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

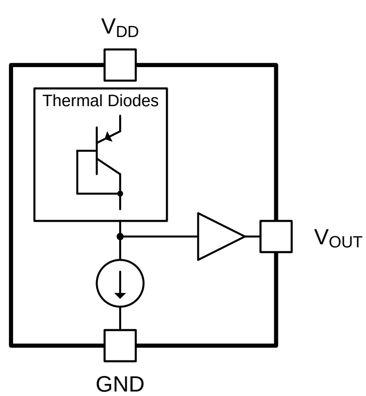
1 Features

- Cost-Effective Alternative to Thermistors
- Wide Temperature Measurement Range:
  - –40°C to +150°C (TMP235)
  - –10°C to +125°C (TMP236)
- Available in Accuracy Level Variants:
  - ±0.5°C (Typical)
  - ±1°C (Typical)
- Positive Slope Sensor Gain, Offset (Typical):
  - 10 mV/°C, 500 mV at 0°C (TMP235)
  - 19.5 mV/°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 Up To 1000-pF Load
- Available Package Options:
  - 5-Pin SC70 (DCK) Surface Mount
  - 3-Pin SOT-23 (DBZ) Surface Mount

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, making the series suitable for multiple analog temperature sensing applications. These temperature sensors are more accurate than similar pin-compatible devices on the market, featuring accuracy from 0°C to +70°C of ±1°C and ±2°C. The increased accuracy makes this series suitable for many analog temperature sensing applications. The TMP235 device provides a positive slope output of 10 mV/°C over the full –40°C to +150°C temperature range and a 2.3 V to 5.5 V supply range. The higher gain TMP236 sensor provides a positive slope output of 19.5 mV/°C from –10°C to +150°C and a 3.1 V to 5.5 V supply range.

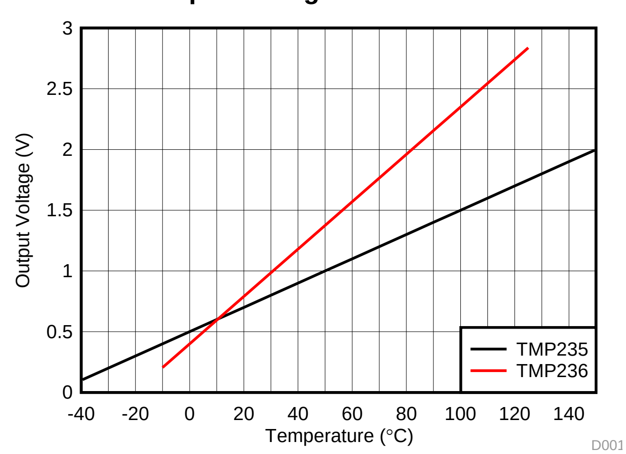
The 9-µA typical quiescent current and 800-µs typical power-on time enable effective power-cycling architectures to minimize power consumption for battery-powered devices. A class-AB output driver provides a strong 500 µA maximum output to drive capacitive loads up to 1000 pF and is well-suited to directly 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 excellent, cost-effective alternatives to passive thermistors.

Device Information(1)

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

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

Output Voltage vs Ambient



ADVANCE INFORMATION

Table of Contents

4 Revision History

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

DATE	REVISION	NOTES
September 2017	*	Initial release.

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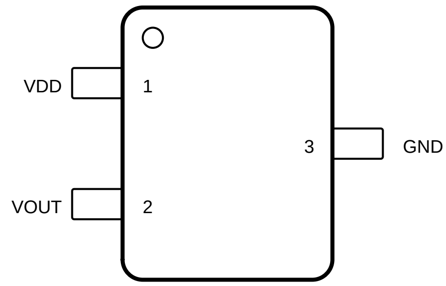
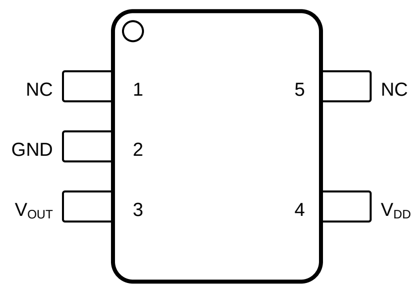
5 Pin Configuration and Functions

DBZ Package
3-Pin SOT-23
Top View



DCK Package
5-Pin SC70
Top View



NC- no internal connection. Initial samples may contain bond wire.

