

# ESD441 1-Channel $\pm 30$ kV Unidirectional ESD Diode in an 0201 Package

## 1 Features

- IEC 61000-4-2 level 4 ESD protection
  - $\pm 30$  kV contact discharge
  - $\pm 30$  kV air gap discharge
- IEC 61000-4-5 surge protection
  - 6.2 A (8/20  $\mu$ s)
- IO capacitance:
  - 1 pF (typical)
- DC breakdown voltage: 7 V (typical)
- Ultra low leakage current: 50 nA (maximum)
- Extremely low ESD clamping voltage
  - 7.6 V at 16 A TLP
  - $R_{DYN}$ : 0.1  $\Omega$  (I/O to GND)
- Low insertion loss: 2 GHz (–3 dB bandwidth)
- Supports high speed interfaces up to 4 Gbps
- Industrial temperature range:  $-55^{\circ}\text{C}$  to  $+150^{\circ}\text{C}$
- Space-saving industry standard 0201 footprint (0.6 mm  $\times$  0.3 mm  $\times$  0.3 mm)

## 2 Applications

- End equipment:
  - Vacuum robots
  - Wearables
  - Smart speakers
  - Portable electronics
  - Small appliances
  - Retail automation and payment
  - Laptops and desktops
  - TV and monitors
  - Docking stations
- Interfaces:
  - USB 2.0
  - HDMI™ 1.4 and 2.0
  - DisplayPort™
  - SIM card
  - GPIO

## 3 Description

The ESD441 is a unidirectional ESD protection diode for protecting data lines and other I/O ports. The ESD441 is rated to dissipate ESD strikes up to  $\pm 30$  kV per the IEC 61000-4-2 international standard (greater than Level 4).

This device features a 1 pF (typical) IO capacitance enabling high-speed interfaces protection for protocols such as USB 2.0. The extremely low dynamic resistance (0.1  $\Omega$ ) and clamping voltage (7.6 V at 16 TLP) is specified for system level protection against transient events.

The 30 kV ESD rating and 6.2 A surge provides robust transient protection in a tiny package for protecting 5.5 V power rails in portable electronics and other space constrained applications such as wearables.

The ESD441 is offered in the industry standard 0201 (DPL) package.

### Package Information

PART NUMBER	PACKAGE <sup>(1)</sup>	PACKAGE SIZE <sup>(2)</sup>
ESD441	DPL (X2SON, 2)	0.6 mm $\times$ 0.3 mm

- (1) For all available packages, see the orderable addendum at the end of the data sheet.
- (2) The package size (length  $\times$  width) is a nominal value and includes pins, where applicable.



Functional Block Diagram



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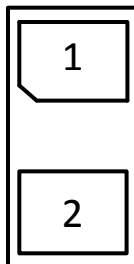
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## 4 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

<b>Changes from Revision * (April 2023) to Revision A (June 2023)</b>	<b>Page</b>
• Changed the status of the data sheet from: <i>Advanced Information</i> to: <i>Production Data</i> .....	1

## 5 Pin Configuration and Functions



**Figure 5-1. DPL Package, 2-Pin X2SON (Top View)**

**Table 5-1. Pin Functions**

PIN		TYPE <sup>(1)</sup>	DESCRIPTION
NAME	NO.		
IO	1	I/O	ESD protected channel
GND	2	GND	Ground. Connect to ground.

(1) I = input, O = output, GND = ground

## 6 Specifications

### 6.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted) <sup>(1)</sup>

		MIN	MAX	UNIT
Peak Pulse <sup>(2) (3)</sup>	IEC 61000-4-5 power ( $t_p - 8/20 \mu s$ )		45	W
	IEC 61000-4-5 Current ( $t_p - 8/20 \mu s$ )		6	A
$T_A$	Ambient Operating Temperature	-55	150	°C
$T_{stg}$	Storage Temperature	-65	155	°C

- (1) Operation outside the *Absolute Maximum Ratings* may cause permanent device damage. Absolute maximum ratings do not imply functional operation of the device at these or any other conditions beyond those listed under *Recommended Operating Conditions*. If briefly operating outside the *Recommended Operating Conditions* but within the *Absolute Maximum Ratings*, the device may not sustain damage, but it may not be fully functional. Operating the device in this manner may affect device reliability, functionality, performance, and shorten the device lifetime.
- (2) Voltages are with respect to GND unless otherwise noted.
- (3) Measured at 25°C

### 6.2 ESD Ratings—JEDEC Specification

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human body model (HBM), per ANSI/ESDA/JEDEC JS-001 <sup>(1)</sup>	±2500	V
		Charged device model (CDM), per JEDEC specification JS-002 <sup>(2)</sup>	±1000	V

