

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

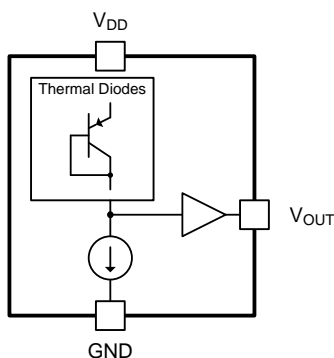
1 Features

- Cost-effective alternative to thermistors
- Tight accuracy across a wide temperature range:
 - $\pm 2.5^{\circ}\text{C}$ (maximum): -40°C to $+150^{\circ}\text{C}$ (TMP235)
 - $\pm 2.5^{\circ}\text{C}$ (maximum): -10°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 mV/ $^{\circ}\text{C}$, 500 mV at 0°C (TMP235)
 - 19.5 mV/ $^{\circ}\text{C}$, 400 mV at 0°C (TMP236)
- Wide operating supply voltage range:
 - 2.3 V to 5.5 V (TMP235)
 - 3.1 V to 5.5 V (TMP236)
- Short-circuit protected output
- Low power: 9 μA (typical)
- Strong output for driving loads up to 1000 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°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 mV/ $^{\circ}\text{C}$ over the full -40°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/ $^{\circ}\text{C}$ from -10°C to $+125^{\circ}\text{C}$ and a supply range from 3.1 V to 5.5 V.

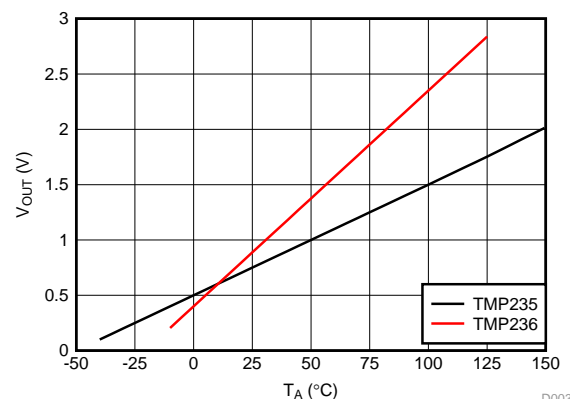
The 9- μA typical quiescent current and 800- μs typical power-on time enable effective power-cycling architectures to minimize power consumption for battery-powered devices. A class-AB output driver provides a strong 500- μA maximum output to drive capacitive loads up to 1000 pF and is designed to directly 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⁽¹⁾

| PART NUMBER | PACKAGE | BODY SIZE (NOM) |
|-------------------|------------|-------------------|
| TMP235, TMP236 | SC70 (5) | 2.00 mm x 1.25 mm |
| | SOT-23 (3) | 2.92 mm x 1.30 mm |

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

Output Voltage vs Ambient



D003



Table of Contents

| | | | |
|--|----------|--|-----------|
| 1 Features | 1 | 7.4 Device Functional Modes..... | 10 |
| 2 Applications | 1 | 8 Application and Implementation | 11 |
| 3 Description | 1 | 8.1 Application Information..... | 11 |
| 4 Revision History | 2 | 8.2 Typical Application | 11 |
| 5 Pin Configuration and Functions | 3 | 9 Power Supply Recommendations | 12 |
| 6 Specifications | 4 | 10 Layout | 12 |
| 6.1 Absolute Maximum Ratings | 4 | 10.1 Layout Guidelines | 12 |
| 6.2 ESD Ratings..... | 4 | 10.2 Layout Examples..... | 12 |
| 6.3 Recommended Operating Conditions..... | 4 | 11 Device and Documentation Support | 13 |
| 6.4 Thermal Information | 4 | 11.1 Related Links | 13 |
| 6.5 Electrical Characteristics..... | 5 | 11.2 Receiving Notification of Documentation Updates | 13 |
| 6.6 Typical Characteristics | 6 | 11.3 Community Resources..... | 13 |
| 7 Detailed Description | 8 | 11.4 Trademarks | 13 |
| 7.1 Overview | 8 | 11.5 Electrostatic Discharge Caution..... | 13 |
| 7.2 Functional Block Diagram | 8 | 11.6 Glossary | 13 |
| 7.3 Feature Description..... | 8 | 12 Mechanical, Packaging, and Orderable Information | 13 |

4 Revision History

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

| Changes from Revision D (August 2018) to Revision E | Page |
|--|-------------|
| • Changed recommended operating temperature range from: –50°C to 150°C to: –40°C to 150°C | 4 |
| • Changed power supply bypassing recommendations on how to avoid noise effect on the device output | 12 |

