# LMT84/LMT84-Q1 1.5V, SC70/TO-92/TO-126, Analog Temperature Sensors with Class-AB Output

## 1 Features

- LMT84-Q1 is AEC-Q100 Grade 0 qualified and is Manufactured on an Automotive Grade Flow
- Low 1.5 V Operation
- Very Accurate: ±0.4°C typical
- Wide Temperature Range of -50°C to 150°C
- Low 5.4μA Quiescent Current
- Average Sensor Gain of -5.5 mV/°C
- Packages:
  - Small SC70 (SOT 5-lead) surface mount
  - Leaded TO-92
  - Leaded heatsink or chassis screw-mount TO-126
- Output is Short-Circuit Protected
- Push-Pull Output with ±50 μA Drive Capability
- Footprint Compatible with the Industry-Standard LM20/19 and LM35 Temperature Sensors
- Cost-effective Alternative to Thermistors

## 2 Applications

- Automotive
- Industrial
- White Goods - Appliances
- Battery Management
- Disk Drives
- Games
- Wireless Transceivers
- Cell Phones

## 3 Description

The LMT84/LMT84-Q1 are precision CMOS integrated-circuit temperature sensors with an analog output voltage that is linearly and inversely proportional to temperature. Its features make it suitable for many general temperature sensing applications. It can operate down to 1.5V supply with 5.4 µA power consumption making it ideal for battery powered devices. Multiple package options including through-hole TO-92 and TO-126 packages also allow the LMT84 to be mounted on-board, off-board, to a heat sink, or on multiple unique locations in the same application. A class-AB output structure gives the LMT84/LMT84-Q1 strong output source and sink current capability that can directly drive up to 1.1 nF capacitive loads. This means it is well suited to drive an analog-to-digital converter sample-and-hold input with its transient load requirements. It has accuracy specified in the operating range of −50°C to 150°C. The accuracy, 3-lead package options, and other features also make the LMT84/LMT84-Q1 an alternative to thermistors.

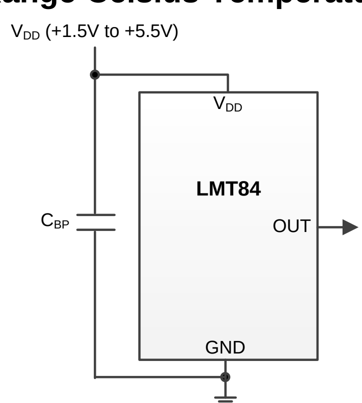
For devices with different average sensor gains and comparable accuracy the LMT85/LM85-Q1, LMT86/LMT86-Q1 and LMT87/LMT87-Q1 (For more details see Table 1 Comparable Alternative Devices.)

**Device Information(1)**

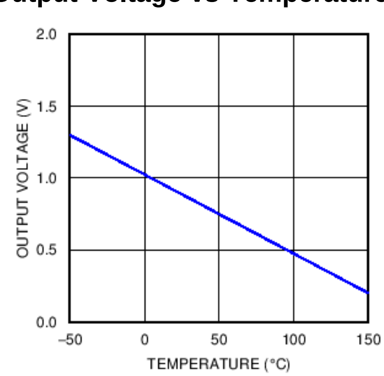
| PART NUMBER | PACKAGE | BODY SIZE (NOM) |
|---|---|---|
| LMT84 | SOT (5) | 2.00 mm x 1.25 mm |
| | TO-92 (3) | 4.3 mm x 3.5 mm |
| | TO-126 (3) | 8 mm x 11 mm |
| LMT84-Q1 | SOT (5) | 2.00 mm x 1.25 mm |

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

## 4 Full-Range Celsius Temperature Sensor (−50°C to 150°C)




**Output Voltage vs Temperature**



## Table of Contents



## 5 Revision History

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

| Changes from Revision A (June 2013) to Revision B | Page |
|---|---|
| • Changed data sheet flow and layout to conform with new TI standards. Added the following sections: Application and Implementation, Power Supply Recommendations, Layout, Device and Documentation Support, Mechanical, Packaging, and Orderable Information. | 1 |
| • Added TO-92 and TO-126 package information throughout document. | 1 |
| • Changed from 450°C/W to 275 °C/W. New specification is derived using TI ' s latest methodology. | 5 |
| • Deleted Note: The input current is leakage only and is highest at high temperature. It is typically only 0.001 µA. The 1 µA limit is solely based on a testing limitation and does not reflect the actual performance of the part. | 5 |

