

TPD4E004 4-Channel ESD-Protection Array For High-Speed Data Interfaces

1 Features

- IEC 61000-4-2 ESD Protection
 - ± 8 -kV IEC 61000-4-2 Contact Discharge
 - ± 12 -kV IEC 61000-4-2 Air-Gap Discharge
- ANSI/ESDA/JEDEC JS-001
 - ± 15 -kV Human Body Model (HBM)
- Low 1.6-pF Input Capacitance
- 0.9-V to 5.5-V Supply Voltage Range
- 4-Channel Device
- Space-Saving SON (DRY) Package

2 Applications

- USB
- Ethernet
- FireWire
- Videos
- Cell Phones
- SVGA Video Connections
- Glucose Meters

3 Description

The TPD4E004 is a low-capacitance transient voltage suppression (TVS) device. TPD4E004 is designed to protect sensitive electronics attached to communication lines from electrostatic discharge (ESD). Each of the four channels consists of a pair of diodes that steer ESD current pulses to V_{CC} or GND. The TPD4E004 protects against ESD pulses up to ± 15 -kV Human-Body Model (HBM) and, as specified in IEC 61000-4-2, ± 8 -kV contact discharge and ± 12 -kV air-gap Discharge. This device has 1.6-pF of capacitance per channel, making it ideal for use in high-speed data IO interfaces.

The TPD4E004 is a quad-ESD structure designed for USB, ethernet, and other high-speed applications.

Device Information⁽¹⁾

| PART NUMBER | PACKAGE | BODY SIZE (NOM) |
|-------------|---------|-------------------|
| TPD4E004 | SON (6) | 1.45 mm x 1.00 mm |

(1) For all available packages, see the orderable addendum at the end of the data sheet.

Application Schematic

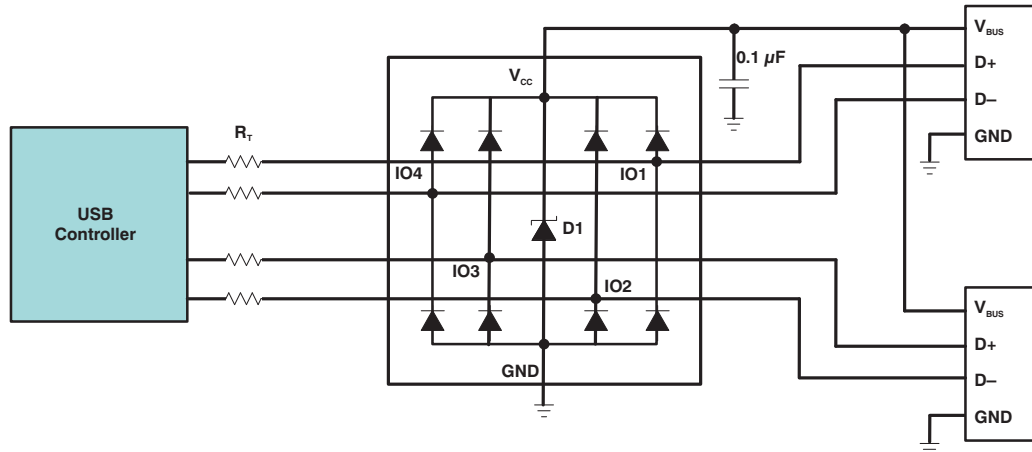


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4 Revision History

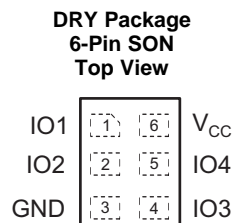
NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Revision A (February 2008) to Revision B

Page

- Added *Device Information* table, *ESD Ratings* table, *Feature Description* section, *Device Functional Modes*, *Application and Implementation* section, *Power Supply Recommendations* section, *Layout* section, *Device and Documentation Support* section, and *Mechanical, Packaging, and Orderable Information* section. **1**
- Deleted the ordering information

