TPD2S017 具有串联电阻器隔离功能的 2 通道、超低钳位电压 ESD 解决方案

1 特性

- 超低钳位电压可确保在 ESD 事件期间保护超低电压核心芯片组
- IEC 61000-4-2 ESD 保护
- 串联电阻器 (R = 1Ω) 匹配为 ±8mΩ（典型值）
- 差分通道输入电容匹配为 0.02pF（典型值）
- 高频下的高速数据速率和 EMI 滤波器操作（–3dB 带宽，≠3GHz）
- 采用 6 引脚小外形尺寸晶体管 [SOT-23 (DBV)] 封装
- 简易直通布线封装

2 应用

- 高速 USB
- IEEE 1394 接口
- 低电压差分信号 (LVDS)
- 移动显示数字接口 (MDDI) 和移动行业处理器接口 (MIPI)
- HS 信号

3 说明

TPD2S017 是一款双通道静电放电 (ESD) 保护器件。该保护产品在每条线路中提供两级 ESD 瞬态电压抑制 (TVS) 二极管，并具有典型的 1Ω 串联电阻器隔离。这种架构允许器件于系统级 ESD 冲击期间钳位在非常低的电压。

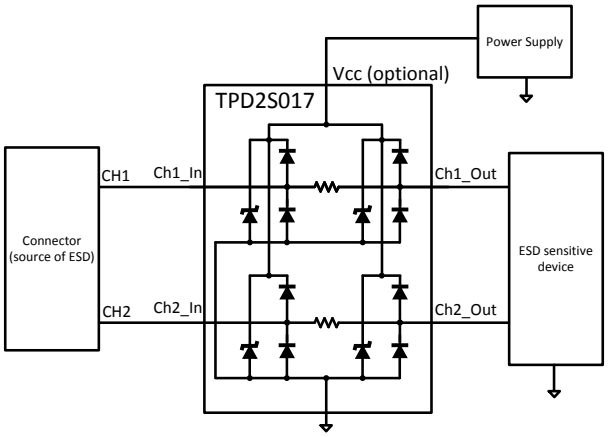
TPD2S017 符合 IEC61000-4-2 ESD 保护标准。由于串联电阻器元件，TPD2S017 可提供受控滤波器滚降，以实现更出色的杂散 EMI 抑制和信号完整性。单片器件技术允许元件值的良好匹配，包括钳位电容和差分信号对之间的串联电阻器。线路电容和串联电阻器的紧密匹配，可确保由于添加 ESD 钳位而导致的差分信号失真较小，并且还允许部件以高速差分数据速率（超过 1.5Gbps）运行。DBV 封装提供直通式引脚映射，可简化电路板布局布线。

这种 ESD 保护器件的典型应用是 USB 数据线、IEEE 1394 接口、LVDS、MDDI/MIPI 和 HS 信号的电路保护。

封装信息(1)

器件型号	封装	封装尺寸（标称值）
TPD2S017	DBV (SOT-23, 6)	2.90mm × 1.60mm

(1) 如需了解所有可用封装，请参阅数据表末尾的可订购产品附录。



应用原理图

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4 Revision History

注：以前版本的页码可能与当前版本的页码不同

Changes from Revision B (December 2015) to Revision C (Janurary 2023) **Page**

- 更新了整个文档中的表格、图和交叉参考的编号格式.....1
- Updated the maximum IO voltage for V_{IO} from *5 V* to *6 V* in the *Absolute Maximum Ratings* section.....4
- Updated the maximum operating voltage for V_{CC} from *5 V* to *5.5 V* in the *Recommended Operating Conditions* section.....4

Changes from Revision A (July 2015) to Revision B (December 2015) **Page**

- Added f = *10 MHz* to the test condition of *IO capacitance* in the *Electrical Characteristics* table 4

Changes from Revision * (September 2009) to Revision A (July 2015) **Page**

- 添加了 *引脚配置和功能* 部分、*ESD 等级* 表、*特性说明* 部分、*器件功能模式*、*应用和实施* 部分、*电源相关建议* 部分、*布局* 部分、*器件和文档支持* 部分以及 *机械、封装和可订购信息* 部分.....1