### Device Comparison Table(1)

| ORDER NUMBER | PACKAGE | PIN | BODY SIZE (NOM) | Mounting Type |
|---|---|---|---|---|
| LMT84DCK | SOT (AKA(2): SC70, DCK) | 5 | 2.00 mm x 1.25 mm | Surface Mount |
| LMT84LP | TO-92 (AKA(2): LP) | 3 | 4.3 mm x 3.5 mm | Through-hole |
| LMT84LPC | TO-126 (AKA(2): LPC) | 3 | 8 mm x 11 mm | Screw-mount, Through-hole |
| LMT84DCK-Q1 | SOT (AKA(2): SC70, DCK) | 5 | 2.00 mm x 1.25 mm | Surface Mount |

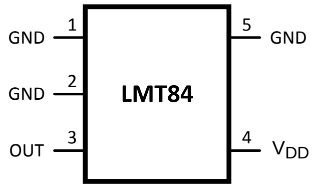
(1) For all available packages and complete order numbers, see the Package Option addendum at the end of the data sheet.
(2) AKA = Also Known As

### Table 1. Comparable Alternative Devices

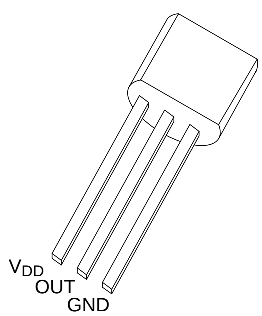
| DEVICE NAME | AVERAGE OUTPUT SENSOR GAIN | POWER SUPPLY RANGE |
|---|---|---|
| LMT84/LMT84-Q1 | –5.5 mV/°C | 1.5V to 5.5V |
| LMT85/LMT85-Q1 | –8.2 mV/°C | 1.8V to 5.5V |
| LMT86/LMT86-Q1 | –10.9 mV/°C | 2.2V to 5.5V |
| LMT87/LMT87-Q1 | –13.6 mV/°C | 2.7V to 5.5V |

## 6 Pin Configuration and Functions

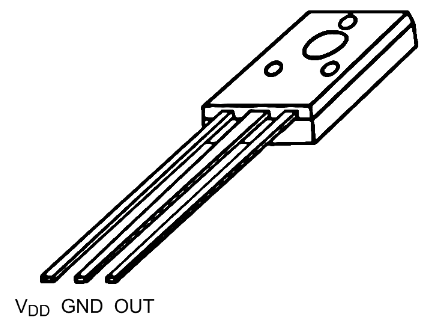
**5-Pin SOT (SC70)**
**DCK Package**
**(Top View)**



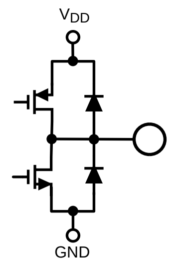

**3-Pin TO92**
**LP Package**




**3-Pin TO126**
**LPC Package**



**Pin Functions**

| PIN | | | | DESCRIPTION | | |
|---|---|---|---|---|---|---|
| LABEL | DCK NUMBER | LP NUMBER | LPC NUMBER | TYPE | EQUIVALENT CIRCUIT | FUNCTION |
| GND | 5 | | | Ground | | Power Supply Ground |
| GND | 1 | | | Ground | | Power Supply Ground |
| OUT | 3 | See Pin Diagram | See Pin Diagram | Analog Output |  | Outputs a voltage which is inversely proportional to temperature |
| $V_{DD}$ | 4 | | | Power | | Positive Supply Voltage |
| GND | 2 | | | Ground | | Power Supply Ground, (direct connection to the back side of the die) |

# 7 Specifications

## 7.1 Absolute Maximum Ratings(1)(2)

| | MIN | MAX | UNIT |
|---|---|---|---|
| Supply Voltage | −0.3 | 6 | V |
| Voltage at Output Pin | −0.3 | ($V_{DD}$ + 0.5) | V |
| Output Current | -7 | 7 | mA |
| Input Current at any pin(3) | -5 | 5 | mA |
| Maximum Junction Temperature ($T_{JMAX}$) | | 150 | °C |

(1) Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not specified specific performance limits. For specifications and test conditions, see the *Electrical Characteristics*. The specifications apply only for the test conditions listed. Some performance characteristics may degrade when the device is not operated under the listed test conditions.
(2) *Soldering process must comply with Reflow Temperature Profile specifications. Refer to* www.ti.com/packaging.
(3) When the input voltage ($V_I$) at any pin exceeds power supplies ($V_I$ < GND or $V_I$ > V), the current at that pin should be limited to 5 mA.

