

## TPD6E004 Low-Capacitance, 6-Channel $\pm 15$ -kV ESD Protection Array for High-Speed Data Interfaces

### 1 Features

- ESD Protection Exceeds JESD
  - $\pm 15$ -kV Human-Body Model (HBM)
  - $\pm 8$ -kV IEC 61000-4-2 Contact Discharge
  - $\pm 12$ -kV IEC 61000-4-2 Air-Gap Discharge
- Low 1.6-pF I/O Capacitance
- 0.9-V to 5.5-V Supply-Voltage Range
- 6-Channel Device
- Space-Saving UQFN (RSE) Package

### 2 Applications

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

### 3 Description

The TPD6E004 device is a low-capacitance,  $\pm 15$ -kV ESD-protection diode array designed to protect sensitive electronics attached to communication lines. Each channel consists of a pair of diodes that steers ESD current pulses to  $V_{CC}$  or GND. The TPD6E004 protects against ESD pulses up to  $\pm 15$ -kV human-body model (HBM),  $\pm 8$ -kV contact ESD, and  $\pm 12$ -kV air-gap ESD as specified in IEC 61000-4-2. This device has a typical 1.6-pF capacitance per channel, making it ideal for use in high-speed data I/O interfaces.

The TPD6E004 device is available in the RSE package and is specified for  $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$  operation.

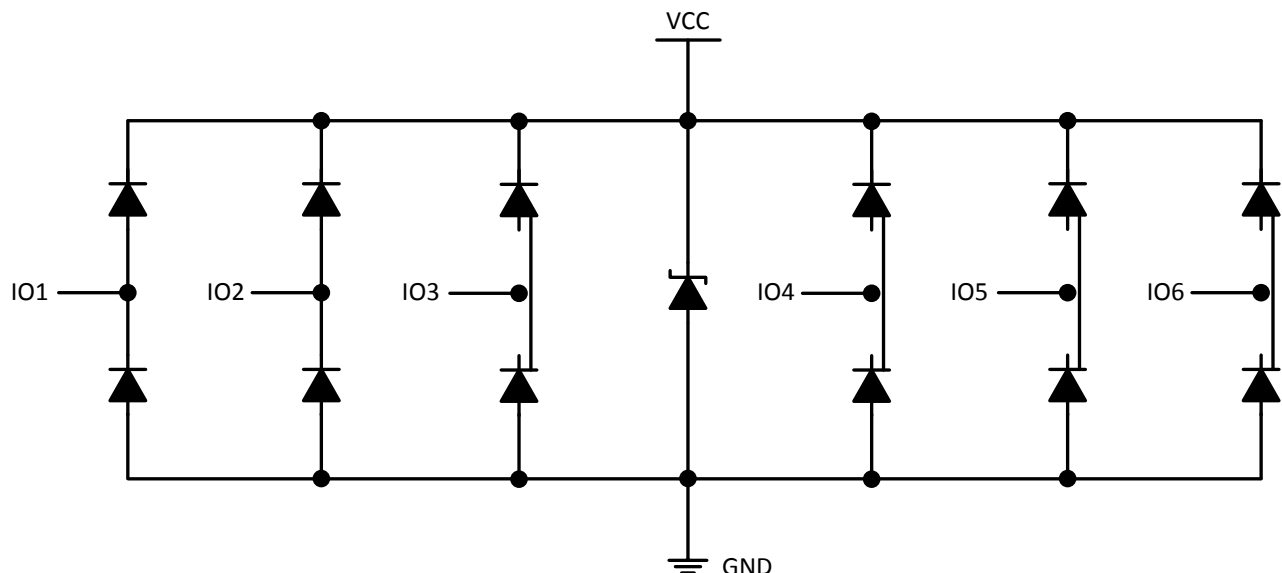
The TPD6E004 device is a six-channel ESD structure designed for USB, Ethernet, and FireWire applications.