5 Pin Configuration and Functions

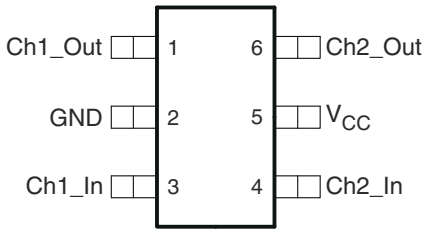


图 5-1. DBV Package
6-Pin SOT-23
Top View

表 5-1. Pin Functions

PIN		I/O	DESCRIPTION
NAME	NO.		
Ch1_In	3	I	High-speed ESD clamp input
Ch2_In	4		
Ch1_Out	1	O	High-speed ESD clamp output
Ch2_Out	6		
GND	2	—	Ground
V_{CC}	5	—	Optional power

6 Specifications

6.1 Absolute Maximum Ratings

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

		MIN	MAX	UNIT
V_{IO}	IO voltage	0	6	V
T_A	Operating temperature	– 40	85	°C
T_{stg}	Storage temperature	– 85	125	°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(1)	±15000	V
		Charged-device model (CDM), per JEDEC specification JESD22-C101(2)	±1500	
		IEC 61000-4-2 Contact Discharge	±11000	

(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 Recommended Operating Conditions

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

		MIN	NOM	MAX	UNIT
Operating free-air temperature, T_A		– 40		85	°C
Operating voltage	V_{CC}	0		5.5	V
	Ch1_In	0		V_{CC}	
	Ch2_In	0		V_{CC}	

6.4 Thermal Information

THERMAL METRIC(1)		TPD2S017 DBV (SOT-23) 6 PINS	UNIT
$R_{\theta JA}$	Junction-to-ambient thermal resistance	192.7	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	166.2	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	39.8	°C/W
ψ_{JT}	Junction-to-top characterization parameter	44.7	°C/W
ψ_{JB}	Junction-to-board characterization parameter	39.4	°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.

6.5 Electrical Characteristics

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

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
R	Series resistor			1		Ω
I_{IO}	Current from I/O pins	V_{IO} = 3 V		0.01	0.1	μA

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

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
Δ RS	Channel-to-channel resistance match	V_{IO} = 3 V		±8	±15	mΩ
V_D	Diode forward voltage for lower clamp	I_D = 8 mA	– 0.6	– 0.8	– 0.95	V
R_{DYN}	Dynamic resistance (for I/O clamp)	I = 9 A		0.8		Ω
C_{IO}	IO capacitance	V_{IO} = 2.5 V; f = 10 MHz		1		pF
V_{BR}	Break-down voltage	I_O = 1 mA	11	12		V

6.6 Dissipation Ratings

PACKAGE	$T_A \leqslant$ 25°C POWER RATING	DERATING FACTOR(1) ABOVE $T_A \leqslant$ 25°C	T_A = 70°C POWER RATING
DBV	463.18 mW	– 4.63 mW/C	254.75 mW

(1) Derating factor is defined as the inverse of the traditional junction-to-ambient thermal resistance ($R_{\theta JA}$).

6.7 Typical Characteristics

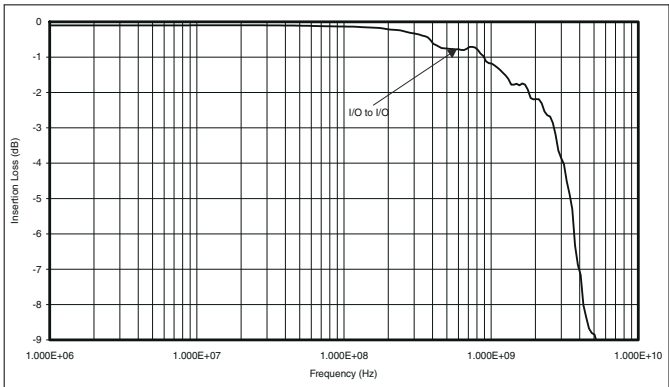


图 6-1. Insertion Loss Data (S21)

