TPD13S523 13-Channel ESD Protection Solution With Current-Limit Load Switch For HDMI Transmitter Ports

1 Features

- IEC 61000-4-2 Level 4 Contact ESD Protection
  - ±12-kV Contact Discharge on External Lines
- Single-Chip ESD Solution for HDMI 1.4 and HDMI 1.3 Interface
- On-Chip 5-V Load Switch With Current Limit and Reverse Current Protection
- Supports UTILITY Line Protection for HDMI 1.4 Audio Return Line
- <0.05-pF Differential Capacitance Between the TMDS Signal Pair
- Industry Standard 16-TSSOP and Space-Saving 16-RSV Package
- Supports Data Rates in Excess of 3.4 Gbps
- \( R_{\text{DYN}} = 0.5 \, \Omega \) (Typical)
- Commercial Temperature Range: –40°C to 85°C

2 Applications

- End Equipment
  - Set Top Boxes
  - E-Books
  - Tablets
  - Smart Phones
  - Camcorders
- Interfaces
  - HDMI

3 Description

The TPD13S523 device is a single-chip integrated IEC 61000-4-2 ESD protection solution for HDMI 1.4 or HDMI 1.3 interfaces. This device offers 13 channels of TVS diodes with flow-through pin mapping that matches HDMI connector high-speed lines. While providing ESD protection, the TPD13S523 adds little to no additional distortion to the high-speed differential signals. The monolithic integrated circuit technology ensures that there is excellent matching between the two-signal pair of the differential line (< 0.05-pF differential matching between TMDS lines). This offers an advantage over discrete ESD solutions where variations between two different ESD protection circuits may significantly degrade the differential signal quality.

The TPD13S523 incorporates an on-chip current limited load switch that is compliant with HDMI 5-V out electrical specifications. The short-circuit protection at 5V_OUT ensures that the device is not damaged in case there is an accidental short to GND. The load switch also incorporates a reverse-current blocking feature which ensures that the HDMI driver side is not erroneously turned on when two HDMI drivers are connected together.

Typical applications for the TPD13S523 include set top boxes (STB), e-books, tablets, smart phones, and camcorders.

Device Information(1)

<table>
<thead>
<tr>
<th>PART NUMBER</th>
<th>PACKAGE</th>
<th>BODY SIZE (NOM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPD13S523</td>
<td>TSSOP (16)</td>
<td>5.00 mm × 4.40 mm</td>
</tr>
<tr>
<td></td>
<td>UQFN (16)</td>
<td>2.60 mm × 1.80 mm</td>
</tr>
</tbody>
</table>

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

An IMPORTANT NOTICE at the end of this data sheet addresses availability, warranty, changes, use in safety-critical applications, intellectual property matters and other important disclaimers. PRODUCTION DATA.
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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 C (June 2015) to Revision D Page
• Added table note to Absolute Maximum Ratings ......................... 4
• Added test condition frequency to capacitance ............................. 5

Changes from Revision B (December 2012) to Revision C Page
• Added 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

Changes from Revision A (May 2012) to Revision B Page
• Added RSV package to ORDERING INFORMATION table............. 1
• Removed PREVIEW status from RSV package............................ 3
5 Pin Configuration and Functions

### Pin Functions

<table>
<thead>
<tr>
<th>PIN</th>
<th>I/O</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NAME</strong></td>
<td><strong>UQFN</strong></td>
<td><strong>TSSOP</strong></td>
</tr>
<tr>
<td>CTRL1</td>
<td>15</td>
<td>1</td>
</tr>
<tr>
<td>CTRL2</td>
<td>16</td>
<td>2</td>
</tr>
<tr>
<td>CTRL3</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>CTRL4</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>CTRL5</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>5V_SUPPLY</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>5V_OUT</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>GND</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>D0+</td>
<td>14</td>
<td>16</td>
</tr>
<tr>
<td>D0–</td>
<td>13</td>
<td>15</td>
</tr>
<tr>
<td>D1+</td>
<td>12</td>
<td>14</td>
</tr>
<tr>
<td>D1–</td>
<td>11</td>
<td>13</td>
</tr>
<tr>
<td>D2+</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>D2–</td>
<td>9</td>
<td>11</td>
</tr>
<tr>
<td>D3+</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>D3–</td>
<td>7</td>
<td>9</td>
</tr>
</tbody>
</table>

