This user's guide describes the characteristics, operation, and use of the TPD3S014EVM evaluation module (EVM). This EVM includes five TPD3S014’s in various configurations for testing. One TPD3S014 is configured for IEC61000-4-2 compliance testing, one is configured for 4-port s-parameter analysis, one is pinned out for evaluating the current limiting switch, one is configured for throughput on USB 2.0 Type A connectors for throughput analysis, and one is configured for the capture of clamping waveforms during an ESD event. This user's guide includes setup instructions, schematic diagrams, a bill of materials, and printed-circuit board layout drawings for the evaluation module.

1 Introduction

Texas Instrument’s TPD3S014 evaluation module helps designers evaluate the operation and performance of the TPD3S014 device. The TPD3S014 is a current limiting switch intended for applications such as USB where heavy capacitive loads and short-circuits are likely to be encountered; TPD3S014 provides short-circuit and over-current protection. This device has a fixed current-limit threshold of 0.5 A. ESD protection for D+ and D– is also provided.

The EVM contains five TPD3S014s. TPD3S014 (U1) is configured with two USB2.0 Type A connectors (USB1 & USB2) for capturing Eye Diagrams and evaluating current limiting with a system. TPD3S014 (U2) is configured with 4 SMA (J1 – J4) connectors to allow 4-port analysis with a vector network analyzer. TPD3S014 (U4) is configured with test points for striking ESD to the protection pins. TPD3S014 (U3) is configured for capturing clamping waveforms with an oscilloscope during an ESD test. Caution must be taken when capturing clamping waveforms during an ESD event so as not to damage the oscilloscope. A proper procedure is outlined below in Section 3.4.1.

2 Definitions

Contact Discharge — a method of testing in which the electrode of the ESD simulator is held in contact with the device-under-test (DUT).

Air Discharge — a method of testing in which the charged electrode of the ESD simulator approaches the DUT, and a spark to the DUT actuates the discharge.

ESD simulator — a device that outputs IEC61000-4-2 compliance ESD waveforms shown in Figure 1 with adjustable ranges shown in Table 1 and Table 2.

IEC61000-4-2 has 4 classes of protection levels. Classes 1 – 4 are shown in Table 1. Stress tests should be incrementally tested to level 4 as shown in Table 2 until the point of failure. If the DUT does not fail at 8kV, testing can continue in 2 kV increments until failure.

<table>
<thead>
<tr>
<th>Class</th>
<th>Test Voltage [± kV]</th>
<th>Class</th>
<th>Test Voltage [± kV]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>2</td>
<td>4</td>
</tr>
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<td>6</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>4</td>
<td>8</td>
<td>4</td>
<td>15</td>
</tr>
</tbody>
</table>

Table 1. IEC61000-4-2 Test Levels
### Table 2. Waveform Parameters in Contact Discharge Mode

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
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<td>1</td>
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<td>7.5</td>
<td>0.8</td>
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<td>2</td>
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<tr>
<td>2</td>
<td>4</td>
<td>15</td>
<td>0.8</td>
<td>8</td>
<td>4</td>
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<tr>
<td>3</td>
<td>6</td>
<td>22.5</td>
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<td>4</td>
<td>8</td>
<td>30</td>
<td>0.8</td>
<td>16</td>
<td>8</td>
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</table>

![Figure 1. Ideal Contact Discharge Waveform of the Output Current of the ESD Simulator at 4 kV](image)

### 3 Setup

This section describes the intended use of the EVM. A generalized outline of the procedure given in IEC-61000-4-2 is described here. IEC-61000-4-2 should be referred to for a more specific testing outline. Basic configurations for collecting S-parameters, Eye Diagrams, and ESD clamping waveforms are outlined as well. Attach 5 V to the +5-V test point and ground to GND. Tests can be performed will device enable pins set HI or LO. For TPD3S014 the device is active-low, so set EN to LO to enable the devices on the board.

#### 3.1 U1

A single TPD3S014 (U1) is configured with two USB2.0 Type A connectors (USB1 & USB2) for capturing Eye Diagrams. Using USB2 as input and USB1 as output, attach to a USB2.0 compliant Eye Diagram tester setup for the intended application, either transmitter or receiver.

