# ESD Protection Diode

## Low Capacitance ESD Protection Diodes for High Speed Data Lines

# ESD9101

The ESD9101 is designed to protect a single high speed data line from ESD. Ultra-low capacitance and low ESD clamping voltage via SCR technology make this device an ideal solution for protecting voltage sensitive high speed data lines. The SOD-923 mico-package allows for easy PCB layout and the ability to be placed in space constrained applications where board area comes at a premium.

### Features

- Low Capacitance (0.5 pF Max, I/O to GND)
- Protection for the Following Standards: IEC 61000-4-2 (Level 4) & ISO 10605
- Low ESD Clamping Voltage
- SZ Prefix for Automotive and Other Applications Requiring Unique Site and Control Change Requirements; AEC-Q101 Qualified and PPAP Capable
- These Devices are Pb-Free, Halogen Free/BFR Free and are RoHS Compliant

### Typical Applications

- USB 3.0/3.1
- HDMI 1.3/1.4/2.0
- DisplayPort
- GPS Antenna

**MAXIMUM RATINGS** ($T_A$ = 25 °C unless otherwise noted)

| Rating | Symbol | Max | Unit |
|---|---|---|---|
| Junction and Storage Temperature Range | $T_J$, $T_{stg}$ | −55 to +150 | °C |
| Lead Solder Temperature – Maximum (10 Second Duration) | $T_L$ | 260 | °C |
| Human Body Model (HBM)<br>Machine Model (MM)<br>IEC 61000-4-2 Contact (ESD)<br>IEC 61000-4-2 Air (ESD)<br>ISO 10605 Contact (330 pF / 330 Ω)<br>ISO 10605 Contact (330 pF / 2 kΩ)<br>ISO 10605 Contact (150 pF / 2 kΩ) | ESD | ±8<br>±0.4<br>±25<br>±25<br>±30<br>±30<br>±20 | kV |

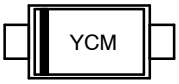
Stresses exceeding those listed in the Maximum Ratings table may damage the device. If any of these limits are exceeded, device functionality should not be assumed, damage may occur and reliability may be affected.

See Application Note AND8308/D for further description of survivability specs.

**MARKING DIAGRAM**

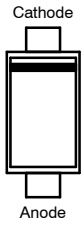


SOD-923
CASE 514AB



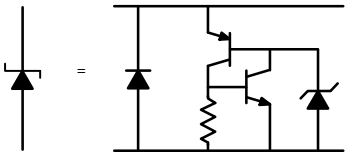

YC = Specific Device Code
M = Date Code

**PIN CONFIGURATIONS AND SCHEMATICS**









**ORDERING INFORMATION**

See detailed ordering and shipping information on page 7 of this data sheet.

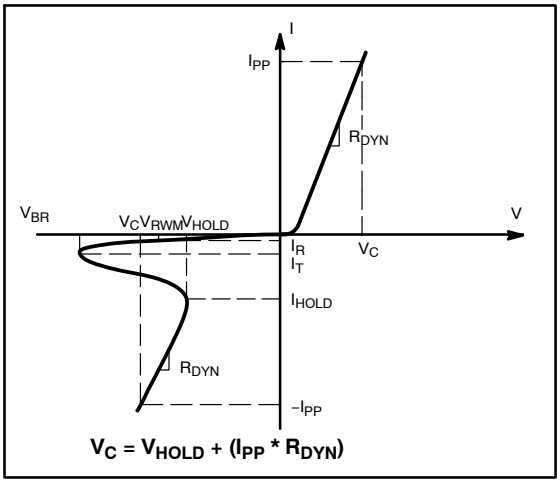
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## ELECTRICAL CHARACTERISTICS

($T_A$ = 25 °C unless otherwise noted)

| Symbol | Parameter |
|---|---|
| $V_{RWM}$ | Working Peak Voltage |
| $I_R$ | Maximum Reverse Leakage Current @ $V_{RWM}$ |
| $V_{BR}$ | Breakdown Voltage @ $I_T$ |
| $I_T$ | Test Current |
| $V_{HOLD}$ | Holding Reverse Voltage |
| $I_{HOLD}$ | Holding Reverse Current |
| $R_{DYN}$ | Dynamic Resistance |
| $I_{PP}$ | Maximum Peak Pulse Current |
| $V_C$ | Clamping Voltage @ $I_{PP}$<br>$V_C = V_{HOLD} + (I_{PP} * R_{DYN})$ |




