ESD401 1-Channel ESD Protection Diode With Robust IEC ESD Performance

1 Features

- Robust IEC 61000-4-2 Level 4 ESD Protection
  - ±24-kV Contact Discharge
  - ±30-kV Air Gap Discharge
- IEC 61000-4-5 Surge Protection
  - 4.5 A (8/20 µs)
  - Low V_{clamp} of 12 V at 1.8 A I_{PP} (8/20 µs)
- IEC 61000-4-4 EFT Protection
  - 80 A (5/50 ns)
- Bi-directional ESD diode to protect interfaces up to ± 5.5 V
- IO Capacitance: 0.77 pF (Typical)
- High DC Breakdown Voltage: 8.3 V (Typical)
- Ultra Low Leakage Current: 30 pA (Typical)
- Low Dynamic Resistance 0.7 Ω (Typical)
- Industrial Temperature Range: –40°C to +125°C
- Industry Standard 0402 Package

2 Applications

- End Equipment
  - Wearables
  - Laptops and Desktops
  - Mobile and Tablets
  - Set-Top Boxes
  - DVR and NVR
  - TV and Monitors
  - EPOS (Electronic Point of Sale)
- Interfaces
  - 1 Gbps Ethernet
  - USB 2.0/1.1 with 5.5 V tolerance
  - GPIO
  - Pushbuttons/Keypad
  - Audio

3 Description

The ESD401 is a bidirectional TVS ESD protection diode featuring low R_{DYN} and low clamping voltage. The ESD401 is rated to dissipate ESD strikes exceeding the maximum level specified in the IEC 61000-4-2 international standard (Level 4). The low dynamic resistance (0.7 Ω) to ensure system level protection against transient events. This device features a 0.77 pF IO capacitance making it ideal for protecting interfaces such as USB 2.0. The device can operate with ultra-low leakage up to ±5.5 V and survive DC faults up to 8.3 V.

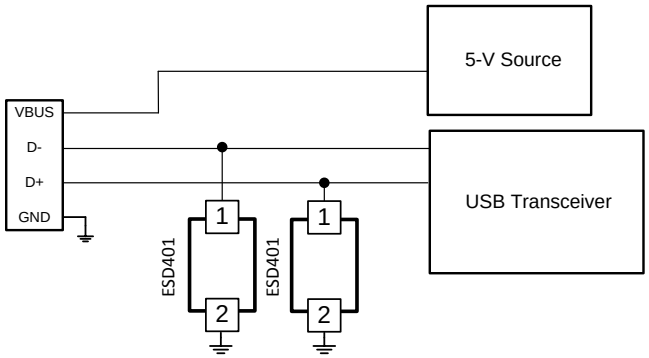
The ESD401 is offered in the industry standard 0402 (DPY) package.

Device Information[1]

PART NUMBER	PACKAGE	BODY SIZE (NOM)
ESD401DPY	X1SON (2)	0.60 mm × 1.00 mm

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

Typical USB 2.0 Application Schematic



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4 Revision History

Changes from Original (July 2017) to Revision A	Page
• Updated Figure 9 andFigure 13	6

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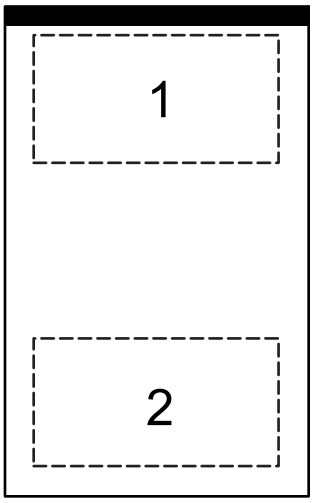
5 Pin Configuration and Functions

DPY Package
2-Pin X1SON
Top View



Pin Functions

PIN		I/O	DESCRIPTION
NO.	NAME		
1	IO	I/O	ESD Protected Channel. If used as ESD IO, connect pin 2 to ground
2	IO	I/O	ESD Protected Channel. If used as ESD IO, connect pin 1 to ground

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6 Specifications

6.1 Absolute Maximum Ratings

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

		MIN	MAX	UNIT
Electrical fast transient	IEC 61000-4-4 (5/50 ns) at 25°C		80	A
Peak pulse	IEC 61000-4-5 power (t_p - 8/20 µs) at 25°C		67	W
	IEC 61000-4-5 current (t_p - 8/20 µs) at 25°C		4.5	A
T_A	Operating free-air temperature	–40	125	°C
T_{stg}	Storage temperature	–65	155	°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 — JEDEC Specification

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001(1)	±2500	V
		Charged-device model (CDM), per JEDEC specification JESD22-C101(2)	±1000	

(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 ESD Ratings—IEC Specification

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	IEC 61000-4-2 contact discharge	±24000	V
		IEC 61000-4-2 air-gap discharge	±30000	

6.4 Recommended Operating Conditions

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

		MIN	MAX	UNIT
V_{IO}	Input pin voltage	–5.5	5.5	V
T_A	Operating free-air temperature	–40	125	°C

6.5 Thermal Information

THERMAL METRIC(1)		ESD401 DPY (X1SON) 2 PINS	UNIT
$R_{\theta JA}$	Junction-to-ambient thermal resistance	420	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	169.3	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	276.1	°C/W
ψ_{JT}	Junction-to-top characterization parameter	122.1	°C/W
ψ_{JB}	Junction-to-board characterization parameter	157.3	°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.

