



## 目录

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## 4 修订历史记录

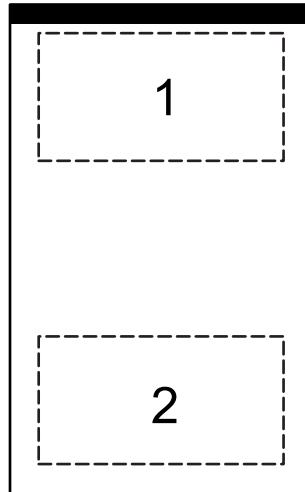
### Changes from Original (March 2016) to Revision A

### Page

|                      |   |
|----------------------|---|
| • 已将器件状态从产品预览更改为量产数据 | 1 |
|----------------------|---|

## 5 Pin Configuration and Functions

DPY Package  
2-Pin X1SON  
Top View



**Pin Functions**

| PIN |      | TYPE   | DESCRIPTION               |
|-----|------|--------|---------------------------|
| NO. | NAME |        |                           |
| 1   | IO   | I/O    | ESD Protected Channel     |
| 2   | GND  | Ground | Ground. Connect to ground |

## 6 Specifications

### 6.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)<sup>(1)</sup>

|                           |                                               | MIN | MAX | UNIT |
|---------------------------|-----------------------------------------------|-----|-----|------|
| Electrical fast transient | IEC 61000-4-4 (5/50 ns)                       |     | 80  | A    |
| Peak pulse                | IEC 61000-4-5 power ( $t_p$ - 8/20 $\mu$ s)   |     | 19  | W    |
|                           | IEC 61000-4-5 current ( $t_p$ - 8/20 $\mu$ s) |     | 2.5 | A    |
| $T_A$                     | Operating free-air temperature                | -40 | 125 | °C   |
| $T_{stg}$                 | Storage temperature                           | -65 | 155 | °C   |

- (1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

### 6.2 ESD Ratings

|                                     |                                                                                | VALUE | UNIT |
|-------------------------------------|--------------------------------------------------------------------------------|-------|------|
| $V_{(ESD)}$ Electrostatic discharge | Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 <sup>(1)</sup>              | ±2500 | V    |
|                                     | Charged-device model (CDM), per JEDEC specification JESD22-C101 <sup>(2)</sup> | ±1000 |      |

- (1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.

- (2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

### 6.3 ESD Ratings—IEC Specification

|                                     |                                 | VALUE  | UNIT |
|-------------------------------------|---------------------------------|--------|------|
| $V_{(ESD)}$ Electrostatic discharge | IEC 61000-4-2 contact discharge | ±16000 | V    |
|                                     | IEC 61000-4-2 air-gap discharge | ±16000 |      |

### 6.4 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

|          |                                | MIN | MAX | UNIT |
|----------|--------------------------------|-----|-----|------|
| $V_{IO}$ | Input pin voltage              | 0   | 3.6 | V    |
| $T_A$    | Operating free-air temperature | -40 | 125 | °C   |

### 6.5 Thermal Information

| THERMAL METRIC <sup>(1)</sup> |                                              | TPD1E04U04  | UNIT |
|-------------------------------|----------------------------------------------|-------------|------|
|                               |                                              | DPY (X1SON) |      |
|                               |                                              | 2 PINS      |      |
| $R_{\theta JA}$               | Junction-to-ambient thermal resistance       | 683.6       | °C/W |
| $R_{\theta JC(top)}$          | Junction-to-case (top) thermal resistance    | 494.2       | °C/W |
| $R_{\theta JB}$               | Junction-to-board thermal resistance         | 568.7       | °C/W |
| $\Psi_{JT}$                   | Junction-to-top characterization parameter   | 217.4       | °C/W |
| $\Psi_{JB}$                   | Junction-to-board characterization parameter | 568.7       | °C/W |
| $R_{\theta JC(bot)}$          | Junction-to-case (bottom) thermal resistance | n/a         | °C/W |

- (1) For more information about traditional and new thermal metrics, see the *Semiconductor and IC Package Thermal Metrics* application report, [SPRA953](#).

## 6.6 Electrical Characteristics

over operating free-air temperature range (unless otherwise noted)

| PARAMETER          |                                      | TEST CONDITIONS                                                    | MIN | TYP  | MAX  | UNIT |
|--------------------|--------------------------------------|--------------------------------------------------------------------|-----|------|------|------|
| V <sub>RWM</sub>   | Reverse stand-off voltage            | I <sub>IO</sub> < 10 nA                                            |     |      | 3.6  | V    |
| V <sub>BR</sub>    | Breakdown voltage, IO pin to GND     | T <sub>A</sub> = 25°C <sup>(1)</sup>                               | 5   | 6.2  | 7.5  | V    |
| V <sub>F</sub>     | Forward diode voltage, GND to IO pin | I <sub>IO</sub> = 1 mA, T <sub>A</sub> = 25°C                      |     | 0.8  |      | V    |
| V <sub>HOLD</sub>  | Holding voltage                      | I <sub>IO</sub> = 1 mA                                             |     | 5.3  |      | V    |
| V <sub>CLAMP</sub> | Clamping voltage                     | I <sub>PP</sub> = 1 A, TLP, from IO to GND                         |     | 5.3  |      | V    |
|                    |                                      | I <sub>PP</sub> = 16 A, TLP, from IO to GND                        |     | 8.9  |      |      |
|                    |                                      | I <sub>PP</sub> = 1 A, TLP, from GND to IO                         |     | 1.3  |      |      |
|                    |                                      | I <sub>PP</sub> = 16 A, TLP, from GND to IO                        |     | 4.6  |      |      |
| I <sub>LEAK</sub>  | Leakage current, any IO to GND       | V <sub>IO</sub> = 2.5 V                                            |     | 0.1  | 10   | nA   |
| R <sub>DYN</sub>   | Dynamic resistance                   | IO to GND                                                          |     | 0.25 |      | Ω    |
|                    |                                      | GND to IO                                                          |     | 0.18 |      |      |
| C <sub>L</sub>     | Line capacitance                     | V <sub>IO</sub> = 0 V, f = 1 MHz, IO to GND, T <sub>A</sub> = 25°C |     | 0.5  | 0.65 | pF   |

(1) Measured as the maximum voltage before device snaps back into V<sub>HOLD</sub> voltage.