## ELECTRICAL CHARACTERISTICS ($T_A$ = 25 °C unless otherwise specified)

| Parameter | Symbol | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Reverse Working Voltage | $V_{RWM}$ | I/O Pin to GND | | | 5.0 | V |
| Breakdown Voltage | $V_{BR}$ | $I_T$ = 1 mA, I/O Pin to GND | 5.3 | 7.0 | 8.0 | V |
| Reverse Leakage Current | $I_R$ | $V_{RWM}$ = 5.0 V, I/O Pin to GND | | | 1.0 | μA |
| Holding Reverse Voltage | $V_{HOLD}$ | I/O Pin to GND | | 2.2 | | V |
| Holding Reverse Current | $I_{HOLD}$ | I/O Pin to GND | 65 | 97 | | mA |
| Clamping Voltage | $V_C$ | IEC61000-4-2, ±8 KV Contact | | See Figures 7 and 8 | | V |
| Clamping Voltage TLP | $V_C$ | $I_{TLP}$ = 8 A<br>$I_{TLP}$ = –8 A<br>$I_{TLP}$ = 16 A<br>$I_{TLP}$ = –16 A | | 5.0<br>–4.0<br>7.0<br>–7.0 | | V |
| Clamping Voltage<br>8/20 s Waveform<br>(See Figures 4–5) | $V_C$ | IPP = 1 A<br>IPP = 3 A<br>IPP = 5 A<br>IPP = 7 A | | 7.7<br>7.3<br>3.8<br>5.0 | | V |
| Dynamic Resistance | $R_{DYN}$ | I/O Pin to GND<br>GND to I/O Pin | | 0.30<br>0.38 | | Ω |
| Junction Capacitance | $C_J$ | $V_R$ = 0 V, f = 1 MHz between I/O Pins and GND<br>$V_R$ = 0 V, f = 2.5 GHz between I/O Pins and GND<br>$V_R$ = 0 V, f = 5.0 GHz between I/O Pins and GND | | 0.36<br>0.36<br>0.36 | 0.50<br>0.45<br>0.45 | pF |
| Insertion Loss | $I_L$ | f = 1 GHz<br>f = 5 GHz | | 0.12<br>0.66 | | dB |
| Return Loss | $R_L$ | f = 1 GHz<br>f = 5 GHz | | 31.3<br>18.0 | | dB |

Product parametric performance is indicated in the Electrical Characteristics for the listed test conditions, unless otherwise noted. Product performance may not be indicated by the Electrical Characteristics if operated under different conditions.



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## TYPICAL CHARACTERISTICS ($T_J$ = 25 °C unless otherwise noted)

