ESD2CAN24-Q1 Automotive 24-V, 2-Channel ESD Protection Diode for In-Vehicle Networks

1 Features

- IEC 61000-4-2 level 4 ESD protection:
  - ±30-kV contact discharge
  - ±30-kV air-gap discharge
- ISO 10605 (330 pF, 330 Ω) ESD protection:
  - ±30-kV contact discharge
  - ±30-kV air-gap discharge
- Tested in compliance to IEC 61000-4-5
- 24 V working voltage
- Bidirectional ESD protection
- 2-channel device provides complete ESD protection with single component
- Low clamping voltage protects downstream components
- AEC-Q101 qualified
- I/O capacitance = 3 pF (typical)
- SOT-23 (DBZ) small, standard, common footprint
- SOT-323, SC-70 (DCK) very small, standard, space saving, common footprint
- Leaded packages used for automatic optical inspection (AOI)

2 Applications

- Automotive in-vehicle networks:
  - Controller area network (CAN)
  - Controlled area network flexible data-rate (CAN-FD)
  - Low, fault tolerant CAN
  - High-speed CAN
- Industrial control networks:
  - DeviceNet IEC 62026-3
  - CANopen – CiA 301/302-2 and EN 50325-4

3 Description

The ESD2CAN24-Q1 is a bidirectional ESD protection diode for Controller Area Network (CAN) interface protection. The ESD2CAN24-Q1 is rated to dissipate contact ESD strikes beyond the maximum level specified in the ISO 10605 automotive standard (±30-kV Contact, ±30-kV Airgap). The low dynamic resistance and low clamping voltage ensures system level protection against transient events. This protection is key as automotive systems require a high level of robustness and reliability for safety applications.

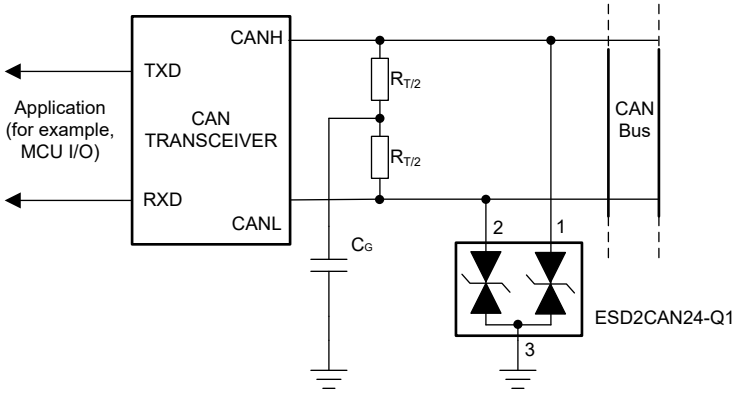
This device features a low IO capacitance per channel and a pin-out to suit two automotive CAN bus lines (CANH and CANL) from the damage caused by ElectroStatic Discharge (ESD) and other transients. Additionally, the 3 pF line capacitance of the ESD2CAN24-Q1 is suitable for CAN, CANFD, CAN SiC, and CAN-XL applications that can support data rates up to 10 Mbps.

The ESD2CAN24-Q1 is offered in two leaded packages for easy flow through routing.

Device Information(1)

PART NUMBER	PACKAGE	BODY SIZE (NOM)
ESD2CAN24-Q1	SOT-23 (3)	2.92 mm × 1.30 mm
	SOT-323, SC-70 (3)	2.00 mm × 1.25 mm

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



ESD2CAN24-Q1 Typical Application

ADVANCE INFORMATION

ADVANCE INFORMATION

Table of Contents

4 Revision History

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

Changes from Revision * (April 2022) to Revision A (June 2022)	Page
• Updated Ipp specification to be equal to 6 A in the the *Absolute Maximum Ratings* and *Electrical Characteristics* sections	4

5 Pin Configuration and Functions

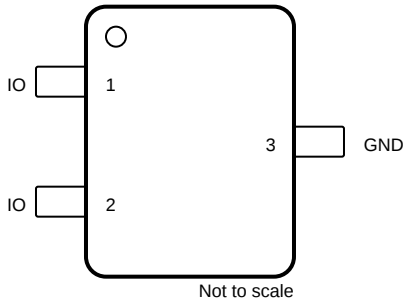


Figure 5-1. DCK and DBZ Package, 3-Pin SOT (Top View)

Table 5-1. Pin Functions

PIN		TYPE[1]	DESCRIPTION
NAME	NO.		
IO	1, 2	I/O	ESD protected IO
GND	3	—	Connect to ground.

(1) I/O = Input or Output,

ADVANCE INFORMATION

ADVANCE INFORMATION

6 Specifications

6.1 Absolute Maximum Ratings

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

		MIN	MAX	UNIT
Peak pulse	IEC 61000-4-5 Power (t_p - 8/20 µs) at 25°C		147	W
Peak pulse	IEC 61000-4-5 current (t_p - 8/20 µs) at 25°C		6	A
T_A	Operating free-air temperature	-55	150	°C
TJ	Junction 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.

