TPD4E1B06 4-Channel Ultra Low Leakage ESD Protection Device

1 Features
- Ultra Low Leakage Current 0.5 nA (Max)
- Transient Protection for 4 I/O Lines
  - IEC 61000-4-2 Contact Discharge ±12 kV
  - IEC 61000-4-2 Air-Gap Discharge ±15 kV
  - IEC 61000-4-5 Surge 3.0 A (8/20 µs)
- I/O Capacitance 0.7 pF (Typ)
- Bi-directional TVS Diode Array
- Low ESD Clamping Voltage
- Industrial Temperature Range: –40°C to 125°C
- Small, Easy-to-Route DRL and DCK Packages

2 Applications
- Glucose Meter
- Tablets
- GPS
- Portable Media Players
- TV
- Set-top Box

3 Description
The TPD4E1B06 is a 4-channel bi-directional Transient Voltage Suppressor (TVS) diode array. This device features ultra low leakage current (0.5 nA) for precision analog measurements. The ±12 kV contact and ±15 kV air gap ESD protection exceeds IEC 61000-4-2 level 4 requirements. The TPD4E1B06’s 0.7 pF line capacitance makes it suitable for precision analog, USB2.0, Ethernet, SATA, LVDS, and 1394 interfaces.

4 Simplified Schematic

Device Information(1)

<table>
<thead>
<tr>
<th>PART NUMBER</th>
<th>PACKAGE</th>
<th>BODY SIZE (NOM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPD4E1B06</td>
<td>SC70 (6)</td>
<td>2.00 mm × 2.10 mm</td>
</tr>
<tr>
<td></td>
<td>SOT (6)</td>
<td>1.60 mm x 1.60 mm</td>
</tr>
</tbody>
</table>

(1) For all available packages, see the orderable addendum at the end of the datasheet.
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5 Revision History

Changes from Revision B (May 2014) to Revision C Page 8

  • Changed 2 device names from TPD4E6B06 to TPD4E1B06 ................................................................. 8

Changes from Revision A (January 2013) to Revision B Page 4

  • Added DRL package to datasheet ................................................................. 1
  • Changed $I_{pp}$, peak pulse current from 3.5 A to 3.0 A .................................................. 4
  • Added Handling Ratings table. ................................................................. 4
  • Added Recommended Operating Conditions table ........................................... 4
  • Changed Electrical Characteristics table to reflect operating conditions at 25 °C ........................................... 4
  • Added MIN $V_{RWM}$ value of $-5.5$ V ............................................................... 4
  • Changed $V_{CLAMP}$ at $I_{pp} = 1$ A from 10.5 V to 10.9 V ........................................... 4
  • Changed Line Capacitance TYP value from 1 pF to 0.7 pF ........................................... 4
  • Added Line Capacitance MAX value of 0.95 pF .................................................. 4
  • Changed $I_{LEAK}$ from MAX of 10 nA to 0.5 nA .................................................. 4

Changes from Original (December 2012) to Revision A Page 4

  • Fixed "f" units typo from GHz to MHz for $C_{L}$ parameter in ELECTRICAL CHARACTERISTICS table ........................................... 4
6 Pin Configuration and Functions

<table>
<thead>
<tr>
<th>PIN</th>
<th>NAME</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>IO1</td>
<td>1</td>
<td>ESD protected channel. Connect to data line as close to the connector as possible.</td>
</tr>
<tr>
<td>IO2</td>
<td>2</td>
<td>ESD protected channel. Connect to data line as close to the connector as possible.</td>
</tr>
<tr>
<td>IO3</td>
<td>4</td>
<td>ESD protected channel. Connect to data line as close to the connector as possible.</td>
</tr>
<tr>
<td>IO4</td>
<td>5</td>
<td>ESD protected channel. Connect to data line as close to the connector as possible.</td>
</tr>
<tr>
<td>GND</td>
<td>3</td>
<td>Ground</td>
</tr>
<tr>
<td>NC</td>
<td>6</td>
<td>Not internally connected</td>
</tr>
</tbody>
</table>

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# Specifications

## 7.1 Absolute Maximum Ratings

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

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>MIN</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating temperature range</td>
<td>−40°C</td>
<td>125°C</td>
<td>°C</td>
</tr>
<tr>
<td>I\text{PP}, peak pulse current (tp = 8/20 μs), IO pin to GND</td>
<td>3.0 A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P\text{PP}, peak pulse power (tp = 8/20 μs)</td>
<td>45 W</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## 7.2 Handling Ratings

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>MIN</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>T\text{stg}</td>
<td>−65°C</td>
<td>155°C</td>
<td>°C</td>
</tr>
<tr>
<td>V\text{(ESD)}</td>
<td>−4.0 kV</td>
<td>4.0 kV</td>
<td>kV</td>
</tr>
</tbody>
</table>

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process. Pins listed as 4 kV may actually have higher performance.