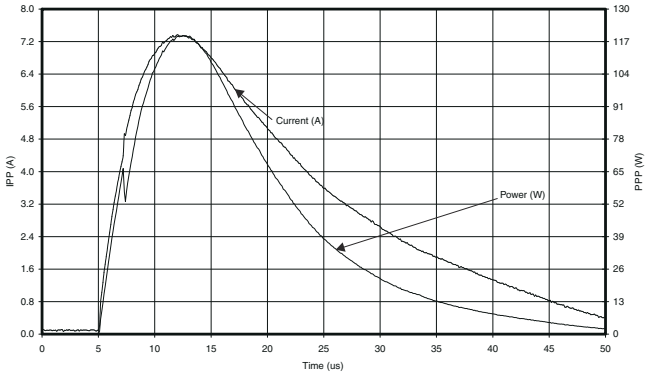


图 6-2. Peak Pulse Waveforms Ch1_Out, PUT with respect to GND, V_{CC} = 5 V

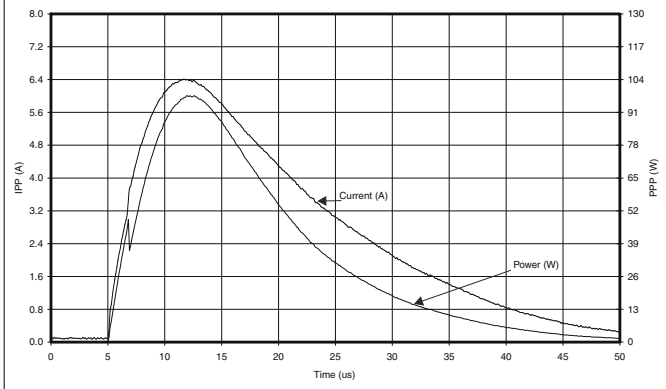


图 6-3. Peak Pulse Waveforms Ch2_In, PUT with respect to GND, V_{CC} = 5 V

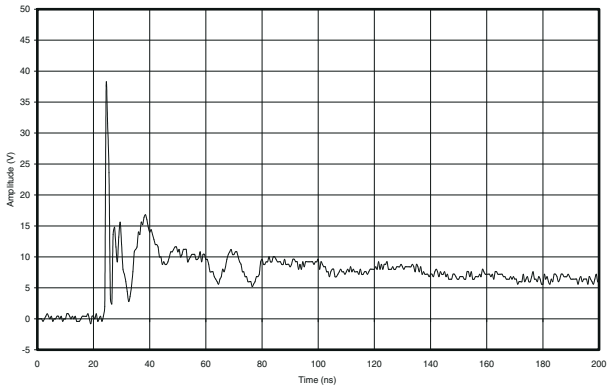


图 6-4. IEC Clamping Waveforms 8 kV Contact, 1 GHz Bandwidth

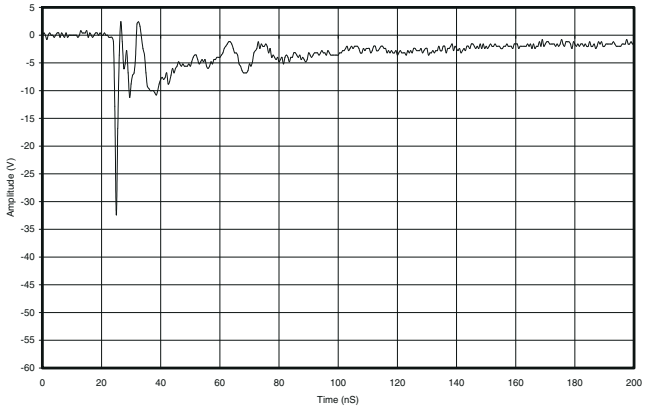


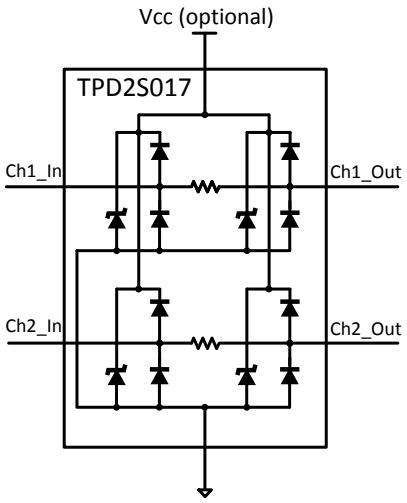
图 6-5. IEC Clamping Waveforms –8 kV Contact, 1 GHz Bandwidth

7 Detailed Description

7.1 Overview

The TPD2S017 is a two-channel ESD protection device. The two-stage ESD diodes and 1-Ω isolation resistor topology of the device gives the system very robust and good protection during ESD strikes. The TPD2S017 conforms to the IEC61000-4-2 ESD protection standard. The TPD2S017 provides a –3 dB frequency at almost 3 GHz which provides enough bandwidth for a vast majority of applications. Thanks to the monolithic silicon technology, the tight matching of the line capacitances and series resistances ensures a minimum distorted differential signal and a high operating differential data rate. The DBV package offers a flow-through pin mapping for ease of board layout.