6.2 ESD Ratings—AEC Specification

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human body model (HBM), per AEC Q101-001	± 2500	V
		Charged device model (CDM), per AEC Q101-005	± 1000	

6.3 ESD Ratings—IEC Specification

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	IEC 61000-4-2 Contact Discharge, all pins	±30000	V
		IEC 61000-4-2 Air-gap Discharge, all pins	±30000	

6.4 ESD Ratings - ISO Specification

				VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	ISO 10605, 150-pF, 330-Ω, IO	Contact discharge	± 30000	V
			Air-gap discharge	± 30000	
		ISO 10605, 330-pF, 330-Ω, IO	Contact discharge	± 30000	
			Air-gap discharge	± 30000	

6.5 Recommended Operating Conditions

		MIN	NOM	MAX	UNIT
V_{IN}	Input voltage	-24		24	V
T_A	Operating free-air temperature	-55		150	°C

6.6 Thermal Information

THERMAL METRIC(1)		ESD2CAN24-Q1		UNIT
		DBZ (SOT-23)	DCK (SOT-323, SC-70)	
		3 PINS	3PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	291.5	283.0	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	147.1	164.1	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	131.1	105.1	°C/W
Ψ_{JT}	Junction-to-top characterization parameter	32.0	67.1	°C/W

6.6 Thermal Information (continued)

THERMAL METRIC[1]		ESD2CAN24-Q1		UNIT
		DBZ (SOT-23)	DCK (SOT-323, SC-70)	
		3 PINS	3PINS	
Ψ_{JB}	Junction-to-board characterization parameter	130.2	104.4	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	N/A	N/A	°C/W

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

6.7 Electrical Characteristics

over T_A = 25°C (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{RWM}	Reverse stand-off voltage		–24		24	V
V_{BRF}	Forward breakdown voltage, any IO pin to GND[1]	I_{IO} = 1 mA	25.5	27.5	29.5	V
V_{BRR}	Reverse breakdown voltage, any IO pin to GND[1]	I_{IO} = –1 mA	–29.5	-27.5	–25.5	V
V_{CLAMP}	Clamping voltage[3]	I_{PP} = 3.5 A, t_p = 8/20 µs, from IO to GND		31	42	V
		I_{PP} = 6 A, t_p = 8/20 µs, from IO to GND			42	
	Clamping voltage[4]	I_{PP} = 16 A, TLP, from IO to GND		33		
V_{Hold}	Holding voltage after snapback[2]			28.5		V
I_{LEAK}	Leakage current, any IO pin to GND	V_{IO} = ±24 V	-50	1	50	nA
R_{DYN}	Dynamic resistance[4]	IO to GND		0.35		Ω
		GND to IO		0.35		
C_L	Line capacitance, any IO to GND	V_{IO} = 0 V, f = 1 MHz, V_{p-p} = 30 mV		3	5	pF
		V_{IO} = 2.5 V, f = 1 MHz, V_{p-p} = 30 mV		2.5	5	pF

(1) V_{BRF} and V_{BRR} are defined as the voltage when 1 mA is applied in the positive-going direction, before the device latches into the snapback state.
(2) V_{HOLD} is defined as the voltage when 1 mA is applied in the negative-going direction, after the device has successfully latched into the snapback state.
(3) Device stressed with 8/20 µs exponential decay waveform according to IEC 61000-4-5.
(4) Non-repetitive current pulse, Transmission Line Pulse (TLP); square pulse; ANSI / ESD STM5.5.1-2008.