## 6.7 Typical Characteristics

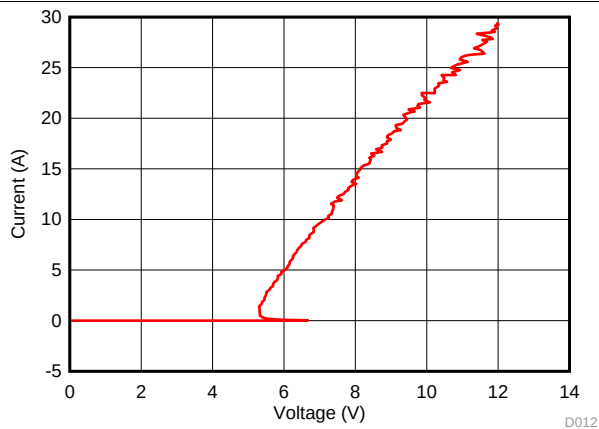


Figure 1. Positive TLP Curve

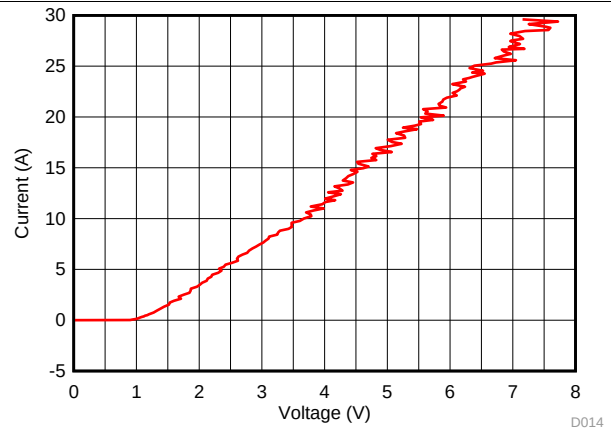


Figure 2. Negative TLP Curve

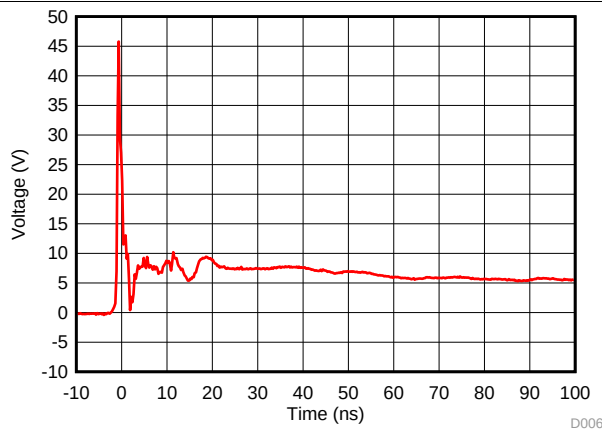


Figure 3. 8-kV IEC Waveform

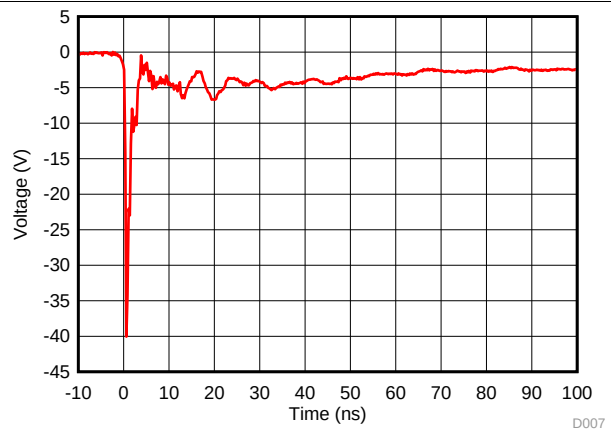


Figure 4. -8-kV IEC Waveform

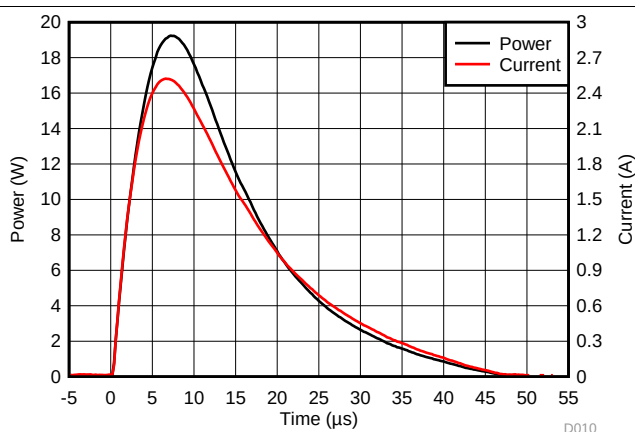


Figure 5. Surge Curve ( $t_p = 8/20\mu s$ ), IO Pin to GND

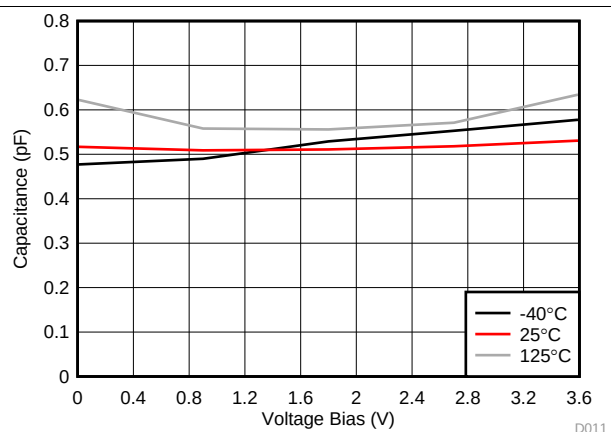


Figure 6. Capacitance vs. Bias Voltage

## Typical Characteristics (continued)

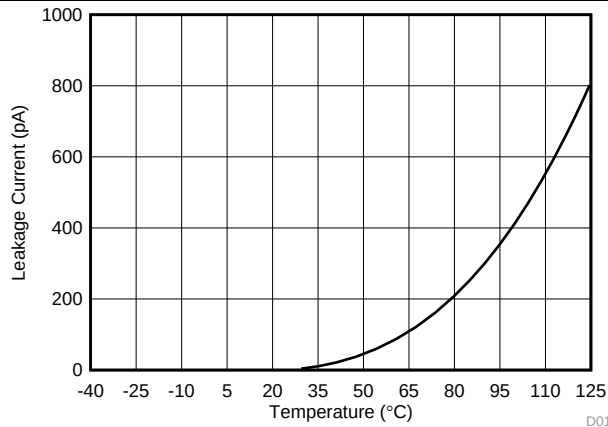


Figure 7. Leakage Current vs. Temperature

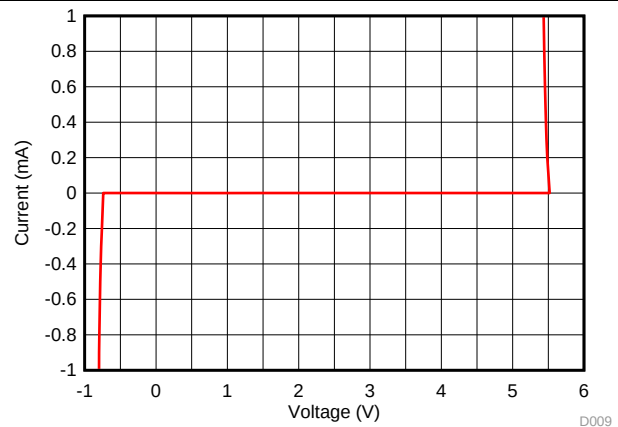


Figure 8. DC Voltage Sweep I-V Curve

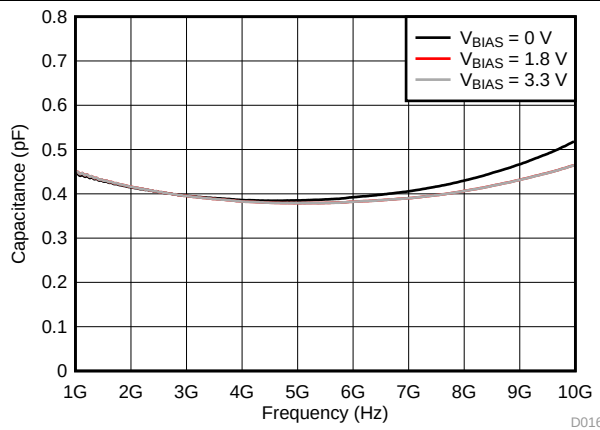


Figure 9. Capacitance vs. Frequency

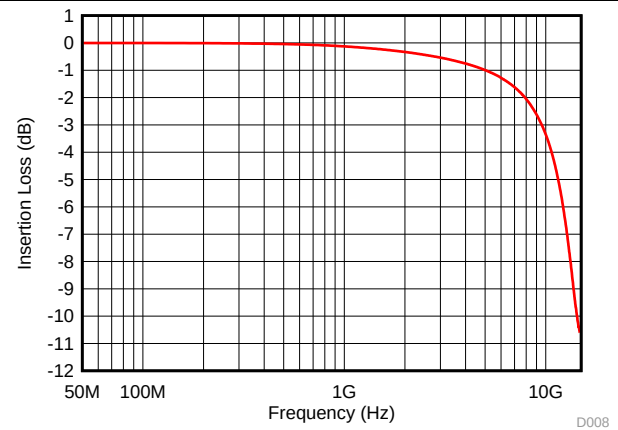


Figure 10. Insertion Loss

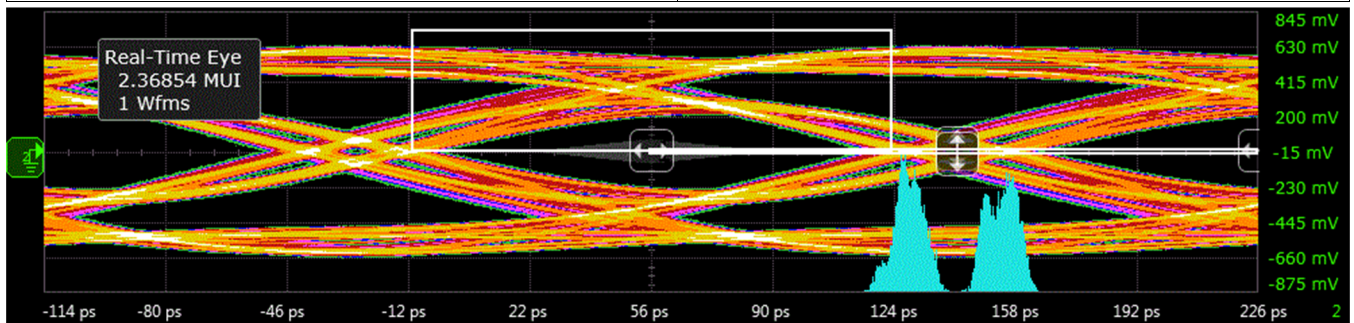


Figure 11. HDMI2.0 6-Gbps TP2 Eye Diagram (Bare Board)

# TPD1E04U04

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## Typical Characteristics (continued)

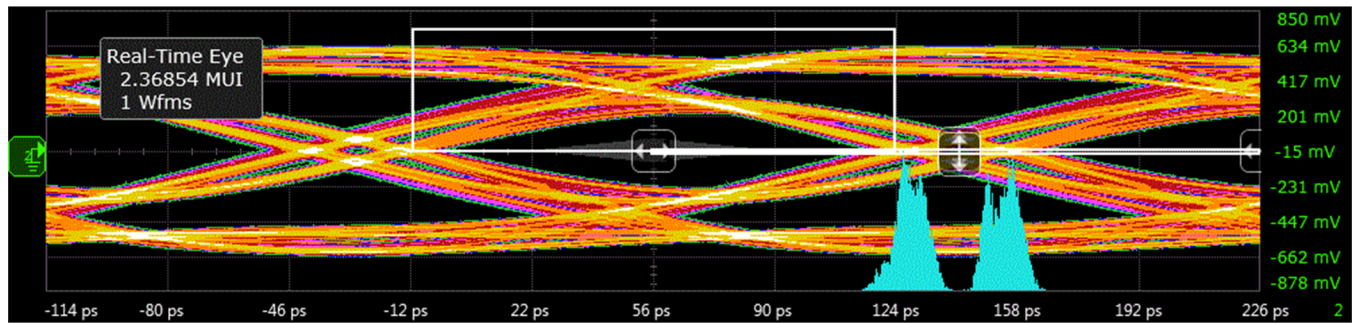


Figure 12. HDMI2.0 6-Gbps TP2 Eye Diagram (with TPD1E04U04)

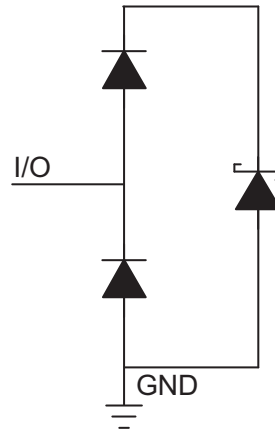


## 7 Detailed Description

### 7.1 Overview

The TPD1E04U04 is a unidirectional ESD Protection Diode with ultra-low capacitance designed for HDMI 2.0 and USB 3.0. This device can dissipate ESD strikes above the maximum level specified by the IEC 61000-4-2 International Standard. The extremely low clamping voltage and low  $R_{DYN}$  make this device ideal for supporting the next-generation small feature size SoCs. The low capacitance also makes this device ideal for protecting any high-speed signal pins on these sensitive interface pins.