## 7.2 Handling Ratings

| | | | MIN | MAX | UNIT |
|---|---|---|---|---|---|
| $T_{stg}$ | Storage temperature range | | −65 | 150 | °C |
| $V_{(ESD)}$ | Electrostatic discharge | Human Body Model (HBM), per ANSI/ESDA/JEDEC JS-001, all pins(1) Applies for TO-92 package LMT84LP | -2.5 | 2.5 | kV |
| | | Human Body Model (HBM), per JESD22-A114, all pins(2) Applies for SC70 package LMT84DCK and LMT84DCK-Q1. | -2.5 | 2.5 | |
| | | Charged Device Model (CDM), per JEDEC specification JESD22-C101, all pins(3) Applies for all parts | -1 | 1 | |
| | | Machine Model ESD stress voltage, per JEDEC specification JESD22-A115 (2) Applies for SC70 package LMT84DCK and LMT84DCK-Q1. | -250 | 250 | V |

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
(2) The machine model is 200 pF capacitor discharged directly into each pin.
(3) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

## 7.3 Recommended Operating Conditions

| | MIN MAX | UNIT |
|---|---|---|
| Specified Temperature Range: | $T_{MIN} \le T_A \le T_{MAX}$ | °C |
| | $-50 \le T_A \le 150$ | °C |

## Recommended Operating Conditions (continued)

| | MIN | MAX | UNIT |
|---|---|---|---|
| Supply Voltage Range ($V_{DD}$) | 1.5 | 5.5 | V |

## 7.4 Thermal Information(1)

| THERMAL METRIC(2) | | LMT84/ LMT84-Q1 | LMT84 | LMT84 | UNIT |
|---|---|---|---|---|---|
| | | DCK | LP | LPC | |
| | | 5 PINS | 3 PINS | 3 PINS | |
| $R_{\theta JA}$ | Junction-to-ambient thermal resistance (3)(4) | 275 | 167 | TBD | °C/W |
| $R_{\theta JC(top)}$ | Junction-to-case (top) thermal resistance | 84 | 90 | TBD | |
| $R_{\theta JB}$ | Junction-to-board thermal resistance | 56 | 146 | TBD | |
| $\psi_{JT}$ | Junction-to-top characterization parameter | 1.2 | 35 | TBD | |
| $\psi_{JB}$ | Junction-to-board characterization parameter | 55 | 146 | TBD | |

(1) For information on self-heating and thermal response time see section Mounting and Thermal Conductivity.
(2) For more information about traditional and new thermal metrics, see the *IC Package Thermal Metrics* application report, SPRA953.
(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.

## 7.5 Accuracy Characteristics

These limits do not include DC load regulation. These stated accuracy limits are with reference to the values in Table 2.

| PARAMETER | TEST CONDITIONS | MIN(1) | TYP(2) | MAX(1) | UNIT |
|---|---|---|---|---|---|
| Temperature Accuracy (3) | 70°C to 150°C; $V_{DD}$ = 1.5 V to 5.5 V | -2.7 | ±0.6 | 2.7 | °C |
| | 0°C to 70°C; $V_{DD}$ = 1.5 V to 5.5 V | -2.7 | ±0.9 | 2.7 | °C |
| | –50°C to 0°C; $V_{DD}$ = 1.6 V to 5.5 V | -2.7 | ±0.9 | 2.7 | °C |
| | –50°C to 150°C; $V_{DD}$ = 2.3 V to 5.5 V | | ±0.4 | | °C |

(1) Limits are specified to TI's AOQL (Average Outgoing Quality Level).
(2) Typicals are at $T_J = T_A$ = 25°C and represent most likely parametric norm.
(3) Accuracy is defined as the error between the measured and reference output voltages, tabulated in the Transfer Table at the specified conditions of supply gain setting, 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.