ADVANCE INFORMATION

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6.8 Typical Characteristics

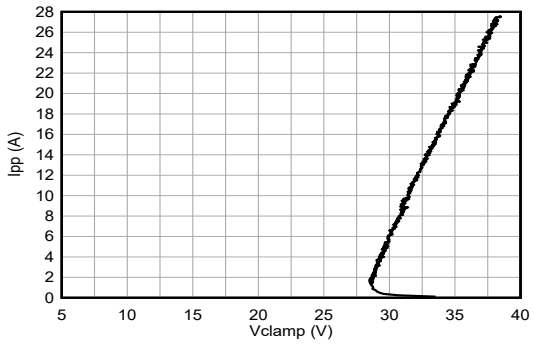


Figure 6-1. Positive TLP Curve

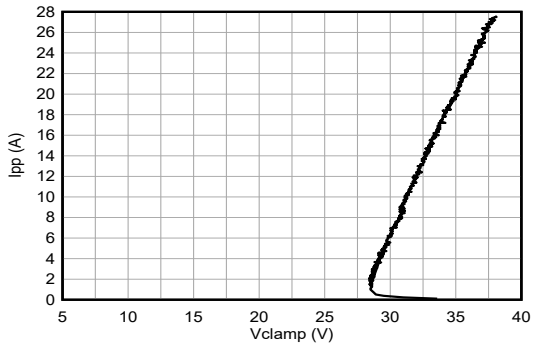


Figure 6-2. Negative TLP Curve

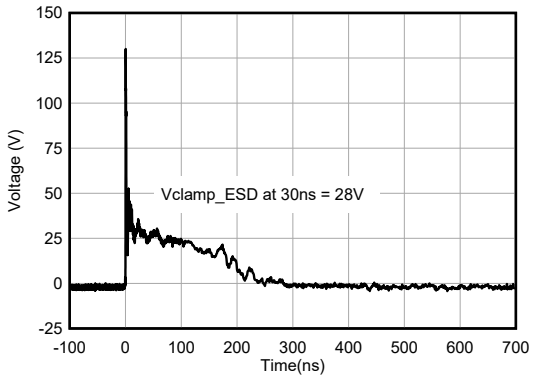


Figure 6-3. +8-kV Clamped IEC Waveform

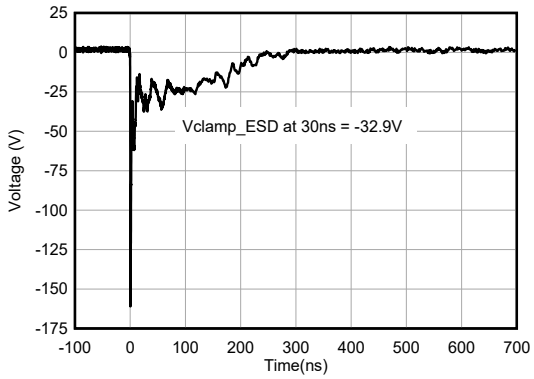


Figure 6-4. -8-kV Clamped IEC Waveform

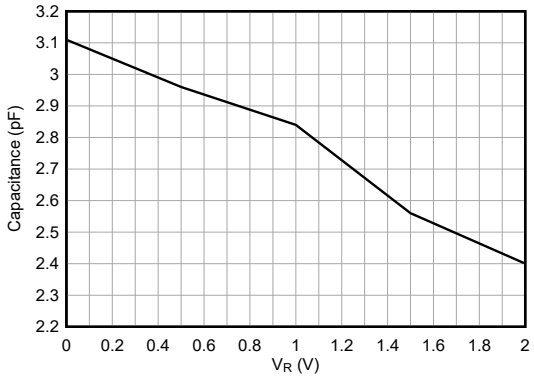


Figure 6-5. Capacitance vs. Bias Voltage

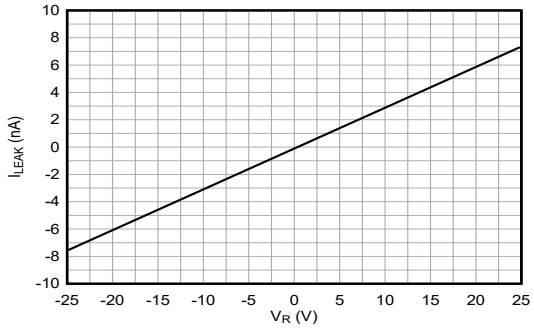


Figure 6-6. Leakage Current vs. Bias Voltage Across Temperature

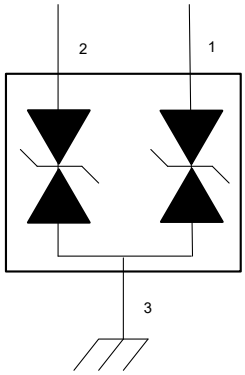
7 Detailed Description

7.1 Overview

The ESD2CAN24-Q1 is a dual-channel ESD TVS diode in SOT-23 and SC-70 leaded packages which are convenient for automatic optical inspection. This product offers ISO ±30-kV air-gap, ±30-kV contact ESD protection, and has a clamp circuit with a back-to-back TVS diode for bidirectional signal support. The 3 pF line capacitance of this ESD protection diode is suitable for CAN, CANFD, CAN SiC, and CAN-XL applications that can support data rates up to 10 Mbps.

Typical application of this product is the ESD circuit protection for CAN transceivers used in automotive applications. The ESD2CAN24-Q1 is a good fit for the ESD protection inside automotive electronic control units (ECUs) for head lights, door modules, climate control, roof control, wipers, cluster, audio, and many other automotive applications.

7.2 Functional Block Diagram



7.3 Feature Description

The ESD2CAN24-Q1 is a bidirectional TVS with a high ESD protection level. This device protects the circuit from ESD strikes up to ±30-kV contact and ±30-kV air-gap specified in the ISO 10605 automotive standard. The device can also handle up to 3.5 A surge current (IEC 61000-4-5 8/20 µs). The I/O capacitance of 3-pF supports a data rate up to 10 Mbps. This clamping device has a small dynamic resistance, which makes the clamping voltage low when the device is actively protecting other circuits. For example, the clamping voltage is only 31 V when the device is taking 3.5 A transient current. The breakdown is bidirectional so this protection device is a good fit for CAN which is a differential signal. Low leakage allows the diode to conserve power when working below the V_{RWM}. The temperature range of -55°C to +150°C makes this ESD device work at extensive temperatures in most environments. The leaded SOT-23 and SC-70 packages are good for applications requiring automatic optical inspection (AOI).

7.3.1 AEC-Q101 Qualified and Temperature Range

This device is qualified to AEC-Q101 standards and is qualified to operate from –55°C to +150°C.

7.3.2 ISO 10605 ESD Protection

The I/O pins can withstand ESD events of at least ±30-kV contact and ±30-kV air-gap in the leaded SOT-23 and SC-70 packages according to the ISO 10605 (330 pF and 330 Ω loading condition) standard. An ESD-surge clamp diverts the current to ground.