#### Device Information<sup>(1)</sup>

PART NUMBER	PACKAGE	BODY SIZE (NOM)
TPD6E004	UQFN (8)	1.50 mm x 1.50 mm

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

#### Functional Block Diagram



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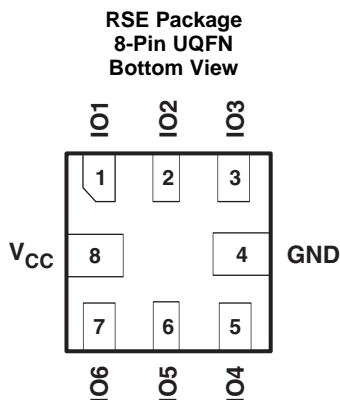
## 4 Revision History

### 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**

## 5 Pin Configuration and Functions



**Pin Functions**

PIN		I/O	DESCRIPTION
NO.	NAME		
1	IO1	I/O	ESD-protected channel
2	IO2	I/O	ESD-protected channel
3	IO3	I/O	ESD-protected channel
4	GND	GND	Ground
5	IO4	I/O	ESD-protected channel
6	IO5	I/O	ESD-protected channel
7	IO6	I/O	ESD-protected channel
8	V <sub>CC</sub>	PWR	Power-supply input. Bypass V <sub>CC</sub> to GND with a 0.1- $\mu$ F ceramic capacitor.

## 6 Specifications

### 6.1 Absolute Maximum Ratings<sup>(1)</sup>

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

		MIN	MAX	UNIT
V <sub>CC</sub>	Operating voltage for pin V <sub>CC</sub>	-0.3	5.5	V
V <sub>I/O</sub>	Operating voltage for pins IO1, IO2, IO3, IO4, IO5 and IO6	-0.3	V <sub>CC</sub> + 0.3	V
	Bump temperature (soldering)	Infrared (15 s)	220	°C
		Vapor phase (60 s)	215	
	Lead temperature (soldering, 10 s)		300	°C
T <sub>J</sub>	Junction temperature		150	°C
T <sub>stg</sub>	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 <sub>(ESD)</sub>	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 <sup>(1)</sup>	±15000	V

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

### 6.3 ESD Ratings – Surge Protection

		VALUE	UNIT
V <sub>(ESD)</sub>	Electrostatic discharge	IEC 61000-4-2 contact discharge	±8000
		IEC 61000-4-2 air-gap discharge	±12000
			V

### 6.4 Recommended Operating Conditions

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

		MIN	MAX	UNIT
T <sub>A</sub>	Operating free-air temperature	–40	85	°C
V <sub>CC</sub>	Operating voltage for pin VCC	0.9	5.5	V
V <sub>I/O</sub>	Operating voltage for pins IO1, IO2, IO3, IO4, IO5 and IO6	0	Minimum of: (5.8, V <sub>CC</sub> )	V

### 6.5 Thermal Information

THERMAL METRIC <sup>(1)</sup>		TPD6E004	UNIT
		RSE (UQFN)	
		8 PINS	
R <sub>θJA</sub>	Junction-to-ambient thermal resistance	138.6	°C/W
R <sub>θJC(top)</sub>	Junction-to-case (top) thermal resistance	74.7	°C/W
R <sub>θJB</sub>	Junction-to-board thermal resistance	43.9	°C/W
Ψ <sub>JT</sub>	Junction-to-top characterization parameter	3.6	°C/W
Ψ <sub>JB</sub>	Junction-to-board characterization parameter	43.6	°C/W
R <sub>θJC(bot)</sub>	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](http://SPRA953).

### 6.6 Electrical Characteristics

 V<sub>CC</sub> = 5 V ± 10%, T<sub>A</sub> = T<sub>MIN</sub> to T<sub>MAX</sub> (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP <sup>(1)</sup>	MAX	UNIT
V <sub>CC</sub>	Supply voltage	0.9		5.5	V
I <sub>CC</sub>	Supply current			500	nA
V <sub>F</sub>	Diode forward voltage	I <sub>F</sub> = 1 mA	0.8		V
I <sub>I</sub>	Channel leakage current		±1		nA
V <sub>BR</sub>	Break-down voltage	I <sub>I</sub> = 10 μA	6	8	V
C <sub>I/O</sub>	Channel input capacitance	V <sub>CC</sub> = 5 V, bias of V <sub>CC</sub> /2, f = 10 MHz	1.6	2	pF

- (1) Typical values are at V<sub>CC</sub> = 5 V and T<sub>A</sub> = 25°C.