7.2 Functional Block Diagram



7.3 Feature Description

Each channel of the TPD2S017 device has a topology of two-stage clamps with isolation resistor. This topology optimizes the clamping performance while supporting a high bandwidth. Due to the low clamping voltage, the down stream circuits that connect to the output of the channels are well-protected. The high IEC 61000-4-2 level ensures the system's robustness during the ESD events. The good matching of the resistor and capacitance values will yield minimal distortion of the signals. The low resistance and capacitance values make sure that this device supports a high differential data rate. The flow-through pinout ensures no additional layout burden on the printed circuit board (PCB).

7.4 Device Functional Modes

The TPD2S017 device stays passive and has low leakage during normal operation when the voltage at the input of each channel is from 0 V to V_{CC} and activates when that voltage exceeds one forward diode drop above V_{CC} or below ground. During IEC ESD events, contact transient voltages as high as ±11 kV can be suppressed. When the voltages on the protected lines fall below the trigger voltage, the device reverts back to the low leakage passive state.

8 Application and Implementation

备注

以下应用部分中的信息不属于 TI 器件规格的范围，TI 不担保其准确性和完整性。TI 的客 户应负责确定器件是否适用于其应用。客户应验证并测试其设计，以确保系统功能。

8.1 Application Information

When a system contains a human interface connector, it becomes vulnerable to large system-level ESD strikes that standard ICs cannot survive. Protection products are typically used to suppress ESD at these connectors. TPD2S017 is a two-channel ESD protection device. In each channel, it contains two-stage TVS diodes and a resistor between the two clamping stages as an isolation. This implementation provides good clamping performance, minimal signal distortion and the support of high data speed.

8.2 Typical Application

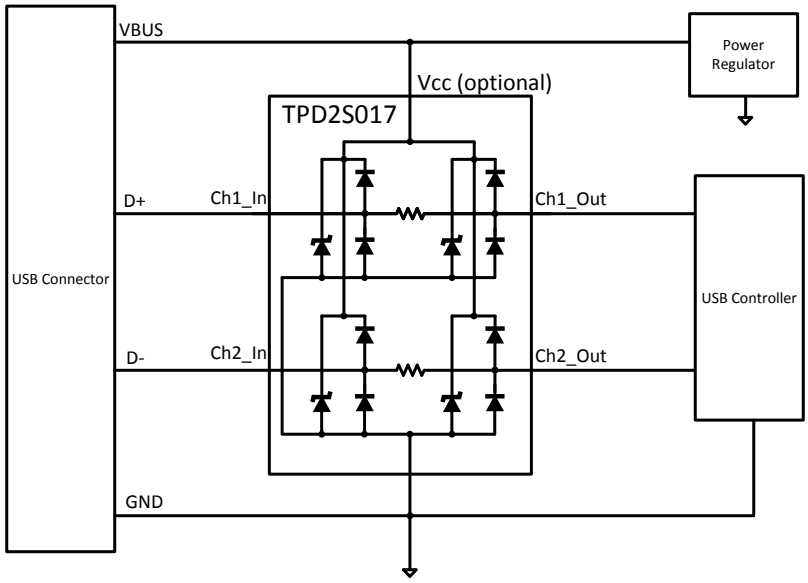


图 8-1. Typical Application Schematic

8.2.1 Design Requirements

For this design example, a TPD2S017 will be used to protect the USB 2.0 high-speed data lines. The following system parameters are known.

表 8-1. Design Parameters

DESIGN PARAMETER	VALUE
High-speed mode high-level output voltage	400 mV ±10%
High-speed mode low-level output voltage	0 V ± 10 mV
USB 2.0 high-speed data rate	480 Mbps
Required IEC 61000-4-2 ESD Protection	±8 kV Contact

8.2.2 Detailed Design Procedure

To begin the design process, some parameters must be decided upon; the designer should make sure:

- Voltage range on the protected lines must not go beyond one forward diode drop above the V_{CC} and must no go below one forward diode drop below the ground.
- Operating frequency is supported by the IO capacitance C_{IO}.
- IEC 61000-4-2 protection requirement is covered by the IEC performance of the TVS diode.

For this application, a high speed USB 2.0 signal that ranges from –10 mV to 440 mV will be applied to each line. Connect a 5 V power supply to V_{CC} pin; therefore, the signal will not fall outside of the normal operation range and the TPD2S017 will stay passive and low leakage during normal operation.