7.3.3 IEC 61000-4-5 Surge Protection

The IO pins can withstand surge events up to 3.5 A (8/20 µs waveform). An ESD-surge clamp diverts this current to ground.

7.3.4 IO Capacitance

The capacitance between the I/O pins is 3 pF. This capacitance supports data rates for CAN, CANFD, CAN SiC, and CAN-XL up to 10 Mbps.

ADVANCE INFORMATION

7.3.5 Dynamic Resistance

The IO pins feature an ESD clamp that has a low R_{DYN} of 0.35 Ω (Pin 1 or Pin 2 to Pin 3) and 0.35 Ω (Pin 3 to Pin 1 or Pin 2) which prevents system damage during ESD events.

7.3.6 DC Breakdown Voltage

The DC breakdown voltage between the IO pins is a minimum of ± 25.5 V. This ensures that sensitive equipment is protected from surges above the reverse standoff voltage of ± 24 V.

7.3.7 Ultra Low Leakage Current

The IO pins feature an ultra-low leakage current of 50 nA (maximum) with a bias of ± 24 V.

7.3.8 Clamping Voltage

The IO pins feature an ESD clamp that is capable of clamping the voltage to 31 V (I_{PP} = 3.5 A) and 33 V (I_{PP} = 16 A for TLP).

7.3.9 Industry Standard Leaded Packages

This device features industry standard SOT-23 (DBZ) and SC-70 (DCK) leaded packages for automatic optical inspection (AOI).

7.4 Device Functional Modes

The ESD2CAN24-Q1 is a dual channel passive clamp that has low leakage during normal operation when the voltage between pin 1 or pin 2 and pin 3 is below V_{RWM}, and activates when the voltage between pin 1 or pin 2 and pin 3 goes above V_{BR}. During ISO ESD events, transient voltages as high as ±30 kV can be clamped on either channel. When the voltages on the protected lines fall below the V_{HOLD}, the device reverts back to the low leakage passive state.

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

8.1 Application Information

The ESD2CAN24-Q1 is a dual channel TVS diode which is used to provide a path to ground for dissipating ESD events on differential CAN signal lines. The CAN signal lines are typically routed throughout the automobile to connect between the different ECUs. 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

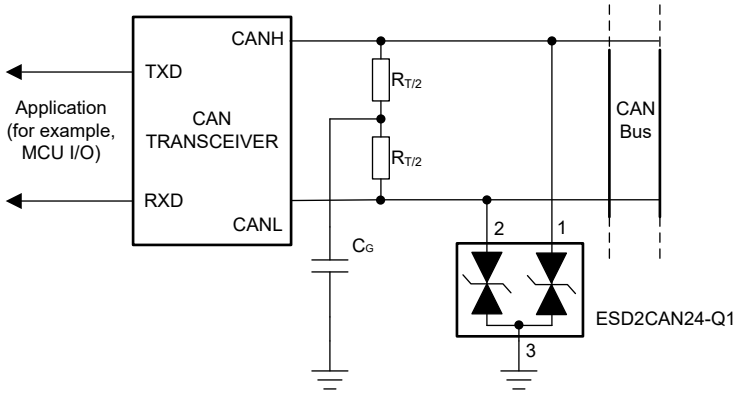

Figure 8-1. ESD2CAN24-Q1 Typical Application

8.2.1 Design Requirements

For this design example, the ESD2CAN24-Q1 is used to provide ESD protection to a CAN transceiver. The parameters listed in Table 8-1 are the known design parameters for this application.

Table 8-1. Design Parameters for the ESD2CAN24-Q1 Typical Application

Design Parameter	Value
Diode configuration	Bidirectional
V_{IO} differential signal range	> ±1.5 V
V_{RWM}	±24 V
Jumpstart short to battery event on V_{IO}	±24 V
Data rate	Up to 10 Mbps
RT/2	60 Ω

ADVANCE INFORMATION

8.2.2 Detailed Design Procedure

The ESD2CAN24-Q1 has a V_{RWM} of ±24 V to protect the diode from being damaged during a short to battery event that can occur by reversing the terminal connections during jumpstart. The bidirectional characteristic ensures the differential CAN signal integrity is not impacted by the diode. The low capacitance of 3 pF ensures data rates up to 10 Mbps, which allows the designer to meet the requirements for CAN, CANFD, CAN SiC, and CAN-XL. The 60 Ω split termination improves the electromagnetic emissions behavior of the network by filtering higher-frequency common-mode noise that may be present on the differential signal lines.

9 Power Supply Recommendations

This device is a passive TVS diode-based ESD protection device, therefore there is no requirement to power it. Ensure that the maximum voltage specifications for each pin are not violated.

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.
- If pin 1, 2, or pin 3 is connected to ground, use a thick and short trace for this return path.

10.2 Layout Example

This application is typical of a differential data pair application, such as CAN.