(1) Connector pins are Dx+, Dx–, CTRLx, and 5V_OUT
6 Specifications

6.1 Absolute Maximum Ratings

<table>
<thead>
<tr>
<th>Parameter</th>
<th>MIN</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>VCC voltage tolerance</td>
<td>5V_SUPPLY</td>
<td>–0.3</td>
<td>6 V</td>
</tr>
<tr>
<td>IO voltage tolerance</td>
<td>Connector pins(2)</td>
<td>–0.3</td>
<td>6 V</td>
</tr>
<tr>
<td>IEC 61000-4-5 peak current (8/20 µs)</td>
<td>Connector pins(2)</td>
<td>3 A</td>
<td></td>
</tr>
<tr>
<td>IEC 61000-4-5 peak power (8/20 µs)</td>
<td>Connector pins(2)</td>
<td>30 W</td>
<td></td>
</tr>
<tr>
<td>Storage temperature, Tstg</td>
<td>–65</td>
<td>125</td>
<td>°C</td>
</tr>
</tbody>
</table>

(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.

(2) Connector pins are Dx+, Dx–, CTRLx, and 5V_OUT

6.2 ESD Ratings

<table>
<thead>
<tr>
<th>Voltage (ESD)</th>
<th>ELECTRIC DISCHARGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>V(HBM)</td>
<td>Human body model (HBM), per ANSI/ESDA/JEDEC JS-001(1)</td>
</tr>
<tr>
<td>V(CDM)</td>
<td>Charged device model (CDM), per JEDEC specification JESD22-C101(2)</td>
</tr>
<tr>
<td>V(IEC 61000-4-2 Contact Discharge)</td>
<td>±12000 V</td>
</tr>
<tr>
<td>V(IEC 61000-4-2 Air-gap Discharge)</td>
<td>±14000 V</td>
</tr>
</tbody>
</table>

(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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>MIN</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>VCC Voltage</td>
<td>4.5</td>
<td>5.5</td>
<td>V</td>
</tr>
<tr>
<td>IO voltage at external signal pins</td>
<td>–0.3</td>
<td>5.5</td>
<td>V</td>
</tr>
<tr>
<td>Operating free-air temperature</td>
<td>–40</td>
<td>85</td>
<td>°C</td>
</tr>
</tbody>
</table>

(1) External Signal pins are Dx+, Dx–, CTRLx, and 5V_OUT

6.4 Thermal Information

<table>
<thead>
<tr>
<th>THERMAL METRIC(1)</th>
<th>TPD13S523</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PW [TSSOP]</td>
</tr>
<tr>
<td></td>
<td>16 PINS</td>
</tr>
<tr>
<td>R(JA) Junction-to-ambient thermal resistance</td>
<td>119.9</td>
</tr>
<tr>
<td>R(JC(top)) Junction-to-case (top) thermal resistance</td>
<td>54.5</td>
</tr>
<tr>
<td>R(JB) Junction-to-board thermal resistance</td>
<td>65.0</td>
</tr>
<tr>
<td>ψJT Junction-to-top characterization parameter</td>
<td>9.7</td>
</tr>
<tr>
<td>ψJB Junction-to-board characterization parameter</td>
<td>n/a</td>
</tr>
<tr>
<td>R(JC(bot)) Junction-to-case (bottom) thermal resistance</td>
<td>n/a</td>
</tr>
</tbody>
</table>

(1) For more information about traditional and new thermal metrics, see the Semiconductor and IC Package Thermal Metrics application report, SPR953.
### 6.5 Electrical Characteristics