- (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	±30000	V
		IEC 61000-4-2 air-gap discharge	±30000	

### 6.4 Recommended Operating Conditions

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

			MIN	NOM	MAX	UNIT
$V_{IO}$	Input pin voltage	Pin 1 to 2	0		5.5	V
$T_A$	Operating free-air temperature		-55		150	°C

### 6.5 Thermal Information

THERMAL METRIC <sup>(1)</sup>		ESD441	UNIT
		DPL (X2SON)	
		2 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	519.9	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	336.9	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	209.2	°C/W
$\Psi_{JT}$	Junction-to-top characterization parameter	136.7	°C/W
$\Psi_{JB}$	Junction-to-board characterization parameter	207.2	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	NA	°C/W

- (1) For more information about traditional and new thermal metrics, see the [Semiconductor and IC Package Thermal Metrics](#) application report.

## 6.6 Electrical Characteristics

At TA=25°C (unless otherwise noted) <sup>(1)</sup>

PARAMETER		TEST CONDITION	MIN	TYP	MAX	UNIT
V <sub>RWM</sub>	Reverse stand-off voltage	I <sub>IO</sub> < 100 nA, across operating temperature range			5.5	V
I <sub>LEAK</sub>	Reverse leakage current	V <sub>IO</sub> = 5.5 V, IO to GND		1	50	nA
V <sub>BR</sub>	Break-down voltage	I <sub>IO</sub> = 1 mA, IO to GND	6	7	8	V
V <sub>FWD</sub>	Forward voltage	I <sub>IO</sub> = 1 mA, GND to IO		0.8		V
V <sub>HOLD</sub>	Holding voltage <sup>(2)</sup>	TLP, IO to GND		6.2		V
V <sub>CLAMP</sub>	Clamping voltage with TLP <sup>(2)</sup>	I <sub>PP</sub> = 1 A, TLP, IO to GND		6.3		V
		I <sub>PP</sub> = 5 A, TLP, IO to GND		6.5		V
		I <sub>PP</sub> = 16 A, TLP, IO to GND		7.6		V
		I <sub>PP</sub> = 16 A, TLP, GND to IO		3.8		V
	Clamping voltage with surge strike <sup>(4)</sup>	I <sub>PP</sub> = 6 A, t <sub>p</sub> = 8/20 μs, IO to GND		7.6		V
R <sub>DYN</sub>	Dynamic resistance <sup>(3)</sup>	IO to GND		0.1		Ω
		GND to IO		0.16		
C <sub>L</sub>	Line capacitance	V <sub>IO</sub> = 0 V; f = 1 MHz, V <sub>pp</sub> = 30 mV, IO to GND		1		pF

- (1) Typical parameters are measured at 25°C
- (2) Transition line pulse with 100 ns width and 10 ns rise and fall time
- (3) Extraction of R<sub>DYN</sub> using least squares fit of TLP characteristics between I = 10 A and I = 20 A
- (4) Nonrepetitive current pulse 8 to 20 μs exponentially decaying waveform according to IEC 61000-4-5