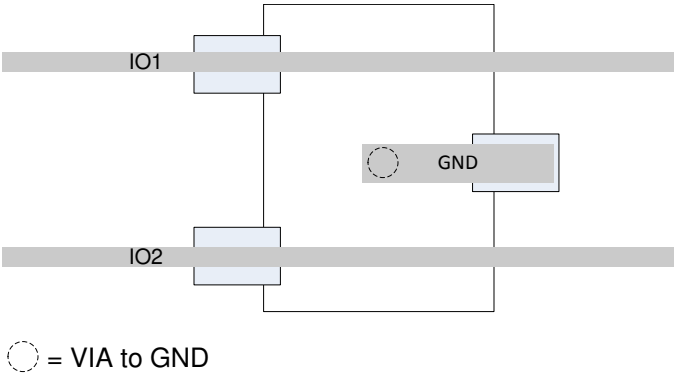

Figure 10-1. Routing with DBZ and DCK Package

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11 Device and Documentation Support

TI offers an extensive line of development tools. Tools and software to evaluate the performance of the device, generate code, and develop solutions are listed below.

11.1 Documentation Support

11.1.1 Related Documentation

For related documentation, see the following:

- Texas Instruments, *ESD Layout Guide* user's guide
- Texas Instruments, *ESD Protection Diodes EVM* user's guide
- Texas Instruments, *Generic ESD Evaluation Module* user's guide
- Texas Instruments, *Reading and Understanding an ESD Protection* data sheet

11.2 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on 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.

11.3 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.

Linked content is 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.

11.4 Trademarks

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All trademarks are the property of their respective owners.

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

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.

ADVANCE INFORMATION

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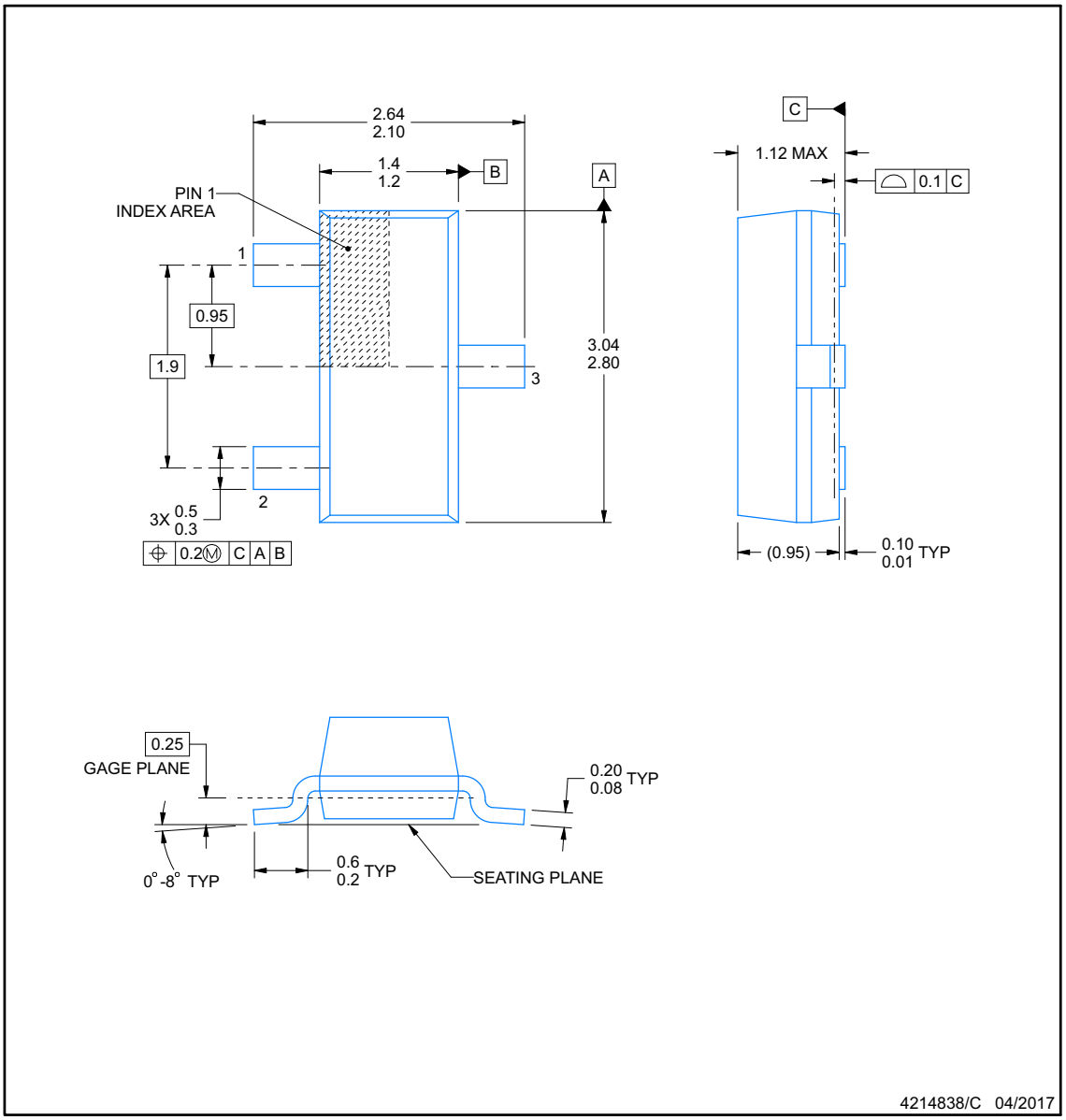
PACKAGE OUTLINE