Next, consider the data rate of this signal and ensure that the TVS I/O capacitance will not distort this signal by filtering it. The speed of a USB 2.0 high-speed signal is 480 Mbit/s. With TPD2S017's ultra low IO capacitance, this device can support 1.5 Gbit/s data rate and thus can pass USB 2.0 high-speed signal with minimal distortion.

Finally, TPD2S017 is rated for the IEC 61000-4-2 (Level 4) so it provides sufficient system-level ESD protection to the human interface in this application. See *节 10.2* for instructions on properly laying out TPD2S017.

8.2.3 Application Curves

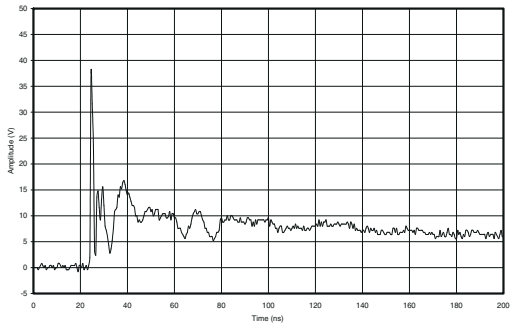


图 8-2. IEC Clamping Waveforms 8 kV Contact, 1 GHz Bandwidth

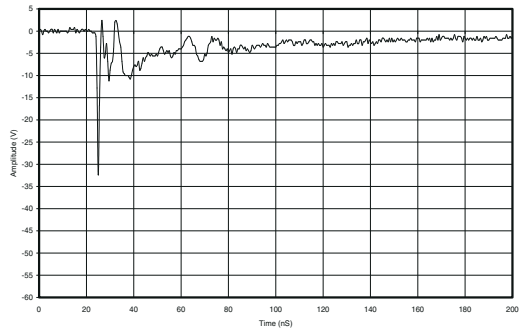


图 8-3. IEC Clamping Waveforms −8 kV Contact, 1 GHz Bandwidth

9 Power Supply Recommendations

The optional V_{CC} power supply bias is recommended to lower the I/O capacitances. Ensure 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 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.
- Use thick and short traces for the power and ground paths.
- Run differential signal lines in pair with small distance to optimize signal integrity.

10.2 Layout Example

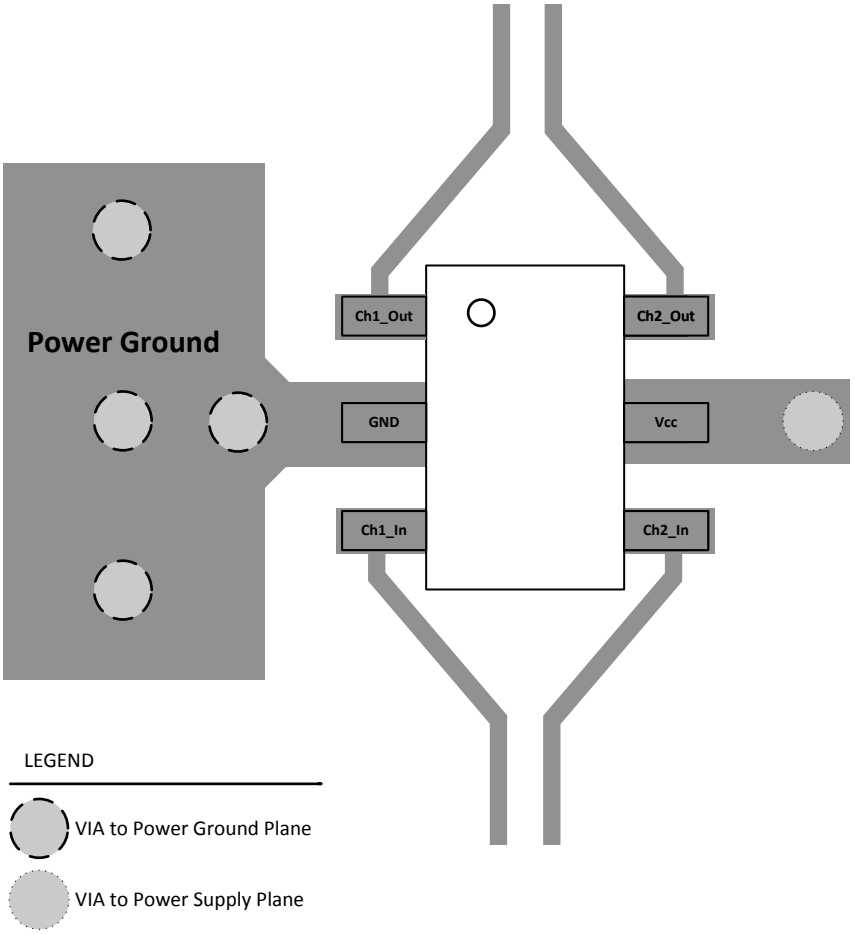


图 10-1. Layout Recommendation

11 Device and Documentation Support

11.1 接收文档更新通知

要接收文档更新通知，请导航至 ti.com 上的器件产品文件夹。点击 *订阅更新* 进行注册，即可每周接收产品信息更改摘要。有关更改的详细信息，请查看任何已修订文档中包含的修订历史记录。