### 7.2 Functional Block Diagram



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### 7.3 Feature Description

#### 7.3.1 IEC 61000-4-2 ESD Protection

The IO pins can withstand ESD events up to  $\pm 16$ -kV contact and  $\pm 16$ -kV air gap. An ESD-surge clamp diverts the current to ground.

#### 7.3.2 IEC 61000-4-4 EFT Protection

The IO pins can withstand an electrical fast transient burst of up to 80 A (5/50 ns waveform, 4 kV with 50- $\Omega$  impedance). An ESD-surge clamp diverts the current to ground.

#### 7.3.3 IEC 61000-4-5 Surge Protection

The IO pins can withstand surge events up to 2.5 A and 19 W (8/20  $\mu$ s waveform). An ESD-surge clamp diverts this current to ground.

#### 7.3.4 IO Capacitance

The capacitance between each IO pin to ground is 0.5-pF (typical) and 0.65-pF (maximum). This device supports data rates up to 6 Gbps.

#### 7.3.5 Ultra-Low ESD Clamping Voltage

The IO pins feature an ESD clamp that is capable of clamping the voltage to 8.9 V ( $I_{TLP} = 16$  A) and  $-4.6$  V ( $I_{TLP} = -16$  A).

#### 7.3.6 Low $R_{DYN}$

The IO pins feature an ESD clamp that has an extremely low  $R_{DYN}$  of 0.25  $\Omega$  (IO to GND) and 0.18  $\Omega$  (GND to IO) which prevents system damage during ESD events.

## **Feature Description (continued)**

### **7.3.7 DC Breakdown Voltage**

The DC breakdown voltage of each IO pin is a minimum of 5 V. This ensures that sensitive equipment is protected from surges above the reverse standoff voltage of 3.6 V.

### **7.3.8 Ultra Low Leakage Current**

The IO pins feature an ultra-low leakage current of 10 nA (maximum) with a bias of 2.5 V

### **7.3.9 Supports High Speed Interfaces**

This device is capable of supporting high speed interfaces up to 6 Gbps, because of the very low IO capacitance.