### 6.7 Typical Characteristics

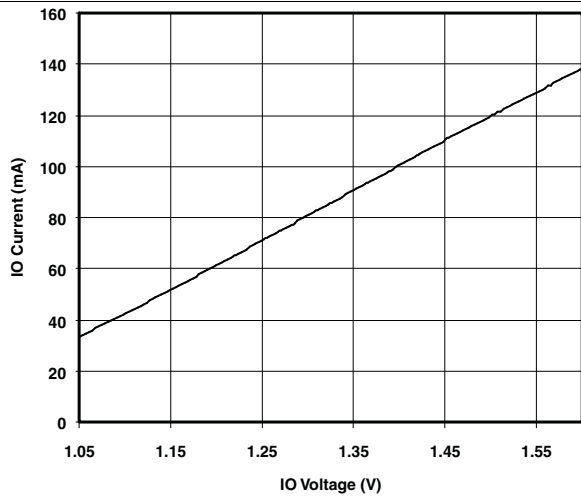


Figure 1. Forward Diode Voltage (Upper Clamp Diode)

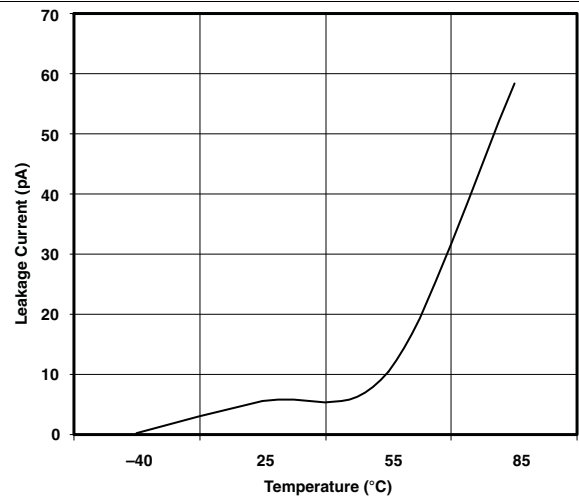


Figure 2. Leakage Current vs Temperature

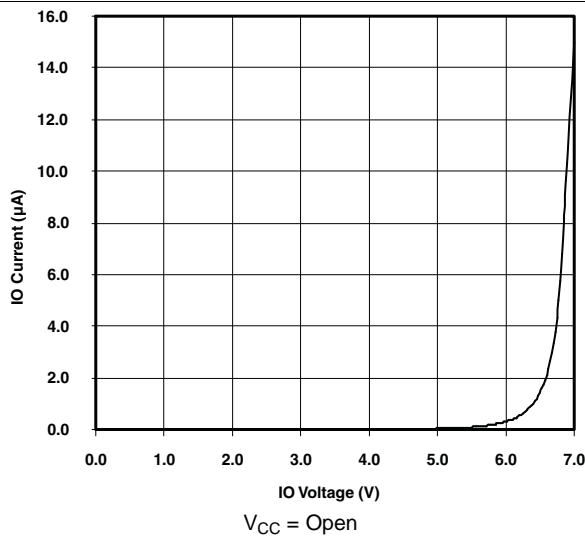


Figure 3. Reverse Diode Curve Current I/O to GND

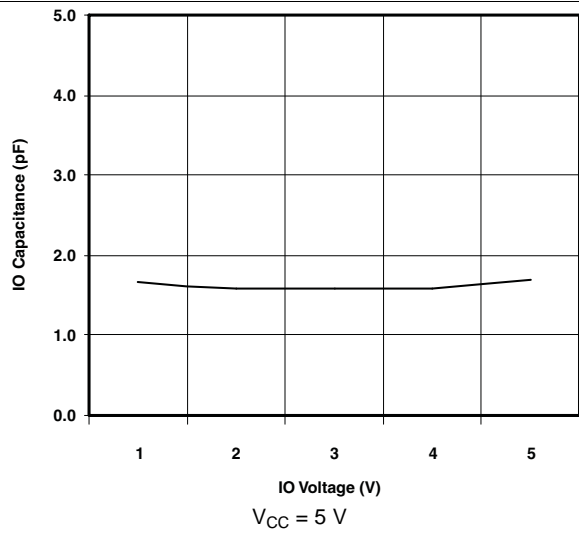


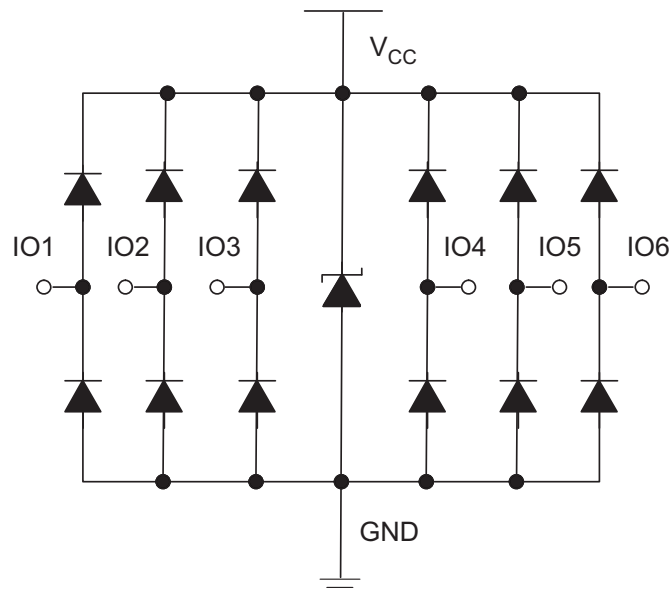
Figure 4. I/O Capacitance vs Input Voltage

