

## TMP23x Low-Power, High-Accuracy Analog Output Temperature Sensors

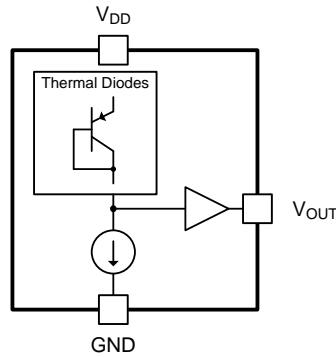
### 1 Features

- Cost-effective alternative to thermistors
- Tight accuracy across a wide temperature range:
  - $\pm 2.5^\circ\text{C}$  (maximum):  $-40^\circ\text{C}$  to  $+150^\circ\text{C}$  (TMP235)
  - $\pm 2.5^\circ\text{C}$  (maximum):  $-10^\circ\text{C}$  to  $+125^\circ\text{C}$  (TMP236)
- Available in two accuracy level variants:
  - A2 level:  $\pm 0.5^\circ\text{C}$  (typical)
  - A4 level:  $\pm 1^\circ\text{C}$  (typical)
- Positive slope sensor gain, offset (typical):
  - $10 \text{ mV}/^\circ\text{C}$ ,  $500 \text{ mV}$  at  $0^\circ\text{C}$  (TMP235)
  - $19.5 \text{ mV}/^\circ\text{C}$ ,  $400 \text{ mV}$  at  $0^\circ\text{C}$  (TMP236)
- Wide operating supply voltage range:
  - $2.3 \text{ V}$  to  $5.5 \text{ V}$  (TMP235)
  - $3.1 \text{ V}$  to  $5.5 \text{ V}$  (TMP236)
- Short-circuit protected output
- Low power:  $9 \mu\text{A}$  (typical)
- Strong output for driving loads up to  $1000 \text{ pF}$
- Available package options:
  - 5-pin SC70 (DCK) surface mount
  - 3-pin SOT-23 (DBZ) surface mount
  - Footprint compatible with industry-standard LMT8x-Q1 and LM20 temperature sensors

### 2 Applications

- Grid infrastructure
- Wireless and telecom infrastructure
- Automotive infotainment
- Factory automation and control
- Test and measurement

**Functional Block Diagram**



### 3 Description

The TMP23x devices are a family of precision CMOS integrated-circuit linear analog temperature sensors with an output voltage proportional to temperature engineers can use in multiple analog temperature-sensing applications. These temperature sensors are more accurate than similar pin-compatible devices on the market, featuring typical accuracy from  $0^\circ\text{C}$  to  $+70^\circ\text{C}$  of  $\pm 0.5^\circ\text{C}$ . The increased accuracy of the series is designed for many analog temperature-sensing applications. The TMP235 device provides a positive slope output of  $10 \text{ mV}/^\circ\text{C}$  over the full  $-40^\circ\text{C}$  to  $+150^\circ\text{C}$  temperature range and a supply range from  $2.3 \text{ V}$  to  $5.5 \text{ V}$ . The higher gain TMP236 sensor provides a positive slope output of  $19.5 \text{ mV}/^\circ\text{C}$  from  $-10^\circ\text{C}$  to  $+125^\circ\text{C}$  and a supply range from  $3.1 \text{ V}$  to  $5.5 \text{ V}$ .

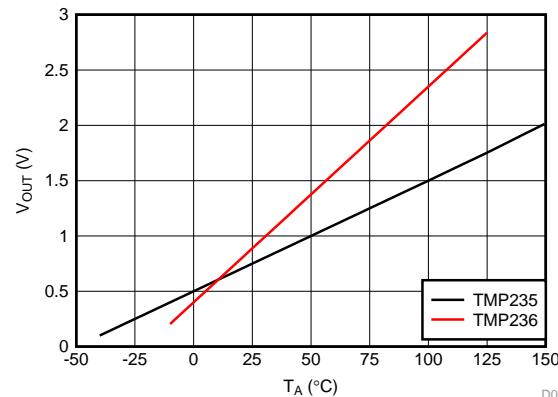
The  $9\text{-}\mu\text{A}$  typical quiescent current and  $800\text{-}\mu\text{s}$  typical power-on time enable effective power-cycling architectures to minimize power consumption for battery-powered devices. A class-AB output driver provides a strong  $500\text{-}\mu\text{A}$  maximum output to drive capacitive loads up to  $1000 \text{ pF}$  and is designed to directly interface to analog-to-digital converter sample and hold inputs. With excellent accuracy and a strong linear output driver, the TMP23x analog output temperature sensors are cost-effective alternatives to passive thermistors.

#### Device Information<sup>(1)</sup>

PART NUMBER	PACKAGE	BODY SIZE (NOM)
TMP235,	SC70 (5)	$2.00 \text{ mm} \times 1.25 \text{ mm}$
TMP236	SOT-23 (3)	$2.92 \text{ mm} \times 1.30 \text{ mm}$

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

**Output Voltage vs Ambient**



An IMPORTANT NOTICE at the end of this data sheet addresses availability, warranty, changes, use in safety-critical applications, intellectual property matters and other important disclaimers. PRODUCTION DATA.

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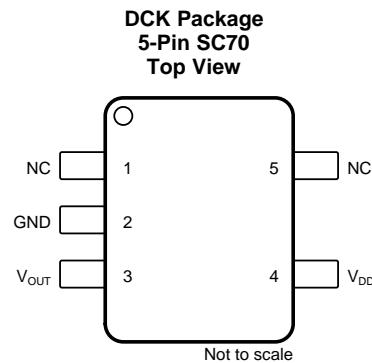
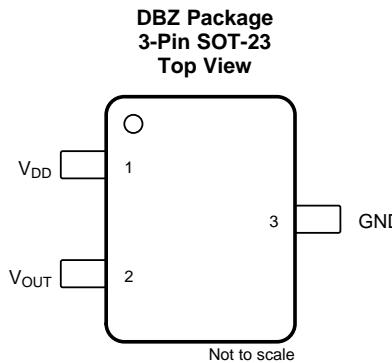
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## 4 Revision History

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

<b>Changes from Revision D (August 2018) to Revision E</b>	<b>Page</b>
• Changed recommended operating temperature range from: $-50^{\circ}\text{C}$ to $150^{\circ}\text{C}$ to: $-40^{\circ}\text{C}$ to $150^{\circ}\text{C}$ .....	4
• Changed power supply bypassing recommendations on how to avoid noise effect on the device output .....	12
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<b>Changes from Revision C (August 2018) to Revision D</b>	<b>Page</b>
• Changed DBZ (SOT-23) package status from preview to production data.....	1
<hr/>	
<b>Changes from Revision B (February 2018) to Revision C</b>	<b>Page</b>
• Added DBZ (SOT-23) preview package .....	1
• Added TMP236 test conditions to the operating current parameters.....	5
• Added SOT-23 and SC70 package test conditions to the Accuracy Level 2 (A2) limits in the $0^{\circ}\text{C}$ to $70^{\circ}\text{C}$ range .....	5
<hr/>	
<b>Changes from Revision A (December 2017) to Revision B</b>	<b>Page</b>
• Changed reference to typical accuracy specifications from: $\pm 1^{\circ}\text{C}$ and $\pm 2^{\circ}\text{C}$ to: $\pm 0.5^{\circ}\text{C}$ and $\pm 1^{\circ}\text{C}$ .....	1
• Deleted erroneous AOQL footnote .....	5
• Changed specification limits indicated in <a href="#">Figure 1</a> .....	6
• Added <i>Device Functional Modes</i> section .....	10
<hr/>	
<b>Changes from Original (September 2017) to Revision A</b>	<b>Page</b>
• Changed document status from Advance Information to Production Data .....	1

## 5 Pin Configuration and Functions



NC- no internal connection

### Pin Functions

NAME	PIN		TYPE	DESCRIPTION
	SOT-23	SC70		
GND	3	2	Ground	Power supply ground.
NC	—	5	—	No internal connection. This pin may be left floating or connected to GND.
NC	—	1	—	No internal connection. This pin may be left floating or connected to GND.
V <sub>OUT</sub>	2	3	O	Outputs voltage proportional to temperature
V <sub>DD</sub>	1	4	I	Positive supply input

## 6 Specifications

### 6.1 Absolute Maximum Ratings

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

	MIN	MAX	UNIT
Supply voltage, $V_{DD}$		+6	
Output voltage, $V_{OUT}$	-0.3	( $V_{DD} + 0.3$ )	V
Output current	-30	+30	
Latch-up current, each pin	-200	+200	mA
Junction temperature ( $T_J$ )		+150	
Storage temperature ( $T_{stg}$ )	-65	+150	°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

	VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM) per JESD22-A114 <sup>(1)</sup>
		Charged-device model (CDM), per JEDEC specification JESD22-C101 <sup>(2)</sup>

(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 Recommended Operating Conditions

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

	MIN	NOM	MAX	UNIT
$V_{DD}$	Input voltage (TMP235)	2.3	5.5	V
	Input voltage (TMP236)	3.1	5.5	
$T_A$	Operating free-air temperature	-40	150	°C

### 6.4 Thermal Information

THERMAL METRIC <sup>(1)(2)</sup>		TMP235		UNIT
		DCK (SC70)	DBZ (SOT-23)	
		PINS	PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance <sup>(3)(4)</sup>	275	167	°C/W
$R_{\theta JC(\text{top})}$	Junction-to-case (top) thermal resistance	84	90	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	56	146	°C/W
$\Psi_{JT}$	Junction-to-top characterization parameter	1.2	35	°C/W
$\Psi_{JB}$	Junction-to-board characterization parameter	55	146	°C/W

- (1) For more information about traditional and new thermal metrics, see the [Semiconductor and IC Package Thermal Metrics](#) application report.
- (2) For information on self-heating and thermal response time see [Layout Guidelines](#) section.
- (3) The junction to ambient thermal resistance ( $R_{\theta JA}$ ) under natural convection is obtained in a simulation on a JEDEC-standard, High-K board as specified in JESD51-7, in an environment described in JESD51-2. Exposed pad packages assume that thermal vias are included in the PCB, per JESD 51-5.
- (4) Changes in output due to self heating can be computed by multiplying the internal dissipation by the thermal resistance.

## 6.5 Electrical Characteristics

TMP235:  $V_{DD} = 2.3$  V to 5.5 V, GND = Ground,  $T_A = -40^\circ\text{C}$  to  $+125^\circ\text{C}$  and no load (unless otherwise noted)

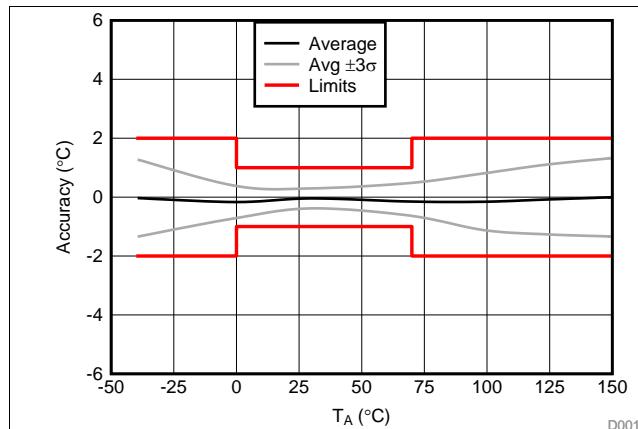
TMP236:  $V_{DD} = 3.1$  V to 5.5 V, GND = Ground,  $T_A = -10^\circ\text{C}$  to  $+125^\circ\text{C}$  and no load (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
<b>POWER SUPPLY</b>						
$I_{DD}$	Operating current	$T_A = 25^\circ\text{C}$ , $V_{DD} = 2.3$ V, TMP235	9			$\mu\text{A}$
		$T_A = 25^\circ\text{C}$ , $V_{DD} = 3.1$ V, TMP236	10			
		$T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$ , TMP235		14.5		
		$T_A = -10^\circ\text{C}$ to $+125^\circ\text{C}$ , TMP236		15		
		$T_A = 150^\circ\text{C}$ , TMP235		17		
$\Delta^\circ\text{C}/\Delta V_{DD}$	Line regulation		-0.1	0.02	0.1	°C/V
<b>SENSOR ACCURACY</b>						
$T_{ACY}$	Temperature accuracy <sup>(1)</sup>	$T_A = 25^\circ\text{C}$ $T_A = 0^\circ\text{C}$ to $70^\circ\text{C}$ (SC70 Package) $T_A = 0^\circ\text{C}$ to $+70^\circ\text{C}$ (SOT-23 Package) $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$ (TMP235A2) $T_A = -10^\circ\text{C}$ to $+125^\circ\text{C}$ (TMP236A2) $T_A = -40^\circ\text{C}$ to $+150^\circ\text{C}$ (TMP235A2)	$\pm 0.5$			°C
			-1	$\pm 0.5$	+1	
			-1.2	$\pm 0.5$	+1.2	
			-2	$\pm 0.5$	+2	
			-2	$\pm 0.5$	+2	
			-2	$\pm 0.5$	+2	
	Accuracy Level 4 (A4)	$T_A = 25^\circ\text{C}$		$\pm 1$		
		$T_A = 0^\circ\text{C}$ to $70^\circ\text{C}$	-2	$\pm 1$	+2	
		$T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$ (TMP235A4)	-4	$\pm 1$	+4	
		$T_A = -10^\circ\text{C}$ to $+125^\circ\text{C}$ (TMP236A4)	-4	$\pm 1$	+4	
		$T_A = -40^\circ\text{C}$ to $+150^\circ\text{C}$ (TMP235A4)	-5	$\pm 1$	+5	
<b>SENSOR OUTPUT</b>						
$V_{0^\circ\text{C}}$	Output voltage offset at $0^\circ\text{C}$		TMP235	500		mV
			TMP236	400		
$T_C$	Temperature coefficient (sensor gain)		TMP235	10		mV/°C
			TMP236	19.5		
$V_{ONL}$	Output nonlinearity <sup>(1)</sup>		$T_A = 0^\circ\text{C}$ to $70^\circ\text{C}$ , no load	$\pm 0.5$		°C
$I_{OUT}$	Output current			500		$\mu\text{A}$
$Z_{OUT}$	Output impedance		$I_{OUT} = 100 \mu\text{A}$ , $f = 100 \text{ Hz}$	20		$\Omega$
			$I_{OUT} = 100 \mu\text{A}$ , $f = 500 \text{ Hz}$	50		
	Output load regulation		$T_A = 0^\circ\text{C}$ to $70^\circ\text{C}$ , $I_{OUT} = 100 \mu\text{A}$ , $\Delta V_{OUT} / \Delta I_{OUT}$	1		$\Omega$
$t_{ON}$	Turn on time		Time to reach accuracy within $\pm 0.5^\circ\text{C}$	800		$\mu\text{s}$
$C_{LOAD}$	Typical load capacitance			1000		pF
$t_{RES}$	Thermal response to 63%	SC70	30°C (Air) to +125°C (Fluid Bath)	1.3		s

- (1) Accuracy is defined as the error between the measured and reference output voltages, tabulated in the [TMP235 Transfer Table](#) and [TMP236 Transfer Table](#) at the specified conditions of supply voltage and temperature (expressed in °C). Accuracy limits include line regulation within the specified conditions. Accuracy limits do not include load regulation; they assume no DC load.

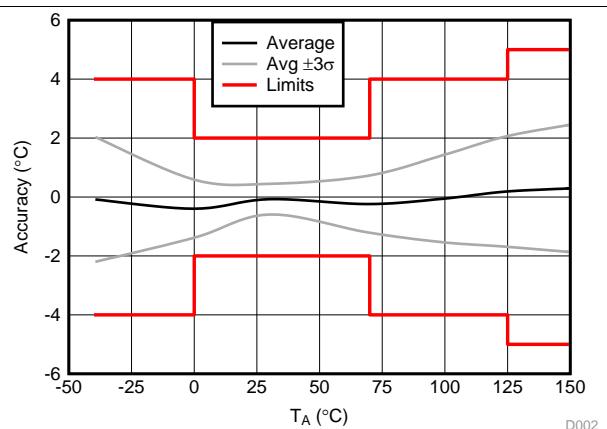
## 6.6 Typical Characteristics

at  $T_A = 25^\circ\text{C}$ , (unless otherwise noted)



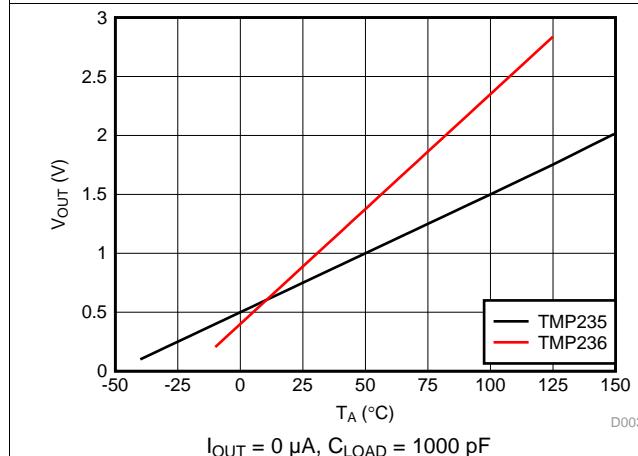
TMP235:  $V_{DD} = 2.3$  to  $5.5$  V,  $I_{OUT} = 0$   $\mu\text{A}$ ,  $C_{LOAD} = 1000$  pF