5 Pin Configuration and Functions



Pin Functions

| PIN | | I/O | DESCRIPTION |
|-----|-----------------|-----|-----------------------|
| NO. | NAME | | |
| 1 | IO1 | IO | ESD-protected channel |
| 2 | IO2 | IO | ESD-protected channel |
| 3 | GND | GND | Ground |
| 4 | IO3 | IO | ESD-protected channel |
| 5 | IO4 | IO | ESD-protected channel |
| 6 | V _{CC} | PWR | Power-supply input |

6 Specifications

6.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted) ⁽¹⁾

| | | MIN | MAX | UNIT |
|------------------|------------------------------------|--------------------|-----------------------|------|
| V _{CC} | Supply voltage | -0.3 | 5.5 | V |
| V _{IO} | Input/output voltage | -0.3 | V _{CC} + 0.3 | V |
| | Bump temperature (soldering) | Infrared (15 s) | 220 | °C |
| | | Vapor phase (60 s) | 215 | |
| | Lead temperature (soldering, 10 s) | | 300 | °C |
| T _J | Junction temperature | | 150 | °C |
| T _{stg} | Storage temperature | -65 | 150 | °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 | ±15000 | V | |
| | | IEC 61000-4-2 | Contact Discharge | | ±8000 |
| | | | Air-Gap Discharge | | ±12000 |

6.3 Recommended Operating Conditions

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

| | | MIN | MAX | UNIT |
|-----------------|---|-----|--|------|
| T _A | Operating free-air temperature | -40 | 85 | °C |
| V _{CC} | Operating voltage for pin V _{CC} | 0.9 | 5.5 | V |
| V _{IO} | Operating voltage for pins IO1, IO2, IO3, and IO4 | 0 | Minimum of: (5.8, V _{CC}) | V |

6.4 Thermal Information

| THERMAL METRIC ⁽¹⁾ | | TPD4E004 | UNIT |
|-------------------------------|--|-----------|------|
| | | DRY (SON) | |
| | | 6 PINS | |
| R _{θJA} | Junction-to-ambient thermal resistance | 414.8 | °C/W |
| R _{θJC(top)} | Junction-to-case (top) thermal resistance | 258.6 | °C/W |
| R _{θJB} | Junction-to-board thermal resistance | 251.6 | °C/W |
| ψ _{JT} | Junction-to-top characterization parameter | 70.6 | °C/W |
| ψ _{JB} | Junction-to-board characterization parameter | 248.2 | °C/W |
| R _{θJC(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](#).

6.5 Electrical Characteristics

$V_{CC} = 0.9\text{ V to }5.5\text{ V}$, $T_A = T_{MIN}$ to T_{MAX} (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | MIN | TYP ⁽¹⁾ | MAX | UNIT |
|-----------|---------------------------|--|-----|--------------------|-----|------|
| V_{CC} | Supply voltage | | 0.9 | | 5.5 | V |
| I_{CC} | Supply current | | | | 500 | nA |
| V_F | Diode forward voltage | $I_F = 1\text{ mA}$ | | 0.8 | | V |
| I_l | Channel leakage current | | | ± 1 | | nA |
| V_{BR} | Break-down voltage | $I_l = 10\text{ }\mu\text{A}$ | 6 | | 8 | V |
| $C_{I/O}$ | Channel input capacitance | $V_{CC} = 5\text{ V}$, Bias of $V_{CC}/2$, $f = 10\text{ MHz}$ | | 1.6 | 2 | pF |

(1) Typical values are at $V_{CC} = 5\text{ V}$ and $T_A = 25^\circ\text{C}$.