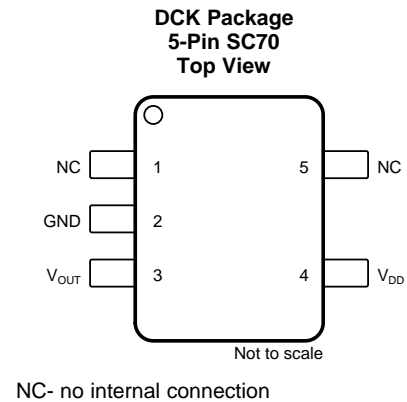
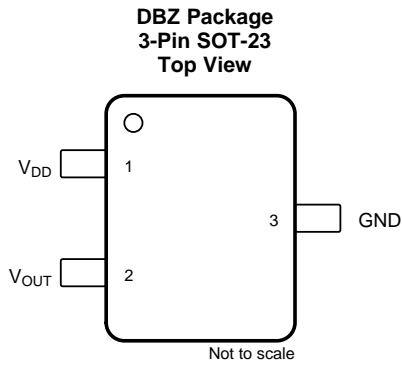
| Changes from Revision C (August 2018) to Revision D | Page |
|--|-------------|
| • Changed DBZ (SOT-23) package status from preview to production data..... | 1 |

| Changes from Revision B (February 2018) to Revision C | Page |
|--|-------------|
| • 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°C to 70°C range | 5 |

| Changes from Revision A (December 2017) to Revision B | Page |
|---|-------------|
| • Changed reference to typical accuracy specifications from: ±1°C and ±2°C to: ±0.5°C and ±1°C..... | 1 |
| • Deleted erroneous AOQL footnote | 5 |
| • Changed specification limits indicated in Figure 1 | 6 |
| • Added <i>Device Functional Modes</i> section | 10 |

| Changes from Original (September 2017) to Revision A | Page |
|---|-------------|
| • Changed document status from Advance Information to Production Data | 1 |

5 Pin Configuration and Functions



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 _{OUT} | 2 | 3 | O | Outputs voltage proportional to temperature |
| V _{DD} | 1 | 4 | I | Positive supply input |

6 Specifications

6.1 Absolute Maximum Ratings

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

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

- (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 ⁽¹⁾ | ±4000 | V |
| | | Charged-device model (CDM), per JEDEC specification JESD22-C101 ⁽²⁾ | ±1000 | |

- (1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
 (2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

6.3 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 ⁽¹⁾⁽²⁾ | | TMP235 | | UNIT |
|----------------------------------|--|------------|--------------|------|
| | | DCK (SC70) | DBZ (SOT-23) | |
| | | PINS | PINS | |
| $R_{\theta JA}$ | Junction-to-ambient thermal resistance ⁽³⁾⁽⁴⁾ | 275 | 167 | °C/W |
| $R_{\theta JC(top)}$ | Junction-to-case (top) thermal resistance | 84 | 90 | °C/W |
| $R_{\theta JB}$ | Junction-to-board thermal resistance | 56 | 146 | °C/W |
| Ψ_{JT} | Junction-to-top characterization parameter | 1.2 | 35 | °C/W |
| Ψ_{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: $V_{DD} = 2.3\text{ V to }5.5\text{ V}$, GND = Ground, $T_A = -40^\circ\text{C to }+125^\circ\text{C}$ and no load (unless otherwise noted)

TMP236: $V_{DD} = 3.1\text{ V to }5.5\text{ V}$, 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 | |
|--|--|--|---|-----------|-----------|----------------------------|---------------------------|------|
| POWER SUPPLY | | | | | | | | |
| I_{DD} | Operating current | $T_A = 25^\circ\text{C}$, $V_{DD} = 2.3\text{ V}$, TMP235 | | 9 | | μA | | |
| | | $T_A = 25^\circ\text{C}$, $V_{DD} = 3.1\text{ V}$, 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 | $^\circ\text{C}/\text{V}$ | |
| SENSOR ACCURACY | | | | | | | | |
| T_{ACY} | Temperature accuracy ⁽¹⁾ | | $T_A = 25^\circ\text{C}$ | ± 0.5 | | $^\circ\text{C}$ | | |
| | | | $T_A = 0^\circ\text{C to }70^\circ\text{C}$ (SC70 Package) | -1 | ± 0.5 | | | +1 |
| | | | $T_A = 0^\circ\text{C to }70^\circ\text{C}$ (SOT-23 Package) | -1.2 | ± 0.5 | | | +1.2 |
| | | | $T_A = -40^\circ\text{C to }+125^\circ\text{C}$ (TMP235A2) | -2 | ± 0.5 | | | +2 |
| | | | $T_A = -10^\circ\text{C to }+125^\circ\text{C}$ (TMP236A2) | -2 | ± 0.5 | | | +2 |
| | | | $T_A = -40^\circ\text{C to }+150^\circ\text{C}$ (TMP235A2) | -2 | ± 0.5 | | | +2 |
| | | Accuracy Level 4 (A4) | $T_A = 25^\circ\text{C}$ | ± 1 | | | | |
| | | | $T_A = 0^\circ\text{C to }70^\circ\text{C}$ | -2 | ± 1 | | | +2 |
| | | | $T_A = -40^\circ\text{C to }+125^\circ\text{C}$ (TMP235A4) | -4 | ± 1 | | | +4 |
| | | | $T_A = -10^\circ\text{C to }+125^\circ\text{C}$ (TMP236A4) | -4 | ± 1 | | | +4 |
| $T_A = -40^\circ\text{C to }+150^\circ\text{C}$ (TMP235A4) | -5 | ± 1 | +5 | | | | | |
| SENSOR OUTPUT | | | | | | | | |
| $V_{0^\circ\text{C}}$ | Output voltage offset at 0°C | TMP235 | | 500 | | mV | | |
| | | TMP236 | | 400 | | | | |
| T_C | Temperature coefficient (sensor gain) | TMP235 | | 10 | | $\text{mV}/^\circ\text{C}$ | | |
| | | TMP236 | | 19.5 | | | | |
| V_{ONL} | Output nonlinearity ⁽¹⁾ | $T_A = 0^\circ\text{C to }70^\circ\text{C}$, no load | | ± 0.5 | | $^\circ\text{C}$ | | |
| I_{OUT} | Output current | | | 500 | | μA | | |
| Z_{OUT} | Output impedance | $I_{OUT} = 100\ \mu\text{A}$, $f = 100\text{ Hz}$ | | 20 | | Ω | | |
| | | $I_{OUT} = 100\ \mu\text{A}$, $f = 500\text{ Hz}$ | | 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 | | Ω | | |
| t_{ON} | Turn on time | Time to reach accuracy within $\pm 0.5^\circ\text{C}$ | | 800 | | μs | | |
| C_{LOAD} | Typical load capacitance | | | 1000 | | pF | | |
| t_{RES} | Thermal response to 63% | SC70 | 30°C (Air) to $+125^\circ\text{C}$ (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 $^\circ\text{C}$). 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)