## 7 Detailed Description

### 7.1 Overview

The TPD6E004 device is a six-channel TVS protection diode array. The TPD6E004 is rated to dissipate ESD strikes of  $\pm 8$ -kV contact and  $\pm 12$ -kV air-gap, as specified in the IEC 61000-4-2 international standard. This device has 1.6-pF capacitance per I/O channel, making it ideal for use in high-speed data I/O interfaces.

### 7.2 Functional Block Diagram



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**Figure 5. Logic Block Diagram**

### 7.3 Feature Description

The TPD6E004 is a TVS that provides ESD protection for up to six channels, withstanding up to  $\pm 8$ -kV contact and  $\pm 12$ -kV air-gap ESD per IEC 61000-4-2. The monolithic technology yields exceptionally small variations in capacitance between any I/O pin of the TPD6E004. The small footprint is ideal for applications where space-saving designs are important.

### 7.4 Device Functional Modes

The TPD6E004 device is a passive integrated circuit that triggers when voltages are above  $V_{BR}$  or below the diodes  $V_F$  of approximately  $-0.8$  V. During ESD events, voltages as high as  $\pm 8$ -kV contact and  $\pm 12$ -kV air-gap ESD can be directed to ground through the internal diodes. When the voltages on the protected line fall below the trigger levels of TPD6E004 (usually within 10s of nano-seconds) the device reverts back to its high-impedance state.

## 8 Application and Implementation

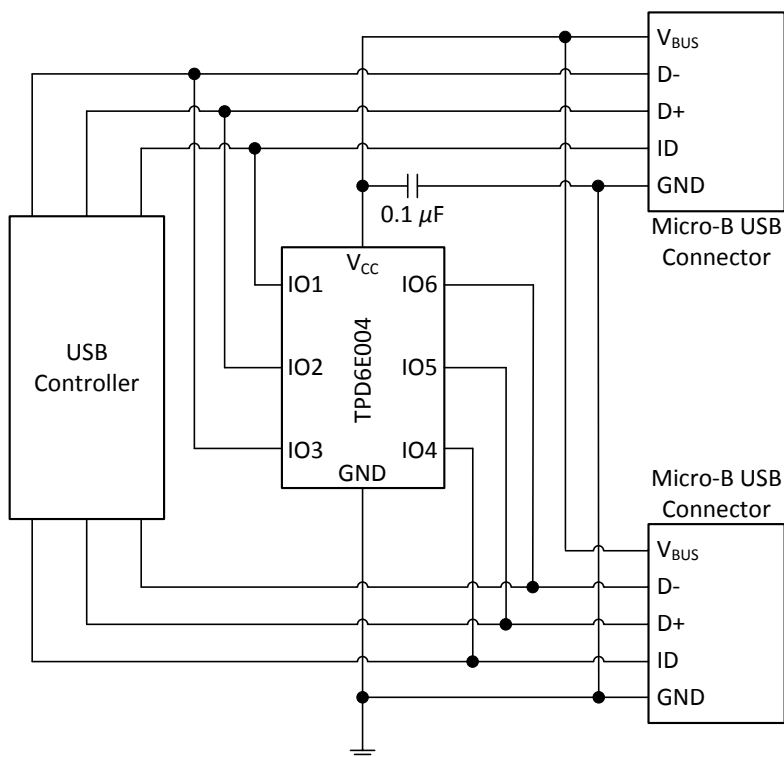
### NOTE

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

The TPD6E004 device is a TVS diode array typically 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 integrated circuit (IC). The triggered TVS holds this voltage,  $V_{CLAMP}$ , to a safe level for the protected IC.

### 8.2 Typical Application



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Figure 6. Two-Port Micro-B USB 2.0 Application

#### 8.2.1 Design Requirements

For this design example, a single TPD6E004 is used to protect all the pins of two USB 2.0 Micro-B connectors. Table 1 lists the design parameters for the USB application.