DBZ0003A

SOT-23 - 1.12 mm max height

SMALL OUTLINE TRANSISTOR



NOTES:

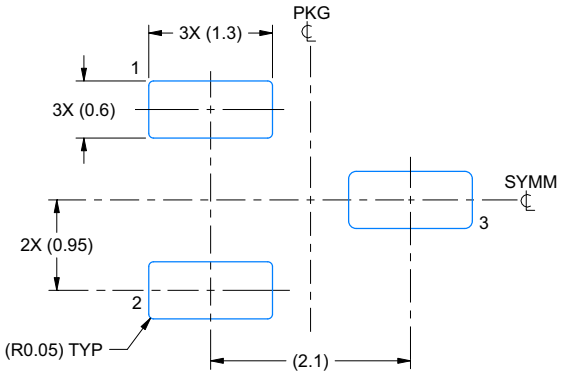
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. Reference JEDEC registration TO-236, except minimum foot length.

EXAMPLE BOARD LAYOUT

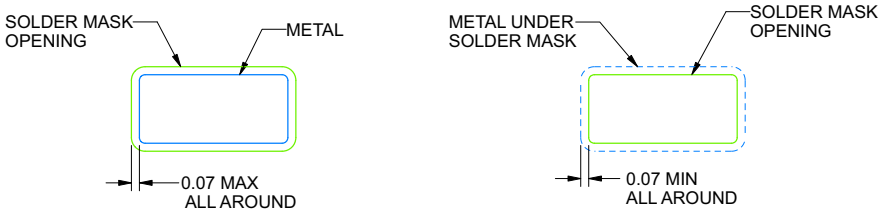
DBZ0003A

SOT-23 - 1.12 mm max height

SMALL OUTLINE TRANSISTOR



LAND PATTERN EXAMPLE
SCALE:15X



SOLDER MASK DETAILS

4214838/C 04/2017

NOTES: (continued)

4. Publication IPC-7351 may have alternate designs.
5. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

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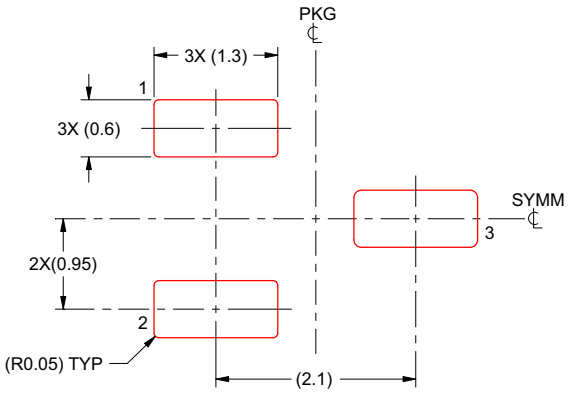
EXAMPLE STENCIL DESIGN

DBZ0003A — **SOT-23 - 1.12 mm max height**

SMALL OUTLINE TRANSISTOR



SOLDER PASTE EXAMPLE
BASED ON 0.125 THICK STENCIL
SCALE:15X

4214838/C 04/2017

NOTES: (continued)