**Figure 1. Accuracy vs.  $T_A$  Temperature (A2 Accuracy Level)**



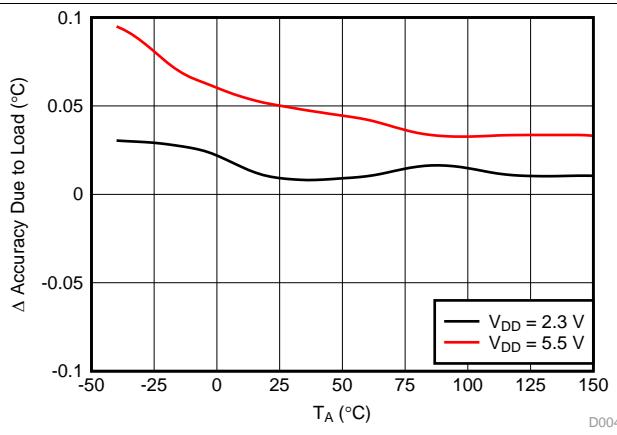
TMP235:  $V_{DD} = 2.3$  to  $5.5$  V,  $I_{OUT} = 0$   $\mu\text{A}$ ,  $C_{LOAD} = 1000$  pF

**Figure 2. Accuracy vs.  $T_A$  Temperature (A4 Accuracy Level)**



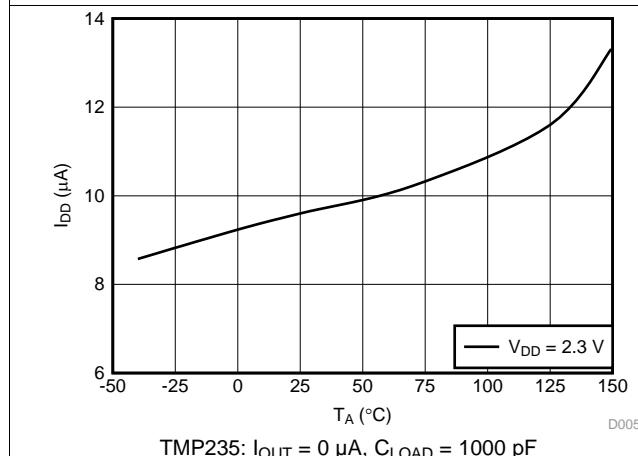
$I_{OUT} = 0$   $\mu\text{A}$ ,  $C_{LOAD} = 1000$  pF

**Figure 3. Output Voltage vs. Ambient Temperature**



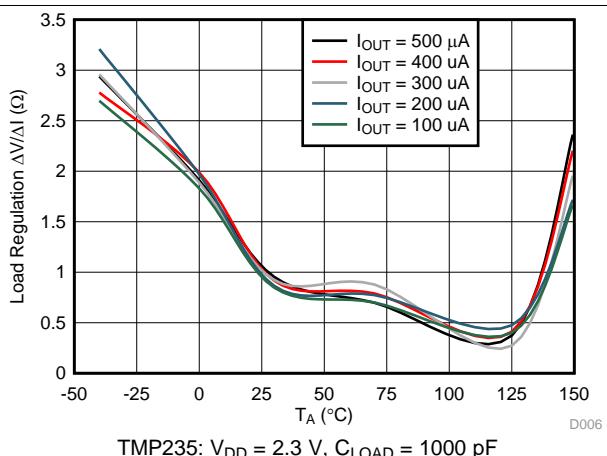
TMP235:  $I_{OUT}$  = from  $0$   $\mu\text{A}$  to  $100$   $\mu\text{A}$ ,  $C_{LOAD} = 1000$  pF

**Figure 4. Changes in Accuracy vs. Ambient Temperature (Due to Load)**



TMP235:  $I_{OUT} = 0$   $\mu\text{A}$ ,  $C_{LOAD} = 1000$  pF

**Figure 5. Supply Current vs. Temperature**

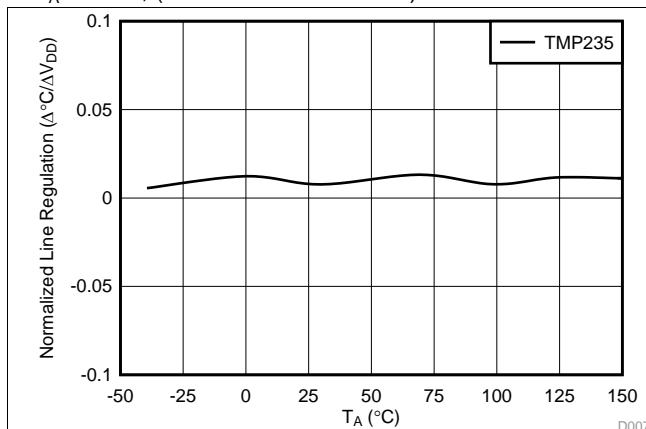


TMP235:  $V_{DD} = 2.3$  V,  $C_{LOAD} = 1000$  pF

**Figure 6. Load Regulation vs. Ambient Temperature**

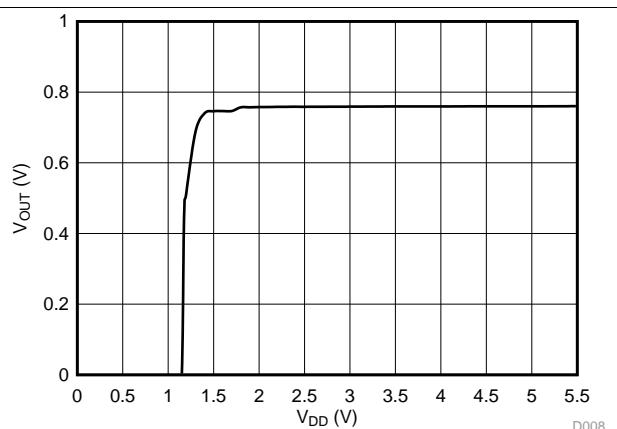
## Typical Characteristics (continued)

at  $T_A = 25^\circ\text{C}$ , (unless otherwise noted)



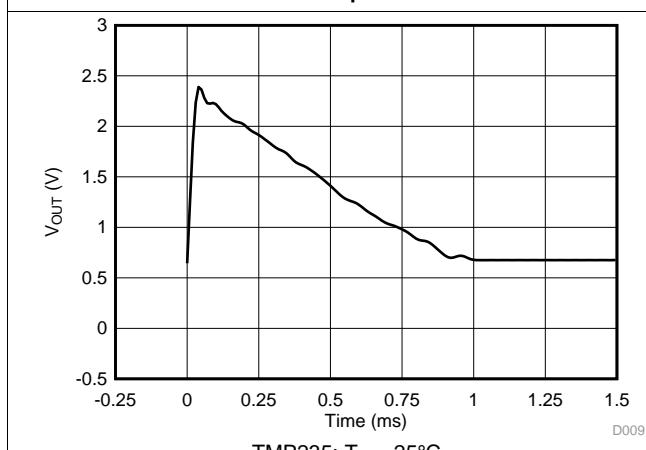
TMP235:  $V_{DD} = 2.3$  to  $5.5$  V,  $I_{OUT} = 0$   $\mu\text{A}$ ,  $C_{LOAD} = 1000$  pF