$T_A = -40^\circ C$ to $85^\circ C$ (unless otherwise noted)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TEST CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LOAD SWITCH</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$I_{CC}$</td>
<td>Supply current at 5V_SUPPLY</td>
<td>5V_SUPPLY = 5V, 5V_OUT = Open</td>
<td>6.5</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>$I_{SC}$</td>
<td>Short-circuit current at 5V_OUT</td>
<td>5V_SUPPLY = 5V, 5V_OUT = GND</td>
<td>100</td>
<td>116</td>
<td>147</td>
</tr>
<tr>
<td>$I_{BACKDRIVE}$</td>
<td>Reverse leakage current at 5VOUT</td>
<td>5V_SUPPLY = 0V, 5V_OUT = 5 V</td>
<td>0.01</td>
<td>0.69</td>
<td>0.95</td>
</tr>
<tr>
<td>$V_{DROP}$</td>
<td>5V_OUT output voltage drop</td>
<td>5V_SUPPLY = 5V, $I_{5V_OUT} = 55 mA$</td>
<td>170</td>
<td>205</td>
<td></td>
</tr>
<tr>
<td><strong>CONNECTOR PINS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V_{RWM}$</td>
<td>Reverse stand-off voltage</td>
<td></td>
<td>5.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V_{CLAMP}$</td>
<td>Clamp voltage with ESD strike</td>
<td>$I_{pp} = 1 A, 8/20 \mu s^{(1)}$</td>
<td>13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$I_{IO}$</td>
<td>Leakage current through external signal pins$^{(2)}$</td>
<td>5V_SUPPLY = 5V, $V_{IO} = 5 V$</td>
<td>2</td>
<td>7</td>
<td>65</td>
</tr>
<tr>
<td>$I_{OFF}$</td>
<td>Current from IO Port to supply pins when powered down through signal pins$^{(3)}$</td>
<td>5V_SUPPLY = 0 V, $V_{IO} = 2.5 V$</td>
<td>1</td>
<td>5</td>
<td>44</td>
</tr>
<tr>
<td>$V_F$</td>
<td>Diode forward voltage through external signal pins$^{(2)}$; lower clamp diode</td>
<td>$I_D = 8 mA$</td>
<td>0.7</td>
<td>0.85</td>
<td>0.95</td>
</tr>
<tr>
<td>$R_{DYN}$</td>
<td>Dynamic resistance of ESD clamps external pins$^{(3)}$</td>
<td>Pin to ground$^{(2)}$</td>
<td>0.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$C_{IO,TMDS}$</td>
<td>IO capacitance Dx+, Dx– pins to GND</td>
<td>5V_SUPPLY = 5 V, $V_{IO} = 2.5 V$; $f = 1 MHz$</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta C_{IO,TMDS}$</td>
<td>Differential capacitance for the Dx+, Dx– lines</td>
<td>5V_SUPPLY = 5 V, $V_{IO} = 2.5 V$; $f = 1 MHz$</td>
<td>0.05</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$C_{IO,CONTROL}$</td>
<td>CTRLx pin capacitance</td>
<td>5V_SUPPLY = 5 V, $V_{IO} = 2.5 V$; $f = 1 MHz$</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V_{BR}$</td>
<td>Break-down voltage through signal pins$^{(3)}$</td>
<td>$I_{IO} = 1 mA$</td>
<td>6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(1) Non-repetitive current pulse of an 8/20 µs exponentially decaying waveform according to IEC 61000-4-5.
(2) Extraction of $R_{DYN}$ using least squares fit of TLP characteristics between $I=1A$ AND $I=10A$.
(3) Signal pins are Dx+, Dx–, and CTRLx.
6.6 Typical Characteristics

Figure 1. Pin Capacitance

Figure 2. IEC 61000-4-5 (Surge) I_{pp} and P_{pp} Waveform

Figure 3. IEC Positive Clamping Waveform Using 8-kV Contact

Figure 4. IEC Negative Clamping Waveform Using –8-kV Contact

Figure 5. TLP Plot On Connector Pins

Figure 6. IV Curve On Signal Pins
Typical Characteristics (continued)

![Graph of Voltage vs Time](image1)

- $C_{IN} = 1 \mu F$
- $C_{OUT} = 1 \mu F$
- $I_{SWITCH} = 55 mA$
- $T_A = 25^\circ C$
- $5V\_SUPPLY = 5 V$
- $5V\_OUT = Open$

Figure 7. Load Switch Start-Up Transient Waveform

![Graph of Current vs Temperature](image2)

Figure 8. Load Switch Supply Current

![Graph of Resistance vs Temperature](image3)

Figure 9. Load Switch Resistance vs Temperature
7 Detailed Description

7.1 Overview

The TPD13S523 device is a single-chip ESD solution for the HDMI transmitter port. By providing system-level ESD protection for a full HDMI port, the TPD13S523 can protect the core IC from ESD strikes and absorb the associated energy.