Pin Functions

NAME	PIN		TYPE	DESCRIPTION
	SOT-23	SC70		
NC	—	1	—	No internal connection
GND	3	2	Ground	Power supply ground
V_{OUT}	2	3	Output	Outputs voltage proportional to temperature
V_{DD}	1	4	Power	Positive supply input
NC	—	5	—	No internal connection

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6 Specifications

6.1 Absolute Maximum Ratings

		MIN	MAX	UNIT
Voltage	Supply, V_{DD}		+6	V
	Output, V_{OUT}	–0.3	(V_{DD} + 0.5)	
Current	Output	–30	+30	mA
	Latch-Up Current, Each Pin	–200	+200	
Temperature	Junction temperature (T_J)		+150	°C
	Storage temperature (T_{stg})	–65	+150	

6.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM) per JESD22-A114	±4000	V
		Charged-device model (CDM), per JEDEC specification JESD22-C101 (1)	±1000	

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

6.3 Recommended Operating Conditions

		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	–50		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 information on self-heating and thermal response time see *Layout Guidelines* section.
(2) For more information about traditional and new thermal metrics, see the *IC Package Thermal Metrics* application report.
(3) The junction to ambient thermal resistance (RθJA) 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: VDD = 2.3 V to 5.5 V, GND = Ground, TA = –40°C to 125°C and No Load (Unless otherwise noted)
TMP236: VDD = 3.1 V to 5.5 V, GND = Ground, TA = –10°C to 125°C and No Load (Unless otherwise noted)

PARAMETER			TEST CONDITIONS	MIN	TYP	MAX	UNIT
POWER SUPPLY							
I_{DD}	Operating Current		T_A = +25°C, VDD = 2.3 V, TMP235		7		µA
			T_A = –40°C to +125°C			14	
			T_A = 150°C			17	
Δ°C/ ΔV_{DD}	Line Regulation				0.02		°C/V
SENSOR ACCURACY							
T_{ACY}	Temperature Accuracy (1)	Accuracy Level 2 (A2)	T_A = +25°C		±0.5		°C
			T_A = 0°C to +70°C	–1	±0.5	+1	
			T_A = –40°C to +125°C (TMP235A2)	–2	±0.5	+2	
			T_A = –10°C to +125°C (TMP236A2)	–2	±0.5	+2	
			T_A = –40°C to +150°C (TMP235A2)	–4	±0.5	+4	
		Accuracy Level 4 (A4)	T_A = +25°C		±1		
			T_A = 0°C to +70°C	–2	±1	+2	
			T_A = –40°C to +125°C (TMP235A4)	–4	±1	+4	
			T_A = –10°C to +125°C (TMP236A4)	–4	±1	+4	
			T_A = –40°C to +150°C (TMP235A4)	–6	±1	+6	
SENSOR OUTPUT							
$V_{0°C}$	Output Voltage Offset at 0 °C		TMP235		500		mV
			TMP236		400		
T_C	Temperature Coefficient (Sensor Gain)		TMP235		10.0		mV/°C
			TMP236		19.5		
V_{ONL}	Output Nonlinearity (2)		T_A = 0 °C to +70 °C, No Load		±0.5		°C
I_{OUT}	Output Current					500	µA
Z_{OUT}	Output Impedance		IOUT = 100 µA, f = 100 Hz		20		Ω
			IOUT = 100 µA, f = 500 Hz		50		
	Output Load Regulation		T_A = 0°C to +70°C, IOUT = 100 µA, $\Delta V_{OUT} / \Delta I_{OUT}$		1		
t_{ON}	Turnon Time				800		µS
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
		SOT-23			(TBC)		

(1) Limits are specified to TI's AOQL (Average Outgoing Quality Level).
(2) Refer to Table 1.