## 7.6 Electrical Characteristics

Unless otherwise noted, these specifications apply for $V_{DD}$ = +1.5V to +5.5V. MIN and MAX limits apply for $T_A = T_J = T_{MIN}$ to $T_{MAX}$ ; typical values apply for $T_A = T_J$ = 25°C.

| PARAMETER | | TEST CONDITIONS | MIN(1) | TYP(2) | MAX (1) | UNITS |
|---|---|---|---|---|---|---|
| | Sensor Gain | | | –5.5 | | mV/°C |
| | Load Regulation (3) | Source ≤ 50 µA, ($V_{DD}$ - $V_{OUT}$) ≥ 200 mV | -1 | –0.22 | | mV |
| | | Sink ≤ 50 µA, $V_{OUT}$ ≥ 200 mV | | 0.26 | 1 | mV |
| | Line Regulation (4) | | | 200 | | µV/V |
| $I_S$ | Supply Current | $T_A$ = 30°C to 150°C, ($V_{DD}$ - $V_{OUT}$) ≥ 100 mV | | 5.4 | 8.1 | µA |
| | | $T_A$ = -50°C to 150°C, ($V_{DD}$ - $V_{OUT}$) ≥ 100 mV | | 5.4 | 9 | µA |
| $C_L$ | Output Load Capacitance | | | 1100 | | pF |
| | Power-on Time (5) | $C_L$= 0 pF to 1100 pF | | 0.7 | 1.9 | ms |
| | Output drive | | | ±50 | | µA |

(1) Limits are specific to TI's AOQL (Average Outgoing Quality Level).
(2) Typicals are at $T_J = T_A$ = 25°C and represent most likely parametric norm.
(3) Source currents are flowing out of the LMT84/LMT84-Q1. Sink currents are flowing into the LMT84/LMT84-Q1.
(4) Line regulation (DC) is calculated by subtracting the output voltage at the highest supply voltage from the output voltage at the lowest supply voltage. The typical DC line regulation specification does not include the output voltage shift discussed in Output Voltage Shift.
(5) Specified by design and characterization.

