SBOS273C − JUNE 2003 − REVISED FEBRUARY 2005

# 1.5°C Accurate Digital Temperature Sensor with SPI™ Interface

## FEATURES

- DIGITAL OUTPUT: SPI-Compatible Interface
- RESOLUTION: 12-Bit + Sign, 0.0625°C
- ACCURACY:
  ±1.5°C from −25°C to +85°C (max)
- LOW QUIESCENT CURRENT: 50μA (max)
- WIDE SUPPLY RANGE: 2.7V to 5.5V
- TINY SOT23-6 PACKAGE
- OPERATION TO 150°C

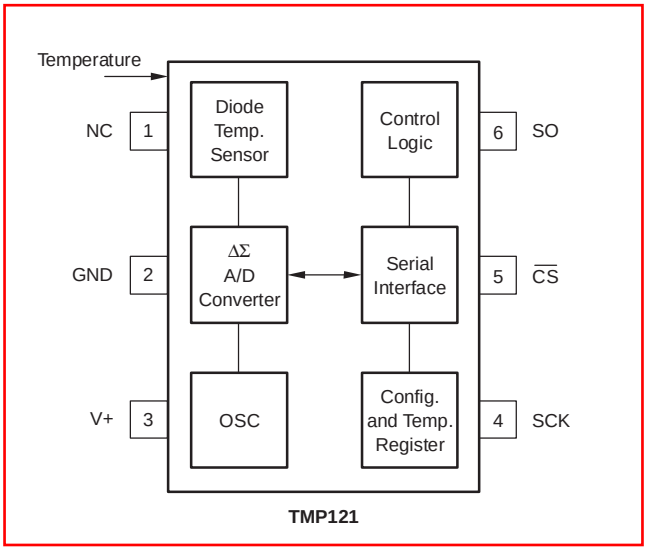
## APPLICATIONS

- POWER-SUPPLY TEMPERATURE MONITORING
- COMPUTER PERIPHERAL THERMAL PROTECTION
- NOTEBOOK COMPUTERS
- CELL PHONES
- BATTERY MANAGEMENT
- OFFICE MACHINES

## DESCRIPTION

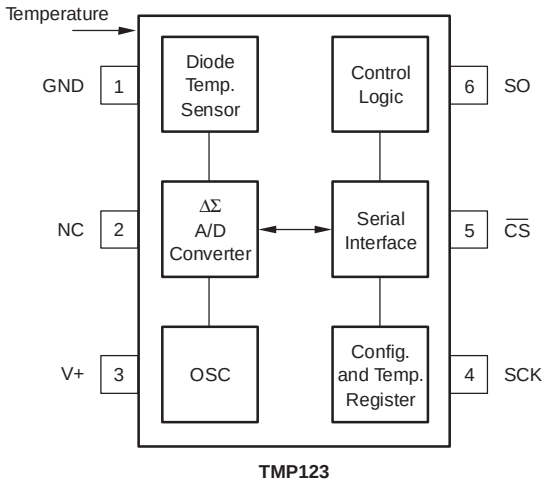
The TMP121 and TMP123 are SPI-compatible temperature sensors available in the tiny SOT23-6 package. Requiring no external components, the TMP121 and TMP123 are capable of measuring temperatures within 2°C of accuracy over a temperature range of −40°C to +125°C. Low supply current, and a supply range from 2.7V to 5.5V, make the TMP121 and TMP123 excellent candidates for low-power applications.

The TMP121 and TMP123 are ideal for extended thermal measurement in a variety of communication, computer, consumer, environmental, industrial, and instrumentation applications.




TMP121

NC = No Connection(1)




TMP123

NC = No Connection(1)

(1) Pins labeled NC should be left floating or connected to GND.

## ABSOLUTE MAXIMUM RATINGS(1)

| | |
|---|---|
| Power Supply, V+ | 7V |
| Input Voltage(2) | −0.3V to +7V |
| Input Current | 10mA |
| Operating Temperature Range | −55°C to +150°C |
| Storage Temperature Range | −60°C to +150°C |
| Junction Temperature ($T_J$ max) | +150°C |
| Lead Temperature (soldering) | +300°C |

(1) Stresses above these ratings may cause permanent damage. Exposure to absolute maximum conditions for extended periods may degrade device reliability. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those specified is not supported.

(2) Input voltage rating applies to all TMP121 and TMP123 input voltages.

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.

## ORDERING INFORMATION(1)

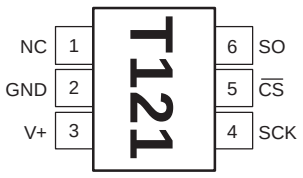
| PRODUCT | PACKAGE-LEAD | PACKAGE DESIGNATOR | PACKAGE MARKING |
|---|---|---|---|
| TMP121 | SOT23-6 | DBV | T121 |
| TMP123 | | | T123 |

(1) For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI web site at www.ti.com.

## PIN CONFIGURATIONS

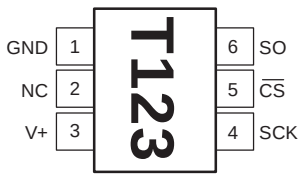
**Top View** **SOT23-6**

**TMP121**(1)




SOT23−6
NC = No Connection(2)

**TMP123**(1)




SOT23−6
NC = No Connection(2)

Pin 1 orientation is determined by package marking.

(1) Pin 1 of the SOT23-6 package is determined by orienting the package marking as shown.
(2) Pins labeled NC should be left floating or connected to GND.

## ELECTRICAL CHARACTERISTICS

At $T_A$ = −40°C to +125°C and V+ = 2.7V to 5.5V, unless otherwise noted.