6.6 Typical Characteristics

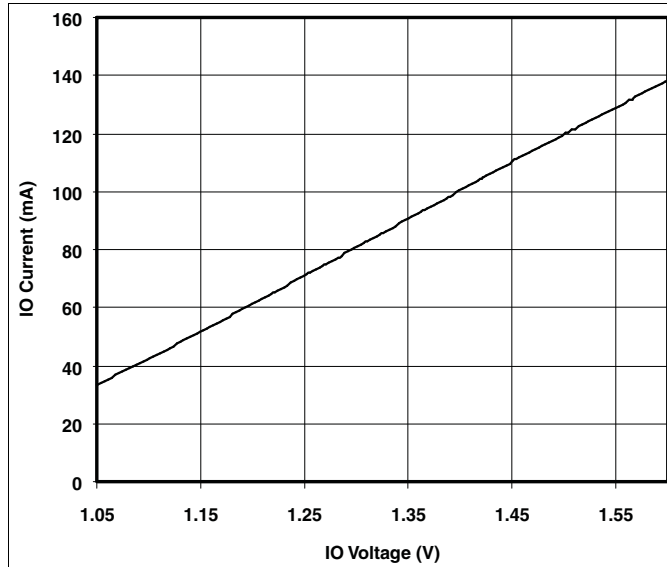


Figure 1. Forward Diode Voltage (Upper Clamp Diode)
($V_{CC} = 0$ V, DC Sweep Across the IO Pin)

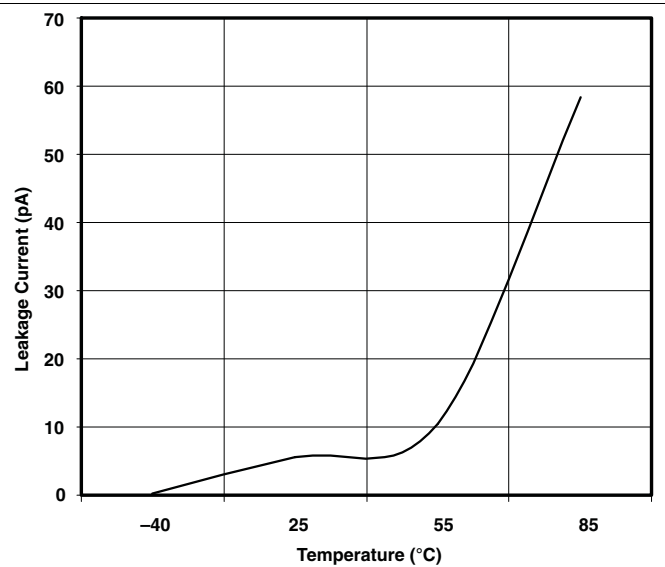


Figure 2. Leakage Current vs Temperature ($V_{IO} = 2.5$ V)

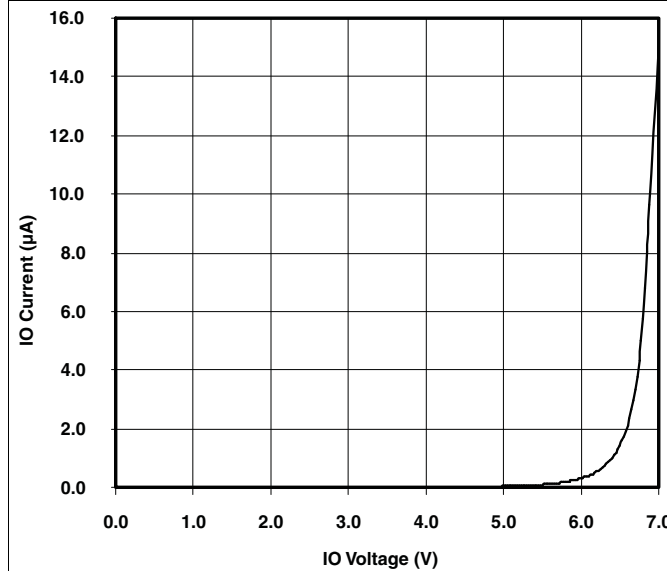


Figure 3. Reverse Diode Curve Current IO to Gnd
($V_{CC} = \text{Open}$)