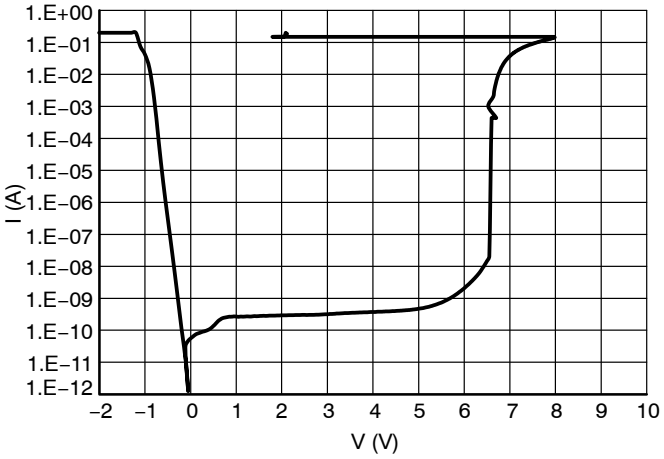



**Figure 1. IV Characteristics**

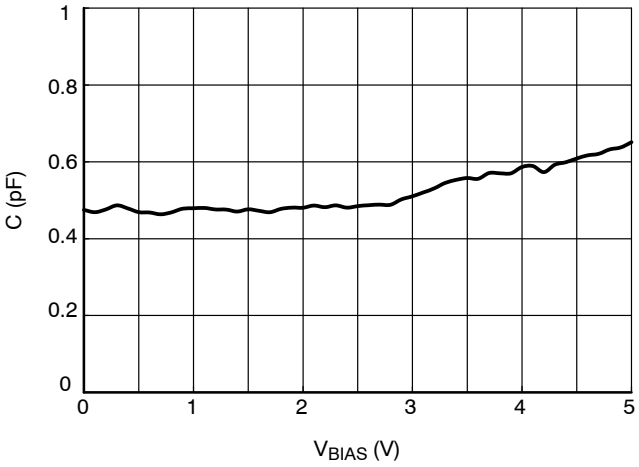



**Figure 2. CV Characteristics**

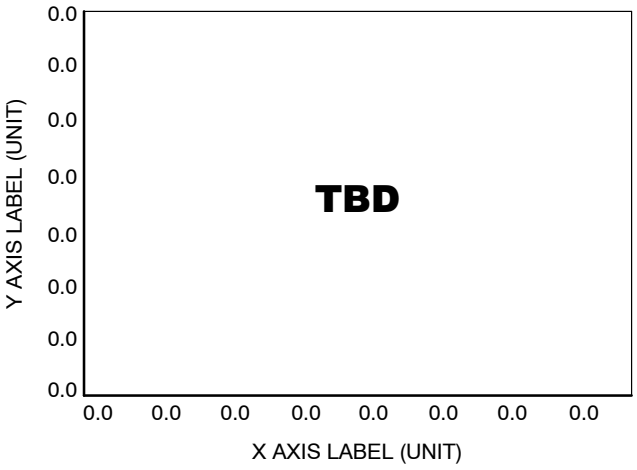



**Figure 3. $I_R$ vs. Temperature Characteristics**

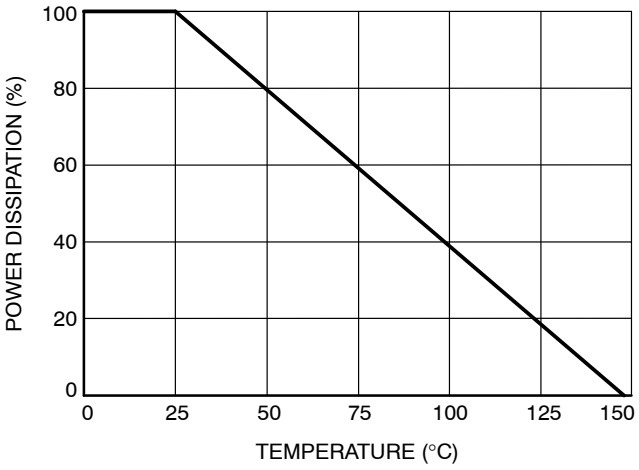



**Figure 4. Steady State Power Derating**

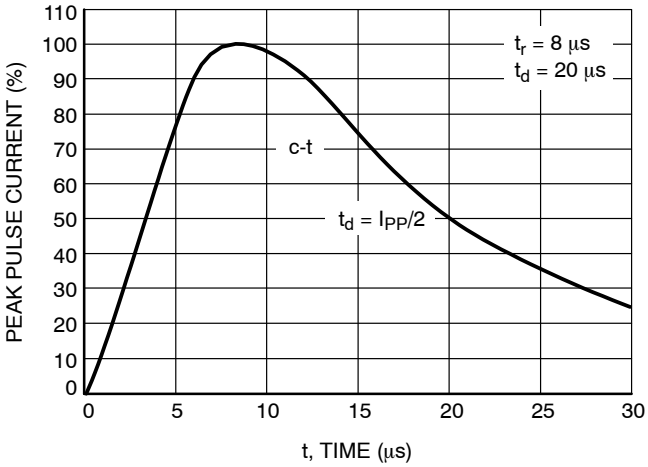



**Figure 5. Pulse Waveform (8/20 μs)**

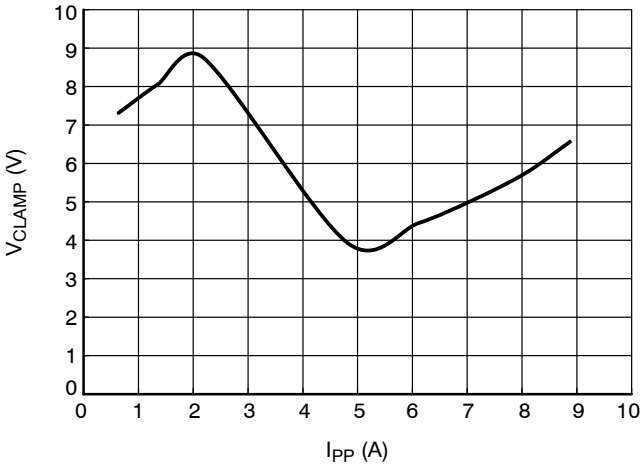



**Figure 6. Clamping Voltage vs. Peak Pulse Current (8/20 μs)**



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## TYPICAL CHARACTERISTICS ($T_J$ = 25 °C unless otherwise noted)