(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process. Pins listed as 1.5 kV may actually have higher performance.

## 7.3 Recommended Operating Conditions

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

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>MIN</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>V\text{IO}</td>
<td>−5.5 V</td>
<td>5.5 V</td>
<td>V</td>
</tr>
<tr>
<td>T\text{A}</td>
<td>−40°C</td>
<td>125°C</td>
<td>°C</td>
</tr>
</tbody>
</table>

## 7.4 Thermal Information

<table>
<thead>
<tr>
<th>THERMAL METRIC\textsuperscript{(1)}</th>
<th>TPD4E1B06 DCK</th>
<th>DRL</th>
</tr>
</thead>
<tbody>
<tr>
<td>R\text{JA}</td>
<td>Junction-to-ambient thermal resistance</td>
<td>227.3°C/W</td>
</tr>
<tr>
<td>R\text{JC(top)}</td>
<td>Junction-to-case (top) thermal resistance</td>
<td>79.5°C/W</td>
</tr>
<tr>
<td>R\text{JB}</td>
<td>Junction-to-board thermal resistance</td>
<td>72.1°C/W</td>
</tr>
<tr>
<td>\text{\psi}_\text{JT}</td>
<td>Junction-to-top characterization parameter</td>
<td>3.6°C/W</td>
</tr>
<tr>
<td>\text{\psi}_\text{JB}</td>
<td>Junction-to-board characterization parameter</td>
<td>70.4°C/W</td>
</tr>
</tbody>
</table>

(1) For more information about traditional and new thermal metrics, see the IC Package Thermal Metrics application report, SPRA953.

## 7.5 Electrical Characteristics

T\text{A} = 25°C

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TEST CONDITION</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>V\text{RWM}</td>
<td>Reverse stand-off voltage</td>
<td>−5.5</td>
<td>5.5 V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>V\text{CLAMP}</td>
<td>Clamp voltage with ESD strike, IO to GND</td>
<td>\text{I}_{\text{PP}} = 1 A, \text{tp} = 8/20 μSec, from I/O to GND or GND to I/O</td>
<td>10.9 V</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>\text{I}_{\text{PP}} = 3 A, \text{tp} = 8/20 μSec, from I/O to GND or GND to I/O</td>
<td>14.5 V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R\text{DYN}</td>
<td>Dynamic resistance</td>
<td>\text{I}_{\text{TLP}} = 10 A to 20 A, I/O to GND</td>
<td>1 Ω</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>\text{I}_{\text{TLP}} = 10 A to 20 A, GND to I/O</td>
<td>0.8 Ω</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C\text{L}</td>
<td>Line capacitance</td>
<td>f = 1 MHz, V\text{BIAS} = 2.5 V</td>
<td>0.7 pF</td>
<td>0.95 pF</td>
<td>pF</td>
</tr>
<tr>
<td>V\text{BR}</td>
<td>Break-down voltage</td>
<td>\text{I}_{\text{IO}} = 1 mA, from I/O to GND or GND to I/O</td>
<td>7 V</td>
<td>9.5 V</td>
<td></td>
</tr>
<tr>
<td>I\text{LEAK}</td>
<td>Leakage current</td>
<td>V\text{IO} = 2.5 V</td>
<td>0.5 nA</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Product Folder Links: TPD4E1B06
7.6 Typical Characteristics

Figure 1. DC Voltage Sweep I-V Curve

Figure 2. Surge Curve (tp = 8/20 μs), Pin IO to GND

Figure 3. TLP Plot IO to GND

Figure 4. Leakage vs Temperature

Figure 5. +8 kV IEC Waveform

Figure 6. –8 kV IEC Waveform
Typical Characteristics (continued)

![Figure 7. Insertion Loss](image1)

![Figure 8. Capacitance vs V\textsubscript{BIAS}](image2)
8 Detailed Description

8.1 Overview

The TPD4E1B06 is a 4-channel bi-directional Transient Voltage Suppressor (TVS) diode array. This device features ultra low leakage current (0.5 nA) for precision analog measurements. The ±12 kV contact and ±15 kV air gap ESD protection exceeds IEC 61000-4-2 level 4 requirements. The TPD4E1B06's 0.7 pF line capacitance makes it suitable for precision analog, USB2.0, Ethernet, SATA, LVDS, and 1394 interfaces.