11.2 支持资源

TI E2E™ 支持论坛是工程师的重要参考资料，可直接从专家获得快速、经过验证的解答和设计帮助。搜索现有解答或提出自己的问题可获得所需的快速设计帮助。

链接的内容由各个贡献者“按原样”提供。这些内容并不构成 TI 技术规范，并且不一定反映 TI 的观点；请参阅 TI 的《使用条款》。

11.3 Trademarks

TI E2E™ is a trademark of Texas Instruments.
所有商标均为其各自所有者的财产。

11.4 静电放电警告

静电放电 (ESD) 会损坏这个集成电路。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 术语表

TI 术语表　　本术语表列出并解释了术语、首字母缩略词和定义。

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
TPD2S017DBVR	ACTIVE	SOT-23	DBV	6	3000	RoHS & Green	SN	Level-1-260C-UNLIM	-40 to 85	NFT	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) **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.

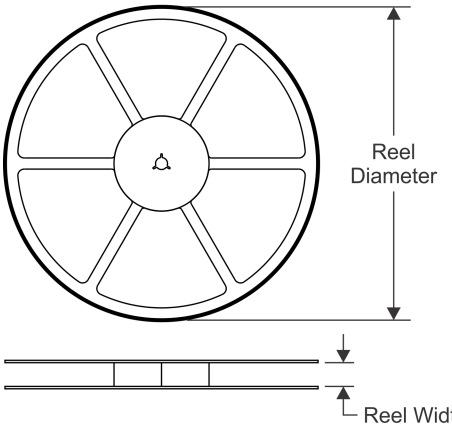
(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(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.

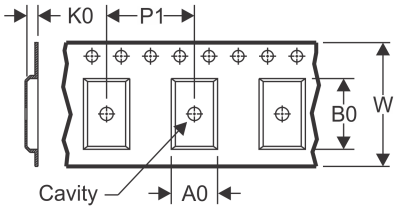
(6) Lead finish/Ball material - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

TAPE AND REEL INFORMATION

REEL DIMENSIONS

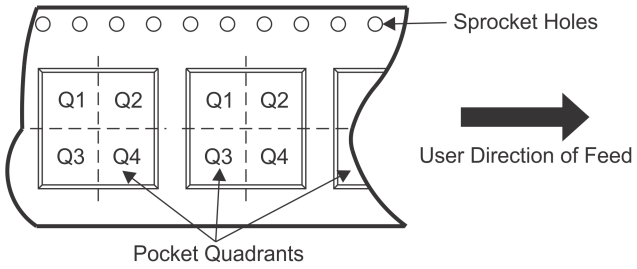


TAPE DIMENSIONS



A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

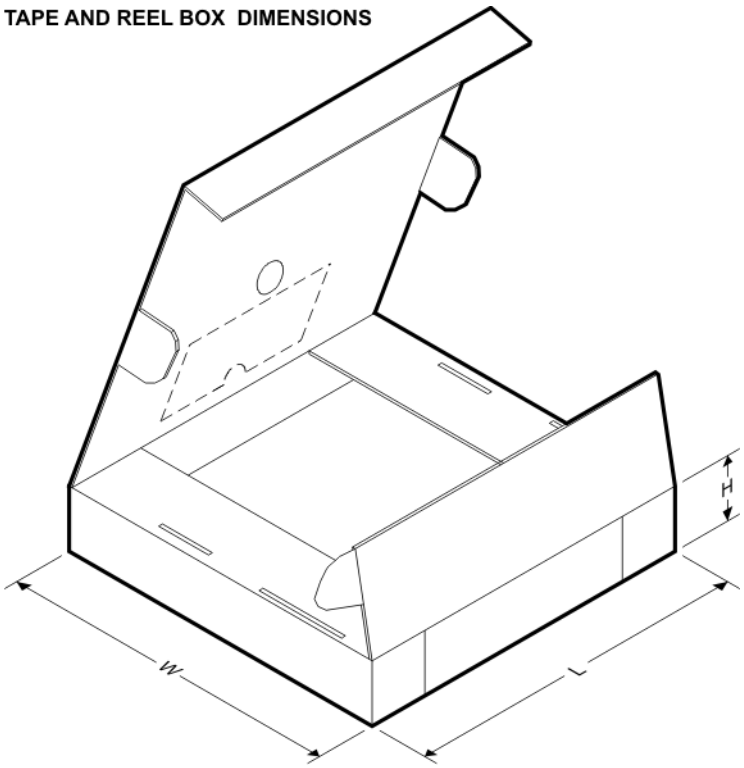
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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
TPD2S017DBVR	SOT-23	DBV	6	3000	178.0	9.0	3.23	3.17	1.37	4.0	8.0	Q3