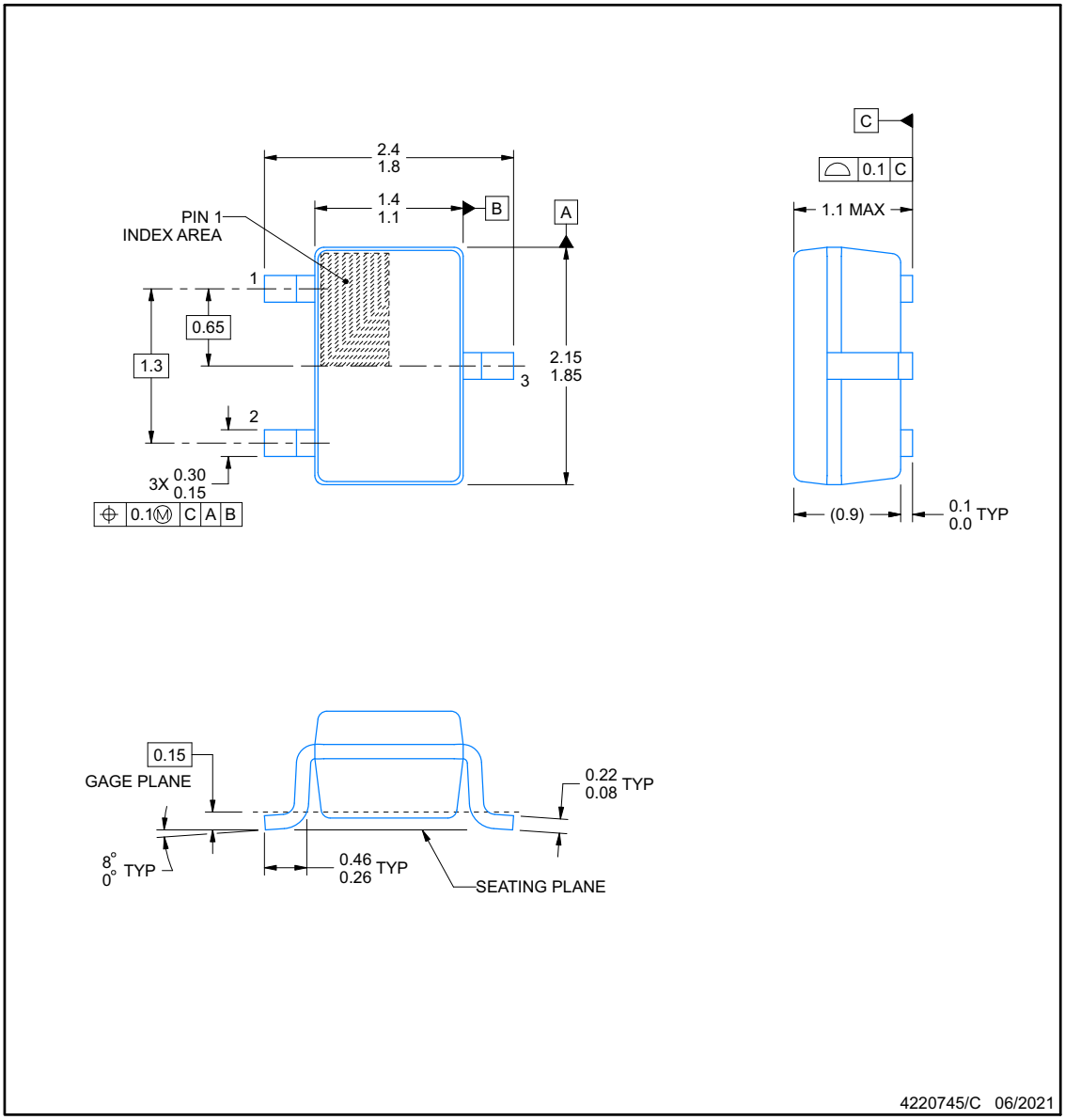
6. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
7. Board assembly site may have different recommendations for stencil design.

PACKAGE OUTLINE

DCK0003A

SOT-SC70 - 1.1 max height

SMALL OUTLINE TRANSISTOR SC70



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.

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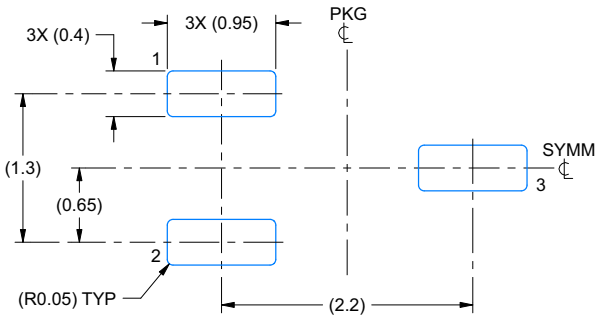
EXAMPLE BOARD LAYOUT

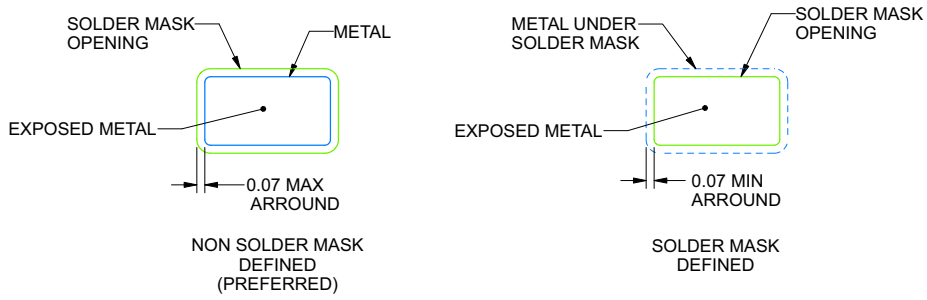
DCK0003A

SOT-SC70 - 1.1 max height

SMALL OUTLINE TRANSISTOR SC70



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:18X



SOLDER MASK DETAILS

4220745/C 06/2021

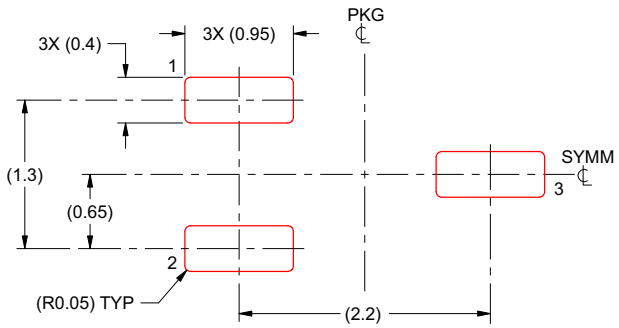
NOTES: (continued)