8.2 Functional Block Diagram

8.3 Feature Description

8.3.1 Ultra low Leakage Current 0.5 nA (Max)

TPD4E1B06 ultra-low leakage current supports long battery life and allows for precision analog measurements.

8.3.2 Transient Protection for 4 I/O Lines

The four I/O pins of TPD4E1B06 can withstand ESD events up to ±12 kV contact and ±15 kV air gap per IEC61000-4-2.

8.3.3 I/O Capacitance 0.7 pF (Typ)

TPD4E1B06 I/O pins present an ultra-low 0.7 pF capacitance to the protected signal lines, making it suitable for a wide range of applications.

8.3.4 Bi-directional TVS diode array

TPD4E1B06 diode array structure uses back to back diode topology to accommodate bi-directional signaling between –5.5 V and 5.5 V.

8.3.5 Low ESD Clamping Voltage

TPD4E1B06 clamps ESD events to a safe level to protect system components.

8.4 Device Functional Modes

TPD4E1B06 is a passive integrated circuit that activates whenever fast transient voltages above \( V_{BR} \) or below \( -V_{BR} \) are present on the circuit being protected. During ESD events, voltages as high as ±12 kV can be directed to ground via the internal diode network. Once the voltages on the protected line fall below the trigger levels of TPD4E1B06 (usually within 10’s of nano-seconds) the device reverts to passive.
9 Application and Implementation

9.1 Application Information
TPD4E1B06 is a TVS diode array 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 diode, only a small voltage drop is present across the diode. This is the voltage presented to the protected IC. The low $R_{\text{DYN}}$ of the triggered TVS holds this voltage, $V_{\text{CLAMP}}$, to a safe level to the protected IC.

9.2 Typical Application

![Figure 9. Protecting a Pair of Bi-Directional Differential Data Lines](image)

The typical application of the TPD4E1B06 is to be placed in between the connector and the system. The low capacitance of the TPD4E1B06 gives flexibility in the end application, as it can be used on many different high speed interfaces.

9.2.1 Design Requirements

<table>
<thead>
<tr>
<th>DESIGN PARAMETER</th>
<th>EXAMPLE VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signal range on IO1, IO2, IO3, IO4 Pins</td>
<td>–5.5 V to 5.5 V</td>
</tr>
<tr>
<td>Operating frequency</td>
<td>1.7 GHz</td>
</tr>
</tbody>
</table>

9.2.2 Detailed Design Procedure

The designer needs to know the following:

- Signal range on all the protected lines
- Operating frequency

9.2.2.1 Signal Range on IO1, IO2, IO3, and IO4 Pins
TPD4E1B06 has 4 protection channels for signal lines. Any I/O will support a signal range of –5.5 V to 5.5 V.

9.2.2.2 Operating Frequency
The 0.7 pF capacitance of each I/O channel supports data rates up to 3.4 Gbps.
9.2.3 Application Curves

Figure 10. 3.4 Gbps HDMI 1.4 Eye Diagram in DCK Package
10 Layout

10.1 Layout Guidelines

- Place the device 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 should 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 Examples

Figure 11 shows a layout example for the TPD4E1B06DCK. Pins 1 & 2 and 4 & 5 are routed differentially. Pin 3 is routed to the ground plane. Pin 6 does not have an internal connection in the device and does not need to be routed anywhere on the board. It is also acceptable to connect pin 6 to the ground plane.

Figure 11. DCK Layout Example Showing Two Data Pairs, D0 and D1

Figure 12 shows a layout example for the TPD4E1B06DRL. Pins 1 & 6 and 3 & 4 are routed differentially. Pin 2 is routed to the ground plane. Pin 5 does not have an internal connection in the device and does not need to be routed anywhere on the board. It is also acceptable to connect pin 5 to the ground plane.