### **7.3.10 Industrial Temperature Range**

This device features an industrial operating range of  $-40^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$ .

### **7.3.11 Easy Flow-Through Routing Package**

The layout of this device makes it simple and easy to add protection to an existing layout. The package offers flow-through routing, requiring minimal modification to an existing layout.

## **7.4 Device Functional Modes**

The TPD1E04U04 is a passive integrated circuit that triggers when voltages are above  $V_{BR}$  or below  $V_F$ . During ESD events, voltages as high as  $\pm 16\text{-kV}$  (air) can be directed to ground via the internal diode network. When the voltages on the protected line fall below the trigger levels of TPD1E04U04 (usually within 10s of nano-seconds) the device reverts to passive.

## 8 Application and Implementation

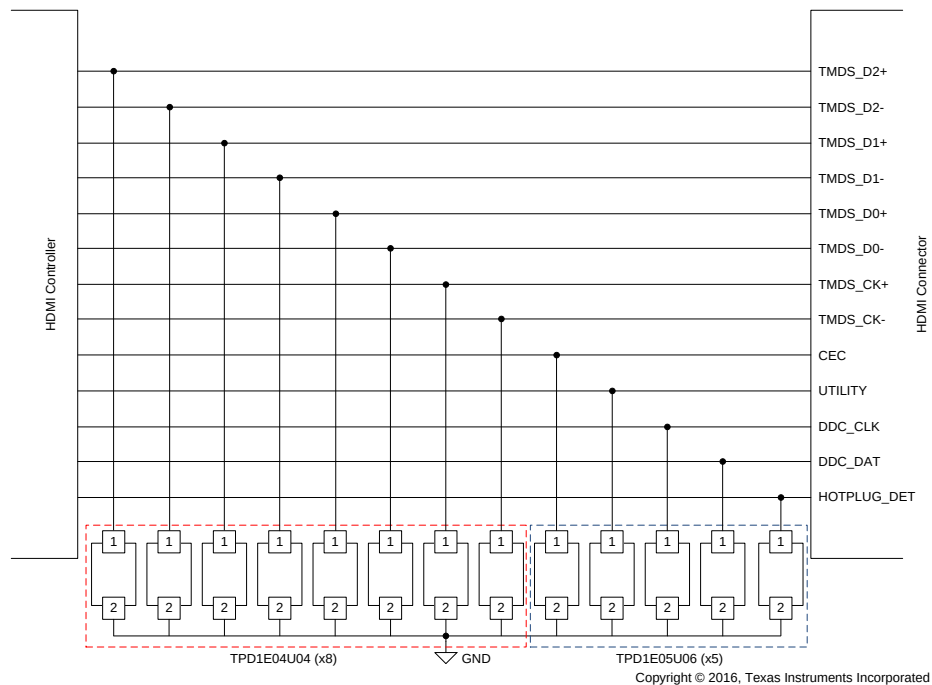
### NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

### 8.1 Application Information

The TPD1E04U04 is a diode type TVS which is used to provide a path to ground for dissipating ESD events on high-speed signal lines between a human interface connector and a system. As the current from ESD passes through the TVS, only a small voltage drop is present across the diode. This is the voltage presented to the protected IC. The low  $R_{DYN}$  of the triggered TVS holds this voltage,  $V_{CLAMP}$ , to a safe level for the protected IC.

### 8.2 Typical Application



**Figure 13. HDMI 2.0 ESD Schematic**

#### 8.2.1 Design Requirements

For this design example eight TPD1E04U04 devices and five TPD1E05U06 devices are being used in a HDMI 2.0 application. This provides a complete ESD protection scheme.

Given the HDMI 2.0 application, the parameters listed in [Table 1](#) are known.

**Table 1. Design Parameters**

| DESIGN PARAMETER                  | VALUE        |
|-----------------------------------|--------------|
| Signal Range on TMDS Lines        | 0 V to 3.6 V |
| Operating Frequency on TMDS Lines | up to 3 GHz  |
| Signal Range on Control Lines     | 0 V to 5.5 V |

## TPD1E04U04

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### 8.2.2 Detailed Design Procedure

#### 8.2.2.1 Signal Range

The TPD1E04U04 supports signal ranges between 0 V and 3.6 V, which supports the TMDS pairs on the HDMI 2.0 application. The TPD1E05U06 supports signal ranges between 0 V and 5.5 V, which supports the control lines.

#### 8.2.2.2 Operating Frequency

The TPD1E04U04 has a 0.5-pF (typical) capacitance, which supports the HDMI 2.0 data rates of 6-Gbps. The TPD1E05U06 has a 0.5-pF (typical) capacitance as well, which easily supports the control line data rates.

### 8.2.3 Application Curves

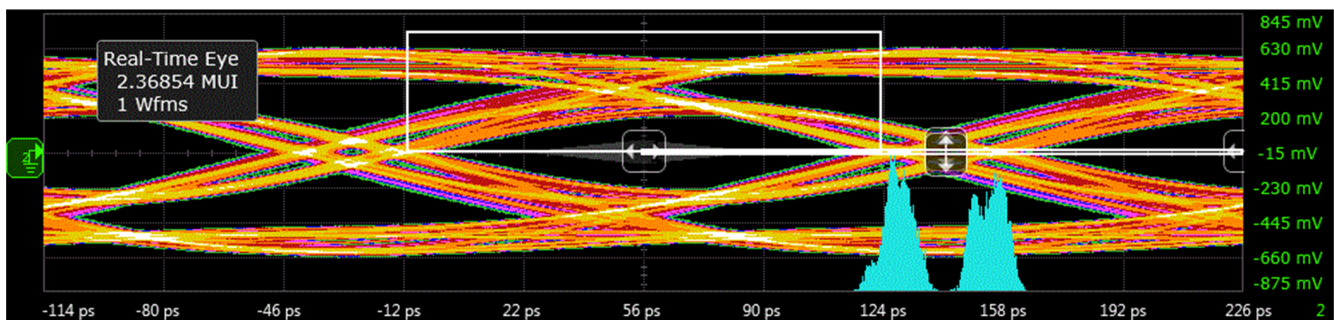


Figure 14. HDMI2.0 6-Gbps TP2 Eye Diagram (Bare Board)

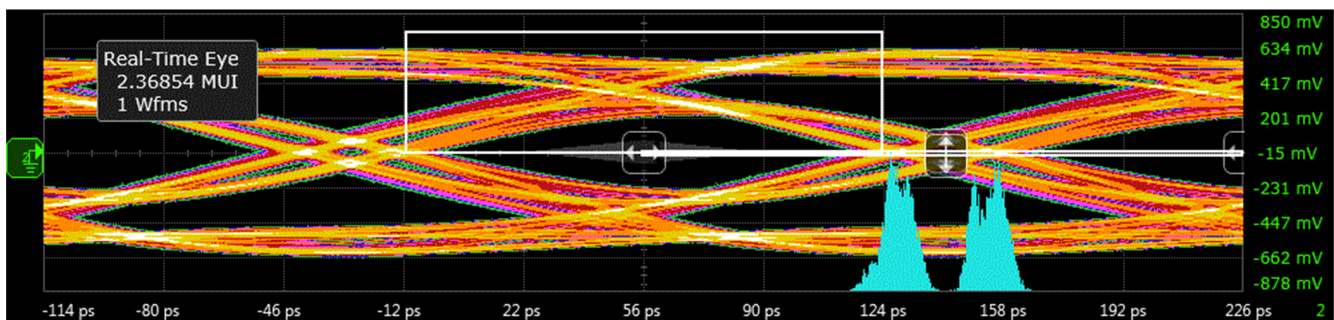


Figure 15. HDMI2.0 6-Gbps TP2 Eye Diagram  
(with TPD1E04U04)

## 9 Power Supply Recommendations

This device is a passive ESD device so there is no need to power it. Take care not to violate the recommended IO specification (0 V to 3.6 V) to ensure the device functions properly.