## 6.7 Typical Characteristics

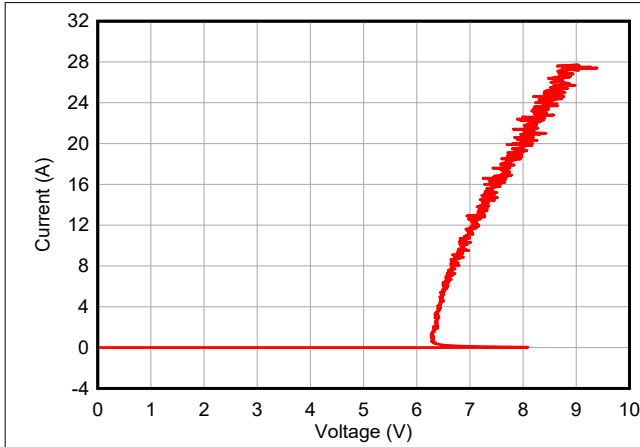


Figure 6-1. Positive TLP Curve

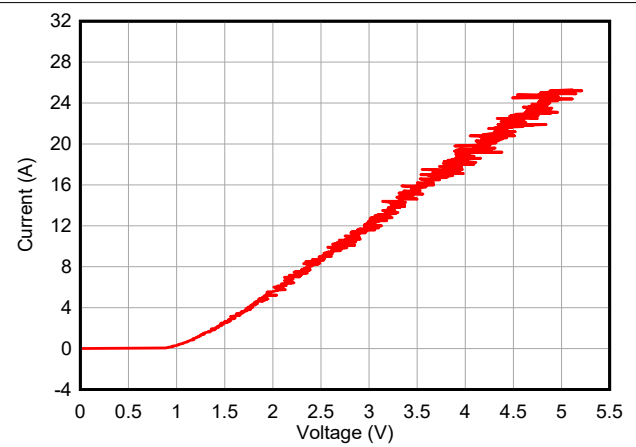


Figure 6-2. Negative TLP Curve

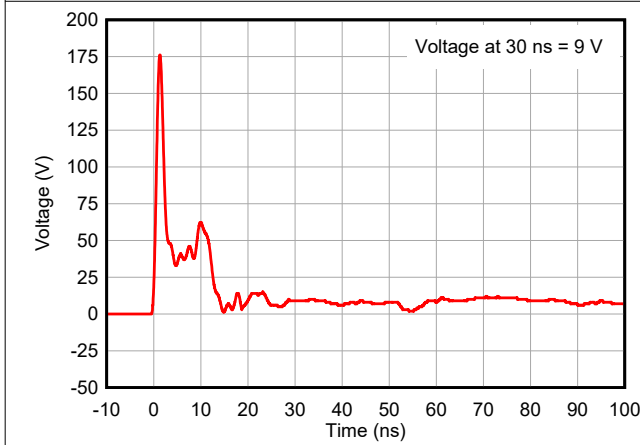


Figure 6-3. +8-kV Clamped IEC Waveform

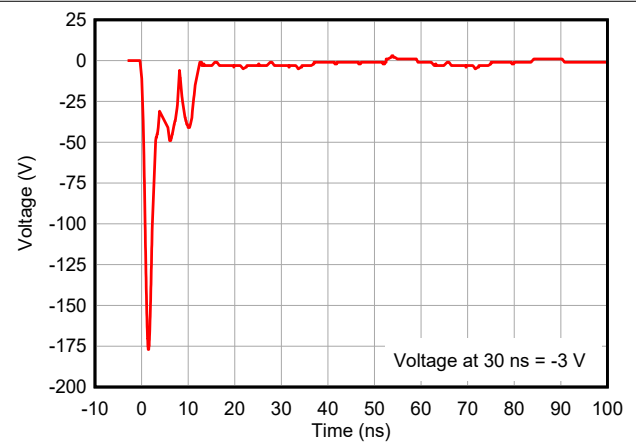


Figure 6-4. -8-kV Clamped IEC Waveform

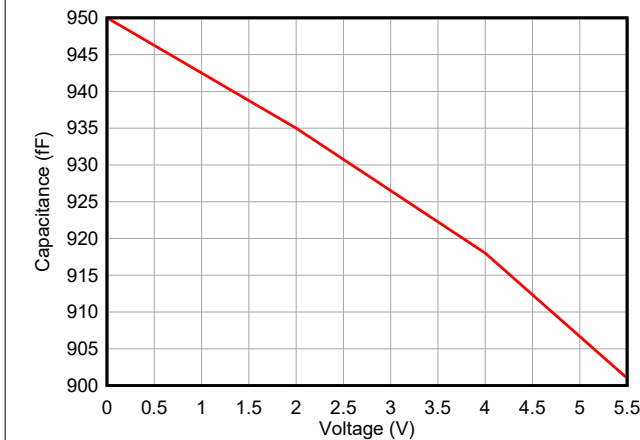


Figure 6-5. Bias Voltage vs. Capacitance

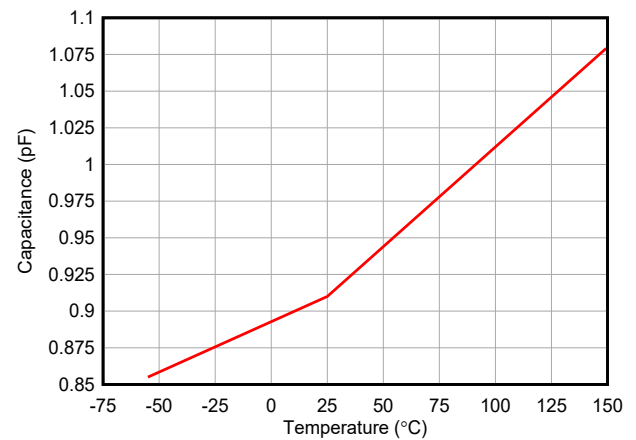


Figure 6-6. Temperature vs. Capacitance

### 6.7 Typical Characteristics (continued)

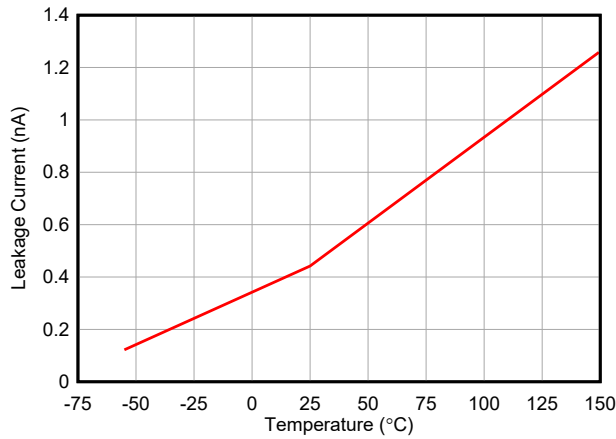


Figure 6-7. Temperature vs. Leakage Current

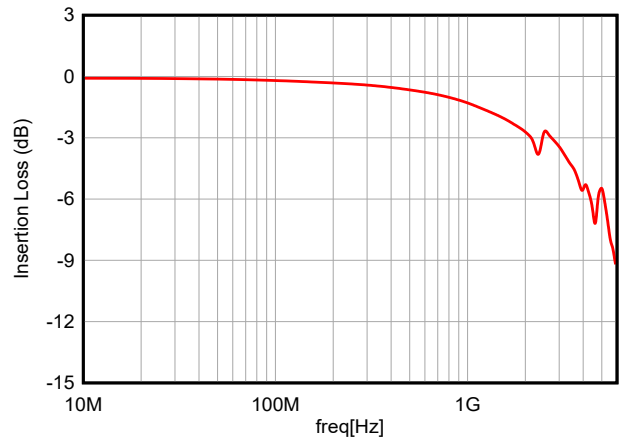


Figure 6-8. Insertion Loss

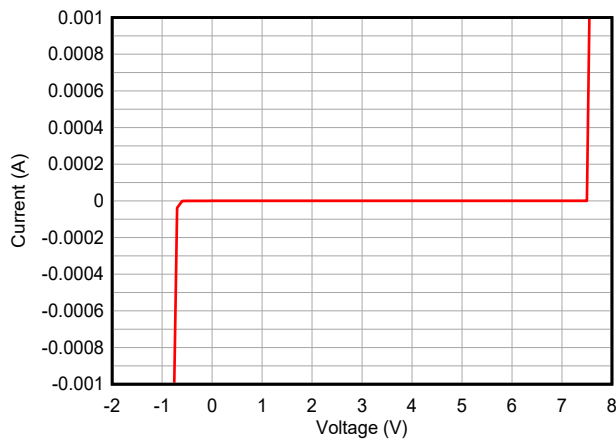


Figure 6-9. DC I-V Curve

## 7 Application and Implementation

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### 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, as well as validating and testing their design implementation to confirm system functionality.

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### 7.1 Application Information

The ESD441 is a diode type TVS which provides a path to ground for dissipating transient voltage spikes, such as ESD or surge, on signal lines and power lines. The device should be connected in parallel to the down stream circuitry it is protecting. As the current from the transient 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. For more information on how to properly use this device, please refer to the [ESD Packaging and Layout Guide](#) for details.



## 8 Device and Documentation Support

### 8.1 Documentation Support

#### 8.1.1 Related Documentation

For related documentation, see the following:

- Texas Instruments, [ESD Packaging and Layout Guide](#)
- Texas Instruments, [ESD Layout Guide application reports](#)
- Texas Instruments, [Generic ESD Evaluation Module user's guide](#)
- Texas Instruments, [Picking ESD Diodes for Ultra High-Speed Data Lines application reports](#)
- Texas Instruments, [Reading and Understanding an ESD Protection data sheet](#)

#### 8.2 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on [ti.com](https://www.ti.com). Click on *Subscribe to updates* 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.

#### 8.3 Support Resources

[TI E2E™ support forums](#) are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

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#### 8.5 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.

#### 8.6 Glossary

[TI Glossary](#) This glossary lists and explains terms, acronyms, and definitions.

## 9 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
ESD441DPLR	ACTIVE	X2SON	DPL	2	15000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 125	E	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.

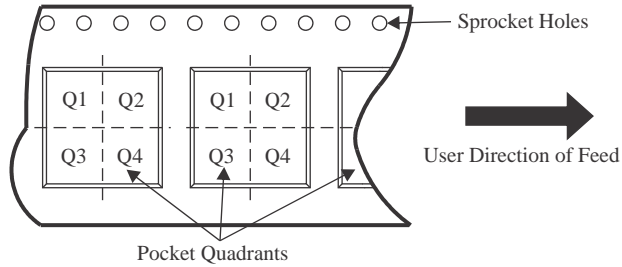
(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(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.

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**TAPE AND REEL INFORMATION**

**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
ESD441DPLR	X2SON	DPL	2	15000	178.0	8.4	0.36	0.66	0.33	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)
ESD441DPLR	X2SON	DPL	2	15000	205.0	200.0	33.0

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