## 7.7 Typical Characteristics

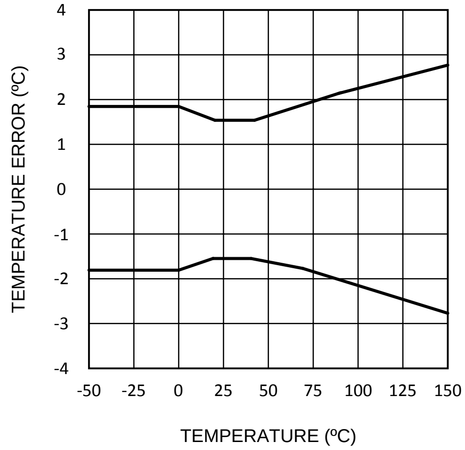



**Figure 1. Temperature Error vs Temperature**

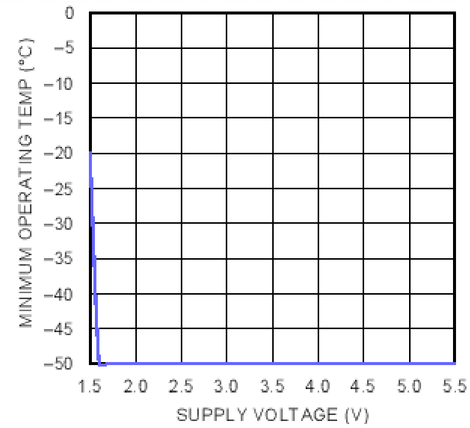



**Figure 2. Minimum Operating Temperature vs Supply Voltage**

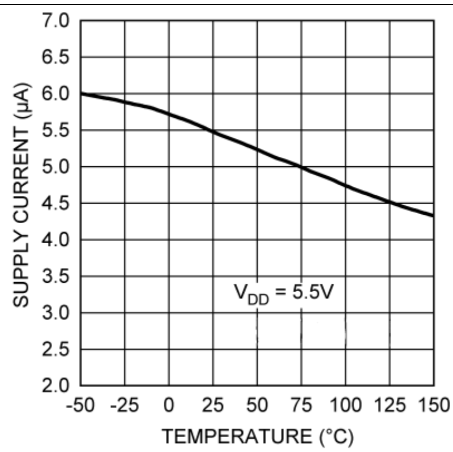



**Figure 3. Supply Current vs Temperature**

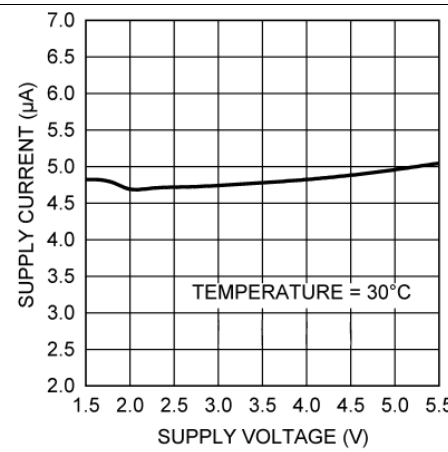



**Figure 4. Supply Current vs Supply Voltage**

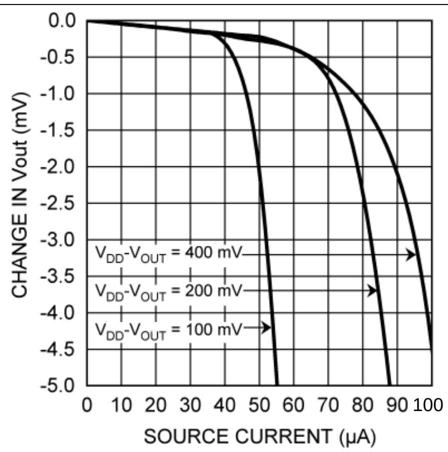



**Figure 5. Load Regulation, Sourcing Current**

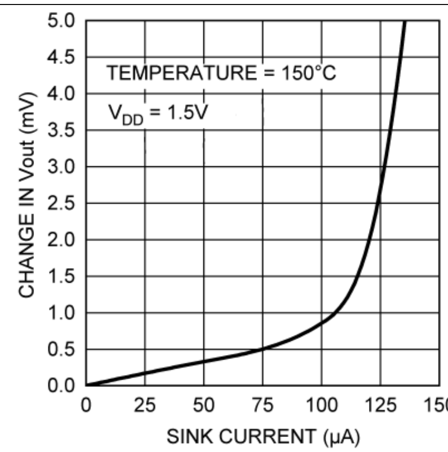



**Figure 6. Load Regulation, Sinking Current**

## Typical Characteristics (continued)

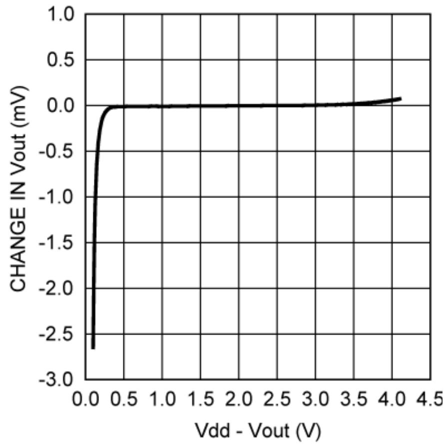



**Figure 7. Change in Vout vs Overhead Voltage**

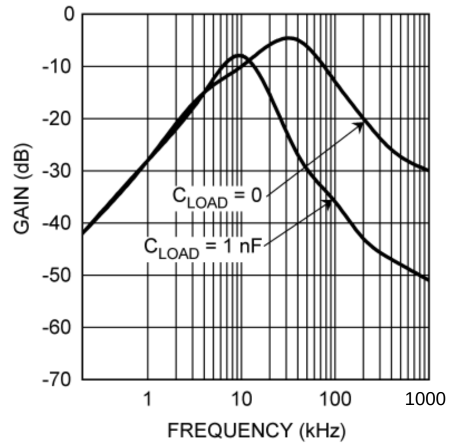



**Figure 8. Supply-Noise Gain vs Frequency**

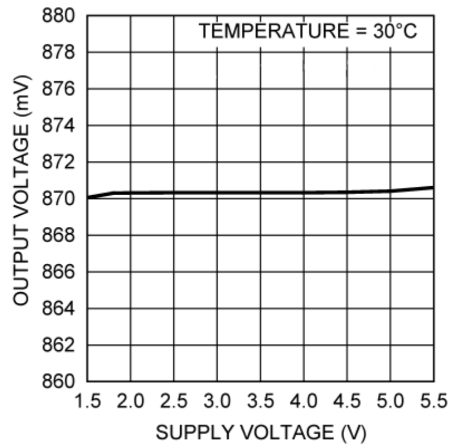



**Figure 9. Output Voltage vs Supply Voltage**

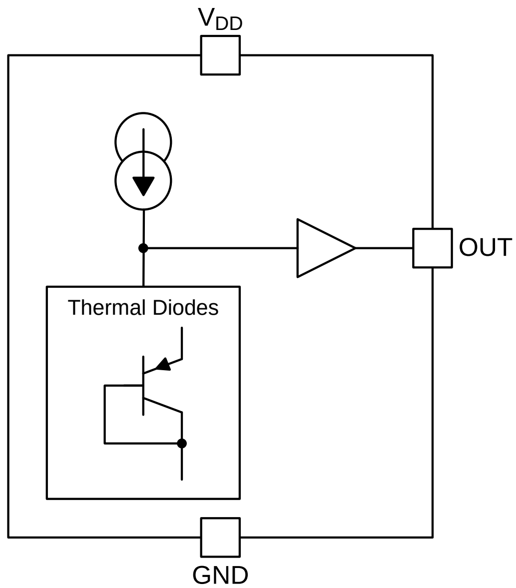
# 8 Detailed Description

## 8.1 Overview

The LMT84/LMT84-Q1 is an analog output temperature sensor. The temperature sensing element is comprised of a simple base emitter junction that is forward biased by a current source. The temperature sensing element is then buffered by an amplifier and provided to the OUT pin. The amplifier has a simple push-pull output stage thus providing a low impedance output source.

## 8.2 Functional Block Diagram

Full-Range Celsius Temperature Sensor (−50°C to 150°C)