Table 1. Design Parameters

DESIGN PARAMETER	VALUE
Signal range on IO1, IO2, IO3, IO4, IO5 and IO6	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 TPD6E004 ESD solution offers little or no signal distortion during normal operation due to low I/O capacitance and ultra-low leakage current specifications. The TPD6E004 ensures that the core circuitry is protected and the system is functioning properly in the event of an ESD strike. For proper operation, the [Layout](#) and following design guidelines must be followed:

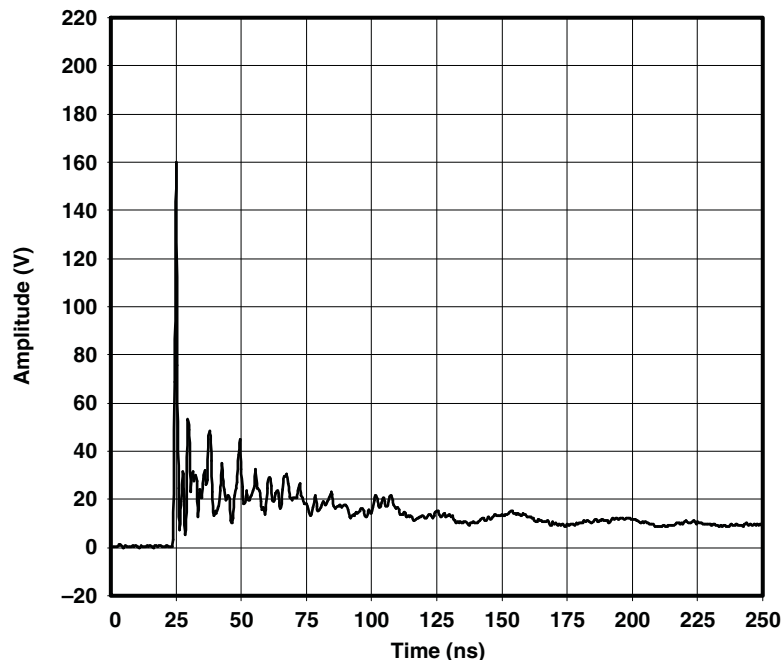
1. Place the TPD6E004 solution close to the connectors. This allows the TPD6E004 to take away the energy associated with ESD strike before it reaches the internal circuitry of the system board.
2. Place a 0.1- $\mu$ F capacitor very close to the  $V_{CC}$  pin. This limits any momentary voltage surge at the I/O pin during the ESD strike event.
3. Ensure that there is enough metallization for the  $V_{CC}$  and GND loop. During normal operation, the TPD6E004 consumes only  $\mu$ A of leakage current, but during an ESD event,  $V_{CC}$  and GND may see 15-A to 30-A of current, depending on the ESD level. A sufficient current path enables the safe discharge of all the energy associated with the ESD strike.
4. Leave any unused I/O pins floating. In this example of protecting two Micro-B USB ports, none of the I/O pins are 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 TPD6E004 works as a transient suppressor for any signal swing above  $V_{CC} + V_F$ . TI recommends a 0.1- $\mu$ F capacitor on the device  $V_{CC}$  pin for ESD bypass.
  - (b) If the  $V_{CC}$  pin is not connected to the system power supply, the TPD6E004 can tolerate a higher signal swing in the range of up to 5.8 V.

#### NOTE

A 0.1- $\mu$ F capacitor is still recommended at the  $V_{CC}$  pin for ESD bypass.

### 8.2.3 Application Curve

Figure 7 is a capture of the voltage clamping waveform of the TPD6E004 during a +8-kV contact IEC 61000-4-2 ESD strike.



**Figure 7. IEC 61000-4-2 +8-kV Contact ESD Clamping Waveform**



## 9 Power Supply Recommendations

The TPD6E004 device is a passive ESD protection device, so there is no need to power it. Do not violate the maximum voltage specifications for each pin.