#### 3.2 U2

A TPD3S014 (U2) is configured with 4 SMA (J1 – J4) connectors to allow 4-port analysis with a vector network analyzer. Connect Port 1 to J1, Port 2 to J2, Port 3 to J3, and Port 4 to J4. This configuration allows for the following terminology in 4 port analysis:

- $S_{11}$: Return loss
- $S_{22}$: Insertion loss
- $S_{31}$: Near end cross talk
- $S_{41}$: Far end cross talk
3.3 **U4**

A TPD3S014 (U3) has an SMB connector (J7) for capturing clamping waveforms with an oscilloscope during an ESD strike. Caution must be taken when capturing clamping waveforms during an ESD event so as not to damage the oscilloscope.

3.3.1 **Test Method and Set-Up**

An example test setup is shown in Figure 2. Details of the testing table and ground planes can be found in the IEC 61000-4-2 test procedure. Ground the EVM using the banana connector labeled GND (J9). Discharge the ESD simulator on any of the Test Points TP1 – TP10. Contact and air-gap discharge are tested using the same simulator with the same discharge waveform. While the simulator is in direct contact with the test point during contact, it is not during air-gap.

![Figure 2. System Level ESD Test Setup](image-url)
3.3.2 Evaluation of Test Results

Connect the tested device on the EVM to a curve tracer both before and after ESD testing. After each incremental level, if the IV curve of the ESD protection diode shifts ±0.1 V, or leakage current increases by a factor of ten, then the device is permanently damaged by ESD.

3.4 U3

A TPD3S014 (U3) has an SMB connector (J7) for capturing clamping waveforms with an oscilloscope during an ESD strike. Caution must be taken when capturing clamping waveforms during an ESD event so as not to damage the oscilloscope.

3.4.1 Oscilloscope setup

Without a proper procedure, capturing ESD clamping waveforms exposes the oscilloscope to potential voltages higher than the rating of the equipment. Proper methodology can mitigate any risk in this operation.

**Recommended equipment:**
- Minimum of 1 GHz bandwidth oscilloscope.
- Either of the following:
  - 2 10X 50 Ω attenuators and a 0 Ω resistor (to be installed at R1).
  - 1 10X 50 Ω attenuator and a 150 Ω resistor (already installed at R1).
- 50 Ω shielded SMB cable.

**Procedure**

In order to protect the oscilloscope, attenuation of the measured signal is required. Here are two possible procedures for testing U3:

1. Using two 10X attenuators:
   - Install a 0 Ω resistor in R1
   - Attach two 10X attenuators to the oscilloscope channel being used.
   - Attach the 50 Ω shielded SMB cable between J7 and the attenuator.
   - Set the scope attenuation factor to 100X.
   - Set the oscilloscope to trigger on a positive edge for (+) ESD and a negative edge for (–) ESD strikes. The magnitude should be set to 20 V.
   - Following Section 3.3.1, strike contact ESD to TP10.

2. Using one 10X attenuator:
   - Attach one 10X attenuator to the oscilloscope.
   - Attach the 50 Ω shielded SMB cable between J7 and the attenuator.
   - Set the scope attenuation factor to 40X.
   - Set the oscilloscope to trigger on a positive edge for (+) ESD and a negative edge for (–) ESD strikes. The magnitude should be set to 20 V.
   - Following Section 3.3.1, strike contact ESD to TP10.

Recommended settings for the time axis is 20 ns/div and for the voltage axis is 10 V division.

The voltage levels of the ESD applied to TP10 should not exceed +/- 8 kV while capturing clamping waveforms.
This section provides the TPD3S014EVM board layout. TPD3S014EVM is a 4-layer board of FR-4 at 0.062 inch thickness. Layers 2 and 3 are ground and power planes, respectively, and not shown.