**Figure 7. Line Regulation ( $\Delta^\circ\text{C} / \Delta V_{DD}$ ) vs. Ambient Temperature**



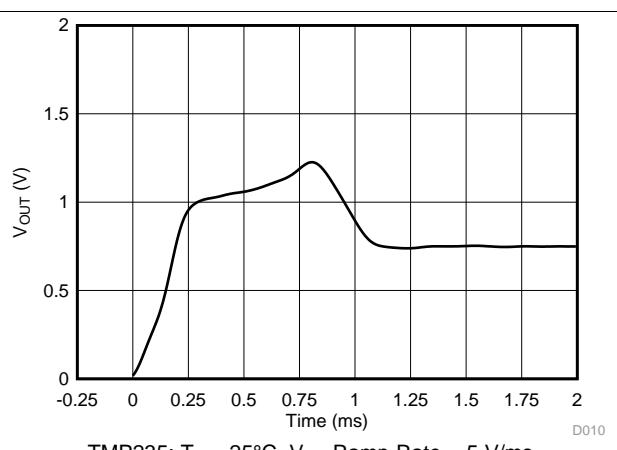
TMP235:  $T_A = 25^\circ\text{C}$

**Figure 8. Output Voltage vs. Power Supply**



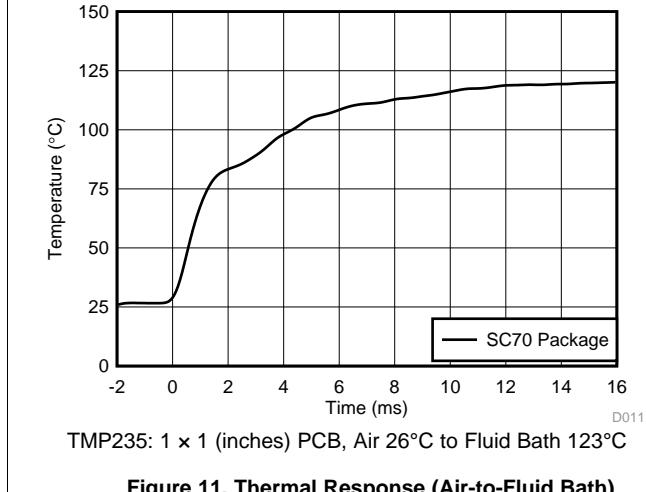
TMP235:  $T_A = 25^\circ\text{C}$

**Figure 9. Output vs. Settling Time to Step  $V_{DD}$**



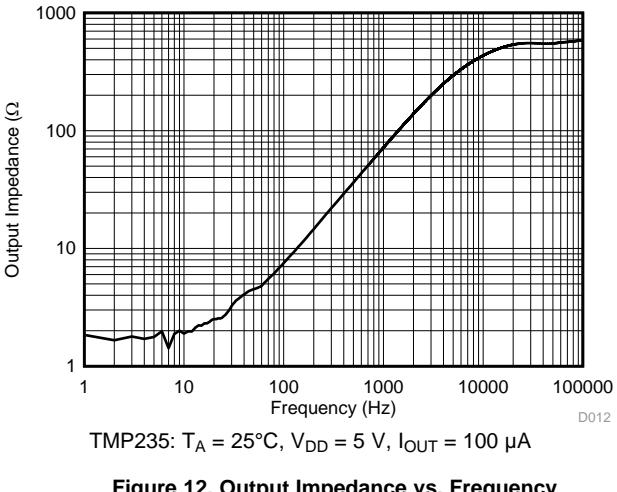
TMP235:  $T_A = 25^\circ\text{C}$ ,  $V_{DD}$  Ramp Rate = 5 V/ms

**Figure 10. Output vs. Settling Time to Ramp  $V_{DD}$**



TMP235: 1 × 1 (inches) PCB, Air 26°C to Fluid Bath 123°C

**Figure 11. Thermal Response (Air-to-Fluid Bath)**



TMP235:  $T_A = 25^\circ\text{C}$ ,  $V_{DD} = 5$  V,  $I_{OUT} = 100$   $\mu\text{A}$

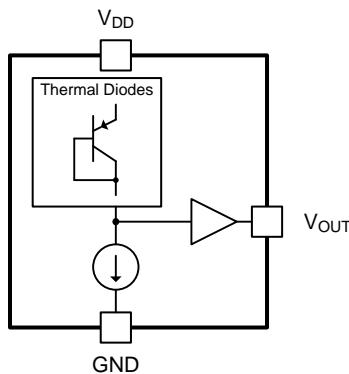
**Figure 12. Output Impedance vs. Frequency**

## 7 Detailed Description

### 7.1 Overview

The TMP23x devices are a family of linear analog temperature sensors with an output voltage proportional to temperature. These temperature sensors have an accuracy from 0°C to 70°C of  $\pm 1.25^\circ\text{C}$  (TMP23xA2) and  $\pm 2^\circ\text{C}$  (TMP23xA4). The TMP235 device provides a positive slope output of 10 mV/°C over the full  $-40^\circ\text{C}$  to  $+150^\circ\text{C}$  temperature range and a supply range from 2.3 V to 5.5 V. The higher gain TMP236 sensor provides a positive slope output of 19.5 mV/°C from  $-10^\circ\text{C}$  to  $+125^\circ\text{C}$  and a supply range from 3.1 V to 5.5 V. A class-AB output driver provides a maximum output of 500  $\mu\text{A}$  to drive capacitive loads up to 1000 pF.

### 7.2 Functional Block Diagram



### 7.3 Feature Description

As shown in [Figure 3](#), the TMP23x devices are linear. A small  $V_{\text{OUT}}$  gain shift, however, is present at temperatures above  $100^\circ\text{C}$ . When small shifts are expected, a piecewise linear function provides the best accuracy and is used for the device accuracy specifications (see [Specifications](#)). Typical output voltages of the TMP23x devices across the full operating temperature range are listed in [Table 3](#) and [Table 4](#). The ideal linear columns represent the ideal linear  $V_{\text{OUT}}$  output response with respect to temperature, while the piecewise linear columns indicate the small voltage shift at elevated temperatures.

The piecewise linear function uses three temperature ranges listed in [Table 1](#) and [Table 2](#). In equation form, the voltage output  $V_{\text{OUT}}$  of the TMP23x is calculated by [Equation 1](#):

$$V_{\text{OUT}} = (T_A - T_{\text{INFL}}) \times T_C + V_{\text{OFFS}}$$

where

- $V_{\text{OUT}}$  is the TMP23x voltage output for a given temperature
  - $T_A$  is the ambient temperature in  $^\circ\text{C}$
  - $T_{\text{INFL}}$  is the temperature inflection point for a piecewise segment in  $^\circ\text{C}$
  - $T_C$  is the TMP23x temperature coefficient or gain
  - $V_{\text{OFFS}}$  is the TMP23x voltage offset
- (1)

Therefore, the  $T_A$  temperature for a given  $V_{\text{OUT}}$  voltage output within a piecewise voltage range ( $V_{\text{RANGE}}$ ) is calculated in [Equation 2](#). For applications where the accuracy enhancement above  $100^\circ\text{C}$  is not required, use the first row of [Table 1](#) and [Table 2](#) for all voltages.

$$T_A = (V_{\text{OUT}} - V_{\text{OFFS}}) / T_C + T_{\text{INFL}} \quad (2)$$

**Table 1. TMP235 Piecewise Linear Function Summary**

$T_A$ RANGE ( $^\circ\text{C}$ )	$V_{\text{RANGE}}$ (mV)	$T_{\text{INFL}}$ ( $^\circ\text{C}$ )	$T_C$ (mV/ $^\circ\text{C}$ )	$V_{\text{OFFS}}$ (mV)
$-40$ to $+100$	< 1500	0	10	500
100 to 125	1500 to 1752.5	100	10.1	1500
125 to 150	> 1752.5	125	10.6	1752.5

**Table 2. TMP236 Piecewise Linear Function Summary**

$T_A$ RANGE (°C)	$V_{RANGE}$ (mV)	$T_{INFL}$ (°C)	$T_C$ (mV/°C)	$V_{OFFS}$ (mV)
-40 to +100	≤ 2350	0	19.5	400
100 to 125	> 2350	100	19.7	2350
125 to 150	—	—	—	—

**Table 3. TMP235 Transfer Table**

TEMPERATURE (°C)	$V_{OUT}$ (mV) IDEAL LINEAR VALUES	$V_{OUT}$ (mV) PIECEWISE LINEAR VALUES
-40	100	100
-35	150	150
-30	200	200
-25	250	250
-20	300	300
-15	350	350
-10	400	400
-5	450	450
0	500	500
5	550	550
10	600	600
15	650	650
20	700	700
25	750	750
30	800	800
35	850	850
40	900	900
45	950	950
50	1000	1000
55	1050	1050
60	1100	1100
65	1150	1150
70	1200	1200
75	1250	1250
80	1300	1300
85	1350	1350
90	1400	1400
95	1450	1450
100	1500	1500
105	1550	1550.5
110	1600	1601
115	1650	1651.5
120	1700	1702
125	1750	1752.5
130	1800	1805.5
135	1850	1858.5
140	1900	1911.5
145	1950	1964.5
150	2000	2017.5

**Table 4. TMP236 Transfer Table**

TEMPERATURE (°C)	$V_{OUT}$ (mV) IDEAL LINEAR VALUES	$V_{OUT}$ (mV) PIECEWISE LINEAR VALUES
-40	—	—
-35	—	—
-30	—	—
-25	—	—
-20	—	—
-15	—	—
-10	205	205
-5	303	303
0	400	400
5	498	498
10	595	595
15	693	693
20	790	790
25	888	888
30	985	985
35	1083	1083
40	1180	1180
45	1278	1278
50	1375	1375
55	1473	1473
60	1570	1570
65	1668	1668
70	1765	1765
75	1863	1863
80	1960	1960
85	2058	2058
90	2155	2155
95	2253	2253
100	2350	2350
105	2448	2448.5
110	2545	2547
115	2643	2645.4
120	2740	2743.9
125	2838	2842.4
130	—	—
135	—	—
140	—	—
145	—	—
150	—	—

## 7.4 Device Functional Modes

The singular functional mode of the TMP23x is an analog output directly proportional to temperature.