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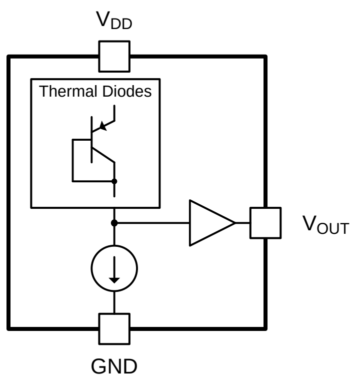
7 Detailed Description

7.1 Overview

The TMP23x devices are a family of linear analog temperature sensors with a output voltage proportional to temperature. These temperature sensors have an accuracy from 0°C to 70°C of ±1°C (TMP23x) and ±2°C (TMP23x). The TMP235 device provides a positive slope output of 10 mV/°C over the full –40°C to +150°C temperature range and a 2.3 V to 5.5 V supply range. The higher gain TMP236 sensor provides a positive slope output of 19.5 mV/°C from –10°C to +125°C and a 3.1 V to 5.5 V supply range. A class-AB output driver provides a maximum output of 100 µA to drive capacitive loads up to 1000 pF.

7.2 Functional Block Diagram



7.3 Feature Description

7.3.1 TMP23x Transfer Function

Table 1 lists the output voltages of the TMP23x devices across the full operating temperature range. The first-order columns of this table are the straight line references that determine the accuracy specifications of the TMP23x devices (see *Electrical Characteristics*). The second-order columns show the small amount of typical nonlinearity in the output.

Table 1. TMP23X Transfer Table

TEMP (°C)	TMP235 V_{OUT} (mV)		TMP236 V_{OUT} (mV)	
	First-Order	Second-Order	First-Order	Second-Order
–40	100	TBD	–	–
–35	150	TBD	–	–
–30	200	TBD	–	–
–25	250	TBD	–	–
–20	300	TBD	–	–
–15	350	TBD	–	–
–10	400	TBD	205	TBD
–5	450	TBD	303	TBD
0	500	TBD	400	TBD
5	550	TBD	498	TBD
10	600	TBD	595	TBD
15	650	TBD	693	TBD
20	700	TBD	790	TBD
25	750	TBD	888	TBD
30	800	TBD	985	TBD
35	850	TBD	1083	TBD

Feature Description (continued)

Table 1. TMP23X Transfer Table (continued)

TEMP (°C)	TMP235 V_{OUT} (mV)		TMP236 V_{OUT} (mV)	
	First-Order	Second-Order	First-Order	Second-Order
40	900	TBD	1180	TBD
45	950	TBD	1278	TBD
50	1000	TBD	1375	TBD
55	1050	TBD	1473	TBD
60	1100	TBD	1570	TBD
65	1150	TBD	1668	TBD
70	1200	TBD	1765	TBD
75	1250	TBD	1863	TBD
80	1300	TBD	1960	TBD
85	1350	TBD	2058	TBD
90	1400	TBD	2155	TBD
95	1450	TBD	2253	TBD
100	1500	TBD	2350	TBD
105	1550	TBD	2448	TBD
110	1600	TBD	2545	TBD
115	1650	TBD	2643	TBD
120	1700	TBD	2740	TBD
125	1750	TBD	2838	TBD
130	1800	TBD	–	–
135	1850	TBD	–	–
140	1900	TBD	–	–
145	1950	TBD	–	–
150	2000	TBD	–	–

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

8.2 Typical Applications

8.2.1 Connection to an ADC

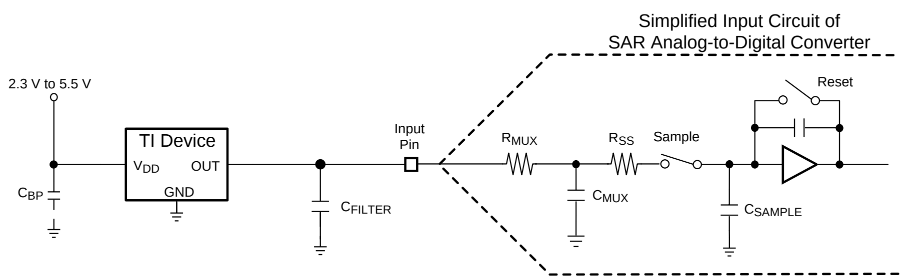


Figure 1. Suggested Connection to a Sampling Analog-to-Digital Converter Input Stage