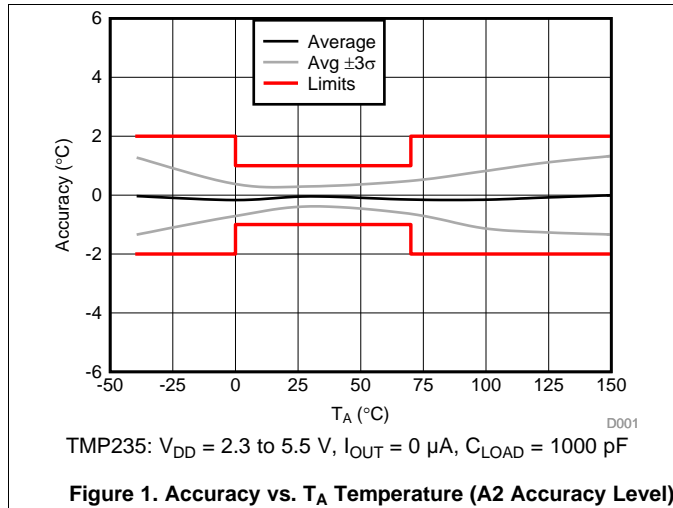


Figure 1. Accuracy vs. T_A Temperature (A2 Accuracy Level)

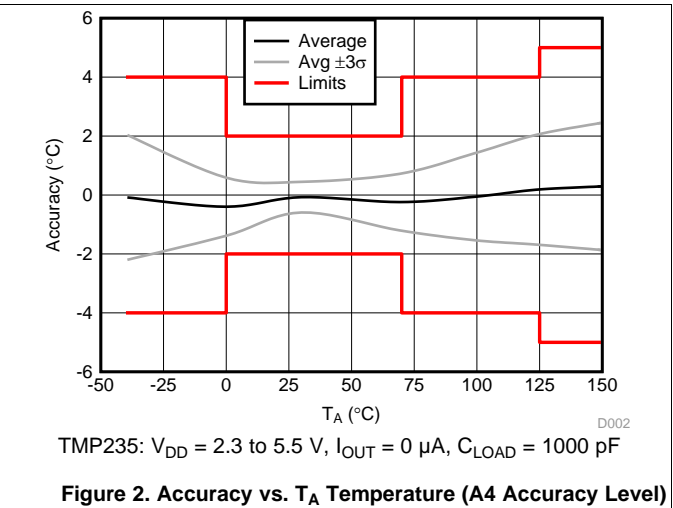


Figure 2. Accuracy vs. T_A Temperature (A4 Accuracy Level)