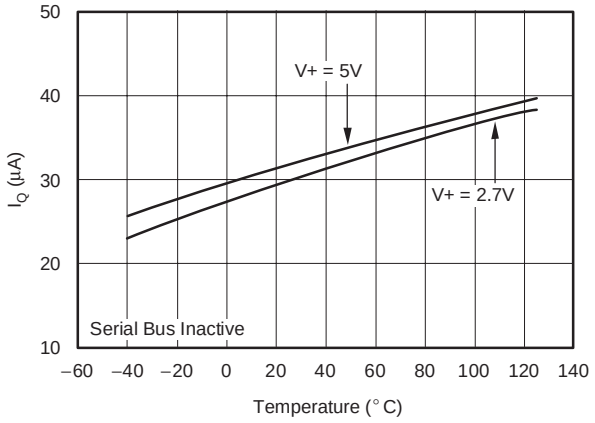
| PARAMETER | | CONDITIONS | TMP121, TMP123 MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|
| **TEMPERATURE INPUT** | | | | | | |
| Range | | | −40 | | +125 | °C |
| Accuracy (temperature error) | | −25°C to +85°C | | ±0.5 | ±1.5 | °C |
| | | −40°C to +125°C | | ±1.0 | ±2.0 | °C |
| | | −40°C to +150°C | | ±1.5 | | °C |
| vs Supply | | | −0.3 | 0.1 | +0.3 | °C/V |
| Resolution | | | | ±0.0625 | | °C |
| **DIGITAL INPUT/OUTPUT** | | | | | | |
| Input Logic Levels: | | | | | | |
| $V_{IH}$ | | | 0.7(V+) | | | V |
| $V_{IL}$ | | | | | 0.3(V+) | V |
| Input Current, SO, SCK, $\overline{CS}$ | $I_{IN}$ | $0V \le V_{IN} \le V+$ | | | ±1 | µA |
| Output Logic Levels: | | | | | | |
| $V_{OL}$ SO | | $I_{SINK}$ = 3mA | | | 0.4 | V |
| $V_{OH}$ SO | | $I_{SOURCE}$ = 2mA | (V+)−0.4 | | | V |
| Resolution | | | | 12 | | Bits |
| Input Capacitance, SO, SCK, $\overline{CS}$ | | | | 2.5 | | pF |
| Conversion Time | | 12-Bit | | 240 | 320 | ms |
| Conversion Period(1) | | 12-Bit | | 480 | 640 | ms |
| **POWER SUPPLY** | | | | | | |
| Operating Range | | | 2.7 | | 5.5 | V |
| Quiescent Current | $I_Q$ | Serial Bus Inactive | | 35 | 50 | µA |
| Shutdown Current (TMP121) | $I_{SD}$ | Serial Bus Inactive | | 0.1 | 1 | µA |
| Shutdown Current (TMP123) | $I_{SD}$ | Serial Bus Inactive | | 0.1 | 3 | µA |
| **TEMPERATURE RANGE** | | | | | | |
| Specified Range | | | −40 | | +125 | °C |
| Operating Range | | | −55 | | +150 | °C |
| Storage Range | | | −60 | | +150 | °C |
| Thermal Resistance | $\theta_{JA}$ | SOT23-6 Surface-Mount | | 200 | | °C/W |

(1) Period indicates time between conversion starts.

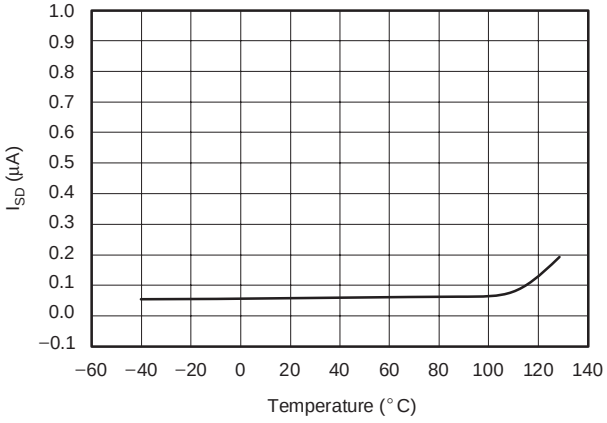
## TYPICAL CHARACTERISTICS

At $T_A$ = +25°C and V+ = 5.0V, unless otherwise noted.

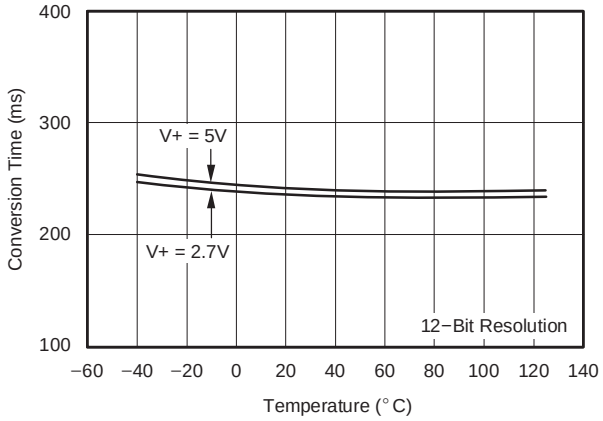
QUIESCENT CURRENT vs TEMPERATURE



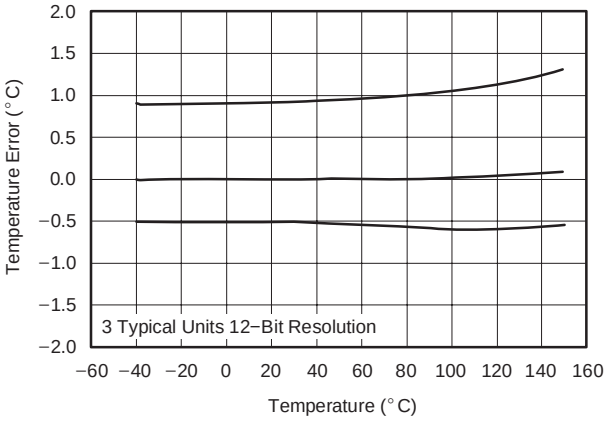

SHUTDOWN CURRENT vs TEMPERATURE




CONVERSION TIME vs TEMPERATURE




TEMPERATURE ACCURACY vs TEMPERATURE



# APPLICATIONS INFORMATION

The TMP121 and TMP123 are 12-bit plus sign read-only digital temperature sensors optimal for thermal management and thermal protection applications. The TMP121 and the TMP123 communicate through a serial interface that is SPI-compatible. Temperature is converted to a 12-bit plus sign data word with 0.0625°C resolution. The TMP121 and TMP123 are specified for a temperature range of −40°C to +125°C, with operation extending from −55°C to +150°C.