While providing the ESD protection, the TPD13S523 adds little-to-no signal distortion to the high-speed differential signals. In addition, the monolithic integrated circuit technology ensures that there is excellent matching between the two-signal pair of the differential line.

The TPD13S523 also provides an on-chip regulator with current output ratings of 55 mA at pin 38. This current enables HDMI receiver detection even when the receiver device is powered off.

7.2 Functional Block Diagram

![Electrical Equivalent Circuit Diagrams](image_url)

Figure 10. Electrical Equivalent Circuit Diagrams

7.3 Feature Description

7.3.1 IEC 61000-4-2 Protection

The connector-facing I/O pins can withstand ESD events up to ±12-kV contact and ±14-kV air. An ESD clamp diverts the current to ground.

7.3.2 Single-Chip ESD Solution

The TPD13S523 provides a complete ESD protection scheme for an HDMI 1.4 compliant port. No additional components are required for ESD protection and current-limiting besides this device.
Feature Description (continued)

7.3.3 On-Chip 5-V Load Switch
The TPD13S523 provides an on-chip regulator with a current output rating of 55-mA. This regulator also prevents reverse current flow from occurring, in compliance with the HDMI 5-V supply specification.

7.3.4 Supports UTILITY Line Protection
This device provides protection for all control lines in HDMI, including the UTILITY pin.

7.3.5 < 0.05-pF Differential Capacitance Between TMDS Pairs
The TPD13S523 has a very low capacitance variation (< 0.05 pF) between different TMDS ESD clamps. This provides excellent matching and does not degrade differential signal quality.

7.3.6 Industry Standard Package and Space-Saving Package
The TPD13S523 is offered in 2 different packages. A 16-pin industry standard TSSOP package is provided for ease of routing and easy layout. A 16-pin UQFN (RSV) is provided where small size is needed in the application.

7.3.7 Supports Data Rates in Excess of 3.4 Gbps
The TMDS ESD clamps have a very low capacitance that is capable of supporting HDMI data rates exceeding 3.4 Gbps.

7.3.8 $R_{\text{DYN}} = 0.5 \, \Omega$
The TMDS ESD clamps have a very low $R_{\text{DYN}}$ of 0.5Ω (typ) which provides excellent ESD protection clamping characteristics for the upstream core transmitter.

7.3.9 Commercial Temperature Range
The TPD13S523 is rated to operate from -40°C to 85°C.

7.4 Device Functional Modes
TPD13S523 is active with the conditions in the Recommended Operating Conditions met. Each connector side pin has an ESD clamp that triggers when voltages are greater than $V_{\text{BR}}$ or less than the lower diode’s $V_f$. During ESD events, voltages as high as ±12-kV contact ESD can be directed to ground through the internal diode network. Once the voltages on the protected line fall below these trigger levels (usually within 10’s of nano-seconds), these pins revert to a nonconductive 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 TPD13S523 provides IEC 61000-4-2 Level 4 Contact ESD protection for an HDMI 1.4 transmitter port. An integrated current limit switch ensures compliance with the HDMI 5-V power supply requirements. This section presents a simplified discussion of the design process for this protection device.

8.2 Typical Application
A typical application schematic for an HDMI 1.4 transmitter port protected by the TPD13S523 is shown in Figure 11. The eight TMDS lines and five control lines are connected to their respective pins for ESD protection. The 5-V power path is connected through the 55-mA current limit switch.

Figure 11. TPD13S523 Configured With an HDMI 1.4 Transmitter Port

8.2.1 Design Requirements
For this design example, use the parameters listed in Table 1 as input parameters.

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>EXAMPLE VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage on 5V_SUPPLY</td>
<td>4.8 V - 5.3 V</td>
</tr>
<tr>
<td>HDMI Data Rate</td>
<td>3.4 Gbps</td>
</tr>
</tbody>
</table>

8.2.2 Detailed Design Procedure
To begin the design process, the designer must know the following parameters:
• 5V_SUPPLY voltage range
• Maximum HDMI data rate
8.2.2.1 5V_SUPPLY Voltage Range

The TPD13S523 is capable of operating the 5V_SUPPLY up to 5.5 V, with recommended voltage from 4.5 V to 5.5 V. In this example, the supply range is 4.8 V to 5.3 V, which satisfies this requirement.