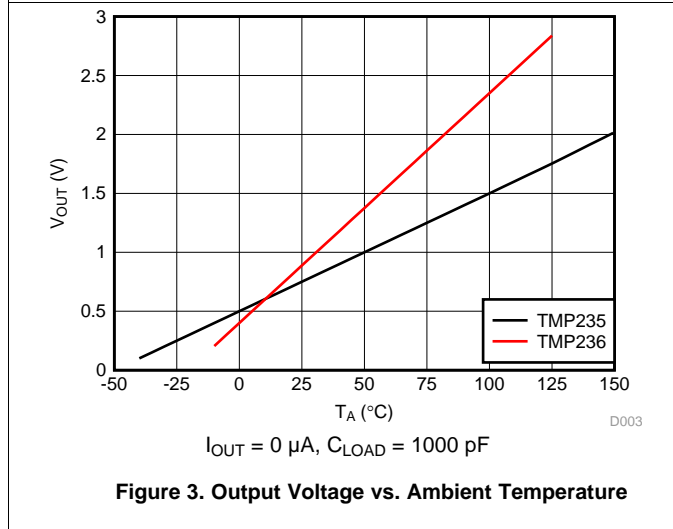


Figure 3. Output Voltage vs. Ambient Temperature

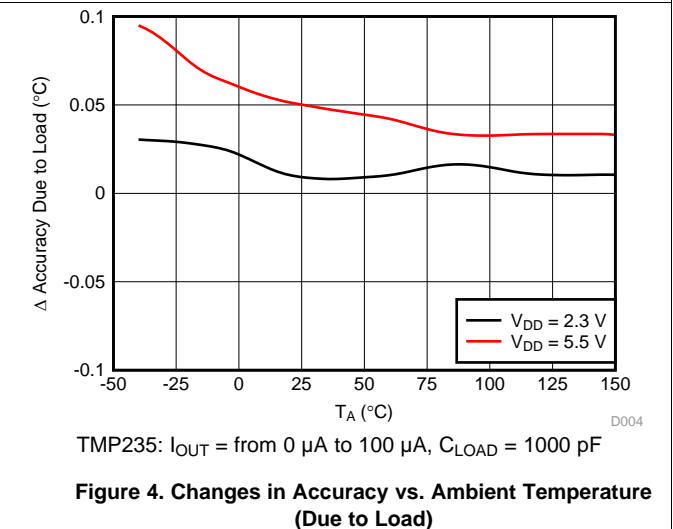


Figure 4. Changes in Accuracy vs. Ambient Temperature (Due to Load)