The TMP121 and TMP123 are optimal for low power applications, with a 0.5s conversion period for reduced power consumption. The TMP121 and TMP123 are specified for a supply voltage range of 2.7V to 5.5V, and also feature a hardware shutdown to provide additional power savings.

The TMP121 and TMP123 require no external components for operation, though a 0.1µF supply bypass capacitor is recommended. Figure 1 shows typical connections for the TMP121 and TMP123.

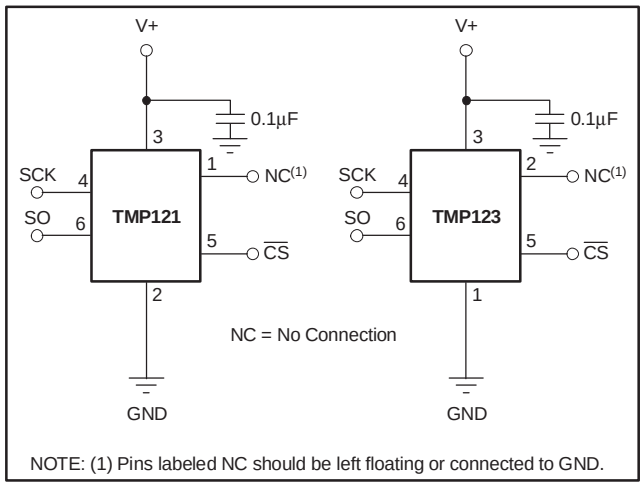



**Figure 1. Typical Connections of the TMP121 and TMP123**

The sensing device of both the TMP121 and TMP123 is the chip itself; the die flag of the lead frame is thermally connected to pin 2 of the TMP121, and of the TMP123. Thermal paths run through the package leads as well as the plastic package, and the lower thermal resistance of metal causes the leads to provide the primary thermal path. The GND pin (pin 2) of the TMP121 and the NC pin (pin 2) of the TMP123 are thermally connected to the metal lead frame, and are the best choice for thermal input.

To maintain accuracy in applications requiring air or surface temperature measurement, care should be taken to isolate the package and leads from ambient air temperature.

## TEMPERATURE REGISTER

The Temperature Register of the TMP121 and TMP123 is a 16-bit, signed read-only register that stores the output of the most recent conversion. Up to 16 bits can be read to obtain data and are described in Table 1. The first 13 bits are used to indicate temperature with bits D2 = 0, and D1, D0 in a high impedance state. Data format for temperature is summarized in Table 2. Following power-up or reset, the Temperature Register will read 0°C until the first conversion is complete.

| D15 | D14 | D13 | D12 | D11 | D10 | D9 | D8 |
|---|---|---|---|---|---|---|---|
| T12 | T11 | T10 | T9 | T8 | T7 | T6 | T5 |

| D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 |
|---|---|---|---|---|---|---|---|
| T4 | T3 | T2 | T1 | T0 | 0 | Z | Z |

**Table 1. Temperature Register**

| TEMPERATURE (°C) | DIGITAL OUTPUT(1) (BINARY) | HEX |
|---|---|---|
| 150 | 0100 1011 0000 0000 | 4B00 |
| 125 | 0011 1110 1000 0000 | 3E80 |
| 25 | 0000 1100 1000 0000 | 0C80 |
| 0.0625 | 0000 0000 0000 1000 | 0008 |
| 0 | 0000 0000 0000 0000 | 0000 |
| −0.0625 | 1111 1111 1111 1000 | FFF8 |
| −25 | 1111 0011 1000 0000 | F380 |
| −55 | 1110 0100 1000 0000 | E480 |

(1) The last two bits are high impedance and are shown as 00 in the table.

**Table 2. Temperature Data Format**

## COMMUNICATING WITH THE TMP121

The TMP121 and TMP123 continuously convert temperatures to digital data while $\overline{CS}$ is high. $\overline{CS}$ must be high for a minimum of one conversion time (320ms max) to update the temperature data. Reading temperature data from the TMP121 and TMP123 is initiated by pulling $\overline{CS}$ low, which will cause any conversion in progress to terminate, and place the device into analog shutdown. Quiescent current is reduced to 1µA during analog shutdown. Once $\overline{CS}$ is pulled low, temperature data from the last completed conversion prior to dropping $\overline{CS}$ is latched into the shift register and clocked out at SO on the falling SCK edge. The 16-bit data word is clocked out sign bit first, followed by the MSB. Any portion of the 16-bit word can be read before raising $\overline{CS}$. The TMP121 and TMP123 typically require 0.25s to complete a conversion and consume 50µA of current during this period. If $\overline{CS}$ is held high for longer than one conversion time period the TMP121 and TMP123 will go into idle mode for 0.25s, requiring only 20µA of current. A new conversion begins every 0.5s. Figure 2 describes the conversion timing for the TMP121 and TMP123.