## 8.3 Feature Description

### 8.3.1 LMT84/LMT84-Q1 Transfer Function

The output voltage of the LMT84/LMT84-Q1, across the complete operating temperature range, is shown in Table 2. This table is the reference from which the LMT84/LMT84-Q1 accuracy specifications (listed in the Accuracy Characteristics section) are determined. This table can be used, for example, in a host processor look-up table. A file containing this data is available for download at the LMT84 product folder under Tools and Software Models.

**Table 2. LMT84/LMT84-Q1 Transfer Table**

| TEMP (°C) | $V_{OUT}$ (mV) | TEMP (°C) | $V_{OUT}$ (mV) | TEMP (°C) | $V_{OUT}$ (mV) | TEMP (°C) | $V_{OUT}$ (mV) | TEMP (°C) | $V_{OUT}$ (mV) |
|---|---|---|---|---|---|---|---|---|---|
| -50 | 1299 | -10 | 1088 | 30 | 871 | 70 | 647 | 110 | 419 |
| -49 | 1294 | -9 | 1082 | 31 | 865 | 71 | 642 | 111 | 413 |
| -48 | 1289 | -8 | 1077 | 32 | 860 | 72 | 636 | 112 | 407 |
| -47 | 1284 | -7 | 1072 | 33 | 854 | 73 | 630 | 113 | 401 |
| -46 | 1278 | -6 | 1066 | 34 | 849 | 74 | 625 | 114 | 396 |
| -45 | 1273 | -5 | 1061 | 35 | 843 | 75 | 619 | 115 | 390 |
| -44 | 1268 | -4 | 1055 | 36 | 838 | 76 | 613 | 116 | 384 |
| -43 | 1263 | -3 | 1050 | 37 | 832 | 77 | 608 | 117 | 378 |
| -42 | 1257 | -2 | 1044 | 38 | 827 | 78 | 602 | 118 | 372 |
| -41 | 1252 | -1 | 1039 | 39 | 821 | 79 | 596 | 119 | 367 |
| -40 | 1247 | 0 | 1034 | 40 | 816 | 80 | 591 | 120 | 361 |