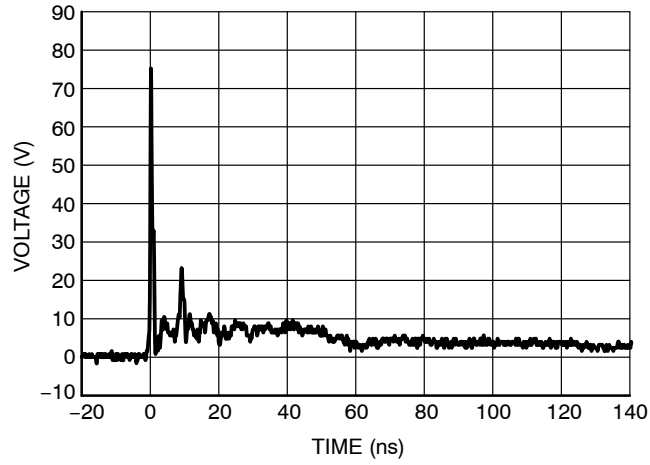



**Figure 7. IEC61000-4-2 +8 kV Contact ESD Clamping Voltage**

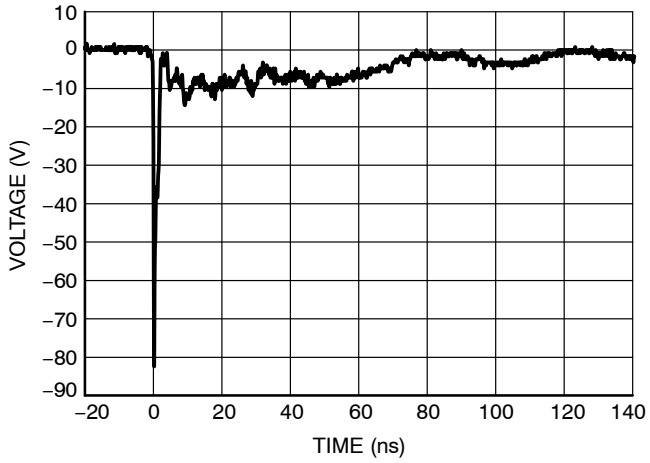



**Figure 8. IEC61000-4-2 −8 kV Contact ESD Clamping Voltage**

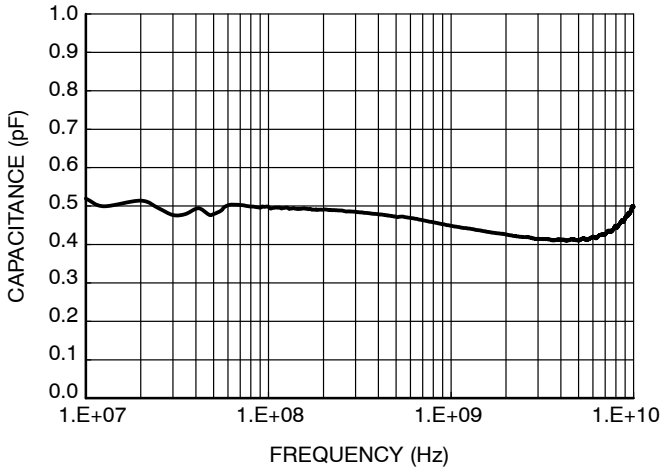



**Figure 9. Typical Capacitance vs. Frequency**

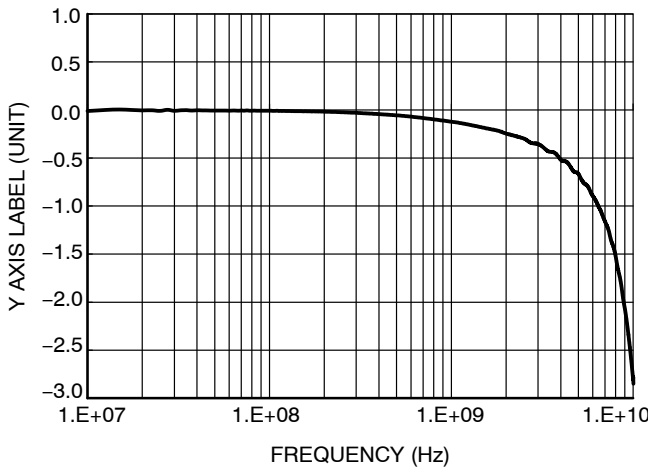



**Figure 10. Typical Insertion Loss**

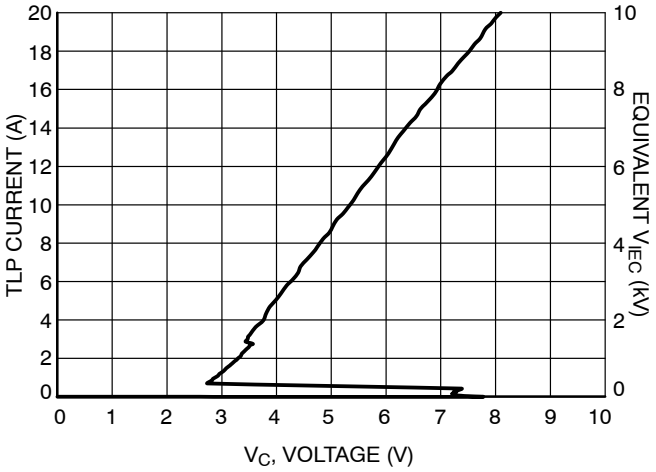



**Figure 11. Positive TLP IV Curve**

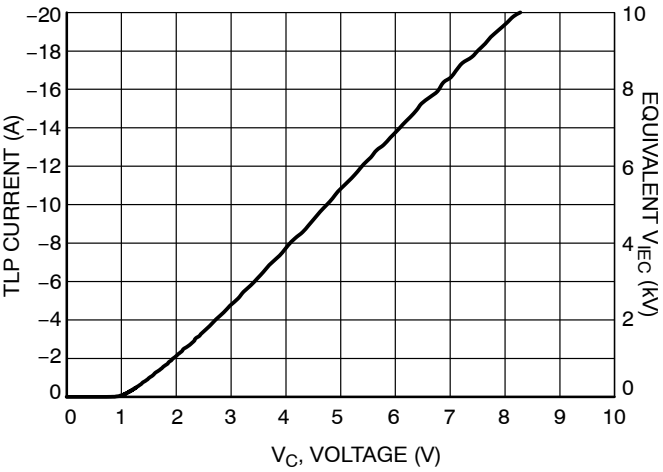



**Figure 12. Negative TLP IV Curve**

NOTE: TLP parameter: $Z_0$ = 50 Ω, $t_p$ = 100 ns, $t_r$ = 300 ps, averaging window: $t_1$ = 30 ns to $t_2$ = 60 ns. $V_{IEC}$ is the equivalent voltage stress level calculated at the secondary peak of the IEC 61000-4-2 waveform at t = 30 ns with 2 A/kV. See TLP description below for more information.



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**IEC 61000-4-2 Spec.**

| Level | Test Voltage (kV) | First Peak Current (A) | Current at 30 ns (A) | Current at 60 ns (A) |
|---|---|---|---|---|
| 1 | 2 | 7.5 | 4 | 2 |
| 2 | 4 | 15 | 8 | 4 |
| 3 | 6 | 22.5 | 12 | 6 |
| 4 | 8 | 30 | 16 | 8 |