8.2.2.2 Maximum HDMI Data Rate

The TPD13S523 is capable of operating at HDMI data rates in excess of 3.4 Gbps, compliant to the HDMI 1.4 maximum data rate. In this example, the maximum HDMI 1.4 data rate of 3.4 Gbps has been chosen.

8.2.3 Application Curves

9 Power Supply Recommendations

The designer must consider the requirement for the 5V_OUT voltage level. To ensure the voltage is within tolerance under load, set 5V_SUPPLY to at least 4.8 V + V_{DROP} (205 mV). Otherwise, TPD13S523 is a passive ESD protection device and there is no need to power it.

10 Layout

10.1 Layout Guidelines

The TPD13S523 device offers little or no signal distortion during normal operation due to low I/O capacitance and ultra-low leakage current specifications. In the event of an ESD stress, this device ensures that the core circuitry is protected and the system is functioning properly. For proper operation, the following layout and design guidelines should be followed:

1. Place the TPD13S523 as close to the connector as possible. This allows the TPD13S523 to remove the energy associated with ESD strike before it reaches the internal circuitry of the system board.
2. Place two 0.1-μF capacitors very close to the 5V_SUPPLY and 5V_OUT pins. These capacitors will help limit the noise at the 5V_OUT power line, and also help with system level ESD protection.
3. Ensure that there is enough metallization for the GND pad. During normal operation, the TPD13S523 ESD pins consume ultra-low leakage current. During the ESD event, GND pin will see multiple amps of current. A sufficient current path enables safe discharge of all the energy associated with the ESD strike.
4. The critical routing paths for HDMI interface are the high-speed TMDS lines. With the PW package, all the TMDS lines (pin Dxx) can be routed in a single signal plane and still maintain the differential coupling and trace symmetry. This helps reduce the overall board manufacturing cost. The slow speed control lines can be routed in another signal layer through vias.
5. If the UTILITY or any other pin is not utilized, tie the pin to a ground rather than leave floating. Use a 75-Ω resistor to protect against shorts to ground.
10.2 Layout Examples

Figure 14. TPD13S523PWR Layout Example 13-Line HDMI Protection
Layout Examples (continued)

Legend

- VIA to GND Plane
- VIA to 5V Plane
- Signal Via
- Pin to GND

TPD13S523

Figure 15. TPD13S523RSVR Layout Example 13-Line HDMI Protection
11 Device and Documentation Support

11.1 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.

11.2 Trademarks
E2E is a trademark of Texas Instruments. All other trademarks are the property of their respective owners.

11.3 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.

11.4 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 (1)</th>
<th>Package Type</th>
<th>Package Drawing</th>
<th>PINS</th>
<th>Package Qty</th>
<th>Eco Plan (2)</th>
<th>Lead/Ball Finish</th>
<th>MSL Peak Temp</th>
<th>Op Temp (°C)</th>
<th>Device Marking (4/5)</th>
<th>Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPD13S523PWR</td>
<td>ACTIVE</td>
<td>TSSOP</td>
<td>PW</td>
<td>16</td>
<td>2000</td>
<td>Green (RoHS &amp; no Sb/Br)</td>
<td>NIPDAU</td>
<td>Level-1-260C-UNLIM</td>
<td>-40 to 85</td>
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<td>RSV</td>
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<td>3000</td>
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<td>Level-1-260C-UNLIM</td>
<td>-40 to 85</td>
<td>ZTT</td>
<td></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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### TAPE AND REEL INFORMATION

#### 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

#### REEL DIMENSIONS

- Reel Diameter
- Reel Width (W1)

#### PACKAGE MATERIALS 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>
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*All dimensions are nominal.*

*Figure illustrating TAPE DIMENSIONS and REEL DIMENSIONS.*

*Figure illustrating TAPE AND REEL INFORMATION.*
## TAPE AND REEL BOX DIMENSIONS

*All dimensions are nominal*

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<th>SPQ</th>
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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.
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.
4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.25 mm per side.
5. Reference JEDEC registration MO-153.
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.
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.
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.
NOTES: (continued)

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