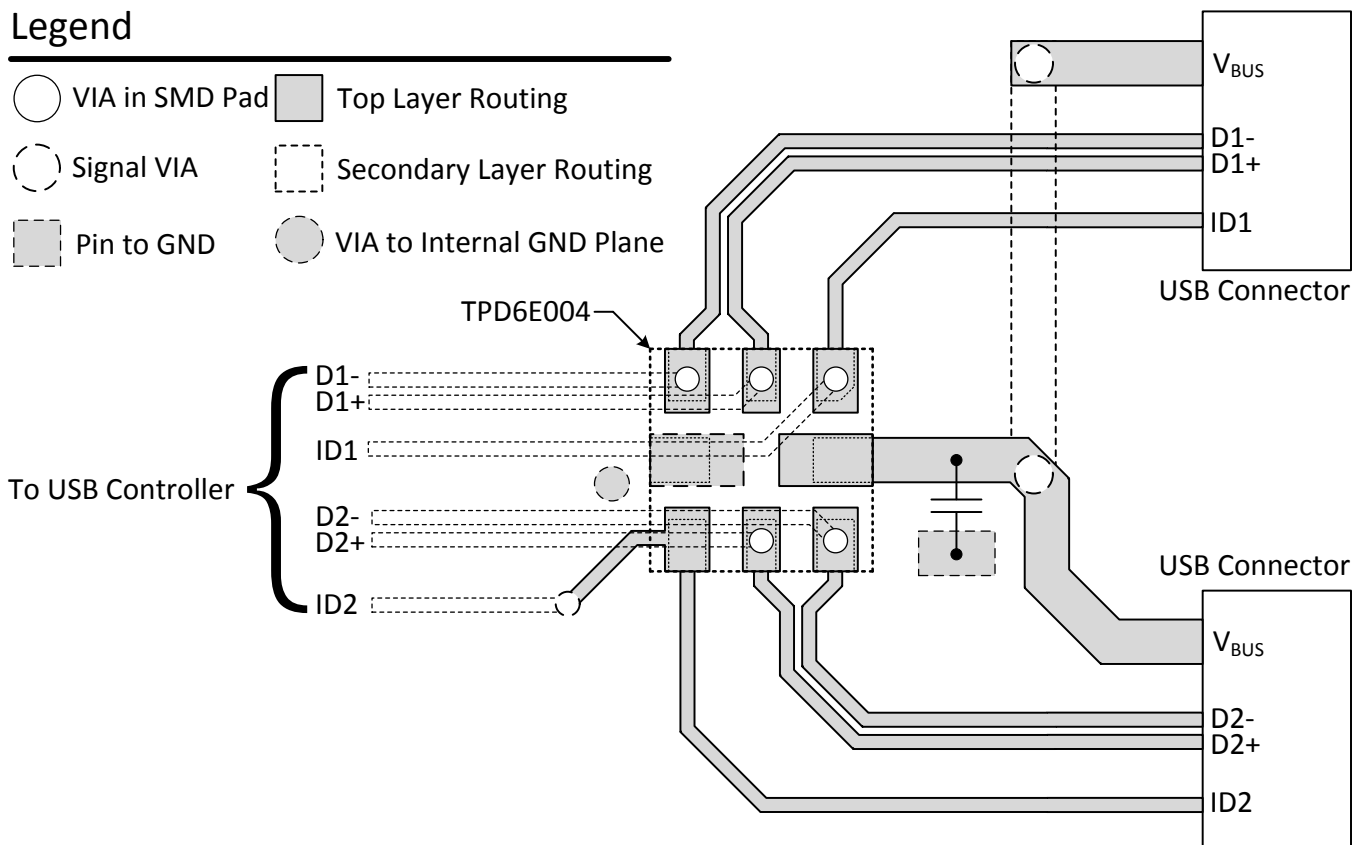
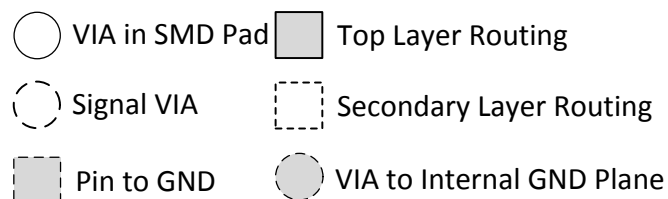
## 10 Layout

### 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 corners less than 135° on the protected traces between the TVS and the connector. Best practice is using rounded corners with the largest radii possible.
  - Electric fields tend to build up on corners, increasing EMI coupling.
- Connect the ground pin to a same layer ground pour which is connected to an internal ground plane with a VIA. Place the VIA very near the ground pin.

### 10.2 Layout Example

#### Legend



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Figure 8. TPD6E004 Layout Example for Two USB 2.0 Micro-B Connectors

## 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.

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### 11.3 Trademarks

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### 11.4 Electrostatic Discharge Caution



This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

### 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 finish/ Ball material (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
TPD6E004RSER	ACTIVE	UQFN	RSE	8	3000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 85	2V	<b>Samples</b>

(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) **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.