3. Publication IPC-7351 may have alternate designs.
4. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

EXAMPLE STENCIL DESIGN

DCK0003A — **SOT-SC70 - 1.1 max height**

SMALL OUTLINE TRANSISTOR SC70



SOLDER PASTE EXAMPLE
BASED ON 0.125 THICK STENCIL
SCALE:18X

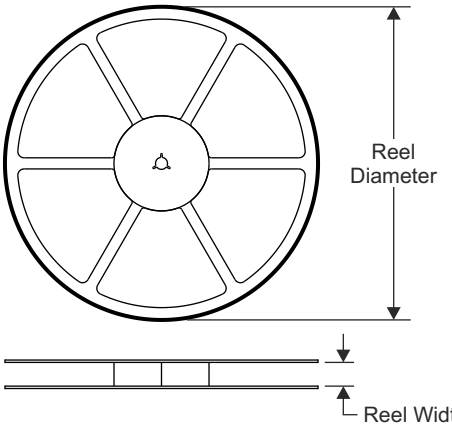
4220745/C 06/2021

NOTES: (continued)

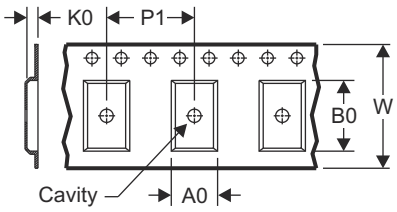
5. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
6. Board assembly site may have different recommendations for stencil design.

12.1 Tape and Reel Information

REEL DIMENSIONS

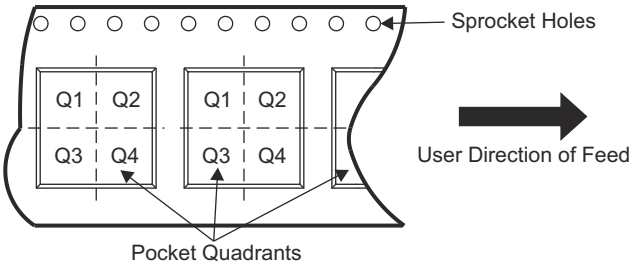


TAPE DIMENSIONS



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

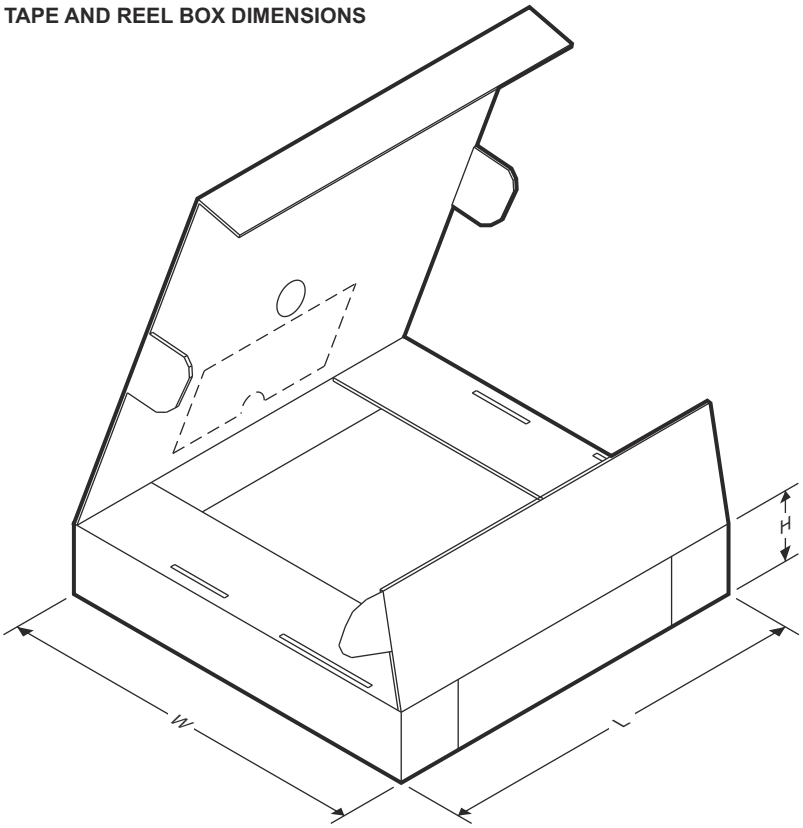
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



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
PESD2CAN24DBZRQ1	SOT-23	DBZ	3	3000	180.0	8.4	2.9	3.35	1.35	4.0	8	Q3
PESD2CAN24DCKRQ1	SC-70	DCK	3	3000	180.0	8.4	2.9	3.35	1.35	4.0	5.30	Q3

ADVANCE INFORMATION

TAPE AND REEL BOX DIMENSIONS



Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
PESD2CAN24DBZRQ1	SOT-23	DBZ	3	3000	210.0	185.0	35.0
PESD2CAN24DCKRQ1	SC-70	DCK	3	3000	210.0	185.0	35.0

ADVANCE INFORMATION

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
PESD2CAN24DBZRQ1	ACTIVE	SOT-23	DBZ	3	3000	TBD	Call TI	Call TI	-55 to 150		Samples
PESD2CAN24DCKRQ1	ACTIVE	SC70	DCK	3	3000	TBD	Call TI	Call TI	-55 to 150		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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