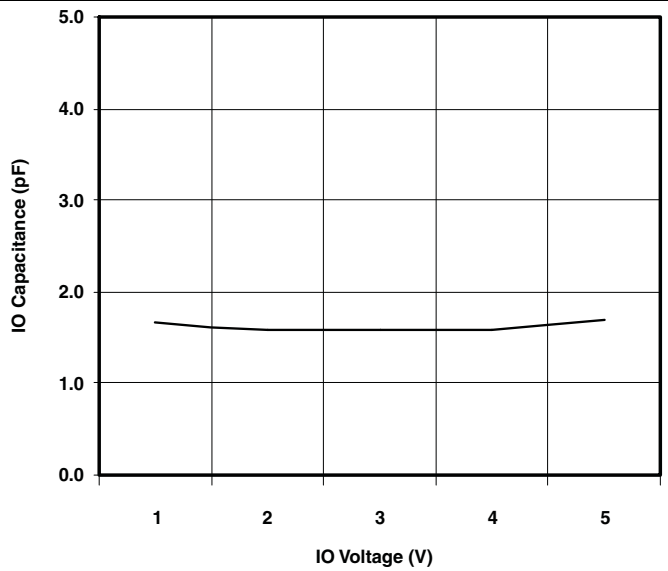


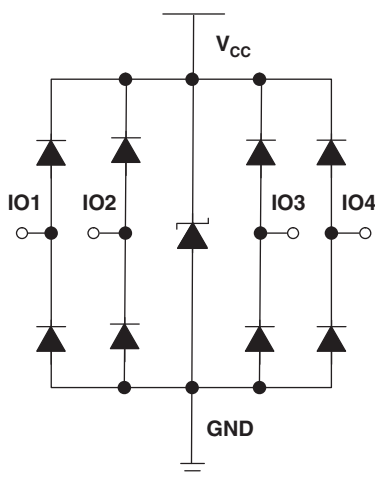
Figure 4. IO Capacitance vs Input Voltage
($V_{CC} = 5$ V)

7 Detailed Description

7.1 Overview

The TPD4E004 is a four-channel TVS protection diode array. The TPD4E004 is rated to dissipate contact ESD strikes of ± 8 -kV contact and ± 12 -kV air-gap, meeting Level 4 as specified in the IEC 61000-4-2 international standard. This device has a 1.6-pF IO capacitance per channel, making it ideal for use in high-speed data IO interfaces.

7.2 Functional Block Diagram



7.3 Feature Description

TPD4E004 is a TVS which provides ESD protection for up to four channels, withstanding up to ± 8 -kV contact and ± 12 -kV air-gap ESD per IEC 61000-4-2. The monolithic technology yields exceptionally small variations in capacitance between any IO pin of TPD4E004. The small footprint is ideal for applications where space-saving designs are important.

7.4 Device Functional Modes

The TPD4E004 device is a passive integrated circuit that triggers when voltages are above V_{BR} or below the diodes V_F of approximately -0.3 V. During ESD events, voltages as high as ± 8 -kV contact and ± 12 -kV air-gap ESD can be directed to ground via the internal diodes. Once the voltages on the protected line fall below the trigger levels of TPD4E004 (usually within 10's of nano-seconds) the device reverts back to its high-impedance state.

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

TPD4E004 is a diode array type TVS which is typically used to provide a path to ground for dissipating ESD events on hi-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 tolerable level for the protected IC.