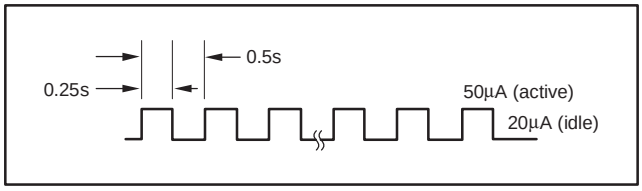



**Figure 2. Conversion Time and Period**

The serial data of the TMP121 and TMP123 consists of 12-bit plus sign temperature data followed by a confirmation bit and two high impedance bits. Data is transmitted in Binary Two's Complement format. Figure 3 describes the output data of the TMP121 and TMP123.

## Timing Diagrams

The TMP121 and TMP123 are SPI-compatible. Figure 4 and Figure 5 describe the various timing requirements, with parameters defined in Table 3.

| PARAMETER | | MIN | MAX | UNITS |
|---|---|---|---|---|
| SCK Period | $t_1$ | 100 | | ns |
| SCK Falling Edge to Output Data Delay | $t_2$ | | 30 | ns |
| $\overline{CS}$ to Rising Edge SCK Set-Up Time | $t_3$ | 40 | | ns |
| $\overline{CS}$ to Output Data Delay | $t_4$ | | 30 | ns |
| $\overline{CS}$ Rising Edge to Output High Impedance | $t_5$ | | 30 | ns |