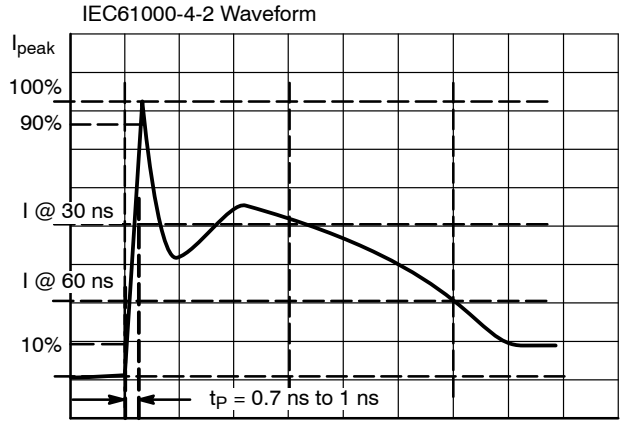



**Figure 13. IEC61000-4-2 Spec**

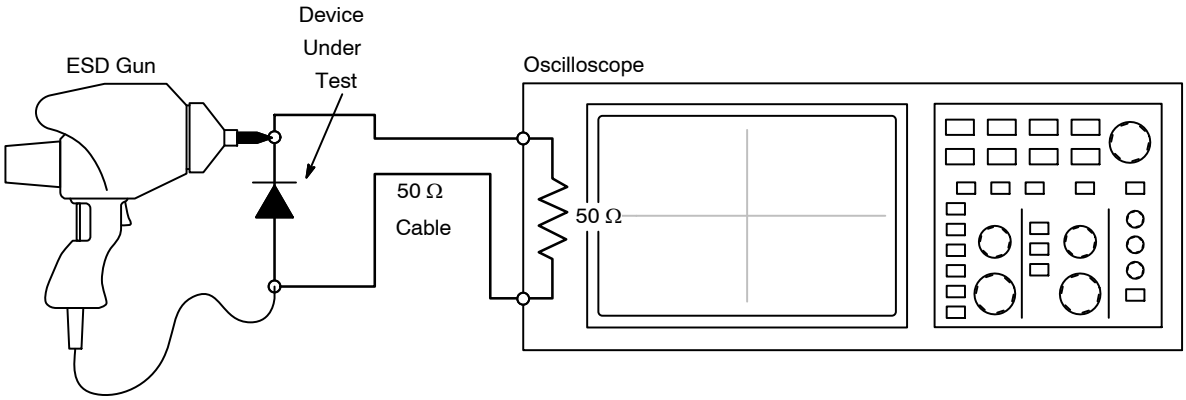



**Figure 14. Diagram of ESD Clamping Voltage Test Setup**

**The following is taken from Application Note AND8307/D – Characterization of ESD Clamping Performance.**

### ESD Voltage Clamping

For sensitive circuit elements it is important to limit the voltage that an IC will be exposed to during an ESD event to as low a voltage as possible. The ESD clamping voltage is the voltage drop across the ESD protection diode during an ESD event per the IEC61000-4-2 waveform. Since the IEC61000-4-2 was written as a pass/fail spec for larger systems such as cell phones or laptop computers it is not clearly defined in the spec how to specify a clamping voltage at the device level. **onsemi** has developed a way to examine the entire voltage waveform across the ESD protection diode over the time domain of an ESD pulse in the form of an oscilloscope screenshot, which can be found on the datasheets for all ESD protection diodes. For more information on how **onsemi** creates these screenshots and how to interpret them please refer to AND8307/D.

### Transmission Line Pulse (TLP) Measurement

Transmission Line Pulse (TLP) provides current versus voltage (I−V) curves in which each data point is obtained from a 100 ns long rectangular pulse from a charged transmission line. A simplified schematic of a typical TLP system is shown in Figure 15. TLP I−V curves of ESD protection devices accurately demonstrate the product's ESD capability because the 10s of amps current levels and under 100 ns time scale match those of an ESD event. This is illustrated in Figure 16 where an 8 kV IEC 61000-4-2 current waveform is compared with TLP current pulses at 8 A and 16 A. A TLP I−V curve shows the voltage at which the device turns on as well as how well the device clamps voltage over a range of current levels. For more information on TLP measurements and how to interpret them please refer to AND9007/D.

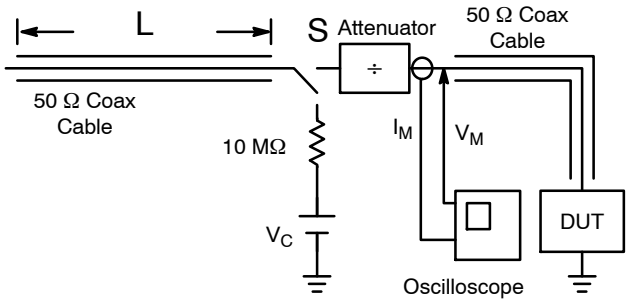



**Figure 15. Simplified Schematic of a Typical TLP System**



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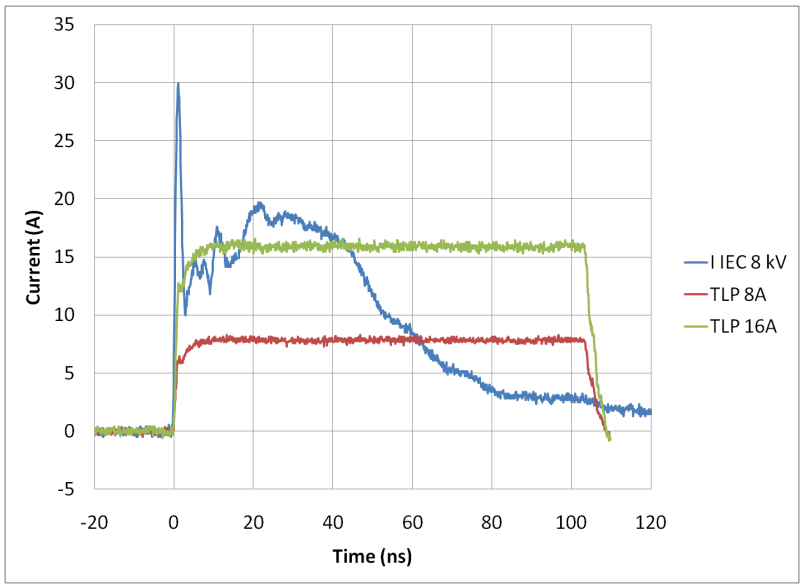