8.2 Typical Application

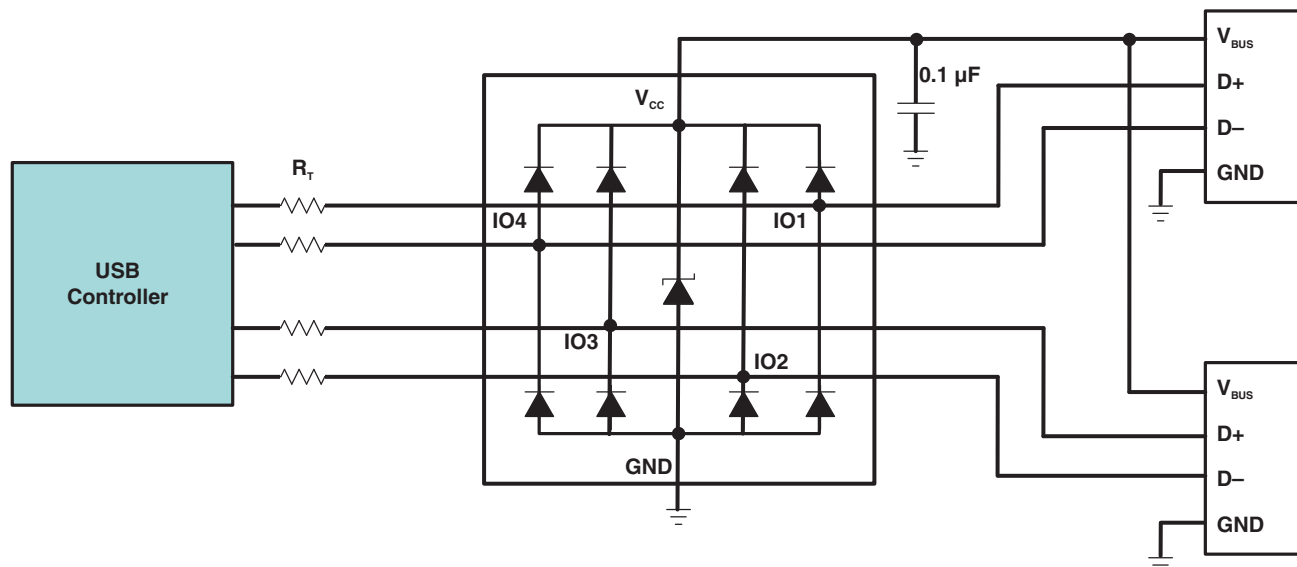


Figure 5. Application Schematic

8.2.1 Design Requirements

For this design example, a single TPD4E004 is used to protect all the pins of two USB2.0 connectors. [Table 1](#) lists the design parameters for the USB application.

Table 1. Design Parameters

| DESIGN PARAMETER | VALUE |
|--|--------------|
| Signal range on IO1, IO2, IO3, and IO4 | 0 V to 3.6 V |
| Signal voltage range on V_{CC} | 0 V to 5.5 V |
| Operating Frequency | 240 MHz |

8.2.2 Detailed Design Procedure

When placed near the USB connectors, the TPD4E004 ESD solution offers little or no signal distortion during normal operation due to low IO capacitance and ultra-low leakage current specifications. The TPD4E004 ensures that the core circuitry is protected and the system is functioning properly in the event of an ESD strike. For proper operation, see the the following layout and design guidelines should be followed:

1. Place the TPD4E004 solution close to the connectors. This allows the TPD4E004 to take away the energy

associated with ESD strike before it reaches the internal circuitry of the system board.

2. Place a 0.1- μ F capacitor very close to the V_{CC} pin. This limits any momentary voltage surge at the IO pin during the ESD strike event.
3. Ensure that there is enough metallization for the V_{CC} and GND loop. During normal operation, the TPD4E004 consumes nA leakage current. But during the ESD event, V_{CC} and GND may see 15-A to 30-A of current, depending on the ESD level. Sufficient current path enables safe discharge of all the energy associated with the ESD strike.
4. Leave the unused IO pins floating. In this example of protecting two USB ports, none of the IO pins will be left unused.
5. The V_{CC} pin can be connected in two different ways:
 - (a) If the V_{CC} pin is connected to the system power supply, the TPD4E004 works as a transient suppressor for any signal swing above $V_{CC} + V_F$. A 0.1- μ F capacitor on the device V_{CC} pin is recommended for ESD bypass.
 - (b) If the V_{CC} pin is not connected to the system power supply, the TPD4E004 can tolerate higher signal swing in the range up to 5.8 V. Please note that a 0.1- μ F capacitor is still recommended at the V_{CC} pin for ESD bypass.

8.2.3 Application Curves

Figure 6 is a capture of the voltage clamping waveform of TPD4E004 during an +8kV Contact IEC 61000-4-2 ESD strike.