## 10 Layout

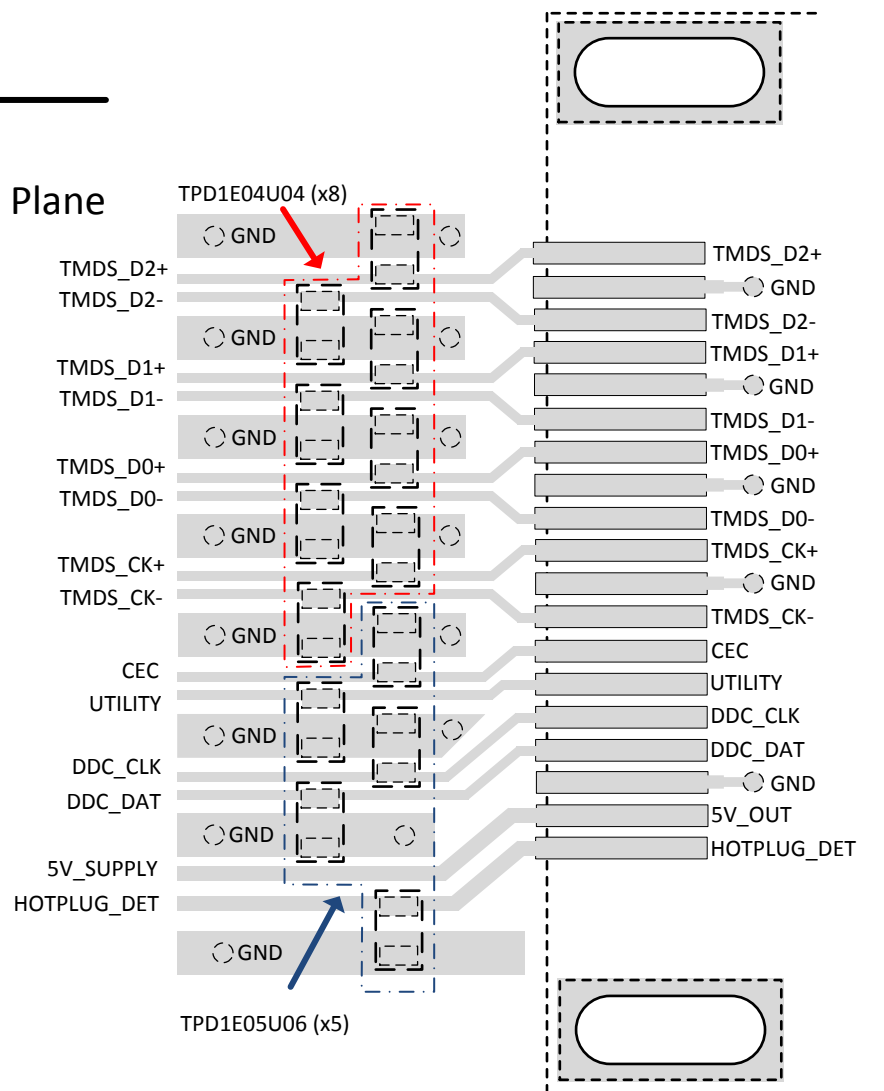
### 10.1 Layout Guidelines

- The optimum placement is as close to the connector as possible.
  - EMI during an ESD event can couple from the trace being struck to other nearby unprotected traces, resulting in early system failures.
  - The PCB designer must minimize the possibility of EMI coupling by keeping any unprotected traces away from the protected traces which are between the TVS and the connector.
- Route the protected traces as straight as possible.
- Eliminate any sharp corners on the protected traces between the TVS and the connector by using rounded corners with the largest radii possible.
  - Electric fields tend to build up on corners, increasing EMI coupling.

## 10.2 Layout Example

### Legend

- Top Layer
- VIA to GND Plane



**Figure 16. HDMI2.0 Type-A Transmitter Port ESD Layout**

## 11 器件和文档支持

### 11.1 文档支持

#### 11.1.1 相关文档

相关文档请参见以下部分：

《TPD1E04U04 评估模块用户指南》，[SLVUAN8](#)

### 11.2 社区资源

The following links connect to TI community resources. Linked contents are provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's [Terms of Use](#).

**TI E2E™ Online Community** *TI's Engineer-to-Engineer (E2E) Community*. Created to foster collaboration among engineers. At [e2e.ti.com](#), you can ask questions, share knowledge, explore ideas and help solve problems with fellow engineers.

**Design Support** *TI's Design Support* Quickly find helpful E2E forums along with design support tools and contact information for technical support.

### 11.3 商标

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### 11.4 静电放电警告



ESD 可能会损坏该集成电路。德州仪器 (TI) 建议通过适当的预防措施处理所有集成电路。如果不遵守正确的处理措施和安装程序，可能会损坏集成电路。

ESD 的损坏小至导致微小的性能降级，大至整个器件故障。精密的集成电路可能更容易受到损坏，这是因为非常细微的参数更改都可能会导致器件与其发布的规格不相符。

### 11.5 Glossary

[SLYZ022](#) — *TI Glossary*.

This glossary lists and explains terms, acronyms, and definitions.

## 12 机械、封装和可订购信息

以下页中包括机械、封装和可订购信息。这些信息是针对指定器件可提供的最新数据。这些数据会在无通知且不对本文档进行修订的情况下发生改变。欲获得该数据表的浏览器版本，请查阅左侧的导航栏



## PACKAGING INFORMATION

| Orderable Device | Status<br>(1) | Package Type | Package<br>Drawing | Pins | Package<br>Qty | Eco Plan<br>(2) | Lead finish/<br>Ball material<br>(6) | MSL Peak Temp<br>(3) | Op Temp (°C) | Device Marking<br>(4/5) | Samples                 |
|------------------|---------------|--------------|--------------------|------|----------------|-----------------|--------------------------------------|----------------------|--------------|-------------------------|-------------------------|
| TPD1E04U04DPLR   | ACTIVE        | X2SON        | DPL                | 2    | 15000          | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 125   | K                       | <a href="#">Samples</a> |
| TPD1E04U04DPLT   | ACTIVE        | X2SON        | DPL                | 2    | 250            | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 125   | K                       | <a href="#">Samples</a> |
| TPD1E04U04DPYR   | ACTIVE        | X1SON        | DPY                | 2    | 10000          | RoHS & Green    | NIPDAU   NIPDAUAG                    | Level-1-260C-UNLIM   | -40 to 125   | (3K, A5)                | <a href="#">Samples</a> |
| TPD1E04U04DPYT   | ACTIVE        | X1SON        | DPY                | 2    | 250            | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 125   | (3K, A5)                | <a href="#">Samples</a> |

<sup>(1)</sup> The marketing status values are defined as follows:

**ACTIVE:** Product device recommended for new designs.

**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.

**OBsolete:** TI has discontinued the production of the device.

<sup>(2)</sup> **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".