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

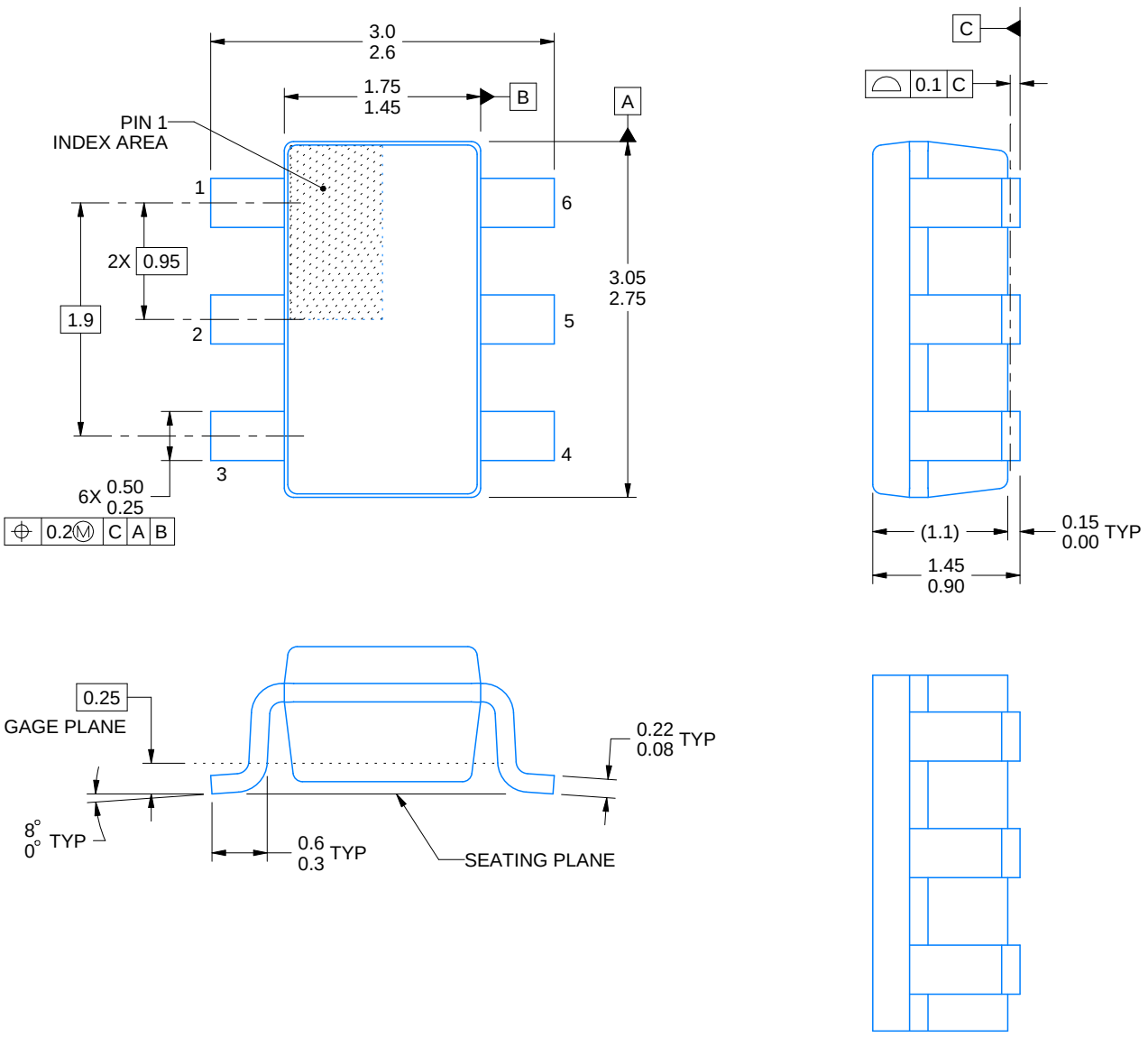
Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TPD2S017DBVR	SOT-23	DBV	6	3000	180.0	180.0	18.0