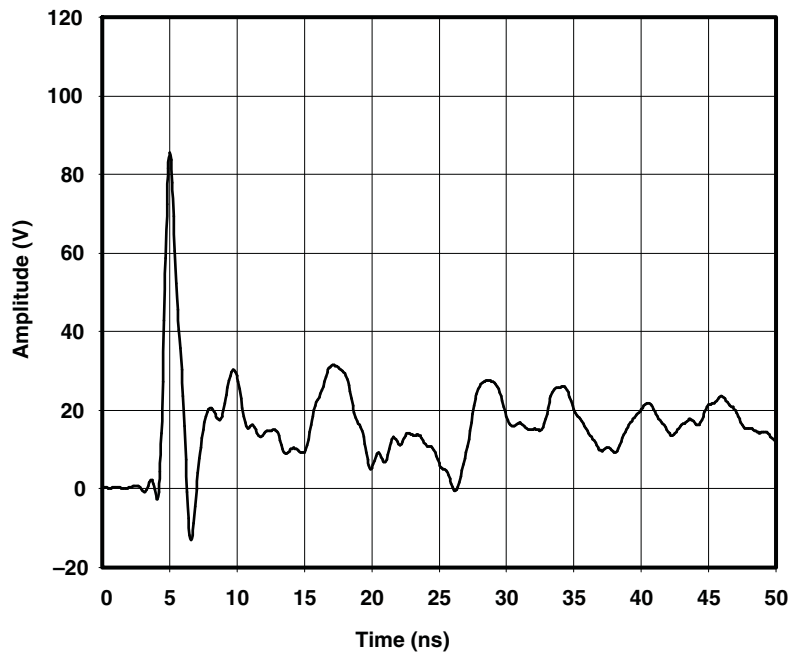


Figure 6. IEC ESD Clamping Waveforms +8-KV Contact

9 Power Supply Recommendations

This device is a passive ESD protection device so there is no need to power it. Make sure that the maximum voltage specifications for each pin are not violated.

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 needs to 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

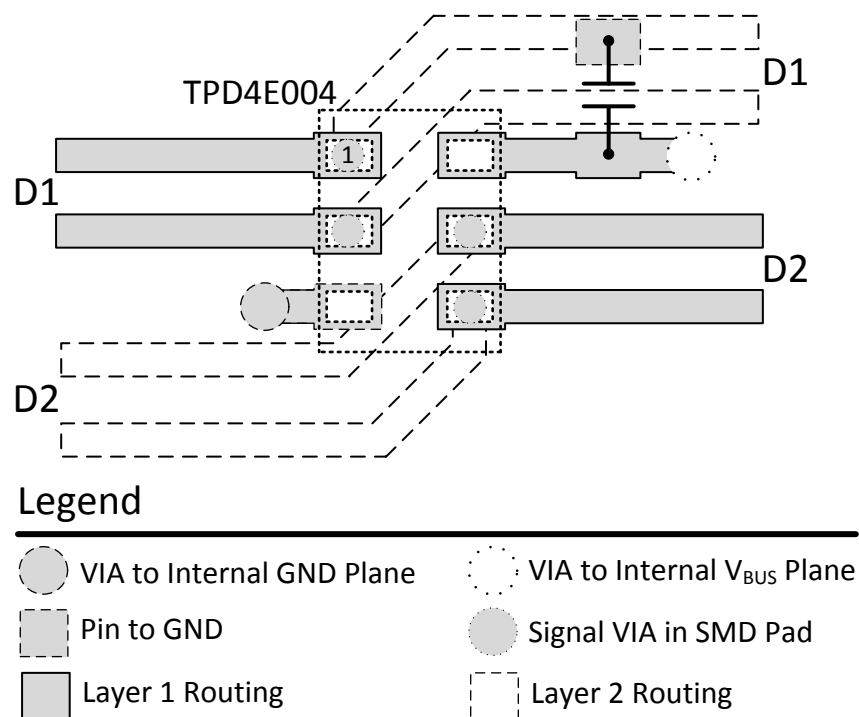


Figure 7. TPD4E004 Layout Example

11 Device and Documentation Support

11.1 Documentation Support

11.1.1 Related Documentation

For related documentation see the following:

- *Reading and Understanding an ESD Protection Datasheet*, [SLLA305](#)
- *ESD Protection Layout Guide*, [SLVA680](#)

11.2 Community Resources

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 Trademarks

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11.4 Electrostatic Discharge Caution



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

11.5 Glossary

[SLYZ022](#) — *TI Glossary*.