## Feature Description (continued)

**Table 2. LMT84/LMT84-Q1 Transfer Table (continued)**

| TEMP (°C) | $V_{OUT}$ (mV) | TEMP (°C) | $V_{OUT}$ (mV) | TEMP (°C) | $V_{OUT}$ (mV) | TEMP (°C) | $V_{OUT}$ (mV) | TEMP (°C) | $V_{OUT}$ (mV) |
|---|---|---|---|---|---|---|---|---|---|
| -39 | 1242 | 1 | 1028 | 41 | 810 | 81 | 585 | 121 | 355 |
| -38 | 1236 | 2 | 1023 | 42 | 804 | 82 | 579 | 122 | 349 |
| -37 | 1231 | 3 | 1017 | 43 | 799 | 83 | 574 | 123 | 343 |
| -36 | 1226 | 4 | 1012 | 44 | 793 | 84 | 568 | 124 | 337 |
| -35 | 1221 | 5 | 1007 | 45 | 788 | 85 | 562 | 125 | 332 |
| -34 | 1215 | 6 | 1001 | 46 | 782 | 86 | 557 | 126 | 326 |
| -33 | 1210 | 7 | 996 | 47 | 777 | 87 | 551 | 127 | 320 |
| -32 | 1205 | 8 | 990 | 48 | 771 | 88 | 545 | 128 | 314 |
| -31 | 1200 | 9 | 985 | 49 | 766 | 89 | 539 | 129 | 308 |
| -30 | 1194 | 10 | 980 | 50 | 760 | 90 | 534 | 130 | 302 |
| -29 | 1189 | 11 | 974 | 51 | 754 | 91 | 528 | 131 | 296 |
| -28 | 1184 | 12 | 969 | 52 | 749 | 92 | 522 | 132 | 291 |
| -27 | 1178 | 13 | 963 | 53 | 743 | 93 | 517 | 133 | 285 |
| -26 | 1173 | 14 | 958 | 54 | 738 | 94 | 511 | 134 | 279 |
| -25 | 1168 | 15 | 952 | 55 | 732 | 95 | 505 | 135 | 273 |
| -24 | 1162 | 16 | 947 | 56 | 726 | 96 | 499 | 136 | 267 |
| -23 | 1157 | 17 | 941 | 57 | 721 | 97 | 494 | 137 | 261 |
| -22 | 1152 | 18 | 936 | 58 | 715 | 98 | 488 | 138 | 255 |
| -21 | 1146 | 19 | 931 | 59 | 710 | 99 | 482 | 139 | 249 |
| -20 | 1141 | 20 | 925 | 60 | 704 | 100 | 476 | 140 | 243 |
| -19 | 1136 | 21 | 920 | 61 | 698 | 101 | 471 | 141 | 237 |
| -18 | 1130 | 22 | 914 | 62 | 693 | 102 | 465 | 142 | 231 |
| -17 | 1125 | 23 | 909 | 63 | 687 | 103 | 459 | 143 | 225 |
| -16 | 1120 | 24 | 903 | 64 | 681 | 104 | 453 | 144 | 219 |
| -15 | 1114 | 25 | 898 | 65 | 676 | 105 | 448 | 145 | 213 |
| -14 | 1109 | 26 | 892 | 66 | 670 | 106 | 442 | 146 | 207 |
| -13 | 1104 | 27 | 887 | 67 | 664 | 107 | 436 | 147 | 201 |
| -12 | 1098 | 28 | 882 | 68 | 659 | 108 | 430 | 148 | 195 |
| -11 | 1093 | 29 | 876 | 69 | 653 | 109 | 425 | 149 | 189 |
| | | | | | | | | 150 | 183 |

Although the LMT84/LMT84-Q1 is very linear, its response does have a slight umbrella parabolic shape. This shape is very accurately reflected in Table 2. The Transfer Table can be calculated by using the parabolic equation.

$$V_{TEMP}\left(mV\right) = 870.6mV - \left[5.506\frac{mV}{°C}\left(T - 30°C\right)\right] - \left[0.00176\frac{mV}{°C^2}\left(T - 30°C\right)^2\right] \tag{1}$$

The parabolic equation is an approximation of the transfer table and the accuracy of the equation degrades slightly at the temperature range extremes. Equation 1 can be solved for T resulting in:

$$T = \frac{5.506 - \sqrt{\left(-5.506\right)^2 + 4 \times 0.00176 \times \left(870.6 - V_{TEMP}\left(mV\right)\right)}}{2 \times \left(-0.00176\right)} + 30 \tag{2}$$

For an even less accurate linear approximation, a line can easily be calculated over the desired temperature range from the Table using the two-point equation:

$$V - V_1 = \left(\frac{V_2 - V_1}{T_2 - T_1}\right) \times \left(T - T_1\right) \tag{3}$$

Where V is in mV, T is in °C, $T_1$ and $V_1$ are the coordinates of the lowest temperature, $T_2$ and $V_2$ are the coordinates of the highest temperature.

For example, if we want to resolve this equation, over a temperature range of 20°C to 50°C, we would proceed as follows:

$$V - 925\text{ mV} = \left(\frac{760\text{ mV} - 925\text{ mV}}{50^{o}\text{C} - 20^{o}\text{C}}\right) \times (T - 20^{o}\text{C}) \quad (4)$$

$$V - 925\text{ mV} = (-5.50\text{ mV} / {}^{o}\text{C}) \times (T - 20^{o}\text{C}) \quad (5)$$

$$V = (-5.50\text{ mV} / {}^{o}\text{C}) \times T + 1035\text{ mV} \quad (6)$$

Using this method of linear approximation, the transfer function can be approximated for one or more temperature ranges of interest.