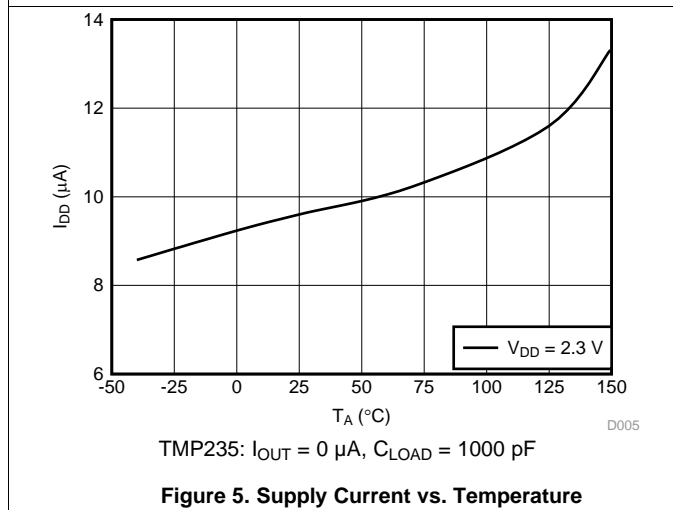


Figure 5. Supply Current vs. Temperature

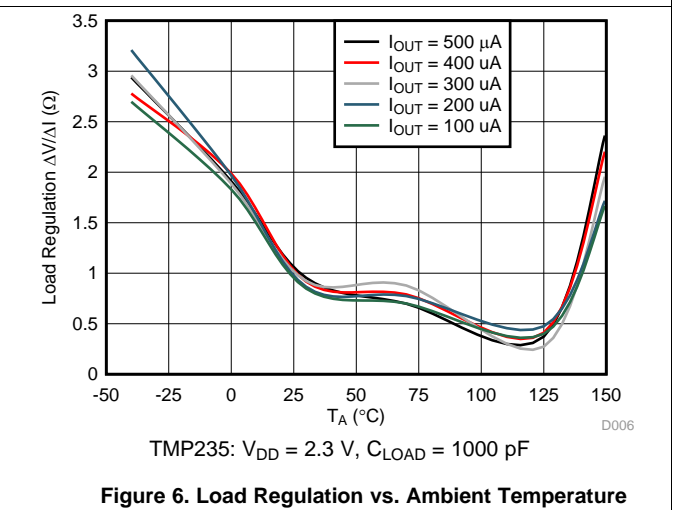
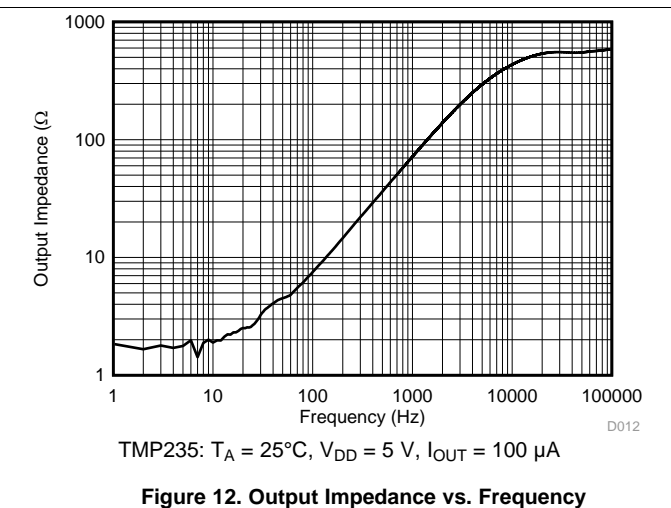
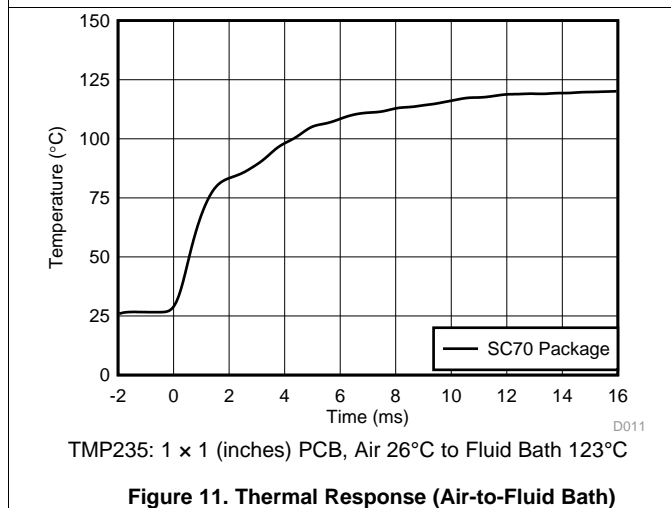
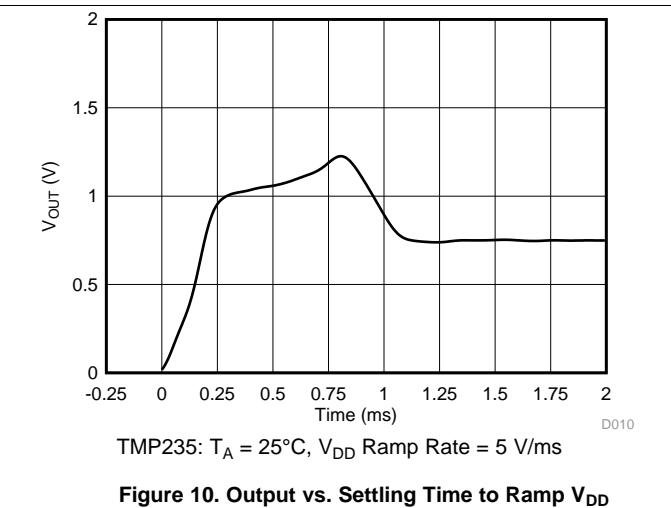
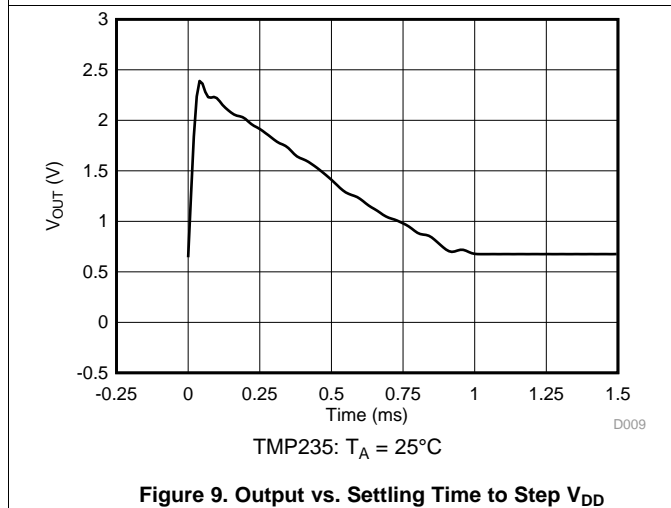
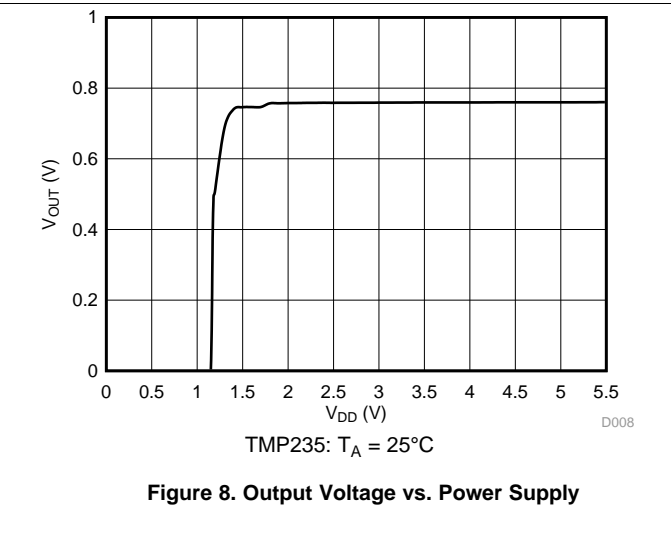
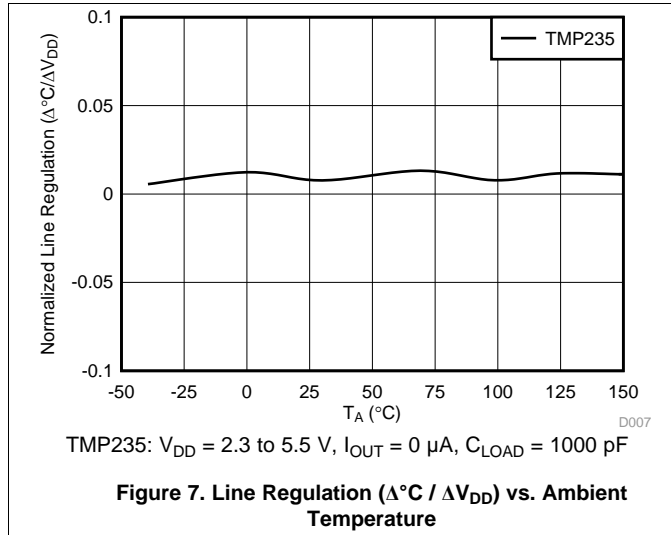


Figure 6. Load Regulation vs. Ambient Temperature

Typical Characteristics (continued)