**Figure 16. Comparison Between 8 kV IEC 61000-4-2 and 8 A and 16 A TLP Waveforms**

### Latch-Up Considerations

**onsemi**'s 9100 series of ESD protection devices utilize a snap-back, SCR type structure. By using this technology, the potential for a latch-up condition was taken into account by performing load line analyses of common high speed serial interfaces. Example load lines for latch-up free applications and applications with the potential for latch-up are shown below with a generic IV characteristic of a snapback, SCR type structured device overlaid on each. In the latch-up free load line case, the IV characteristic of the snapback protection device intersects the load-line in one unique point ($V_{OP}$, $I_{OP}$). This is the only stable operating point of the circuit and the system is therefore latch-up free.

In the non-latch up free load line case, the IV characteristic of the snapback protection device intersects the load-line in two points ($V_{OPA}$, $I_{OPA}$) and ($V_{OPB}$, $I_{OPB}$). Therefore in this case, the potential for latch-up exists if the system settles at ($V_{OPB}$, $I_{OPB}$) after a transient. Due to its high holding current, the ESD9101 is suitable for HDMI and 5 V active antenna applications where previous ESD8000 series devices were not. ***When designing this part into the application, please note the latch-up considerations by performing a loadline analysis corresponding to the data line and ESD9101's SCR characteristics.*** For a more in-depth explanation of latch-up considerations please refer to Application Note AND9116/D.

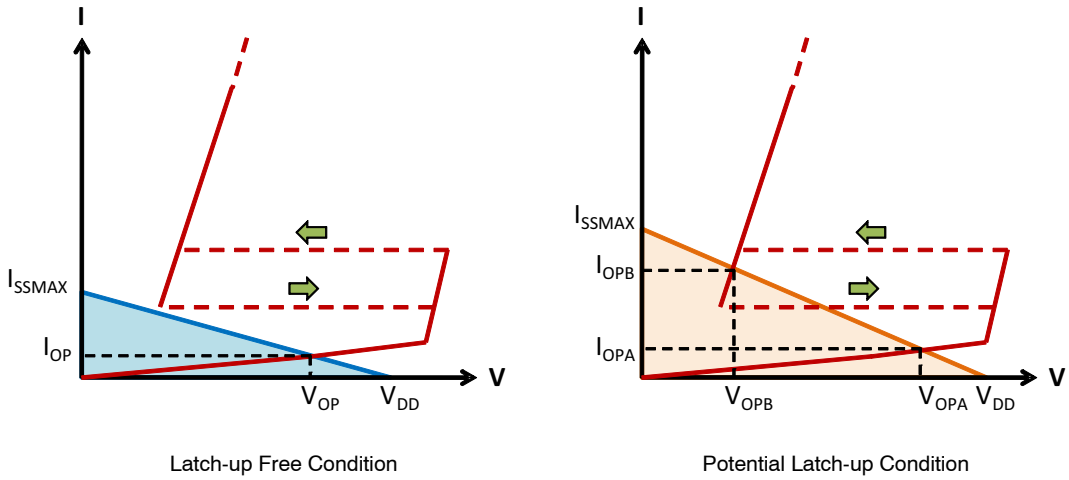



**Figure 17. Example Load Lines for Latch-up Free Applications and Applications with the Potential for Latch-up**



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**Table 1. SUMMARY OF SCR REQUIREMENTS FOR LATCH-UP FREE APPLICATIONS**

| Application | VBR (min) (V) | IH (min) (mA) | VH (min) (V) |
|---|---|---|---|
| HDMI 1.4/1.3a TMDS | 3.465 | 54.78 | 1.0 |
| USB 2.0 LS/FS | 3.301 | 1.76 | 1.0 |
| USB 2.0 HS | 0.482 | N/A | 1.0 |
| USB 3.0/3.1 SS | 2.800 | N/A | 1.0 |
| DisplayPort | 3.600 | 25.00 | 1.0 |
| GPS (Active) | 5.200 | 80.00 | 1.0 |

## ORDERING INFORMATION

| Device | Device Marking | Package | Shipping† |
|---|---|---|---|
| ESD9101P2T5G | YC | SOD-923 (Pb-Free) | 8000 / Tape & Reel |
| SZESD9101P2T5G | YC | | |

† For information on tape and reel specifications, including part orientation and tape sizes, please refer to our Tape and Reel Packaging Specifications Brochure, BRD8011/D.