8.2.1.1 Design Requirements

Most CMOS ADCs in microcontrollers and ASICs have a sampled data comparator input structure. When the ADC charges the sampling capacitor, the capacitor requires instantaneous charge from the output of the analog source (such as the TMP23x temperature sensor). The output impedance of the sensor can affect ADC performance. In most cases, adding an external capacitor (C_{FILTER}) mitigates design challenges. TI recommends a 0.1-µF external capacitor for typical applications. This external capacitor reduces the sensor source impedance and limits noise coupling. TI recommends placing the capacitor as close as possible to the ADC input for optimal performance.

8.2.1.2 Detailed Design Procedure

The size of C_{FILTER} depends on the size of the sampling capacitor and the sampling frequency. The charge requirements may vary because not all ADCs have identical input stages. Figure 1 shows a general ADC application as an example only.

Typical Applications (continued)

8.2.1.3 Application Curve

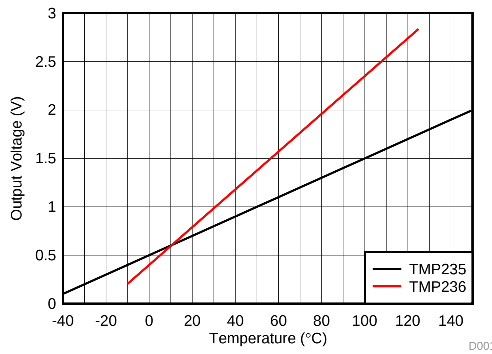


Figure 2. Output Voltage vs. Ambient

9 Power Supply Recommendations

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

Power supply bypassing is optional and is mainly dependent on the noise of the power supply. In noisy environments, TI recommends adding a 0.1-µF capacitor from V+ to GND to bypass the power supply voltage. 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

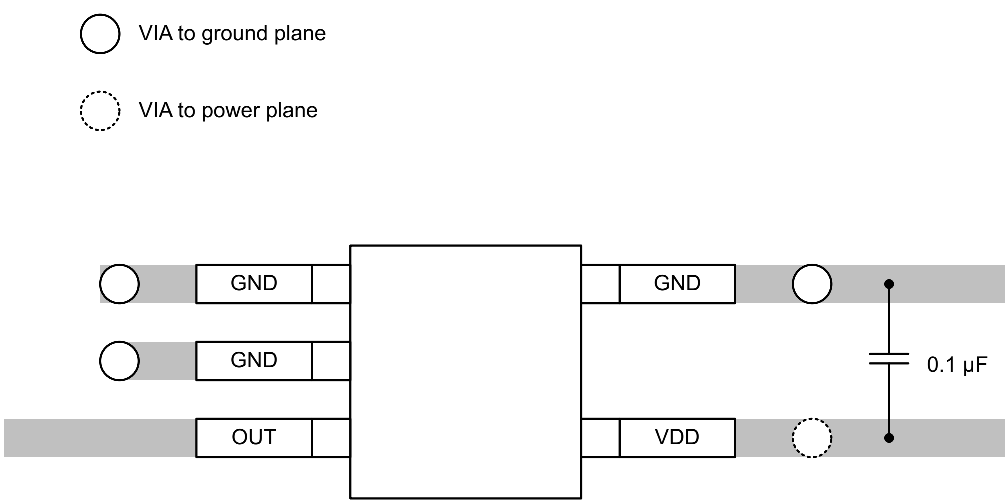


Figure 3. Recommended Layout: SC70 Package

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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 sample or buy.