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6.6 Electrical Characteristics

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

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{RWM}	Reverse stand-off voltage	I_{IO} < 10 nA	–5.5		5.5	V
V_{BRF}	Breakdown voltage, Pin 1 to Pin 2 (1)	I_{IO} =1 mA, at T_A = 25°C	7.5		9.1	V
V_{BRR}	Breakdown voltage, Pin 2 to Pin 1 (1)	I_{IO} =1 mA, at T_A = 25°C	7.5		9.1	V
V_{HOLD}	Holding voltage (2)	I_{IO} =1 mA		8.3		V
V_{CLAMP}	Clamping voltage	I_{PP} = 1 A, TLP, from Pin 1 to Pin 2 and Pin 2 to Pin 1, T_A = 25°C		11		V
		I_{PP} = 5 A, TLP, from Pin 1 to Pin 2 and Pin 2 to Pin 1, T_A = 25°C		16		
		I_{PP} = 16 A, TLP, from Pin 1 to Pin 2 and Pin 2 to Pin 1, T_A = 25°C		24		
		I_{PP} = 1.8 A, IEC-61000-4-5 (t_p - 8/20 µs) from Pin 1 to Pin 2 and Pin 2 to Pin 1, T_A = 25°C		12		
		I_{PP} = 4.5 A, IEC-61000-4-5 (t_p - 8/20 µs) from Pin 1 to Pin 2 and Pin 2 to Pin 1, T_A = 25°C		15		
I_{LEAK}	Leakage current, Pin 1 to Pin2 and PIn2 to Pin 1	V_{IO} = ±2.5 V		0.03	10	nA
R_{DYN}	Dynamic resistance	Measured between TLP I_{PP} of 10 A and 20 A, Pin 2 to Pin 1 and Pin 1 to Pin2, T_A = 25°C		0.7		Ω
C_L	Line capacitance	V_{IO} = 0 V, f = 1 MHz, Pin 1 to Pin 2 and Pin2 to Pin1, T_A = 25°C		0.77	0.95	pF

(1) V_{BRF} and V_{BRR} are defined as the voltage obtained at 1 mA when sweeping the voltage up, before the device latches into the snapback state.
(2) V_{HOLD} is defined as the voltage when 1 mA is applied, after the device has successfully latched into the snapback state.

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6.7 Typical Characteristics

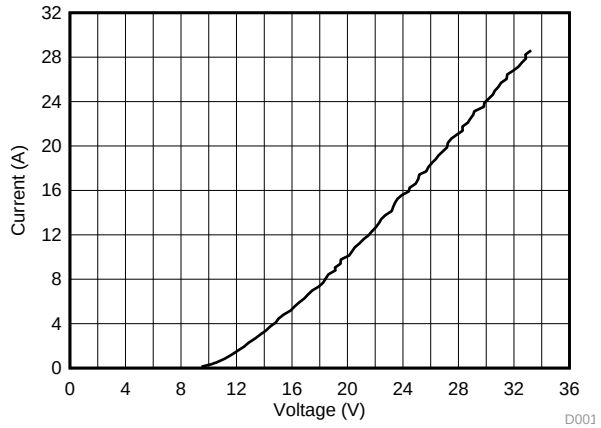

Figure 1. Positive TLP Curve, Pin 1 to Pin 2

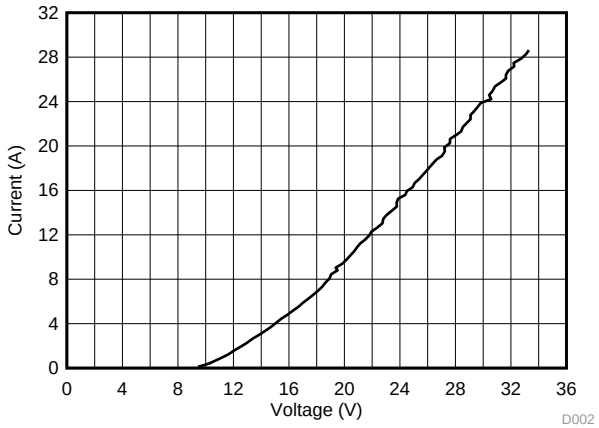

Figure 2. Negative TLP Curve, Pin 1 to Pin 2 (Plotted as Positive TLP Curve Pin 2 to Pin 1