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## REVISION HISTORY

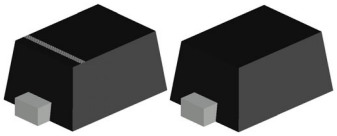
| Revision | Description of Changes | Date |
|---|---|---|
| 3 | Updated Maximum Ratings and Electrical Characteristics tables; added new pages with NUP2205/D formatting; updated and replaced Figures 1−12 per referenced datasheets. | 7/22/2026 |

This document has undergone updates prior to the inclusion of this revision history table. The changes tracked here only reflect updates made on the noted approval dates.



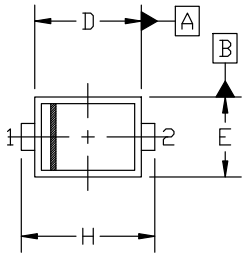
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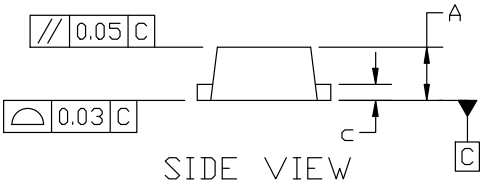


**SOD−923 0.80x0.60x0.37**
CASE 514AB
ISSUE E

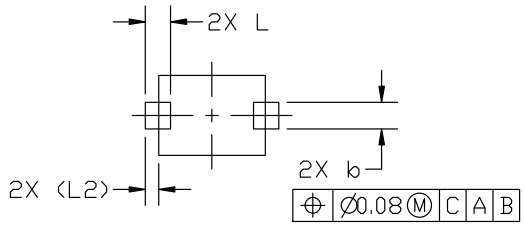
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TOP VIEW



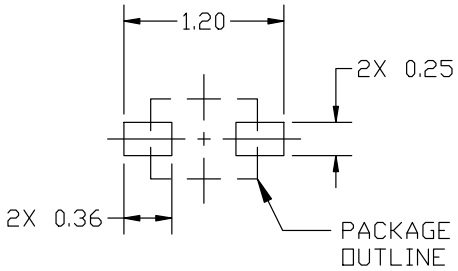

SIDE VIEW




BOTTOM VIEW

NOTES:
1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M, 2018.
2. CONTROLLING DIMENSION: MILLIMETERS.
3. MAXIMUM LEAD THICKNESS INCLUDES LEAD FINISH. MINIMUM LEAD THICKNESS IS THE MINIMUM THICKNESS OF BASE MATERIAL.
4. DIMENSIONS D AND E DO NOT INCLUDE MOLD FLASH, PROTRUSIONS, OR GATE BURRS.
5. DIMENSION L WILL NOT EXCEED 0.30mm.

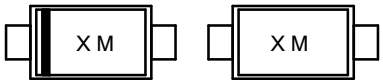
| MILLIMETERS | | | |
|---|---|---|---|
| DIM | MIN. | NOM. | MAX. |
| A | 0.34 | 0.37 | 0.40 |
| b | 0.15 | 0.20 | 0.25 |
| c | 0.07 | 0.12 | 0.17 |
| D | 0.75 | 0.80 | 0.85 |
| E | 0.55 | 0.60 | 0.65 |
| H | 0.95 | 1.00 | 1.05 |
| L | 0.19 REF | | |
| L2 | 0.05 | 0.10 | 0.15 |




RECOMMENDED MOUNTING FOOTPRINT

*For additional information on our Pb-Free strategy and soldering details, please download the ON Semiconductor Soldering and Mounting Techniques Reference Manual, SOLDERRM/D.

**GENERIC MARKING DIAGRAM***




STYLE 1 STYLE 2

X = Specific Device Code
M = Date Code

*This information is generic. Please refer to device data sheet for actual part marking. Pb−Free indicator, “G” or microdot “▪”, may or may not be present. Some products may not follow the Generic Marking.

STYLE 1:
PIN 1. CATHODE (POLARITY BAND)
2. ANODE

STYLE 2:
NO POLARITY

| | | | |
|---|---|---|---|
| **DOCUMENT NUMBER:** | **98AON23284D** | Electronic versions are uncontrolled except when accessed directly from the Document Repository. Printed versions are uncontrolled except when stamped “CONTROLLED COPY” in red. | |
| **DESCRIPTION:** | **SOD−923 0.80x0.60x0.37** | | **PAGE 1 OF 1** |

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