Figure 12. DRL Layout Example Showing Two Data Pairs, D0 and D1
11 Device and Documentation Support

11.1 Trademarks
All trademarks are the property of their respective owners.

11.2 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.

11.3 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

<table>
<thead>
<tr>
<th>Orderable Device</th>
<th>Status</th>
<th>Package Type</th>
<th>Package Drawing</th>
<th>Pins</th>
<th>Package Qty</th>
<th>Eco Plan</th>
<th>Lead/Ball Finish</th>
<th>MSL Peak Temp</th>
<th>Op Temp (°C)</th>
<th>Device Marking</th>
<th>Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPD4E1B06DCKR</td>
<td>ACTIVE</td>
<td>SC70</td>
<td>DCK</td>
<td>6</td>
<td>3000</td>
<td>Green (RoHS &amp; no Sb/Br)</td>
<td>NIPDAU</td>
<td>Level-1-260C-UNLIM</td>
<td>-40 to 125</td>
<td>BYP</td>
<td></td>
</tr>
<tr>
<td>TPD4E1B06DRLR</td>
<td>ACTIVE</td>
<td>SOT-5X3</td>
<td>DRL</td>
<td>6</td>
<td>4000</td>
<td>Green (RoHS &amp; no Sb/Br)</td>
<td>NIPDAU</td>
<td>NIPDAUAG</td>
<td>Level-1-260C-UNLIM</td>
<td>-40 to 125</td>
<td>(BYG, BYH)</td>
</tr>
</tbody>
</table>

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/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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In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.
TAPE AND REEL INFORMATION

<table>
<thead>
<tr>
<th>Device</th>
<th>Package Type</th>
<th>Package Drawing</th>
<th>Pins</th>
<th>SPQ</th>
<th>Reel Diameter (mm)</th>
<th>Reel Width W1 (mm)</th>
<th>A0 (mm)</th>
<th>B0 (mm)</th>
<th>K0 (mm)</th>
<th>P1 (mm)</th>
<th>W (mm)</th>
<th>Pin1 Quadrant</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPD4E1B06DCKR</td>
<td>SC70</td>
<td>DCK</td>
<td>6</td>
<td>3000</td>
<td>178.0</td>
<td>8.4</td>
<td>2.4</td>
<td>2.5</td>
<td>1.2</td>
<td>4.0</td>
<td>8.0</td>
<td>Q3</td>
</tr>
<tr>
<td>TPD4E1B06DRLR</td>
<td>SOT-5X3</td>
<td>DRL</td>
<td>6</td>
<td>4000</td>
<td>180.0</td>
<td>8.4</td>
<td>1.98</td>
<td>1.78</td>
<td>0.69</td>
<td>4.0</td>
<td>8.0</td>
<td>Q3</td>
</tr>
</tbody>
</table>

*All dimensions are nominal.*
### TAPE AND REEL BOX DIMENSIONS

*All dimensions are nominal

<table>
<thead>
<tr>
<th>Device</th>
<th>Package Type</th>
<th>Package Drawing</th>
<th>Pins</th>
<th>SPQ</th>
<th>Length (mm)</th>
<th>Width (mm)</th>
<th>Height (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPD4E1B06DCKR</td>
<td>SC70</td>
<td>DCK</td>
<td>6</td>
<td>3000</td>
<td>180.0</td>
<td>180.0</td>
<td>18.0</td>
</tr>
<tr>
<td>TPD4E1B06DRLR</td>
<td>SOT-5X3</td>
<td>DRL</td>
<td>6</td>
<td>4000</td>
<td>183.0</td>
<td>183.0</td>
<td>20.0</td>
</tr>
</tbody>
</table>
NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion. Mold flash and protrusion shall not exceed 0.15 per side.
D. Falls within JEDEC MO-203 variation AB.
NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Customers should place a note on the circuit board fabrication drawing not to alter the center solder mask defined pad.
D. Publication IPC-7351 is recommended for alternate designs.
E. 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. Example stencil design based on a 50% volumetric metal load solder paste. Refer to IPC-7525 for other stencil recommendations.
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. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.
NOTES: (continued)

4. Publication IPC-7351 may have alternate designs.
5. Solder mask tolerances between and around signal pads can vary based on board fabrication site.
NOTES: (continued)

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