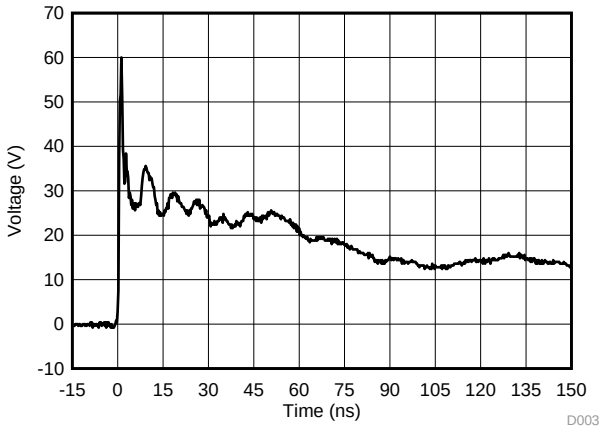

Figure 3. 8-kV IEC 61000-4-2 Waveform, Pin1 to Pin 2

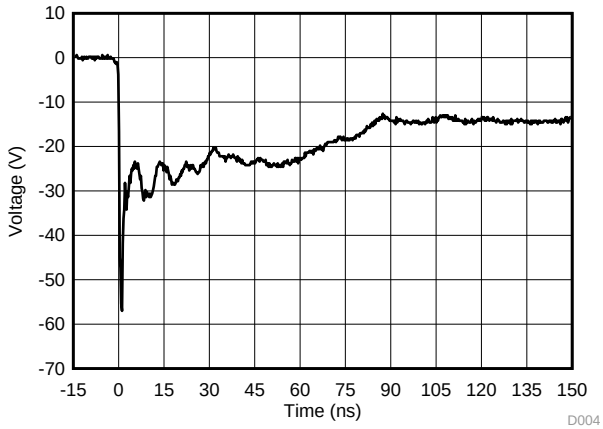

Figure 4. –8-kV IEC 61000-4-2 Waveform, Pin 1 to Pin 2

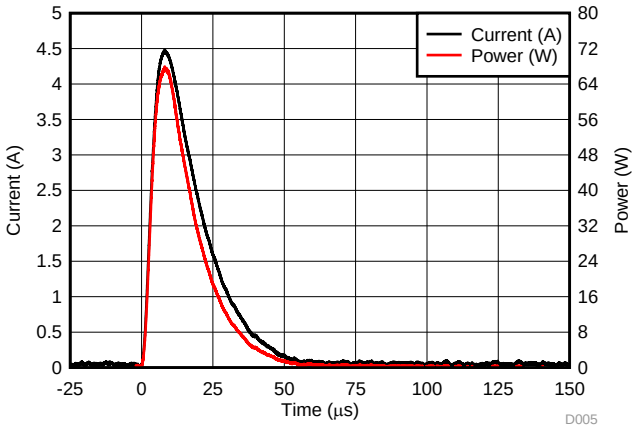

Figure 5. Surge (IEC 61000-4-5) Curve (tp = 8/20 µs), Pin 1 to Pin 2

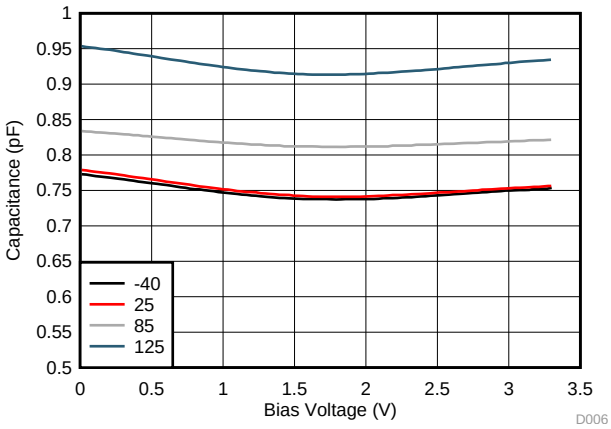

Figure 6. Capacitance vs Bias Voltage, Pin 1 to Pin 2

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Typical Characteristics (continued)