## 8 Application and Implementation

### NOTE

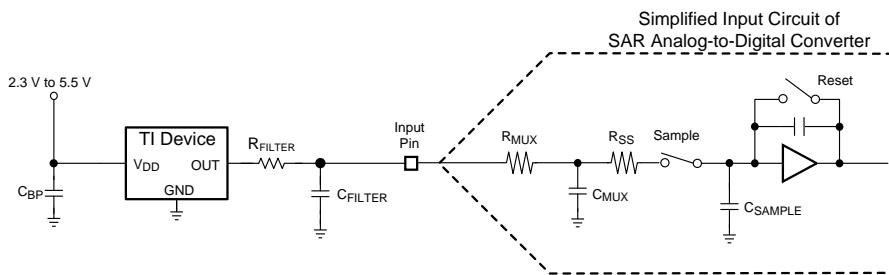
Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

### 8.1 Application Information

The features of the TMP235 make the series of devices designed for various general temperature-sensing applications. The TMP235 and TMP236 devices can operate down to a 2.3-V and a 3.1-V supply with 9- $\mu$ A power consumption, respectively. As a result, the series is designed for battery-powered applications. The TMP23x series is mounted in two surface mount technology packages (SC70 and SOT-23.)

### 8.2 Typical Application

#### 8.2.1 Connection to an ADC



**Figure 13. Suggested Connections to an ADC Input Stage**

##### 8.2.1.1 Design Requirements

See [Figure 13](#) for suggested connections to an ADC input stage. Most CMOS-based ADCs have a sampled data comparator input structure. When the ADC charges the sampling capacitor ( $C_{SAMPLE}$ ), the capacitor requires instantaneous charge from the output of the analog source temperature sensor, such as the TMP23x. Therefore, the output impedance of the temperature sensor can affect ADC performance. In most cases, adding an external capacitor ( $C_{FILTER}$ ) mitigates design challenges. The TMP23x is specified and characterized with a 1000-pF maximum capacitive load ( $C_{LOAD}$ ). [Figure 13](#) shows  $C_{LOAD}$  as the sum of  $C_{FILTER} + C_{MUX} + C_{SAMPLE}$ . TI recommends maximizing the  $C_{FILTER}$  value while allowing for the maximum specified ADC input capacitance ( $C_{MUX} + C_{SAMPLE}$ ) to limit the total  $C_{LOAD}$  at 1000 pF. In most cases, a 680-pF  $C_{FILTER}$  provides a reasonable allowance for ADC input capacitance to minimize ADC sampling error and reduce noise coupling. An optional series resistor ( $R_{FILTER}$ ) and  $C_{FILTER}$  provides additional low-pass filtering to reject system level noise. TI recommends placing  $R_{FILTER}$  and  $C_{FILTER}$  as close as possible to the ADC input for optimal performance.

##### 8.2.1.2 Detailed Design Procedure

Depending on the input characteristics of the ADC, an external  $C_{FILTER}$  may be required. The value of  $C_{FILTER}$  depends on the size of the sampling capacitor ( $C_{SAMPLE}$ ) and the sampling frequency while observing a maximum  $C_{LOAD}$  of 1000 pF. The capacitor requirements can vary because the input stages of all ADCs are not identical. [Figure 13](#) shows a general ADC application as an example only.

## Typical Application (continued)

### 8.2.1.3 Application Curve

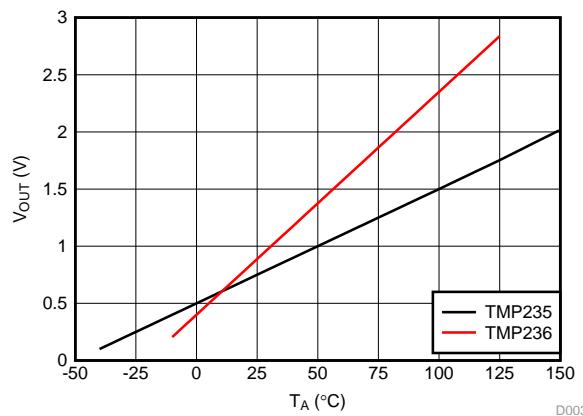


Figure 14. Output Voltage vs. Ambient

## 9 Power Supply Recommendations

The low supply current and supply range of the TMP23x allow the device to be easily powered from many sources.

Power supply bypassing is strongly recommended. In noisy environments, TI recommends to add a filter with  $0.1\text{-}\mu\text{F}$  capacitor and  $100\text{-}\Omega$  resistor between external supply and  $V_{DD}$  to limit the power supply noise. Larger capacitances may be required and are dependent on the noise of the power supply.

## 10 Layout

### 10.1 Layout Guidelines

The layout of the TMP23x series is simple. If a power supply bypass capacitor is used, the capacitor must be connected as [Layout Examples](#) shows.

### 10.2 Layout Examples

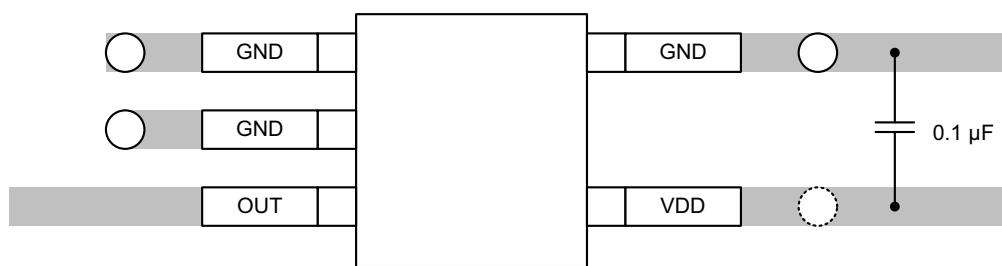
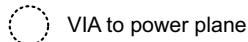
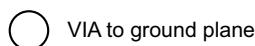


Figure 15. Recommended Layout: SC70 Package

## 11 Device and Documentation Support

### 11.1 Related Links

The table below lists quick access links. Categories include technical documents, support and community resources, tools and software, and quick access to order now.

**Table 5. Related Links**

PARTS	PRODUCT FOLDER	ORDER NOW	TECHNICAL DOCUMENTS	TOOLS & SOFTWARE	SUPPORT & COMMUNITY
TMP235	<a href="#">Click here</a>				
TMP236	<a href="#">Click here</a>				

### 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.

All other 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

[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.