**Table 3. Timing Description**

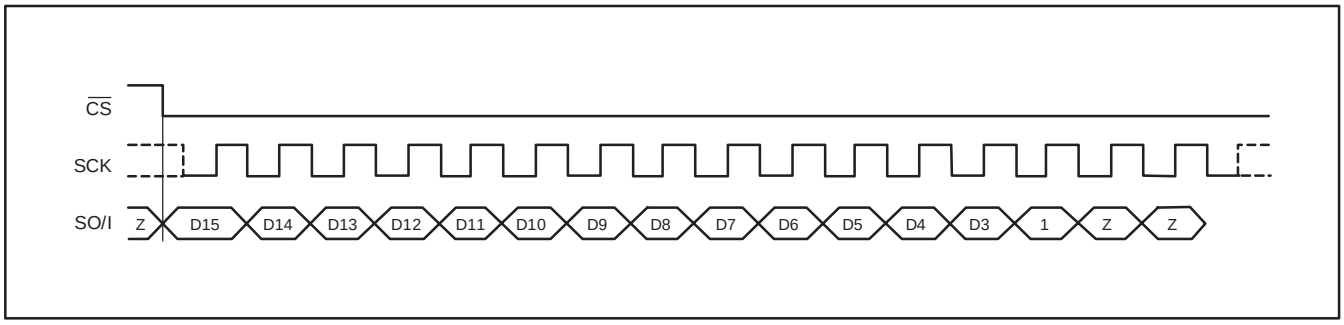



**Figure 3. Data READ**

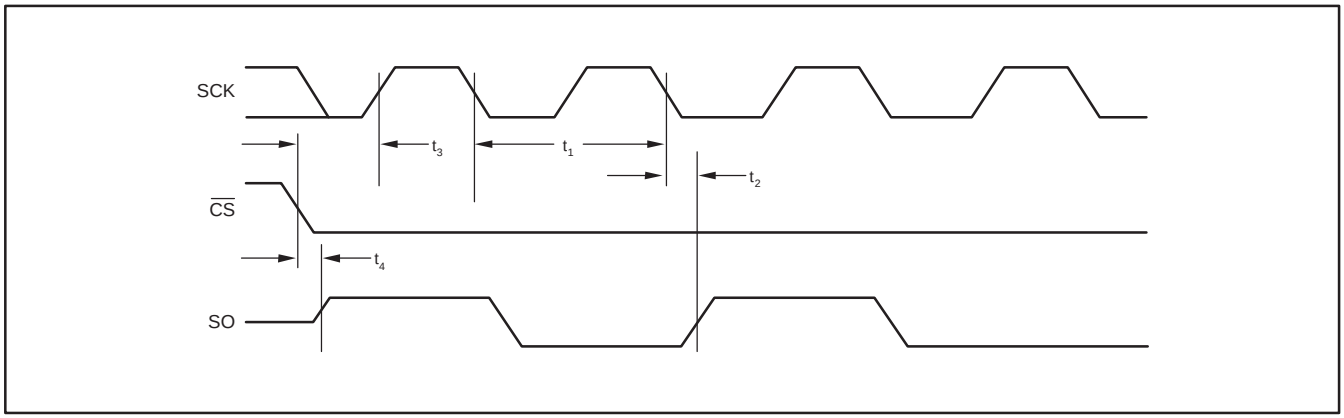



**Figure 4. Output Data Timing Diagram**

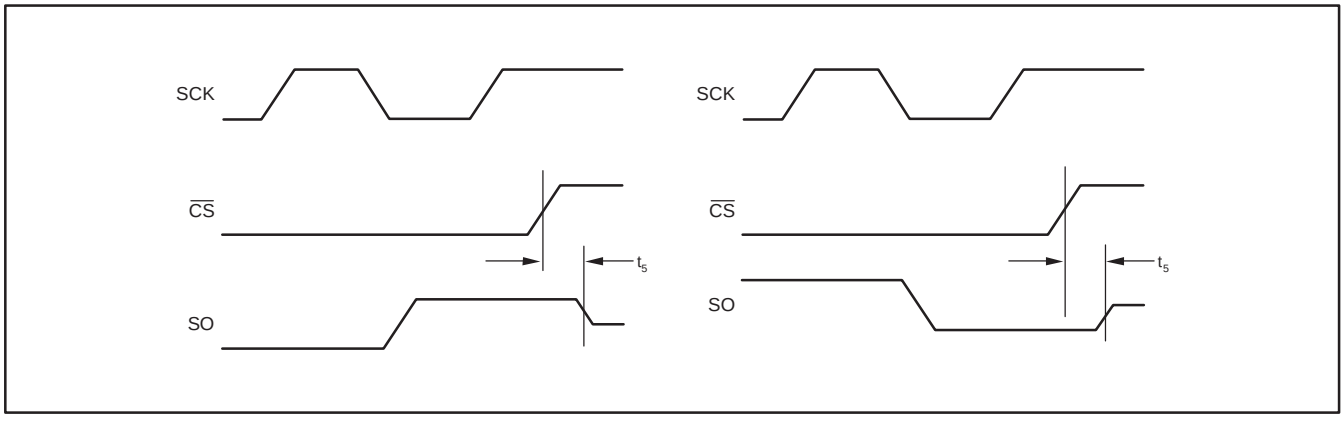



**Figure 5. High Impedance Output Timing Diagram**

## PACKAGING INFORMATION

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead/Ball Finish | MSL Peak Temp (3) |
|---|---|---|---|---|---|---|---|---|
| TMP121AIDBVR | ACTIVE | SOT-23 | DBV | 6 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR |
| TMP121AIDBVRG4 | ACTIVE | SOT-23 | DBV | 6 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR |
| TMP121AIDBVT | ACTIVE | SOT-23 | DBV | 6 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR |
| TMP121AIDBVTG4 | ACTIVE | SOT-23 | DBV | 6 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR |
| TMP123AIDBVR | ACTIVE | SOT-23 | DBV | 6 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR |
| TMP123AIDBVRG4 | ACTIVE | SOT-23 | DBV | 6 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR |
| TMP123AIDBVT | ACTIVE | SOT-23 | DBV | 6 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR |
| TMP123AIDBVTG4 | ACTIVE | SOT-23 | DBV | 6 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR |

(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) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
**TBD:** The Pb-Free/Green conversion plan has not been defined.
**Pb-Free (RoHS):** TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
**Pb-Free (RoHS Exempt):** This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
**Green (RoHS & no Sb/Br):** TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

(3) MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.



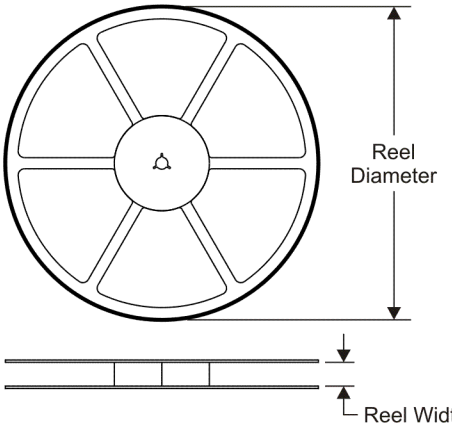
**OTHER QUALIFIED VERSIONS OF TMP121 :**
- Enhanced Product: TMP121-EP

NOTE: Qualified Version Definitions:

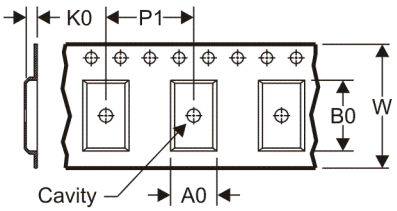
- Enhanced Product - Supports Defense, Aerospace and Medical Applications

## TAPE AND REEL INFORMATION

**REEL DIMENSIONS**

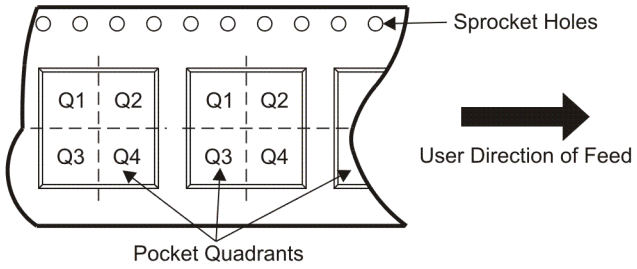



**TAPE DIMENSIONS**




| | |
|---|---|
| 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 |

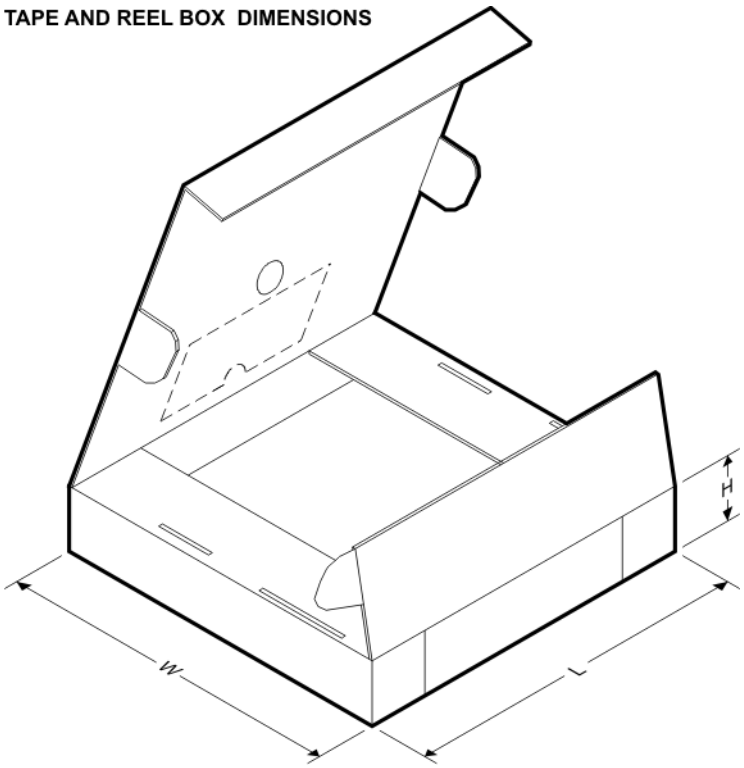
**QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE**