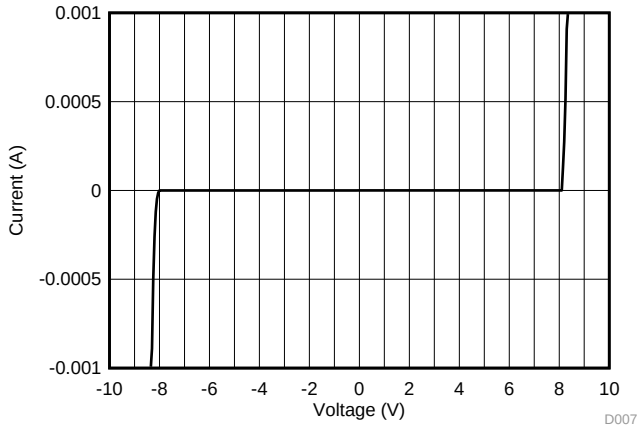

Figure 7. DC Voltage Sweep I-V Curve, Pin 1 to Pin 2

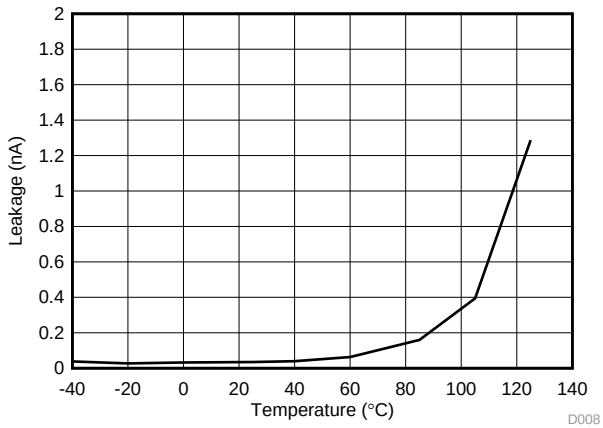

Figure 8. Leakage Current vs. Temperature, Pin 1 to Pin 2

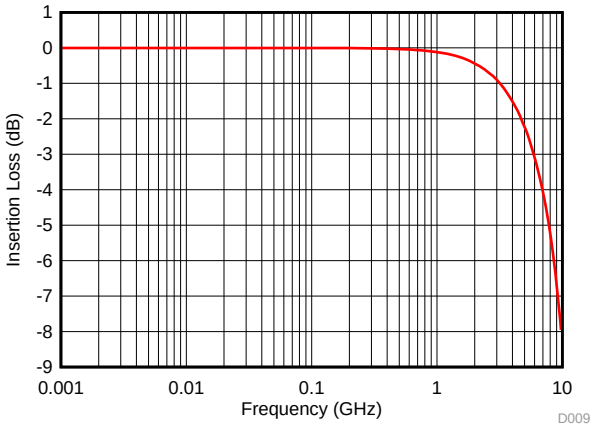

Figure 9. Insertion Loss

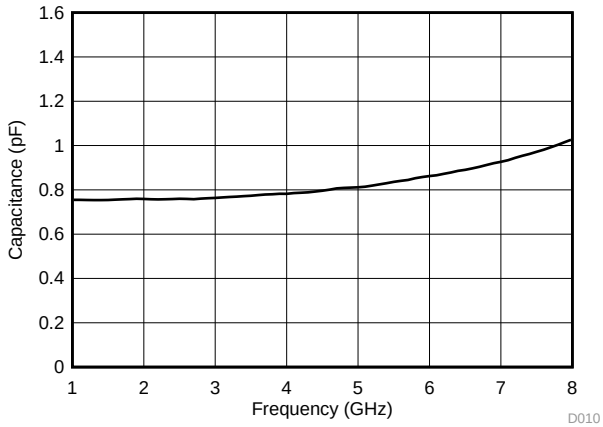

Figure 10. Capacitance vs. Frequency, Pin 1 to Pin 2

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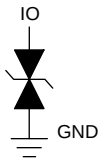
7 Detailed Description

7.1 Overview

The ESD401 is a bidirectional ESD Protection Diode with ultra-low clamping voltage. This device can dissipate ESD strikes above the maximum level specified by the IEC 61000-4-2 International Standard. The ultra-low clamping makes this device ideal for protecting any sensitive signal pins.

7.2 Functional Block Diagram



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7.3 Feature Description

7.3.1 IEC 61000-4-2 ESD Protection

The I/O pins can withstand ESD events up to ±24-kV contact and ±30-kV air gap. An ESD-surge clamp diverts the current to ground.

7.3.2 IEC 61000-4-4 EFT Protection

The I/O pins can withstand an electrical fast transient burst of up to 80 A (5/50 ns waveform, 4 kV with 50-Ω impedance). An ESD-surge clamp diverts the current to ground.

7.3.3 IEC 61000-4-5 Surge Protection

The I/O pins can withstand surge events up to 4.5 A and 67W (8/20 µs waveform). An ESD-surge clamp diverts this current to ground.

7.3.4 IO Capacitance

The capacitance between each I/O pin to ground is 0.77 pF (typical) and 0.95 pF (maximum).

7.3.5 DC Breakdown Voltage

The DC breakdown voltage of each I/O pin is ±8.3 V typical. This ensures that sensitive equipment is protected from surges above the reverse standoff voltage of ±5.5 V.

7.3.6 Low Leakage Current

The I/O pins feature an low leakage current of 10 nA (maximum) with a bias of ±2.5 V.