**PACKAGING INFORMATION**

Orderable part number	Status (1)	Material type (2)	Package   Pins	Package qty   Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
TMP235A2DBZR	Active	Production	SOT-23 (DBZ)   3	3000   LARGE T&R	Yes	NIPDAU   SN   NIPDAUAG	Level-1-260C-UNLIM	-40 to 150	2352
TMP235A2DBZR.A	Active	Production	SOT-23 (DBZ)   3	3000   LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 150	2352
TMP235A2DBZRG4.A	Active	Production	SOT-23 (DBZ)   3	3000   LARGE T&R	-	Call TI	Call TI	-40 to 150	2352
TMP235A2DBZT	Obsolete	Production	SOT-23 (DBZ)   3	-	-	Call TI	Call TI	-40 to 150	2352
TMP235A2DCKR	Active	Production	SC70 (DCK)   5	3000   LARGE T&R	Yes	NIPDAU   SN   NIPDAUAG	Level-1-260C-UNLIM	-40 to 150	19L
TMP235A2DCKR.A	Active	Production	SC70 (DCK)   5	3000   LARGE T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 150	19L
TMP235A4DBZR	Active	Production	SOT-23 (DBZ)   3	3000   LARGE T&R	Yes	NIPDAU   SN   NIPDAUAG	Level-1-260C-UNLIM	-40 to 150	2354
TMP235A4DBZRA	Active	Production	SOT-23 (DBZ)   3	3000   LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 150	2354
TMP235A4DBZRG4	Active	Production	SOT-23 (DBZ)   3	3000   LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 150	2354
TMP235A4DBZRG4.A	Active	Production	SOT-23 (DBZ)   3	3000   LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 150	2354
TMP235A4DBZT	Obsolete	Production	SOT-23 (DBZ)   3	-	-	Call TI	Call TI	-40 to 150	2354
TMP235A4DCKR	Active	Production	SC70 (DCK)   5	3000   LARGE T&R	Yes	NIPDAU   SN   NIPDAUAG	Level-1-260C-UNLIM	-40 to 150	19M
TMP235A4DCKRA	Active	Production	SC70 (DCK)   5	3000   LARGE T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 150	19M
TMP236A2DBZR	Active	Production	SOT-23 (DBZ)   3	3000   LARGE T&R	Yes	NIPDAU   SN   NIPDAUAG	Level-1-260C-UNLIM	-10 to 125	2362
TMP236A2DBZRA	Active	Production	SOT-23 (DBZ)   3	3000   LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-10 to 125	2362
TMP236A2DBZT	Obsolete	Production	SOT-23 (DBZ)   3	-	-	Call TI	Call TI	-10 to 125	2362
TMP236A2DCKR	Active	Production	SC70 (DCK)   5	3000   LARGE T&R	Yes	NIPDAU   SN   NIPDAUAG	Level-1-260C-UNLIM	-10 to 125	1BS
TMP236A2DCKRA	Active	Production	SC70 (DCK)   5	3000   LARGE T&R	Yes	SN	Level-1-260C-UNLIM	-10 to 125	1BS
TMP236A2DCKT	Obsolete	Production	SC70 (DCK)   5	-	-	Call TI	Call TI	-10 to 125	1BS
TMP236A4DBZR	Active	Production	SOT-23 (DBZ)   3	3000   LARGE T&R	Yes	NIPDAU   SN   NIPDAUAG	Level-1-260C-UNLIM	-10 to 125	2364
TMP236A4DBZRA	Active	Production	SOT-23 (DBZ)   3	3000   LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-10 to 125	2364
TMP236A4DBZT	Obsolete	Production	SOT-23 (DBZ)   3	-	-	Call TI	Call TI	-10 to 125	2364
TMP236A4DCKR	Active	Production	SC70 (DCK)   5	3000   LARGE T&R	Yes	NIPDAU   SN   NIPDAUAG	Level-1-260C-UNLIM	-10 to 125	1BT

Orderable part number	Status (1)	Material type (2)	Package   Pins	Package qty   Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
TMP236A4DCKR.A	Active	Production	SC70 (DCK)   5	3000   LARGE T&R	Yes	SN	Level-1-260C-UNLIM	-10 to 125	1BT
<a href="#">TMP236A4DCKT</a>	Obsolete	Production	SC70 (DCK)   5	-	-	Call TI	Call TI	-10 to 125	1BT

<sup>(1)</sup> **Status:** For more details on status, see our [product life cycle](#).

<sup>(2)</sup> **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

<sup>(3)</sup> **RoHS values:** Yes, No, RoHS Exempt. See the [TI RoHS Statement](#) for additional information and value definition.

<sup>(4)</sup> **Lead finish/Ball material:** Parts 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.

<sup>(5)</sup> **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

<sup>(6)</sup> **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

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#### OTHER QUALIFIED VERSIONS OF TMP235, TMP236 :

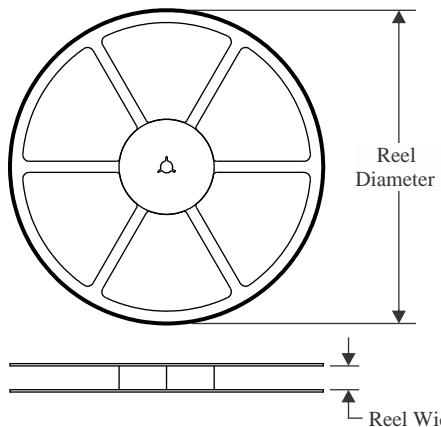
- Automotive : [TMP235-Q1](#), [TMP236-Q1](#)

NOTE: Qualified Version Definitions:

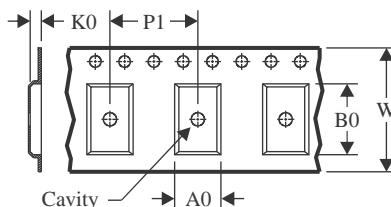
- Automotive - Q100 devices qualified for high-reliability automotive applications targeting zero defects

## TAPE AND REEL INFORMATION

### REEL DIMENSIONS

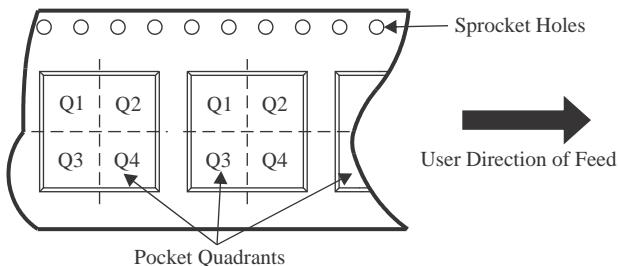


### TAPE DIMENSIONS



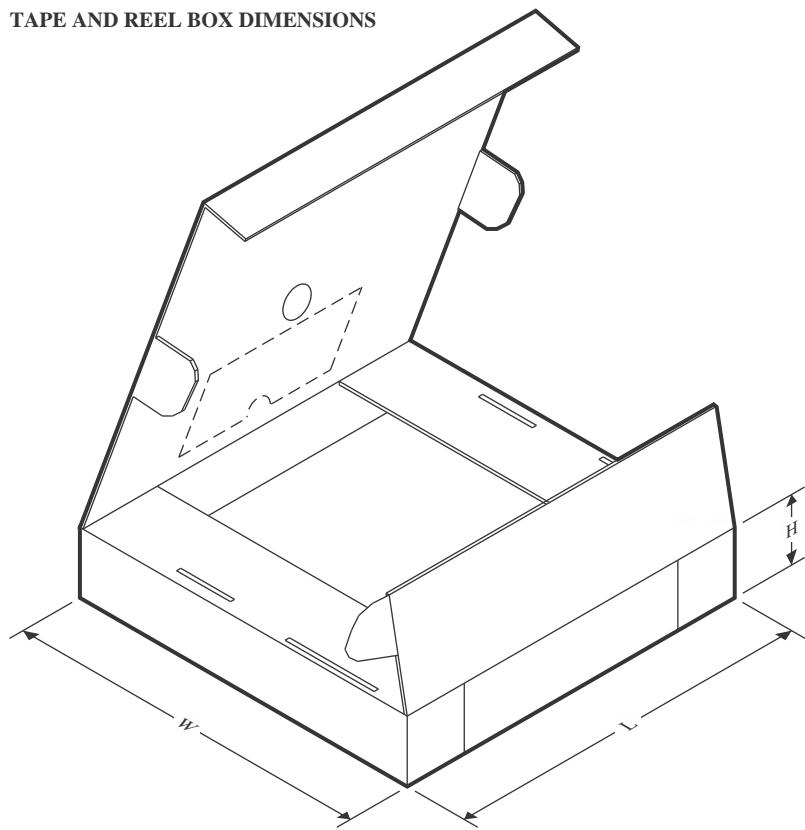
A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

### 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
TMP235A2DBZR	SOT-23	DBZ	3	3000	180.0	8.4	2.9	3.35	1.35	4.0	8.0	Q3
TMP235A2DBZR	SOT-23	DBZ	3	3000	178.0	9.0	3.15	2.77	1.22	4.0	8.0	Q3
TMP235A2DCKR	SC70	DCK	5	3000	180.0	8.4	2.3	2.5	1.2	4.0	8.0	Q3
TMP235A2DCKR	SC70	DCK	5	3000	178.0	8.4	2.25	2.45	1.2	4.0	8.0	Q3
TMP235A4DBZR	SOT-23	DBZ	3	3000	180.0	8.4	2.9	3.35	1.35	4.0	8.0	Q3
TMP235A4DBZRG4	SOT-23	DBZ	3	3000	180.0	8.4	2.9	3.35	1.35	4.0	8.0	Q3
TMP235A4DCKR	SC70	DCK	5	3000	180.0	8.4	2.3	2.5	1.2	4.0	8.0	Q3
TMP235A4DCKR	SC70	DCK	5	3000	178.0	8.4	2.25	2.45	1.2	4.0	8.0	Q3
TMP236A2DBZR	SOT-23	DBZ	3	3000	180.0	8.4	3.2	2.85	1.3	4.0	8.0	Q3
TMP236A2DBZR	SOT-23	DBZ	3	3000	180.0	8.4	2.9	3.35	1.35	4.0	8.0	Q3
TMP236A2DCKR	SC70	DCK	5	3000	180.0	8.4	2.3	2.5	1.2	4.0	8.0	Q3
TMP236A4DBZR	SOT-23	DBZ	3	3000	180.0	8.4	2.9	3.35	1.35	4.0	8.0	Q3
TMP236A4DBZR	SOT-23	DBZ	3	3000	180.0	8.4	3.2	2.85	1.3	4.0	8.0	Q3
TMP236A4DCKR	SC70	DCK	5	3000	180.0	8.4	2.3	2.5	1.2	4.0	8.0	Q3