(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 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



### QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



\*All dimensions are nominal

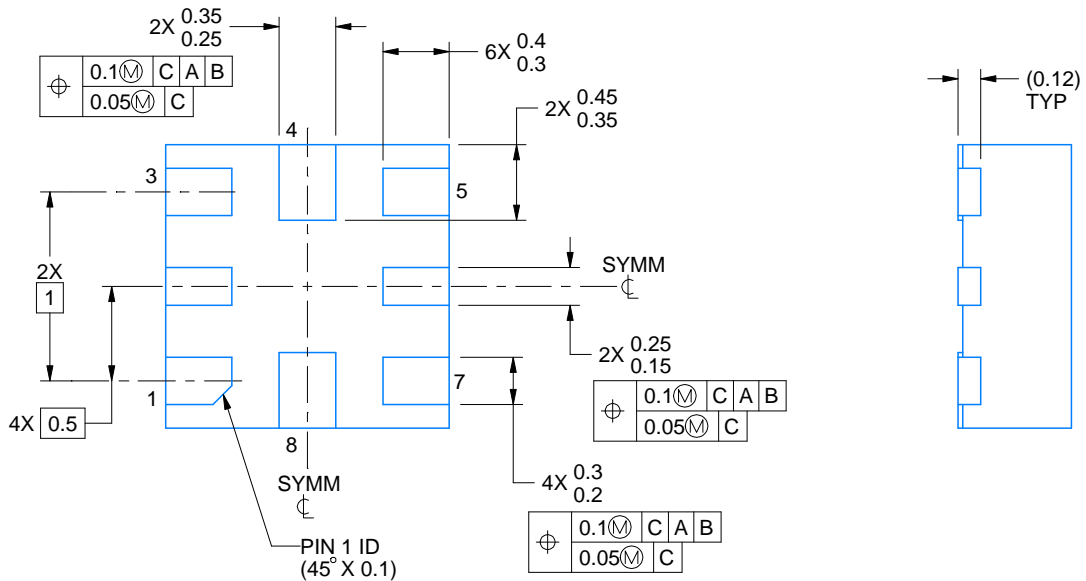
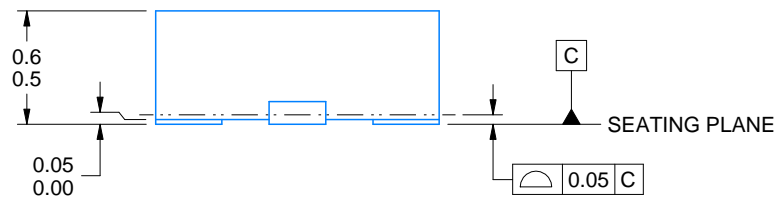
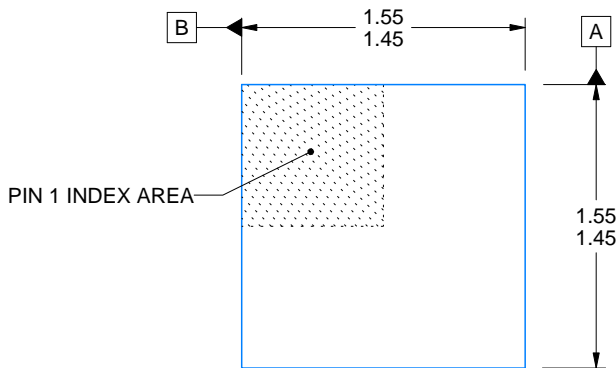
Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
TPD6E004RSER	UQFN	RSE	8	3000	180.0	9.5	1.7	1.7	0.75	4.0	8.0	Q2
TPD6E004RSER	UQFN	RSE	8	3000	179.0	8.4	1.7	1.7	0.76	4.0	8.0	Q2

TAPE AND REEL BOX DIMENSIONS



\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TPD6E004RSER	UQFN	RSE	8	3000	184.0	184.0	19.0
TPD6E004RSER	UQFN	RSE	8	3000	200.0	183.0	25.0



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NOTES:

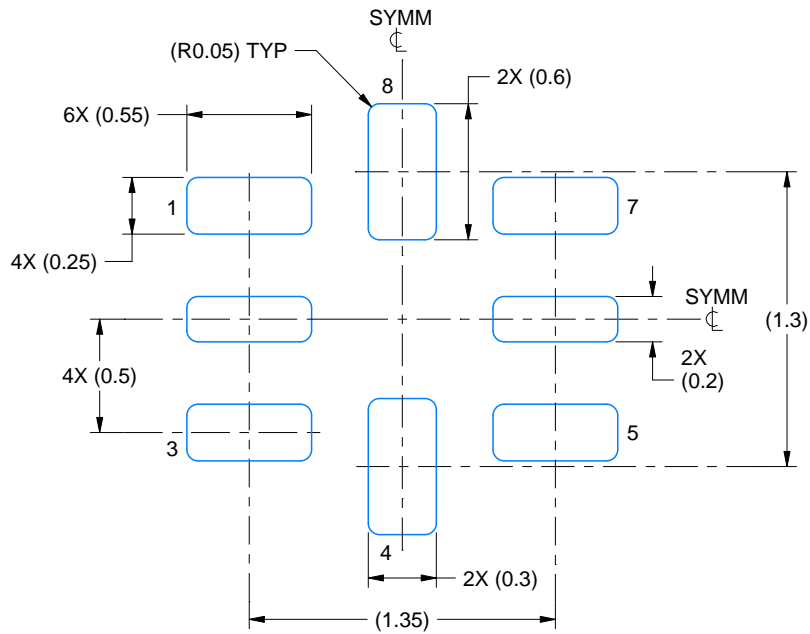
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.

# EXAMPLE BOARD LAYOUT

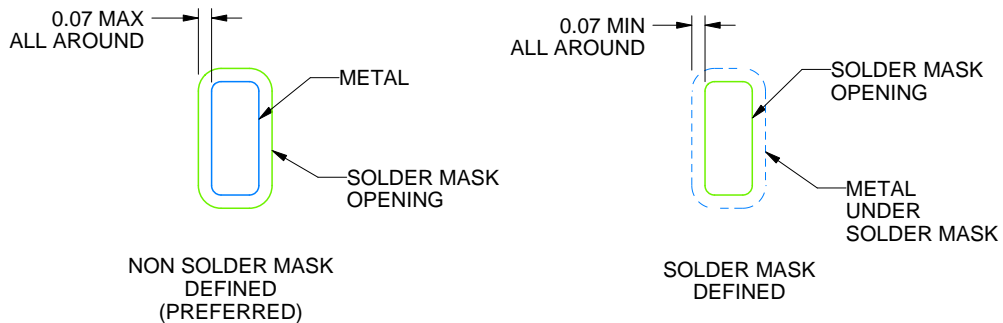
RSE0008A

UQFN - 0.6 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



LAND PATTERN EXAMPLE  
SCALE:30X



SOLDER MASK DETAILS  
NOT TO SCALE

4220323/B 03/2018

NOTES: (continued)

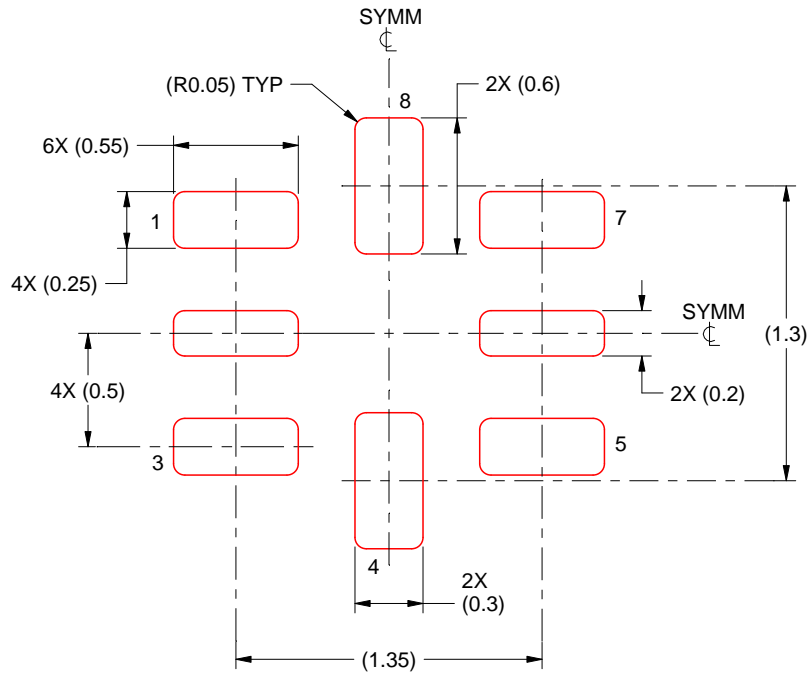
3. For more information, see Texas Instruments literature number SLUA271 ([www.ti.com/lit/slua271](http://www.ti.com/lit/slua271)).

# EXAMPLE STENCIL DESIGN

RSE0008A

UQFN - 0.6 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



SOLDER PASTE EXAMPLE  
BASED ON 0.1 mm THICKNESS  
SCALE: 30X

4220323/B 03/2018

NOTES: (continued)

5. 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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