7.3.7 Low ESD Clamping Voltage

The I/O pins feature an ESD clamp that is capable of clamping the voltage to 24 V (TLP I_{PP} = 16 A).

7.3.8 Industrial Temperature Range

This device features an industrial operating range of –40°C to +125°C.

7.3.9 Industry Standard Footprint

The layout of this device makes it simple and easy to add protection to an existing layout. The packages offers flow-through routing, requiring minimal modification to an existing layout.

7.4 Device Functional Modes

The ESD401 is a passive integrated circuit that triggers when voltages are above V_{BRF} or below V_{BRR}. During ESD events, voltages as high as ±24 kV (contact) or ±30 kV (air) can be directed to ground via the internal diode network. When the voltages on the protected line fall below the trigger levels of ESD401 (usually within 10s of nano-seconds) the device reverts to passive.

Figure 11 shows typical TLP behavior of bi-directional ESD device that does not exhibit snapback.

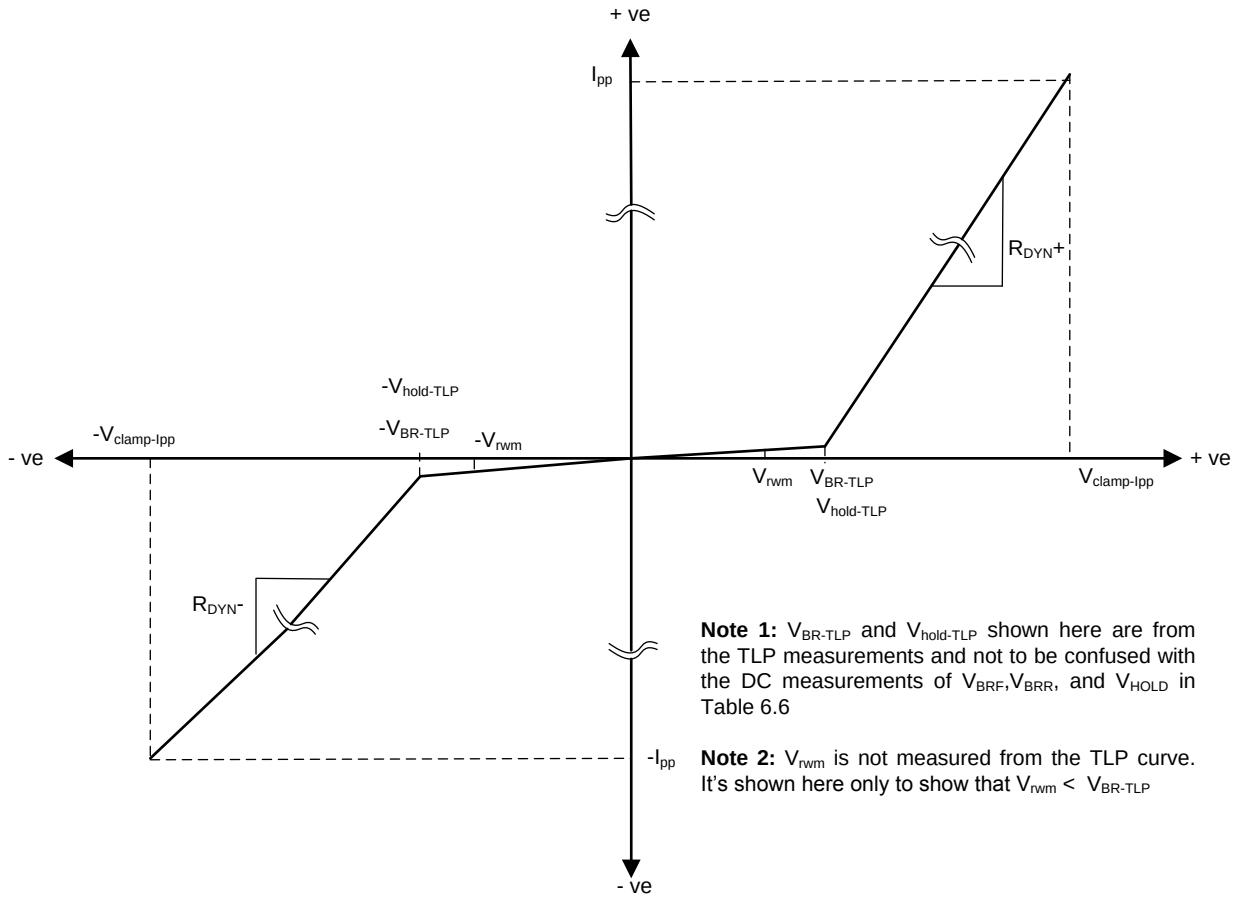

Figure 11. Typical TlpLP Behavior Of Bi-directional ESD Device that Does Not Exhibit Snapback

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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 ESD401 is a diode type TVS which is 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 IC. The low R_{DYN} of the triggered TVS holds this voltage, V_{CLAMP}, to a safe level for the protected IC.