*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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TMP121AIDBVR | SOT-23 | DBV | 6 | 3000 | 180.0 | 8.4 | 3.2 | 3.1 | 1.39 | 4.0 | 8.0 | Q3 |
| TMP121AIDBVT | SOT-23 | DBV | 6 | 250 | 180.0 | 8.4 | 3.2 | 3.1 | 1.39 | 4.0 | 8.0 | Q3 |
| TMP123AIDBVR | SOT-23 | DBV | 6 | 3000 | 180.0 | 8.4 | 3.2 | 3.1 | 1.39 | 4.0 | 8.0 | Q3 |
| TMP123AIDBVT | SOT-23 | DBV | 6 | 250 | 180.0 | 8.4 | 3.2 | 3.1 | 1.39 | 4.0 | 8.0 | Q3 |

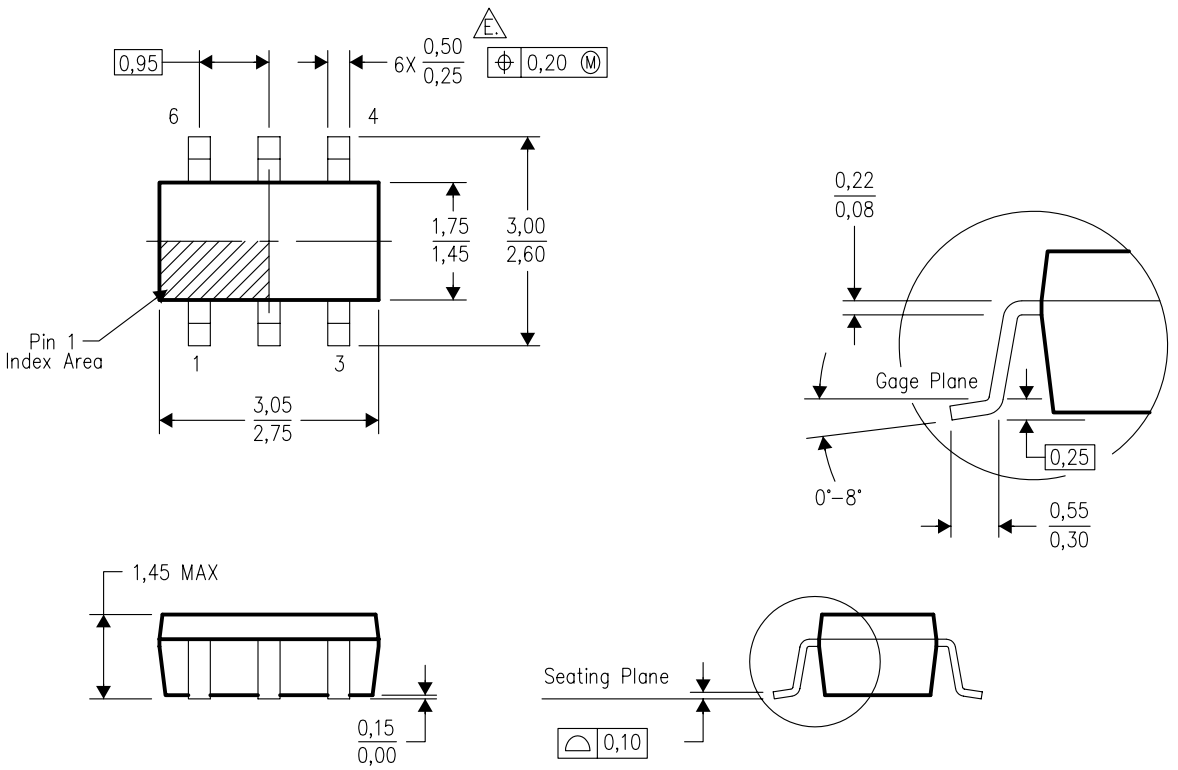
**TAPE AND REEL BOX DIMENSIONS**




*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|---|---|---|---|---|---|---|---|
| TMP121AIDBVR | SOT-23 | DBV | 6 | 3000 | 190.5 | 212.7 | 31.8 |
| TMP121AIDBVT | SOT-23 | DBV | 6 | 250 | 190.5 | 212.7 | 31.8 |
| TMP123AIDBVR | SOT-23 | DBV | 6 | 3000 | 190.5 | 212.7 | 31.8 |
| TMP123AIDBVT | SOT-23 | DBV | 6 | 250 | 190.5 | 212.7 | 31.8 |

## DBV (R–PDSO–G6) PLASTIC SMALL–OUTLINE PACKAGE




4073253–5/K 03/2006

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. Leads 1,2,3 may be wider than leads 4,5,6 for package orientation.
E. Falls within JEDEC MO–178 Variation AB, except minimum lead width.

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| TMP121AIDBVRG4 | ACTIVE | SOT-23 | DBV | 6 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR |
| TMP121AIDBVT | ACTIVE | SOT-23 | DBV | 6 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR |
| TMP121AIDBVTG4 | ACTIVE | SOT-23 | DBV | 6 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR |
| TMP123AIDBVR | ACTIVE | SOT-23 | DBV | 6 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR |
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| TMP123AIDBVTG4 | ACTIVE | SOT-23 | DBV | 6 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR |

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(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
**TBD:** The Pb-Free/Green conversion plan has not been defined.
**Pb-Free (RoHS):** TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
**Pb-Free (RoHS Exempt):** This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
**Green (RoHS & no Sb/Br):** TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

(3) MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.