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

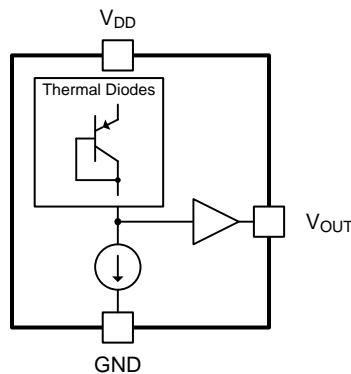


7 Detailed Description

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 ±1.25°C (TMP23xA2) and ±2°C (TMP23xA4). The TMP235 device provides a positive slope output of 10 mV/°C over the full –40°C to +150°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°C to +125°C and a supply range from 3.1 V to 5.5 V. A class-AB output driver provides a maximum output of 500 µA 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_{OUT} gain shift, however, is present at temperatures above 100°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_{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_{OUT} of the TMP23x is calculated by [Equation 1](#):

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

where

- V_{OUT} is the TMP23x voltage output for a given temperature
- T_A is the ambient temperature in °C
- T_{INFL} is the temperature inflection point for a piecewise segment in °C
- T_C is the TMP23x temperature coefficient or gain
- V_{OFFS} is the TMP23x voltage offset

(1)

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

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

(2)

Table 1. TMP235 Piecewise Linear Function Summary

| T_A RANGE (°C) | V_{RANGE} (mV) | T_{INFL} (°C) | T_C (mV/°C) | V_{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- μ 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

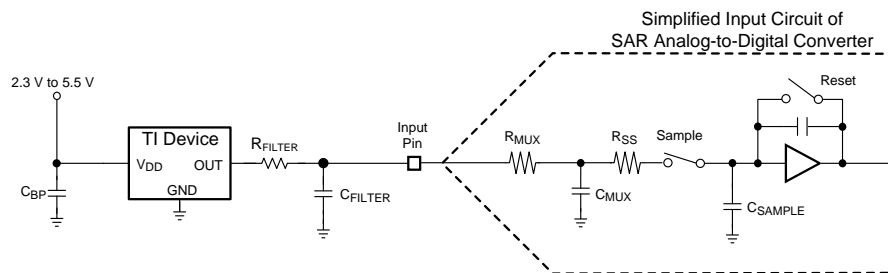


Figure 13. Suggested Connections to an ADC Input Stage

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

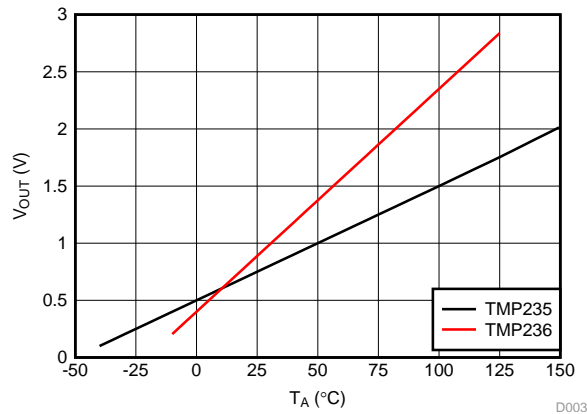


Figure 14. Output Voltage vs. Ambient

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- μ F capacitor and 100- Ω 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

-  VIA to ground plane
-  VIA to power plane

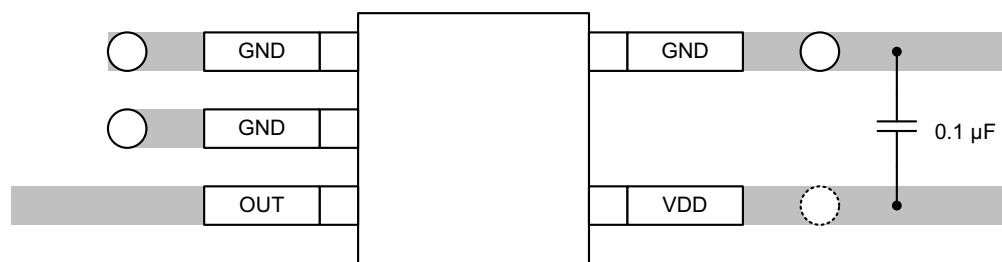


Figure 15. Recommended Layout: SC70 Package

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 | Click here | Click here | Click here | Click here | Click here |
| TMP236 | Click here | Click here | Click here | Click here | Click here |