8.2 Typical Application

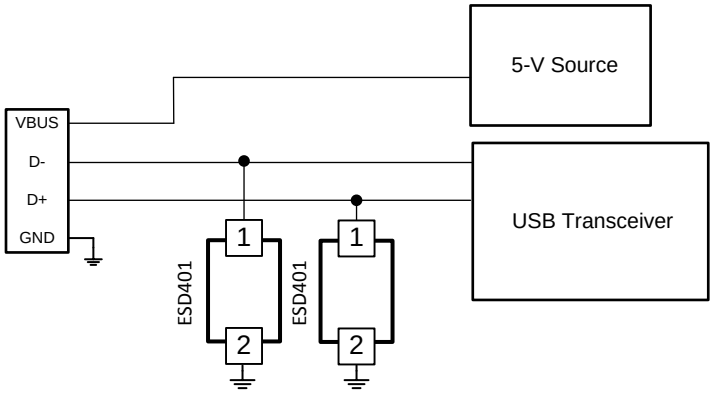

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Figure 12. USB 2.0 ESD Schematic

8.2.1 Design Requirements

For this design example, two ESD401 devices are being used in a USB 2.0 application. This provides a complete ESD protection scheme.

Given the USB 2.0 application, the parameters listed in Table 1 are known.

Table 1. Design Parameters

DESIGN PARAMETER	VALUE
Signal range on DP-DM lines	0 V to 3.6 V
Operating frequency on DP-DM lines	up to 240 MHz or 480 Mbps

8.2.2 Detailed Design Procedure

8.2.2.1 Signal Range

The ESD401 supports signal ranges between –5.5 V and 5.5 V, which supports the USB 2.0 signal range of 0 to 3.6 V on the DM/DP lines..

8.2.2.2 Operating Frequency

The ESD401 has a 0.85 pF (typical) capacitance, which supports the USB 2.0 data rates of 480 Mbps.

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8.2.3 Application Curves

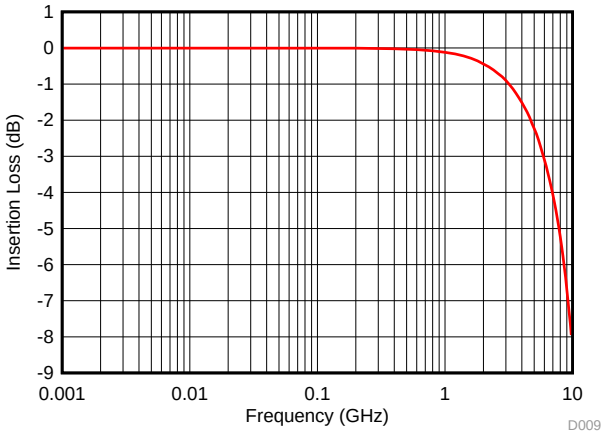

Figure 13. Insertion Loss

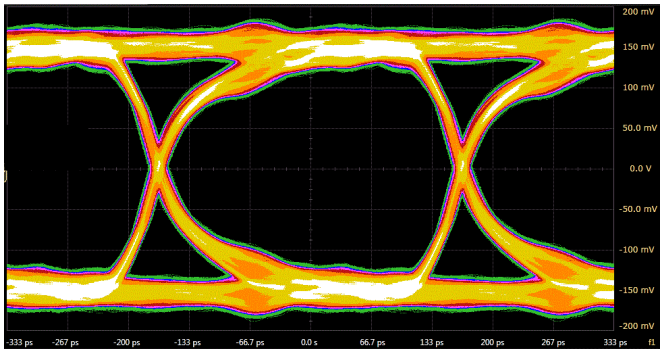

Figure 14. Eye Diagram - 3-Gbps Signal No Device

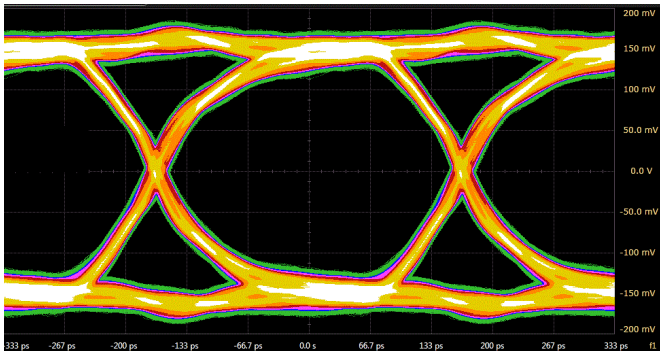

Figure 15. Eye Diagram - 3-Gbps Signal With ESD401

9 Power Supply Recommendations

The ESD401 is a passive ESD device so there is no need to power it. Take care not to violate the recommended I/O specification (–5.5 V to 5.5 V) to ensure the device functions properly.