**TAPE AND REEL BOX DIMENSIONS**


\*All dimensions are nominal

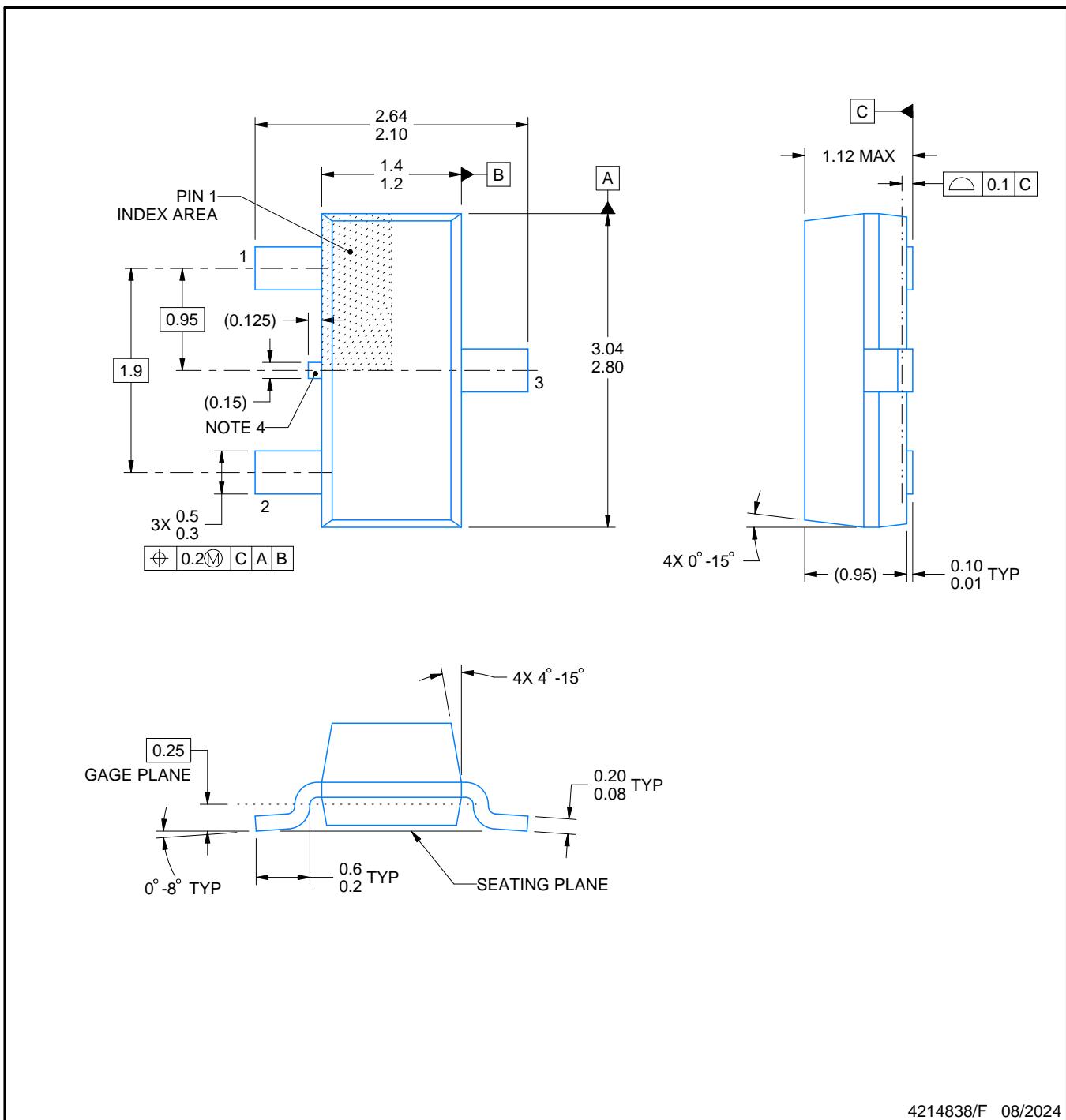
Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TMP235A2DBZR	SOT-23	DBZ	3	3000	210.0	185.0	35.0
TMP235A2DBZR	SOT-23	DBZ	3	3000	180.0	180.0	18.0
TMP235A2DCKR	SC70	DCK	5	3000	210.0	185.0	35.0
TMP235A2DCKR	SC70	DCK	5	3000	208.0	191.0	35.0
TMP235A4DBZR	SOT-23	DBZ	3	3000	210.0	185.0	35.0
TMP235A4DBZRG4	SOT-23	DBZ	3	3000	210.0	185.0	35.0
TMP235A4DCKR	SC70	DCK	5	3000	210.0	185.0	35.0
TMP235A4DCKR	SC70	DCK	5	3000	208.0	191.0	35.0
TMP236A2DBZR	SOT-23	DBZ	3	3000	210.0	185.0	35.0
TMP236A2DBZR	SOT-23	DBZ	3	3000	210.0	185.0	35.0
TMP236A2DCKR	SC70	DCK	5	3000	210.0	185.0	35.0
TMP236A4DBZR	SOT-23	DBZ	3	3000	210.0	185.0	35.0
TMP236A4DBZR	SOT-23	DBZ	3	3000	210.0	185.0	35.0
TMP236A4DCKR	SC70	DCK	5	3000	210.0	185.0	35.0

# PACKAGE OUTLINE

**DBZ0003A**

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

SMALL OUTLINE TRANSISTOR



4214838/F 08/2024

**NOTES:**

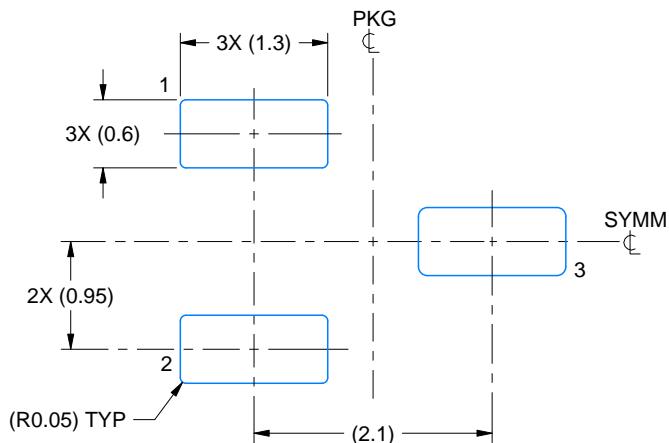
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. Reference JEDEC registration TO-236, except minimum foot length.
4. Support pin may differ or may not be present.
5. Body dimensions do not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.25mm per side

# EXAMPLE BOARD LAYOUT

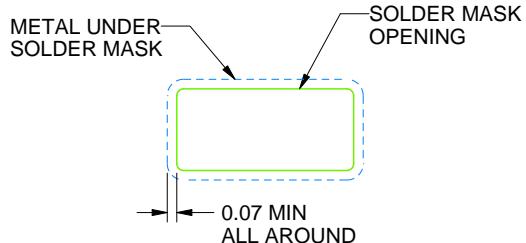
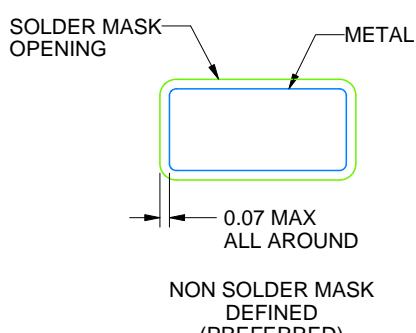
DBZ0003A

SOT-23 - 1.12 mm max height

SMALL OUTLINE TRANSISTOR



LAND PATTERN EXAMPLE  
SCALE:15X



NON SOLDER MASK  
DEFINED  
(PREFERRED)

SOLDER MASK  
DEFINED

SOLDER MASK DETAILS

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NOTES: (continued)

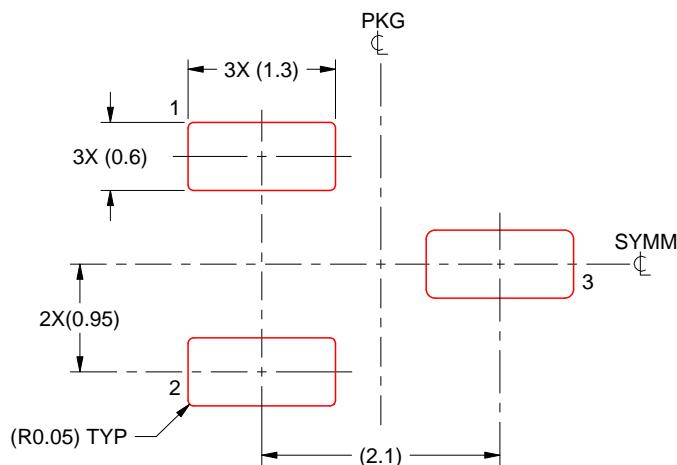
5. Publication IPC-7351 may have alternate designs.
6. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