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 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 |
|------------------|---------------|--------------|-----------------|------|-------------|-----------------|--------------------------------------|----------------------|--------------|-------------------------|-------------------------|
| TMP235A2DBZR | ACTIVE | SOT-23 | DBZ | 3 | 3000 | RoHS & Green | NIPDAUAG SN | Level-1-260C-UNLIM | -40 to 150 | 2352 | Samples |
| TMP235A2DCKR | ACTIVE | SC70 | DCK | 5 | 3000 | RoHS & Green | NIPDAU SN NIPDAUAG | Level-1-260C-UNLIM | -40 to 150 | 19L | Samples |
| TMP235A4DBZR | ACTIVE | SOT-23 | DBZ | 3 | 3000 | RoHS & Green | NIPDAUAG SN | Level-1-260C-UNLIM | -40 to 150 | 2354 | Samples |
| TMP235A4DCKR | ACTIVE | SC70 | DCK | 5 | 3000 | RoHS & Green | NIPDAU SN NIPDAUAG | Level-1-260C-UNLIM | -40 to 150 | 19M | Samples |
| TMP236A2DBZR | ACTIVE | SOT-23 | DBZ | 3 | 3000 | RoHS & Green | NIPDAU SN NIPDAUAG | Level-1-260C-UNLIM | -10 to 125 | 2362 | Samples |
| TMP236A2DCKR | ACTIVE | SC70 | DCK | 5 | 3000 | RoHS & Green | NIPDAU SN NIPDAUAG | Level-1-260C-UNLIM | -10 to 125 | 1BS | Samples |
| TMP236A4DBZR | ACTIVE | SOT-23 | DBZ | 3 | 3000 | RoHS & Green | NIPDAU SN NIPDAUAG | Level-1-260C-UNLIM | -10 to 125 | 2364 | Samples |
| TMP236A4DCKR | ACTIVE | SC70 | DCK | 5 | 3000 | RoHS & Green | NIPDAU SN NIPDAUAG | Level-1-260C-UNLIM | -10 to 125 | 1BT | 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.

OBSELETE: 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.

Important Information and Disclaimer:The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

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



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 | 3.2 | 2.85 | 1.3 | 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 |
| TMP235A4DBZR | SOT-23 | DBZ | 3 | 3000 | 180.0 | 8.4 | 3.2 | 2.85 | 1.3 | 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 |
| TMP236A2DBZR | SOT-23 | DBZ | 3 | 3000 | 180.0 | 8.4 | 3.2 | 2.85 | 1.3 | 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 | 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 |
| TMP235A2DCKR | SC70 | DCK | 5 | 3000 | 210.0 | 185.0 | 35.0 |
| TMP235A4DBZR | SOT-23 | DBZ | 3 | 3000 | 210.0 | 185.0 | 35.0 |
| TMP235A4DCKR | SC70 | DCK | 5 | 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 |
| TMP236A4DCKR | SC70 | DCK | 5 | 3000 | 210.0 | 185.0 | 35.0 |

DCK0005A



PACKAGE OUTLINE

SOT - 1.1 max height

SMALL OUTLINE TRANSISTOR



4214834/E 06/2024

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



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:18X



SOLDER MASK DETAILS

4214834/E 06/2024

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/E 06/2024

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.