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.

10.2 Layout Example

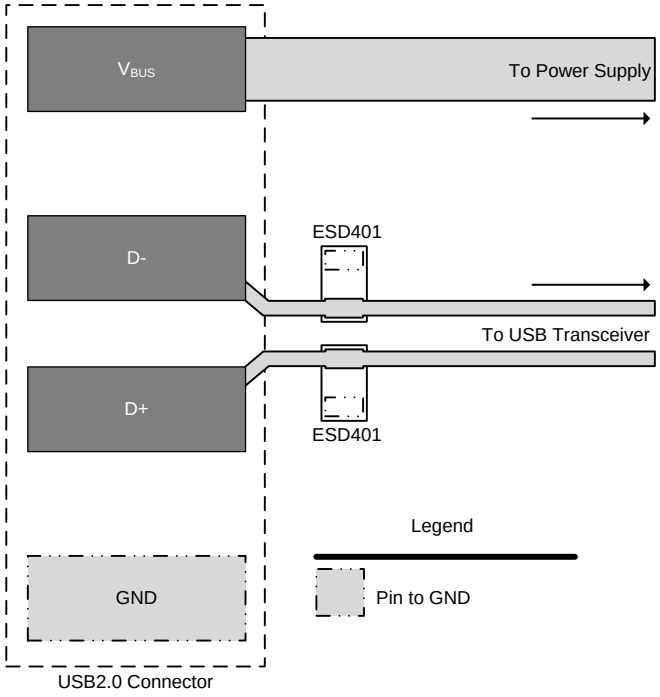

Figure 16. USB 2.0 ESD Layout

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11 Device and Documentation Support

11.1 Documentation Support

For related documentation see the following:

ESD401DPY Evaluation Module

11.2 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. In the upper right corner, click on *Alert me* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

11.3 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.

11.4 Trademarks

E2E is a trademark of Texas Instruments.

11.5 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.

11.6 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.

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PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
ESD401DPYR	ACTIVE	X1SON	DPY	2	10000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 125	8I	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/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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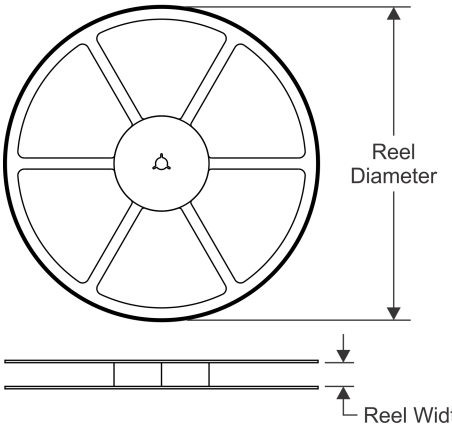
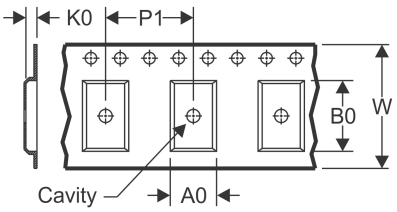
TAPE AND REEL INFORMATION