**RoHS Exempt:** TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.

**Green:** TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

<sup>(3)</sup> MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

<sup>(4)</sup> There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

<sup>(5)</sup> Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

<sup>(6)</sup> Lead finish/Ball material - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

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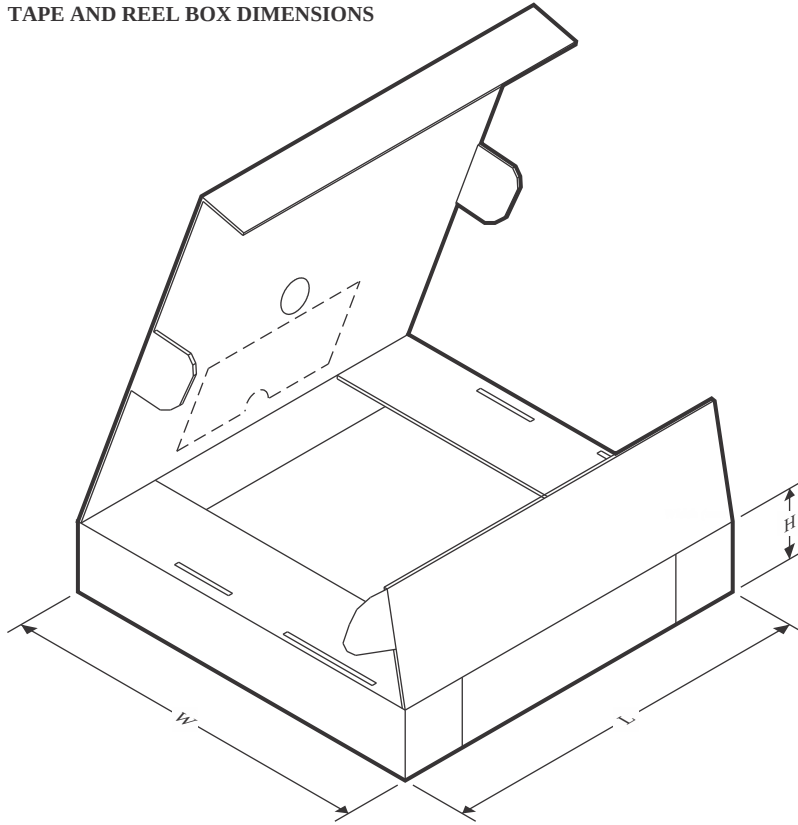
## TAPE AND REEL INFORMATION



\*All dimensions are nominal

| Device         | Package Type | Package Drawing | Pins | SPQ   | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|----------------|--------------|-----------------|------|-------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| TPD1E04U04DPLR | X2SON        | DPL             | 2    | 15000 | 178.0              | 9.5                | 0.39    | 0.68    | 0.38    | 2.0     | 8.0    | Q1            |
| TPD1E04U04DPLR | X2SON        | DPL             | 2    | 15000 | 178.0              | 8.4                | 0.36    | 0.66    | 0.33    | 2.0     | 8.0    | Q1            |
| TPD1E04U04DPLT | X2SON        | DPL             | 2    | 250   | 178.0              | 9.5                | 0.39    | 0.68    | 0.38    | 2.0     | 8.0    | Q1            |
| TPD1E04U04DPLT | X2SON        | DPL             | 2    | 250   | 178.0              | 8.4                | 0.36    | 0.66    | 0.33    | 2.0     | 8.0    | Q1            |

## TAPE AND REEL BOX DIMENSIONS

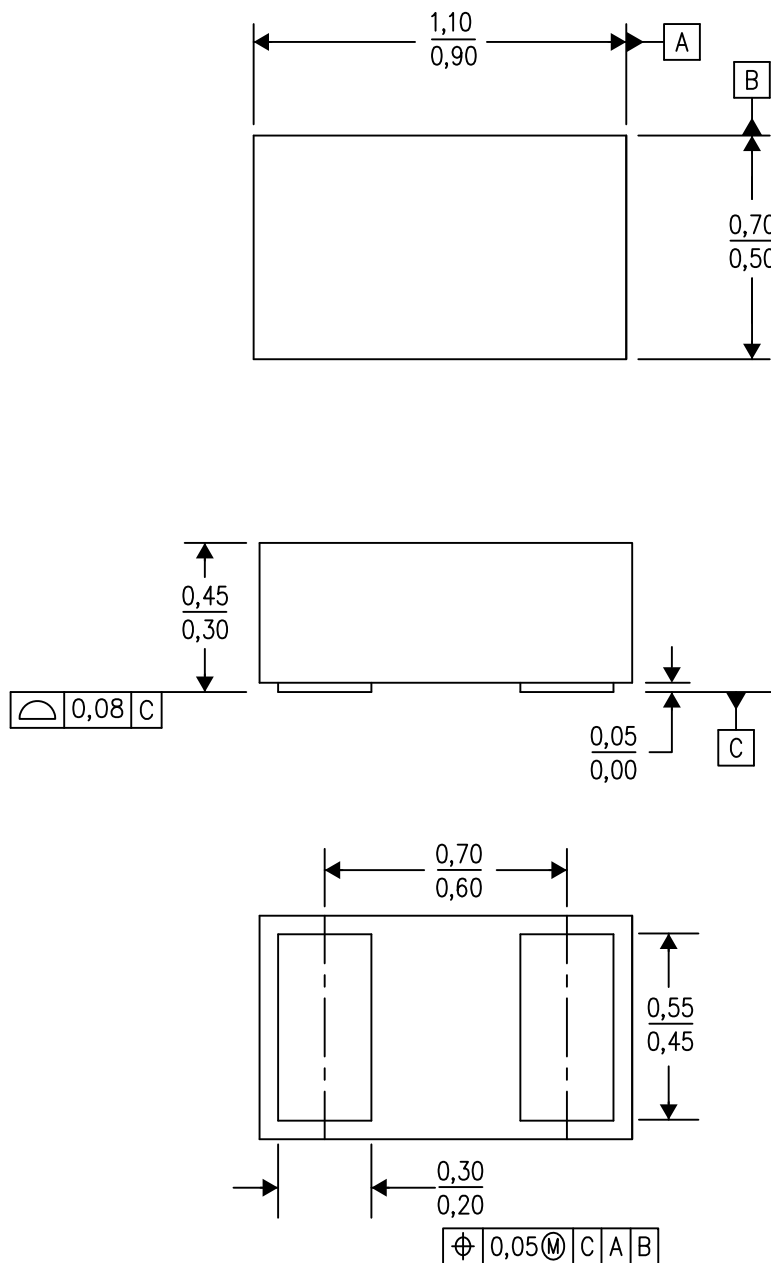


\*All dimensions are nominal

| Device         | Package Type | Package Drawing | Pins | SPQ   | Length (mm) | Width (mm) | Height (mm) |
|----------------|--------------|-----------------|------|-------|-------------|------------|-------------|
| TPD1E04U04DPLR | X2SON        | DPL             | 2    | 15000 | 184.0       | 184.0      | 19.0        |
| TPD1E04U04DPLR | X2SON        | DPL             | 2    | 15000 | 205.0       | 200.0      | 33.0        |
| TPD1E04U04DPLT | X2SON        | DPL             | 2    | 250   | 184.0       | 184.0      | 19.0        |
| TPD1E04U04DPLT | X2SON        | DPL             | 2    | 250   | 205.0       | 200.0      | 33.0        |

DPY (R-PX1SON-N2)

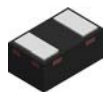
PLASTIC SMALL OUTLINE NO-LEAD



4211012/D 08/14

- NOTES:
- A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5-1994.
  - B. This drawing is subject to change without notice.
  - C. SON (Small Outline No-Lead) package configuration.