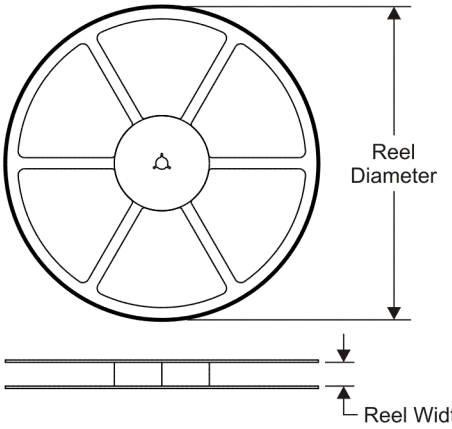
**OTHER QUALIFIED VERSIONS OF TMP121 :**
- Enhanced Product: TMP121-EP

NOTE: Qualified Version Definitions:

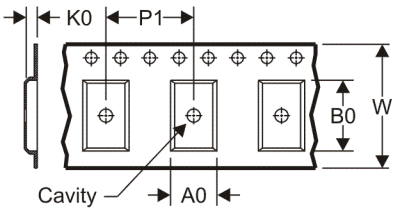
- Enhanced Product - Supports Defense, Aerospace and Medical Applications

## TAPE AND REEL INFORMATION

**REEL DIMENSIONS**

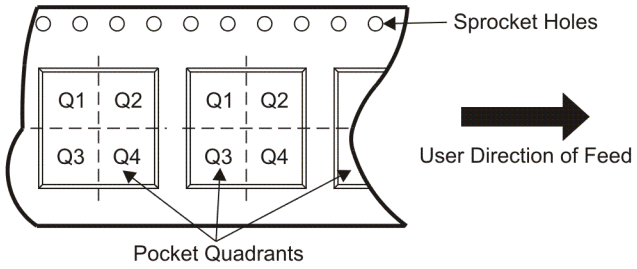



**TAPE DIMENSIONS**




| | |
|---|---|
| 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 |

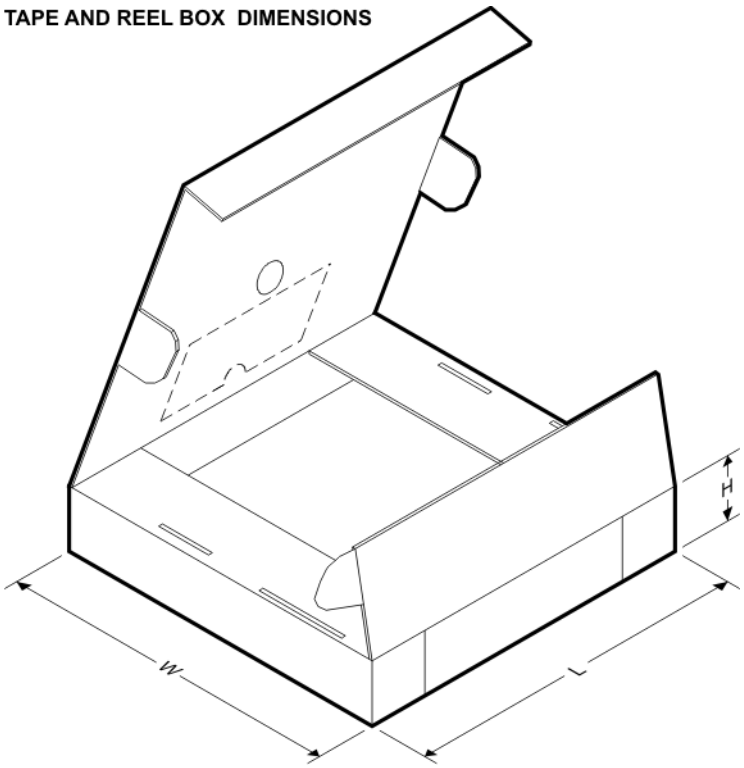
**QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE**




*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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TMP121AIDBVR | SOT-23 | DBV | 6 | 3000 | 178.0 | 9.0 | 3.23 | 3.17 | 1.37 | 4.0 | 8.0 | Q3 |
| TMP121AIDBVT | SOT-23 | DBV | 6 | 250 | 178.0 | 9.0 | 3.23 | 3.17 | 1.37 | 4.0 | 8.0 | Q3 |