REEL DIMENSIONS

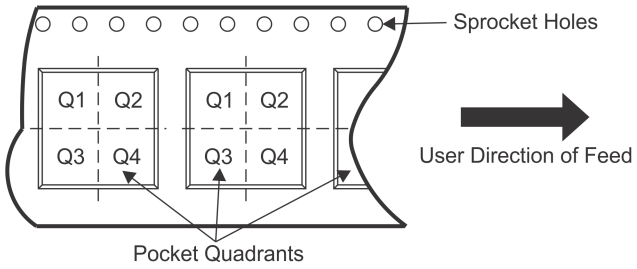


TAPE DIMENSIONS



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

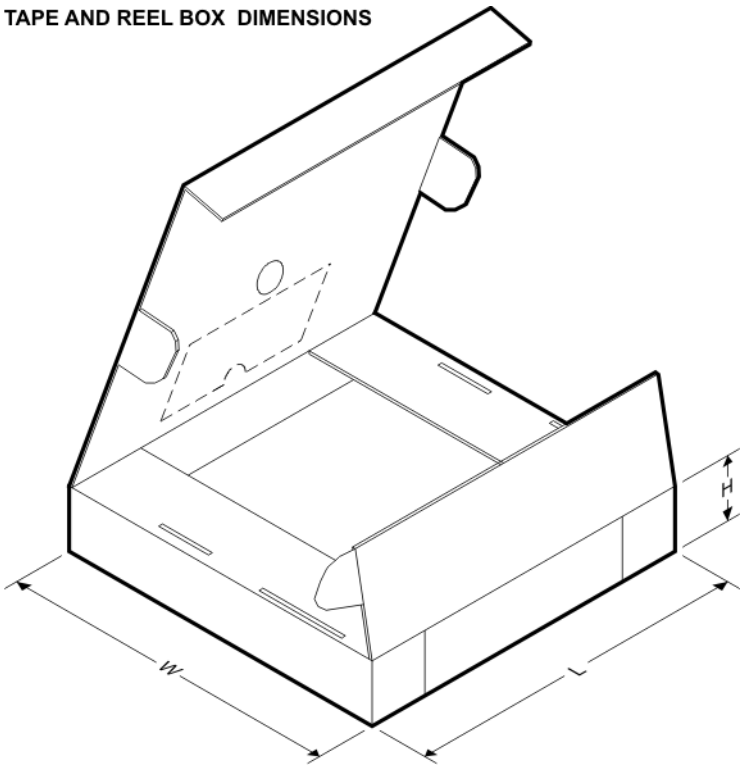
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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
ESD401DPYR	X1SON	DPY	2	10000	180.0	9.5	0.72	1.12	0.43	2.0	8.0	Q1
ESD401DPYR	X1SON	DPY	2	10000	178.0	8.4	0.7	1.15	0.47	2.0	8.0	Q1

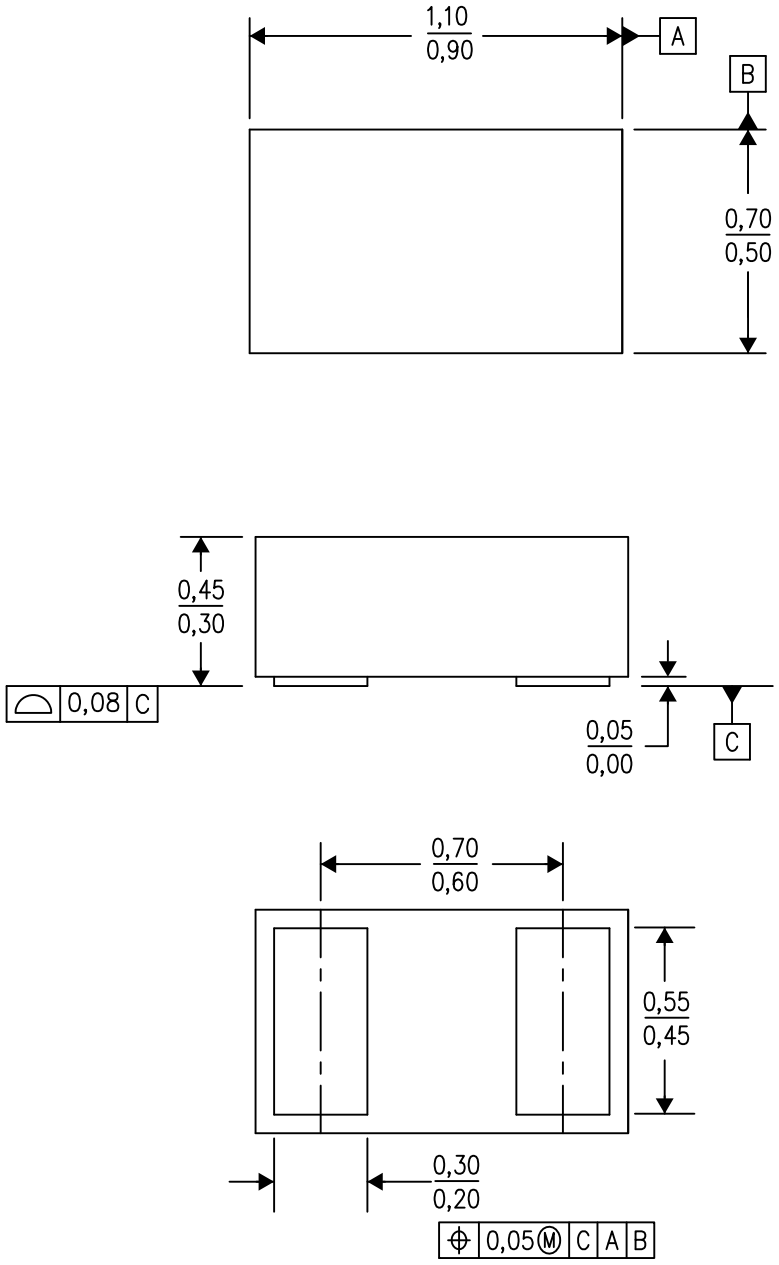
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
ESD401DPYR	X1SON	DPY	2	10000	189.0	185.0	36.0
ESD401DPYR	X1SON	DPY	2	10000	205.0	200.0	33.0

DPY (R–PX1SON–N2) PLASTIC SMALL OUTLINE NO–LEAD



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NOTES:
A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5–1994.
B. This drawing is subject to change without notice.
C. SON (Small Outline No–Lead) package configuration.

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