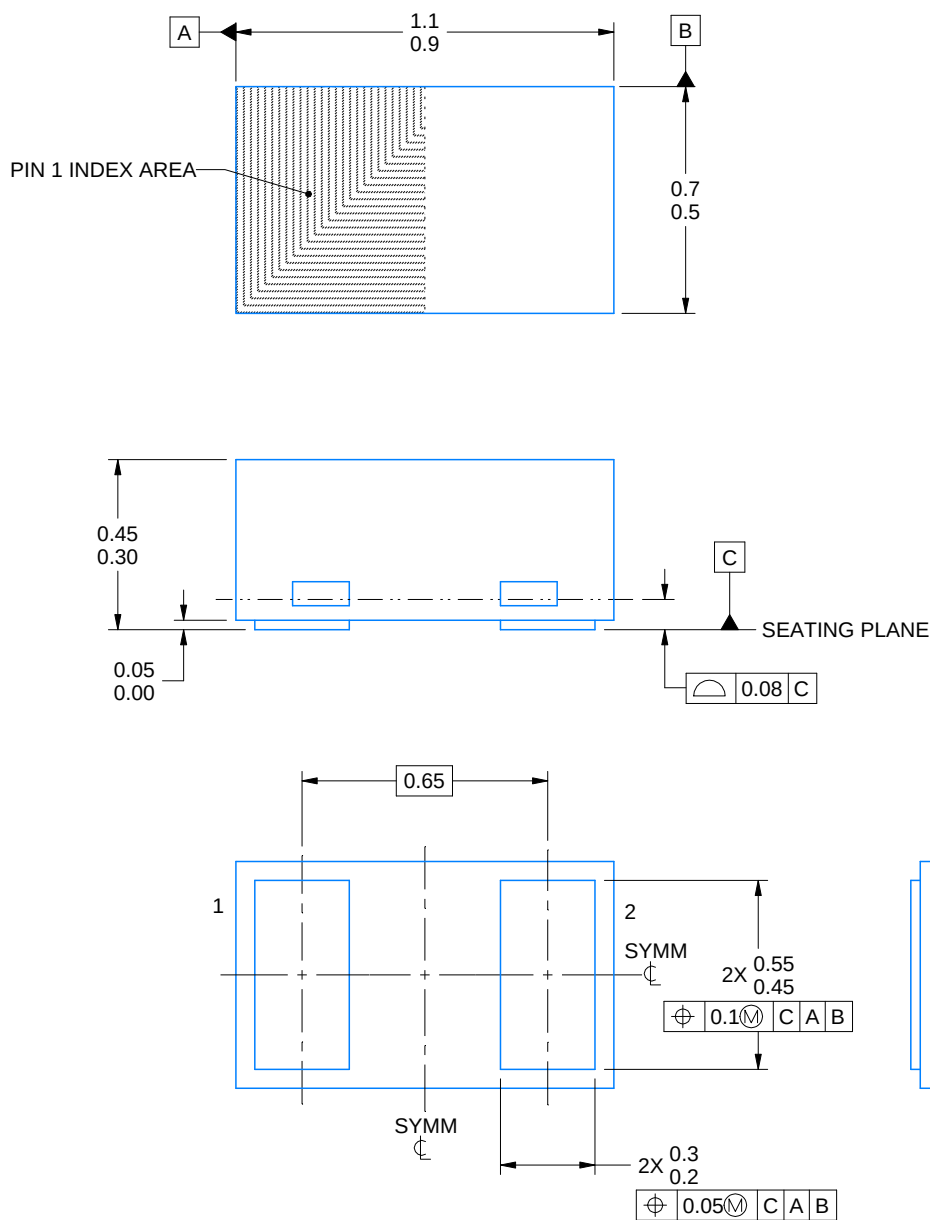
DPY0002A



## PACKAGE OUTLINE

X1SON - 0.45 mm max height

PLASTIC SMALL OUTLINE - NO LEAD



4224561/B 03/2021

### NOTES:

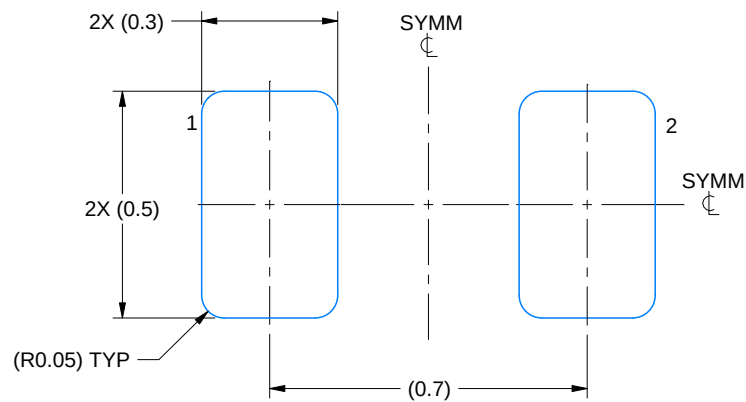
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M
2. This drawing is subject to change without notice.

# EXAMPLE BOARD LAYOUT

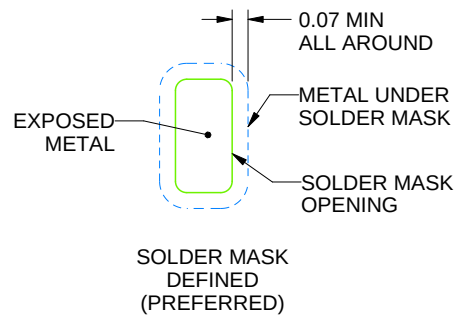
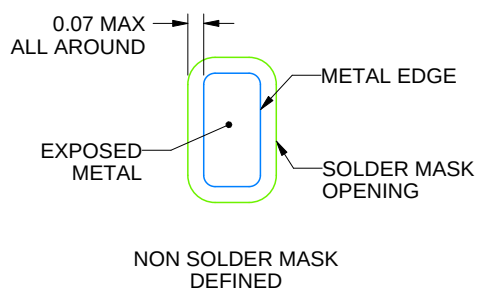
DPY0002A

X1SON - 0.45 mm max height

PLASTIC SMALL OUTLINE - NO LEAD



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE:60X



SOLDER MASK DETAILS

4224561/B 03/2021

NOTES: (continued)

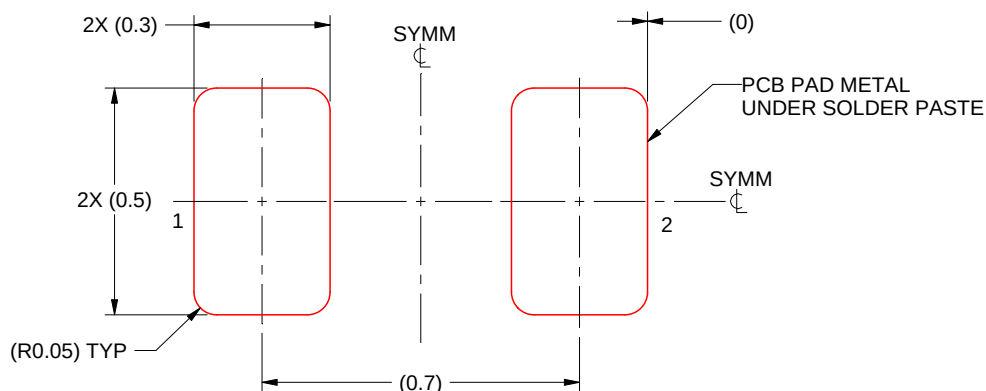
3. For more information, see Texas Instruments literature number SLUA271 ([www.ti.com/lit/sluea271](http://www.ti.com/lit/sluea271)).
4. Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view. It is recommended that vias under paste be filled, plugged or tented.