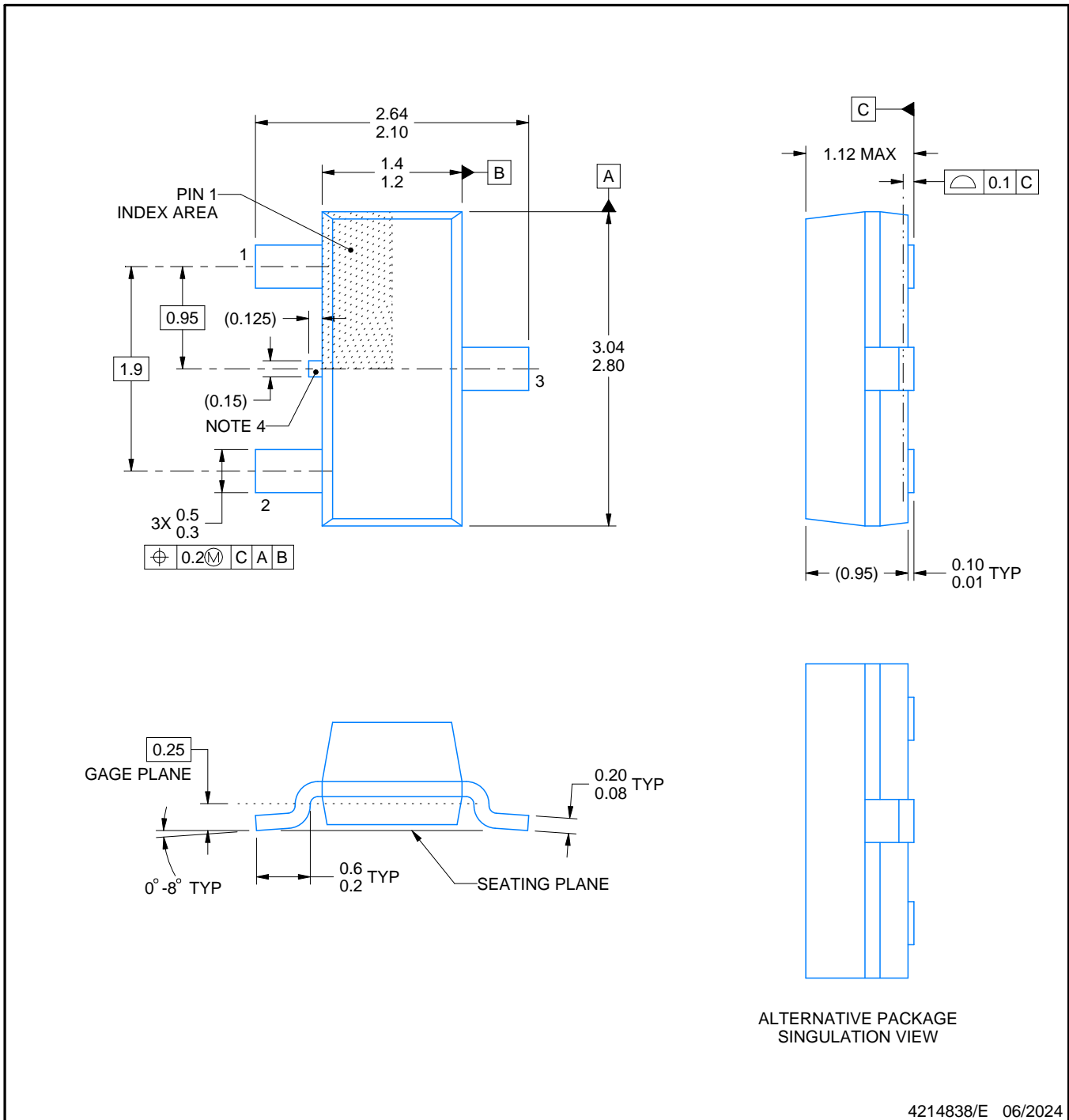
DBZ0003A



PACKAGE OUTLINE

SOT-23 - 1.12 mm max height

SMALL OUTLINE TRANSISTOR



4214838/E 06/2024

NOTES:

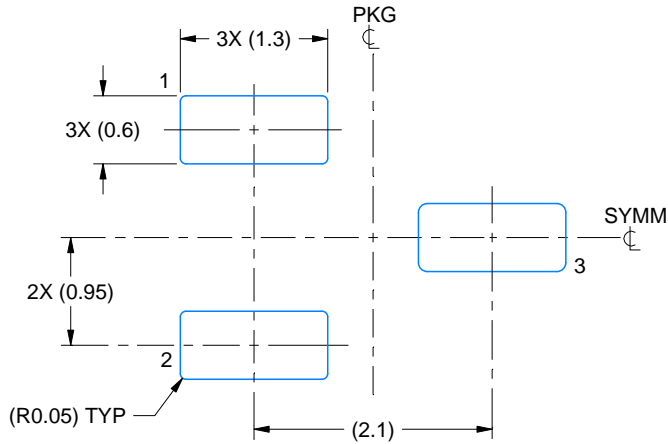
- All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
- This drawing is subject to change without notice.
- Reference JEDEC registration TO-236, except minimum foot length.
- Support pin may differ or may not be present.
- 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

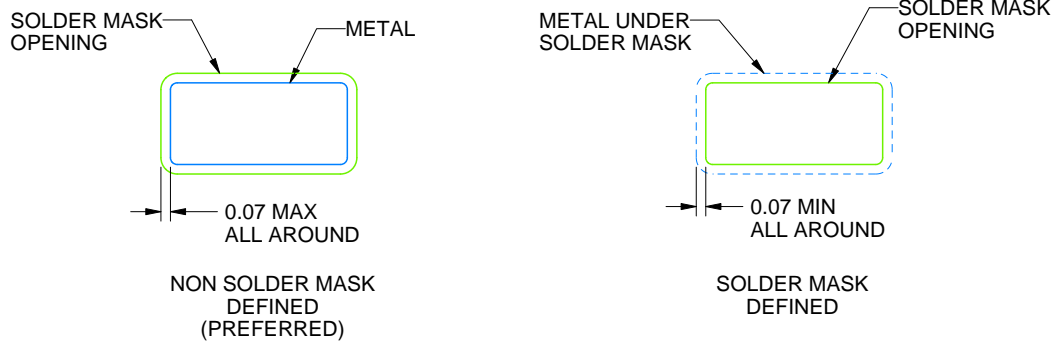
DBZ0003A

SOT-23 - 1.12 mm max height

SMALL OUTLINE TRANSISTOR



LAND PATTERN EXAMPLE
SCALE:15X



SOLDER MASK DETAILS

4214838/E 06/2024

NOTES: (continued)

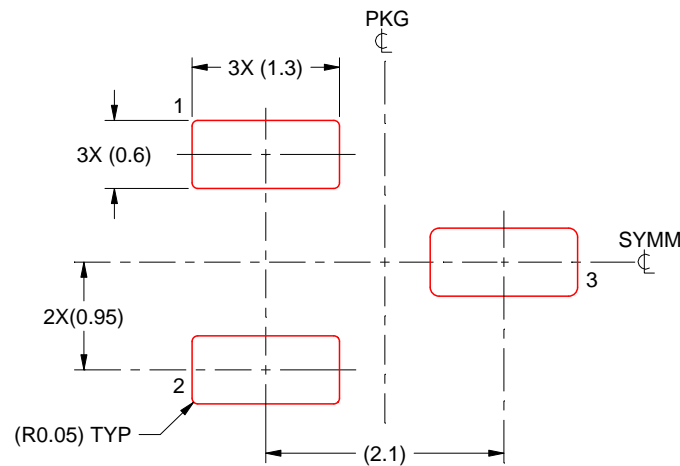
5. Publication IPC-7351 may have alternate designs.
6. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

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

4214838/E 06/2024

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.

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATA SHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES "AS IS" AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI's products are provided subject to [TI's Terms of Sale](#) or other applicable terms available either on [ti.com](https://www.ti.com) or provided in conjunction with such TI products. TI's provision of these resources does not expand or otherwise alter TI's applicable warranties or warranty disclaimers for TI products.

TI objects to and rejects any additional or different terms you may have proposed.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2024, Texas Instruments Incorporated