Table 2. 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 Trademarks

11.3 Electrostatic Discharge Caution

These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

11.4 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/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
PTMP235DCKT	ACTIVE	SC70	DCK	5	250	TBD	Call TI	Call TI	-40 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/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

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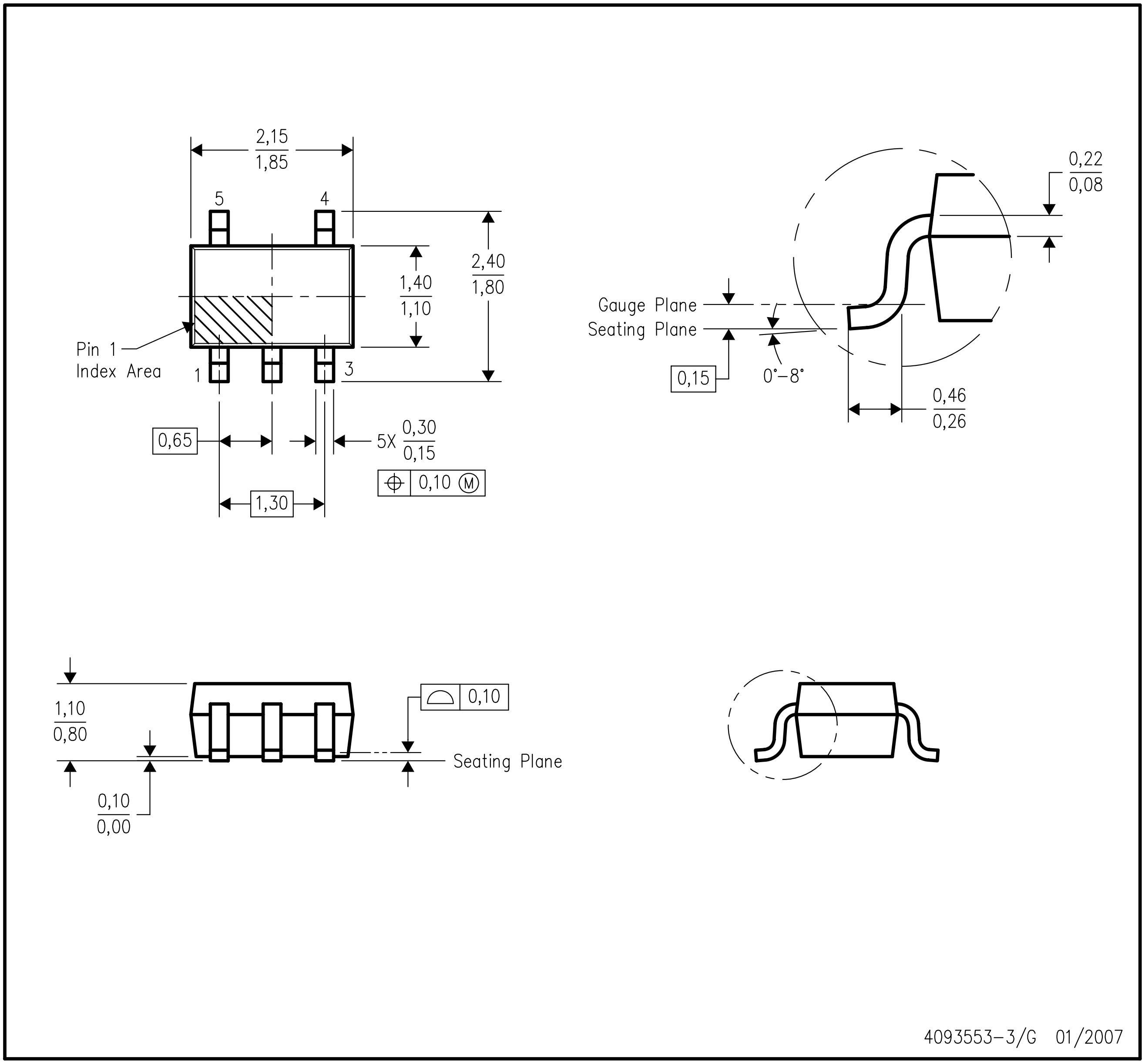
DCK (R-PDSO-G5) PLASTIC SMALL-OUTLINE PACKAGE



NOTES:
- A. All linear dimensions are in millimeters.
- B. This drawing is subject to change without notice.
- C. Body dimensions do not include mold flash or protrusion. Mold flash and protrusion shall not exceed 0.15 per side.
- D. Falls within JEDEC MO-203 variation AA.