# 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

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NOTES: (continued)

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

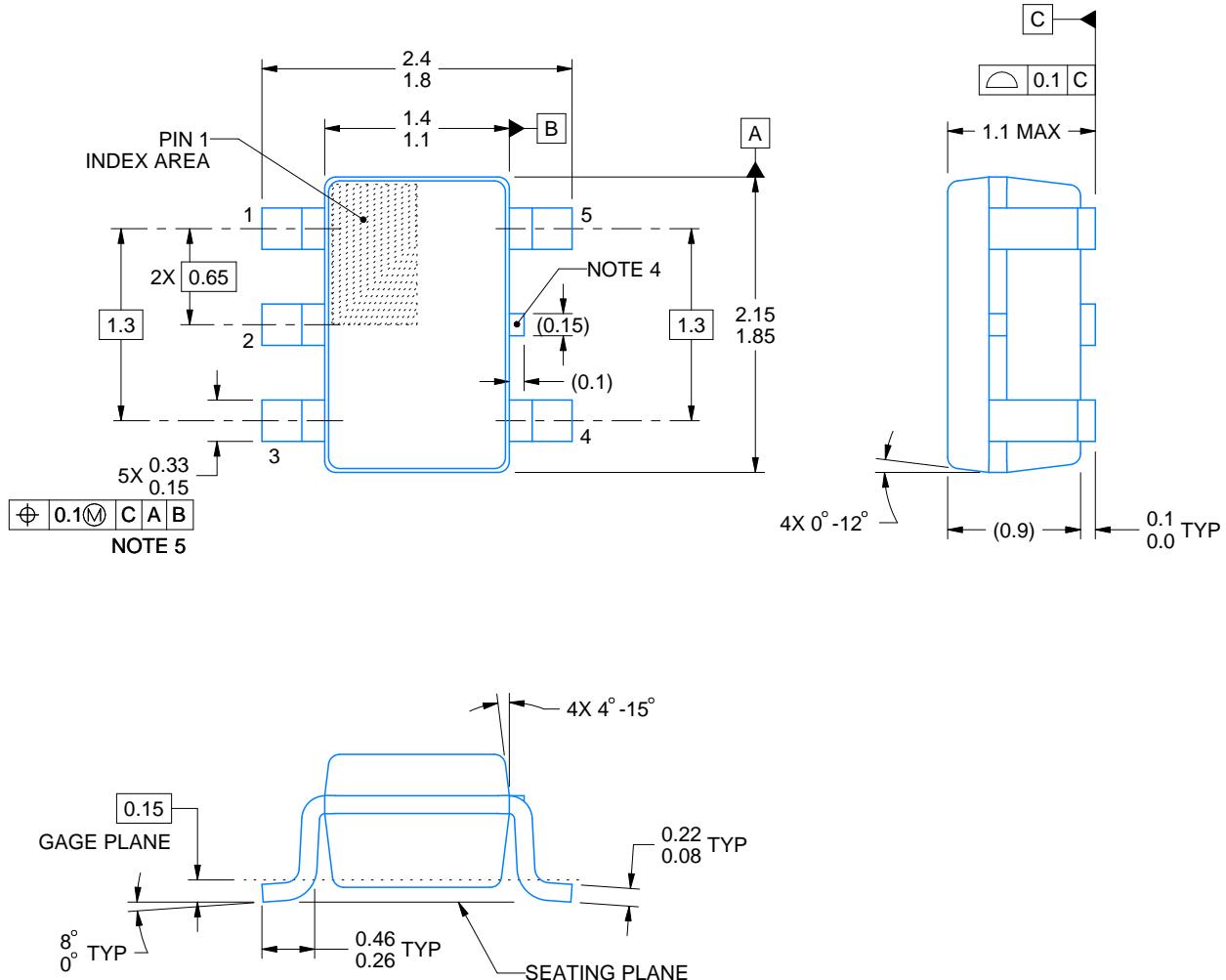
# PACKAGE OUTLINE

**DCK0005A**



## SOT - 1.1 max height

#### SMALL OUTLINE TRANSISTOR



4214834/G 11/2024

## NOTES:

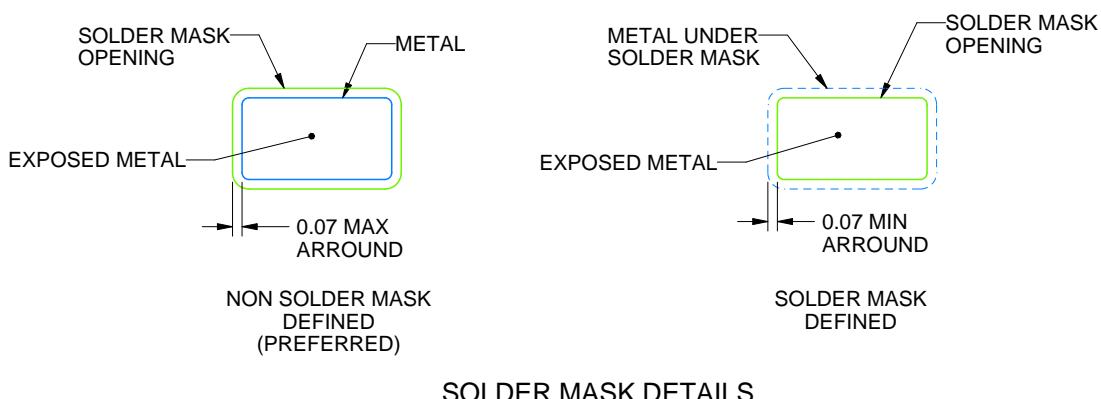
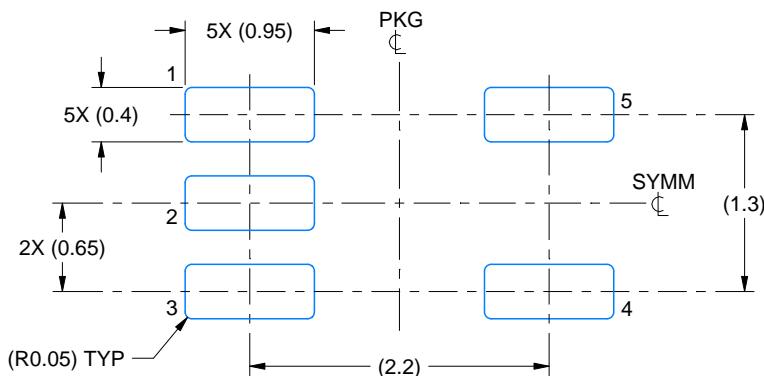
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
  2. This drawing is subject to change without notice.
  3. Reference JEDEC MO-203.
  4. Support pin may differ or may not be present.
  5. Lead width does not comply with JEDEC.
  6. Body dimensions do not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.25mm per side

# EXAMPLE BOARD LAYOUT

DCK0005A

SOT - 1.1 max height

SMALL OUTLINE TRANSISTOR



4214834/G 11/2024

NOTES: (continued)

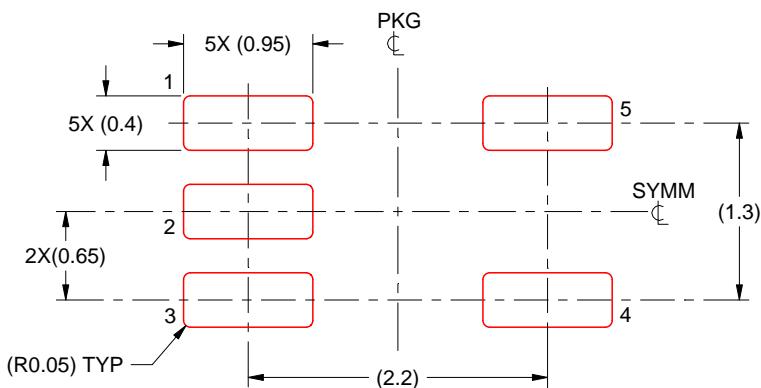
7. Publication IPC-7351 may have alternate designs.
8. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

# EXAMPLE STENCIL DESIGN

DCK0005A

SOT - 1.1 max height

SMALL OUTLINE TRANSISTOR



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

4214834/G 11/2024

NOTES: (continued)

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

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