Figure 3. TPD3S014EVM Top Layer
Figure 4. TPD3S014EVM Bottom Layer
5 Schematics and Bill Of Materials

5.1 Schematics

Figure 5. TPD3S014EVM Schematic
### Table 3. Bill of Materials

<table>
<thead>
<tr>
<th>Count</th>
<th>RefDes</th>
<th>Description</th>
<th>Package Reference</th>
<th>Part Number</th>
<th>MFR</th>
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<tr>
<td>1</td>
<td>+5V</td>
<td>Test Point, Miniature, Red, TH</td>
<td>Red Miniature Test point</td>
<td>5000</td>
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<td>5</td>
<td>C1, C4, C6, C8, C10</td>
<td>CAP, TA, 150uF, 6.3V, +/-10%, 0.15 ohm, SMD</td>
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<td>TPSC157K006R0150</td>
<td>AVX</td>
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<tr>
<td>5</td>
<td>C2, C3, C5, C7, C9</td>
<td>CAP, CERM, 10 uF, 50V, +/-10%, X7R, 1206</td>
<td>1206</td>
<td>GMK316F106ZL-T</td>
<td>Taiyo Yuden</td>
</tr>
<tr>
<td>2</td>
<td>EN_ALL, EN_U5</td>
<td>Header, Male 3-pin, 100mil spacing,</td>
<td>0.100 inch x 3</td>
<td>PEC03SAAN</td>
<td>Sullins</td>
</tr>
<tr>
<td>3</td>
<td>GND, J5, J6</td>
<td>Standard Banana Jack, Uninsulated, 5.5mm</td>
<td>Keystone 575-4</td>
<td>575-4</td>
<td>Keystone</td>
</tr>
<tr>
<td>4</td>
<td>H1, H2, H3, H4</td>
<td>Machine Screw, Round, #4-40 x 1/4, Nylon, Philips panhead</td>
<td>Screw</td>
<td>NY PMS 440 0025 PH</td>
<td>B&amp;F Fastener Supply</td>
</tr>
<tr>
<td>4</td>
<td>H5, H6, H7, H8</td>
<td>Standoff, Hex, 0.5&quot;L, #4-40 Nylon</td>
<td>Standoff</td>
<td>1902C</td>
<td>Keystone</td>
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<tr>
<td>4</td>
<td>J1, J2, J3, J4</td>
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<td>SMA</td>
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<td>Emerson Network Power</td>
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<td>603</td>
<td>CRCW0603150RFK EA</td>
<td>Vishay-Dale</td>
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<td>5</td>
<td>U1, U2, U3, U4, U5</td>
<td>IC, Low-Capacitance 4-Channel +15-kV ESD-Protection Array For High-Speed Data Interfaces</td>
<td>SOT-23</td>
<td>TPD3S014DBV</td>
<td>TI</td>
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<td>USB Type A connector, receptacle, 4 POS SMD</td>
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<td>USB Type A right angle</td>
<td>48037-1000</td>
<td>Molex</td>
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</table>
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*Caution*

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation. Changes or modifications could void the user’s authority to operate the equipment.

**FCC Interference Statement for Class A EVM devices**

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at its own expense.

**FCC Interference Statement for Class B EVM devices**

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

**Industry Canada Compliance (English)**

**For EVMs Annotated as IC – INDUSTRY CANADA Compliant:**

This Class A or B digital apparatus complies with Canadian ICES-003. Changes or modifications not expressly approved by the party responsible for compliance could void the user’s authority to operate the equipment.

**Concerning EVMs Including Radio Transmitters**

This device complies with Industry Canada licence-exempt RSS standard(s). Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

**Concerning EVMs Including Detachable Antennas**

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication.

This radio transmitter has been approved by Industry Canada to operate with the antenna types listed in the user guide with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

**Canada Industry Canada Compliance (French)**

Cet appareil numérique de la classe A ou B est conforme à la norme NMB-003 du Canada.
Les changements ou les modifications pas expressément approuvés par la partie responsable de la conformité ont pu vider l'autorité de l'utilisateur pour actionner l'équipement.

**Concernant les EVMs avec appareils radio**

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes : (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

**Concernant les EVMs avec antennes détachables**

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Le présent émetteur radio a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés dans le manuel d'usage et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur.

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1. Use EVMs in a shielded room or any other test facility as defined in the notification #173 issued by Ministry of Internal Affairs and Communications on March 28, 2006, based on Sub-section 1.1 of Article 6 of the Ministry’s Rule for Enforcement of Radio Law of Japan,
2. Use EVMs only after user obtains the license of Test Radio Station as provided in Radio Law of Japan with respect to EVMs, or
3. Use of EVMs only after user obtains the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to EVMs. Also, do not transfer EVMs, unless user gives the same notice above to the transferee. Please note that if user does not follow the instructions above, user will be subject to penalties of Radio Law of Japan.

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