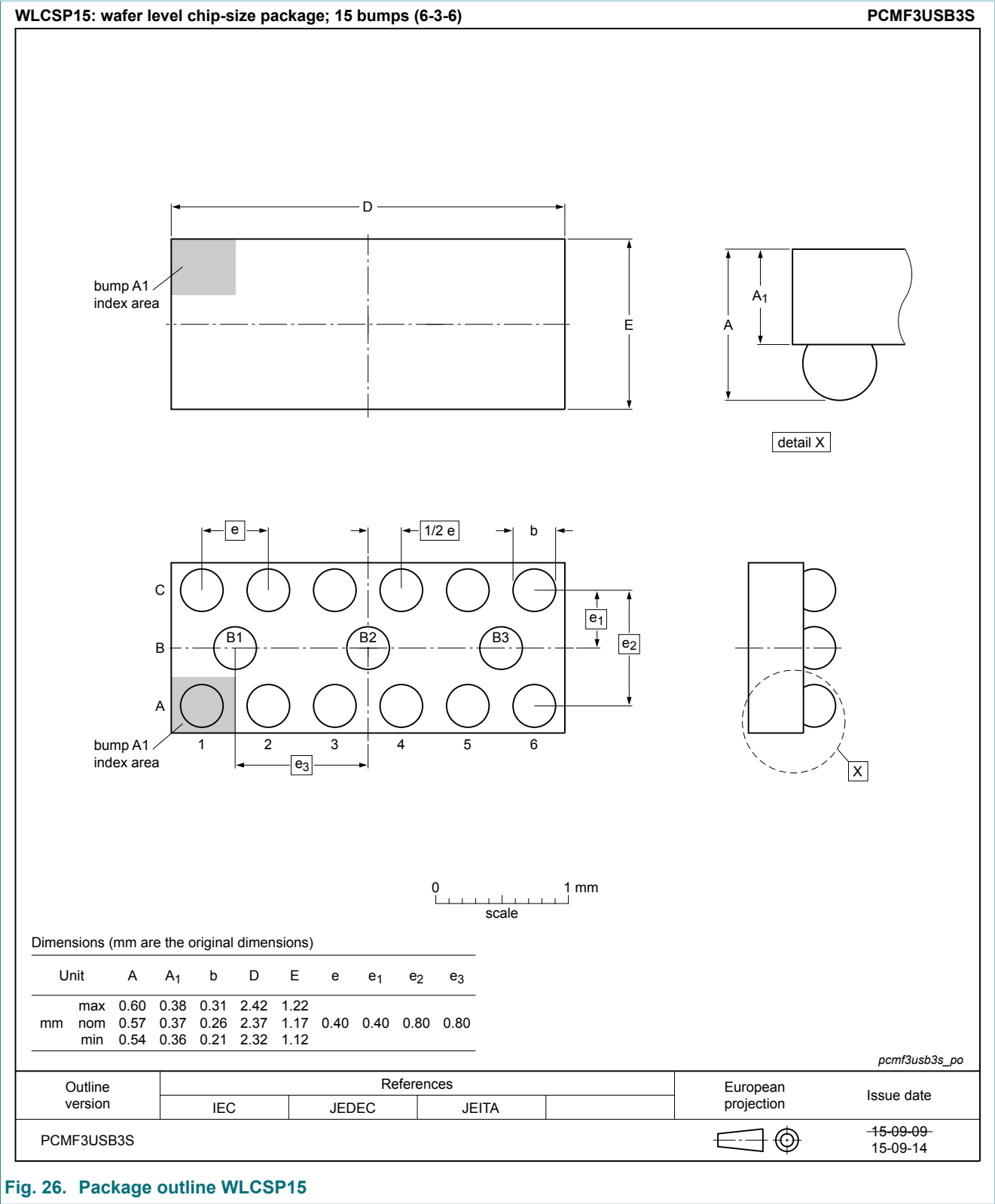
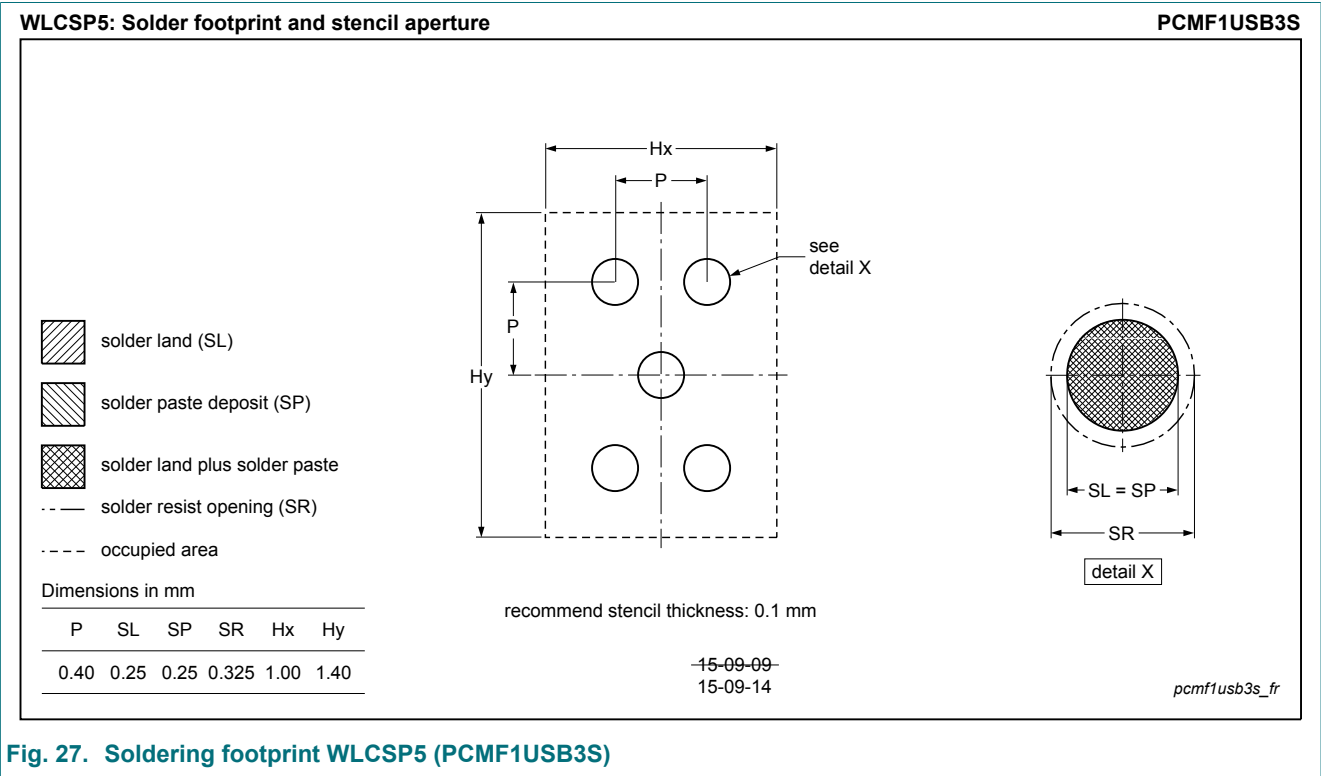
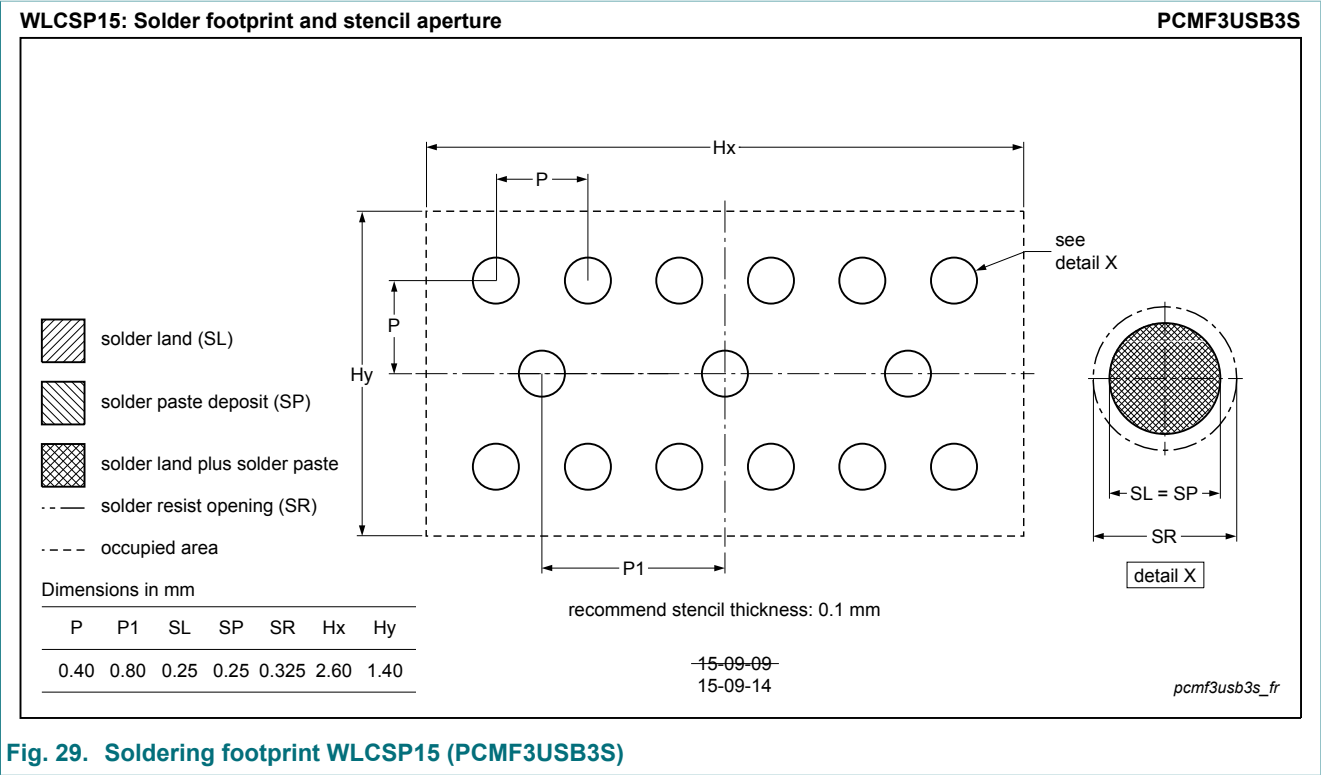


Fig. 25. Package outline WLCSP10



11. Soldering





## 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<br>[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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