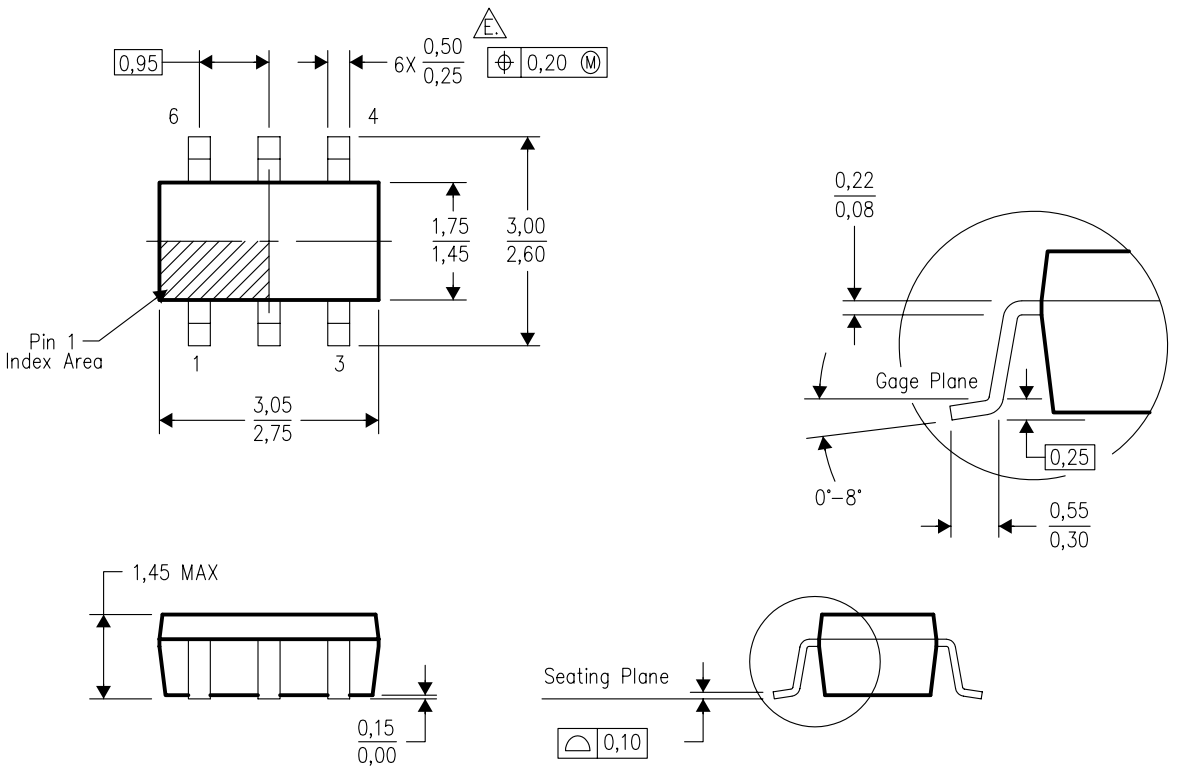
TAPE AND REEL BOX DIMENSIONS




*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|---|---|---|---|---|---|---|---|
| TMP121AIDBVR | SOT-23 | DBV | 6 | 3000 | 180.0 | 180.0 | 18.0 |
| TMP121AIDBVT | SOT-23 | DBV | 6 | 250 | 180.0 | 180.0 | 18.0 |

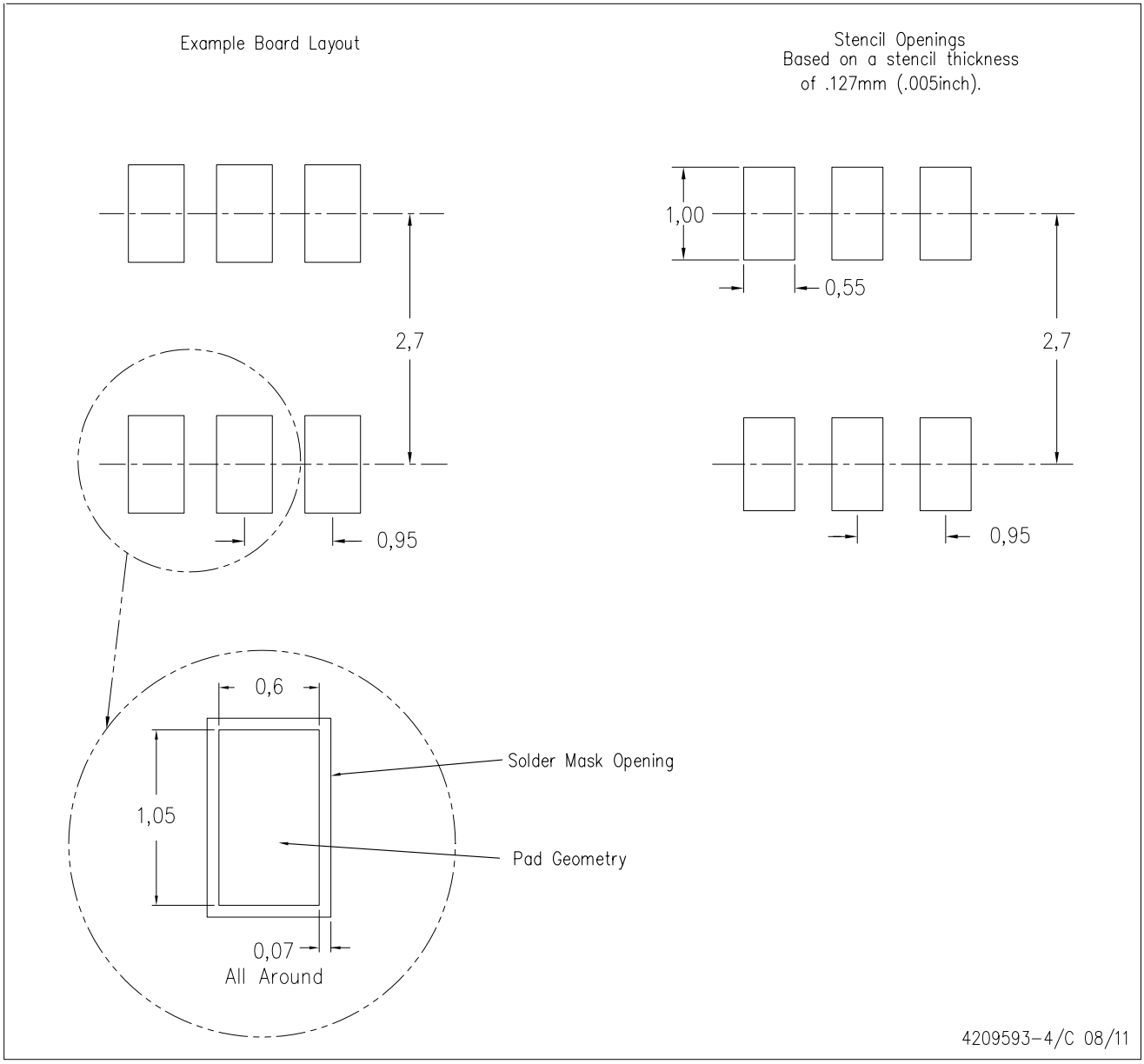
## DBV (R–PDSO–G6) PLASTIC SMALL–OUTLINE PACKAGE




4073253–5/K 03/2006

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. Leads 1,2,3 may be wider than leads 4,5,6 for package orientation.
E. Falls within JEDEC MO–178 Variation AB, except minimum lead width.

DBV (R–PDSO–G6) PLASTIC SMALL OUTLINE




NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Customers should place a note on the circuit board fabrication drawing not to alter the center solder mask defined pad.
D. Publication IPC–7351 is recommended for alternate designs.
E. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Example stencil design based on a 50% volumetric metal load solder paste. Refer to IPC–7525 for other stencil recommendations.

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