PACKAGE OUTLINE

DBV0006A

SOT-23 - 1.45 mm max height

SMALL OUTLINE TRANSISTOR

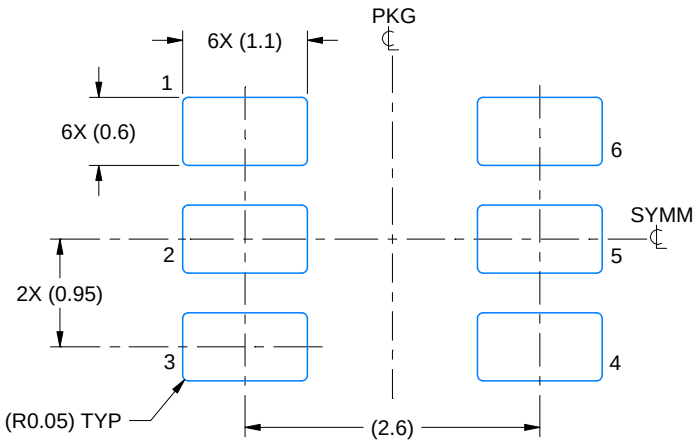


ALTERNATIVE PACKAGE SINGULATION VIEW

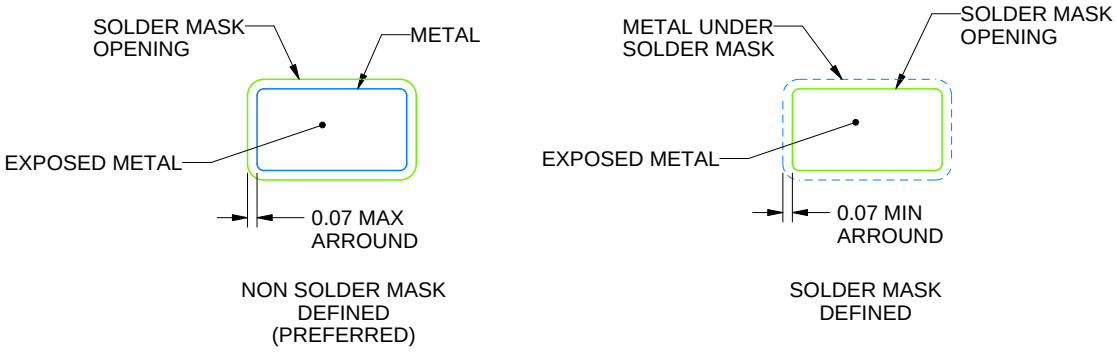
4214840/F 05/2024

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.
3. Body dimensions do not include mold flash or protrusion. Mold flash and protrusion shall not exceed 0.25 per side.
4. Leads 1,2,3 may be wider than leads 4,5,6 for package orientation.
5. Refernce JEDEC MO-178.



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:15X



SOLDER MASK DETAILS

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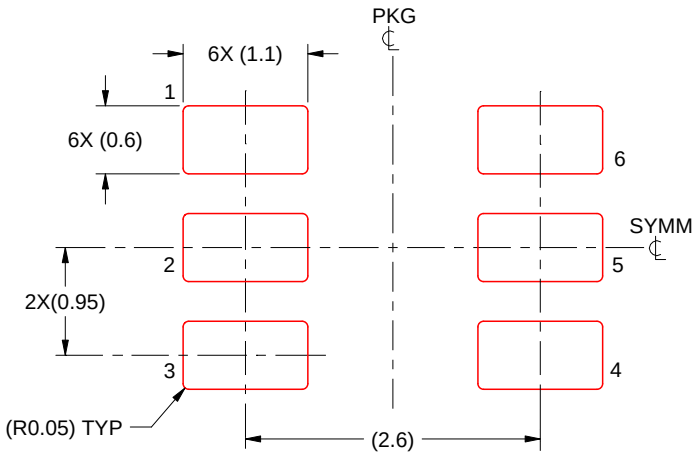
NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.



SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL
SCALE:15X

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NOTES: (continued)

8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.

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