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

12 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

PACKAGING INFORMATION

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead/Ball Finish (6) | MSL Peak Temp (3) | Op Temp (°C) | Device Marking (4/5) | Samples |
|------------------|---------------|--------------|-----------------|------|-------------|-------------------------|-------------------------|----------------------|--------------|-------------------------|-------------------------|
| TPD4E004DRYR | ACTIVE | SON | DRY | 6 | 5000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 85 | 2P | Samples |
| TPD4E004DRYRG4 | ACTIVE | SON | DRY | 6 | 5000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 85 | 2P | Samples |

(1) 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.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

TBD: The Pb-Free/Green conversion plan has not been defined.

Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

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

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

(5) 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.

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

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TAPE AND REEL INFORMATION



QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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 |
|--------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| TPD4E004DRYR | SON | DRY | 6 | 5000 | 179.0 | 8.4 | 1.2 | 1.65 | 0.7 | 4.0 | 8.0 | Q1 |
| TPD4E004DRYR | SON | DRY | 6 | 5000 | 180.0 | 9.5 | 1.2 | 1.65 | 0.7 | 4.0 | 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) |
|--------------|--------------|-----------------|------|------|-------------|------------|-------------|
| TPD4E004DRYR | SON | DRY | 6 | 5000 | 203.0 | 203.0 | 35.0 |
| TPD4E004DRYR | SON | DRY | 6 | 5000 | 189.0 | 185.0 | 36.0 |

GENERIC PACKAGE VIEW

DRY 6

USON - 0.6 mm max height

PLASTIC SMALL OUTLINE - NO LEAD



Images above are just a representation of the package family, actual package may vary.
Refer to the product data sheet for package details.

4207181/G

DRY0006A



PACKAGE OUTLINE

USON - 0.6 mm max height

PLASTIC SMALL OUTLINE - NO LEAD



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

DRY0006A

USON - 0.6 mm max height

PLASTIC SMALL OUTLINE - NO LEAD



LAND PATTERN EXAMPLE
1:1 RATIO WITH PKG SOLDER PADS
EXPOSED METAL SHOWN
SCALE:40X



SOLDER MASK DETAILS

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NOTES: (continued)

3. For more information, see QFN/SON PCB application report in literature No. SLUA271 (www.ti.com/lit/sluea271).

EXAMPLE STENCIL DESIGN

DRY0006A

USON - 0.6 mm max height

PLASTIC SMALL OUTLINE - NO LEAD



SOLDER PASTE EXAMPLE
BASED ON 0.075 - 0.1 mm THICK STENCIL
SCALE:40X

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NOTES: (continued)

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

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Where TI specifically promotes products as facilitating functional safety or as compliant with industry functional safety standards, such products are intended to help enable customers to design and create their own applications that meet applicable functional safety standards and requirements. Using products in an application does not by itself establish any safety features in the application. Designers must ensure compliance with safety-related requirements and standards applicable to their applications. Designer may not use any TI products in life-critical medical equipment unless authorized officers of the parties have executed a special contract specifically governing such use. Life-critical medical equipment is medical equipment where failure of such equipment would cause serious bodily injury or death (e.g., life support, pacemakers, defibrillators, heart pumps, neurostimulators, and implantables). Such equipment includes, without limitation, all medical devices identified by the U.S. Food and Drug Administration as Class III devices and equivalent classifications outside the U.S.

TI may expressly designate certain products as completing a particular qualification (e.g., Q100, Military Grade, or Enhanced Product). Designers agree that it has the necessary expertise to select the product with the appropriate qualification designation for their applications and that proper product selection is at Designers' own risk. Designers are solely responsible for compliance with all legal and regulatory requirements in connection with such selection.

Designer will fully indemnify TI and its representatives against any damages, costs, losses, and/or liabilities arising out of Designer's non-compliance with the terms and provisions of this Notice.