## EXAMPLE STENCIL DESIGN

DPY0002A

X1SON - 0.45 mm max height

PLASTIC SMALL OUTLINE - NO LEAD



SOLDER PASTE EXAMPLE  
BASED ON 0.1 mm THICK STENCIL  
SCALE:60X

4224561/B 03/2021

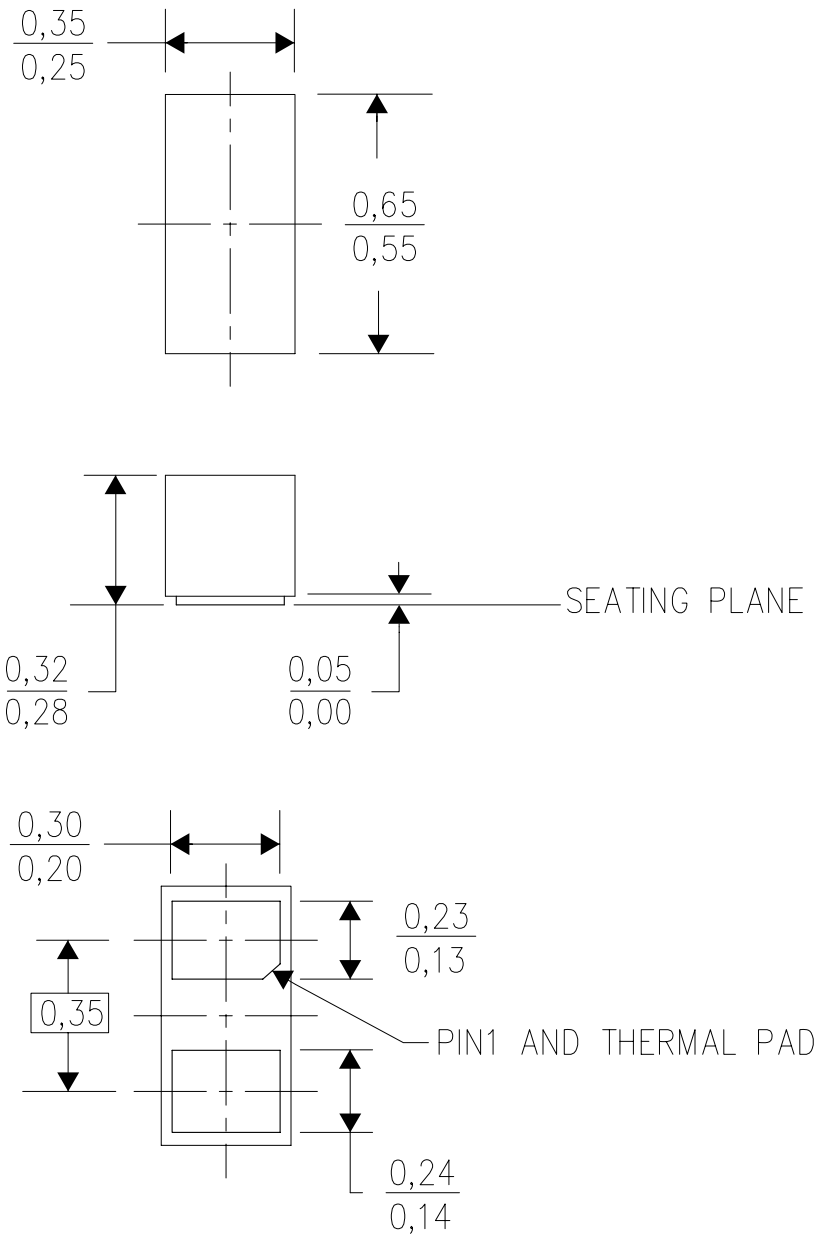
NOTES: (continued)

5. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.



DPL (R-PX2SON-N2)

PLASTIC SMALL OUTLINE NO-LEAD



4212149/B 10/11

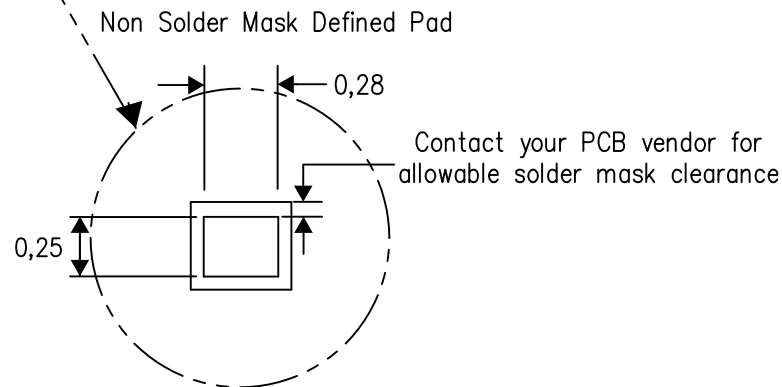
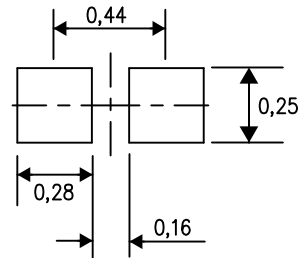
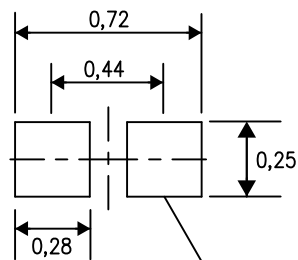
- NOTES:
- A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.
  - B. This drawing is subject to change without notice.
  - C. Small Outline No-Lead (SON) package configuration.
  - D. The package thermal pad must be soldered to the board for thermal and mechanical performance.

DPL (R-PX2SON-N2)

SMALL PACKAGE OUTLINE NO-LEAD

Example Board Layout

Example Stencil Design  
(Note E)



4217903/A 08/12

- NOTES:
- A. All linear dimensions are in millimeters.
  - B. This drawing is subject to change without notice.
  - C. Publication IPC-7351 is recommended for alternate designs.
  - D. Customers should contact their board fabrication site for minimum solder mask web tolerances between signal pads.
  - E. Maximum stencil thickness 0,127 mm (5 mils). All linear dimensions are in millimeters.
  - F. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC 7525 for stencil design considerations.
  - G. Side aperture dimensions over-print land for acceptable area ratio > 0.66. Customer may reduce side aperture dimensions if stencil manufacturing process allows for sufficient release at smaller opening.

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