## 8.4 Device Functional Modes

### 8.4.1 Mounting and Thermal Conductivity

The LMT84/LMT84-Q1 can be applied easily in the same way as other integrated-circuit temperature sensors. It can be glued or cemented to a surface.

To ensure good thermal conductivity, the backside of the LMT84/LMT84-Q1 die is directly attached to the GND pin. The temperatures of the lands and traces to the other leads of the LMT84/LMT84-Q1 will also affect the temperature reading.

Alternatively, the LMT84/LMT84-Q1 can be mounted inside a sealed-end metal tube, and can then be dipped into a bath or screwed into a threaded hole in a tank. As with any IC, the LMT84/LMT84-Q1 and accompanying wiring and circuits must be kept insulated and dry, to avoid leakage and corrosion. This is especially true if the circuit may operate at cold temperatures where condensation can occur. If moisture creates a short circuit from the output to ground or $V_{DD}$, the output from the LMT84/LMT84-Q1 will not be correct. Printed-circuit coatings are often used to ensure that moisture cannot corrode the leads or circuit traces.

The thermal resistance junction to ambient ($R_{\theta JA}$ or $\theta_{JA}$) is the parameter used to calculate the rise of a device junction temperature due to its power dissipation. The equation used to calculate the rise in the LMT84/LMT84-Q1's die temperature is:

$$T_J = T_A + \theta_{JA}\left[(V_{DD}I_S) + (V_{DD} - V_O)\, I_L\right] \quad (7)$$

where $T_A$ is the ambient temperature, $I_S$ is the supply current, $I_L$is the load current on the output, and $V_O$ is the output voltage. For example, in an application where $T_A$ = 30°C, $V_{DD}$ = 5 V, $I_S$ = 5.4 µA, $V_{OUT}$ = 871 mV, and $I_L$ = 2 µA, the junction temperature would be 30.015°C, showing a self-heating error of only 0.015°C. Since the LMT84/LMT84-Q1's junction temperature is the actual temperature being measured, care should be taken to minimize the load current that the LMT84/LMT84-Q1 is required to drive. Thermal Information[(1)] shows the thermal resistance of the LMT84/LMT84-Q1.

### 8.4.2 Output Noise Considerations

A push-pull output gives the LMT84/LMT84-Q1 the ability to sink and source significant current. This is beneficial when, for example, driving dynamic loads like an input stage on an analog-to-digital converter (ADC). In these applications the source current is required to quickly charge the input capacitor of the ADC. See the ??? section for more discussion of this topic. The LMT84/LMT84-Q1 is ideal for this and other applications which require strong source or sink current.

The LMT84/LMT84-Q1 supply-noise gain (the ratio of the AC signal on $V_{OUT}$ to the AC signal on $V_{DD}$) was measured during bench tests. Its typical attenuation is shown in Figure 8 found in the Typical Characteristics section. A load capacitor on the output can help to filter noise.

For operation in very noisy environments, some bypass capacitance should be present on the supply within approximately 5 centimeters of the LMT84/LMT84-Q1.

### 8.4.3 Capacitive Loads

The LMT84/LMT84-Q1 handles capacitive loading well. In an extremely noisy environment, or when driving a switched sampling input on an ADC, it may be necessary to add some filtering to minimize noise coupling. Without any precautions, the LMT84/LMT84-Q1 can drive a capacitive load less than or equal to 1100 pF as shown in Figure 10. For capacitive loads greater than 1100 pF, a series resistor may be required on the output, as shown in Figure 11.

(1) For information on self-heating and thermal response time see section Mounting and Thermal Conductivity.

## Device Functional Modes (continued)

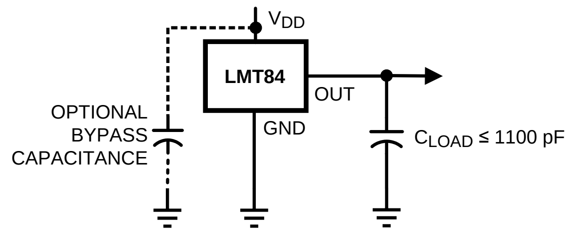



**Figure 10. LMT84 No Decoupling Required for Capacitive Loads Less than 1100 pF**

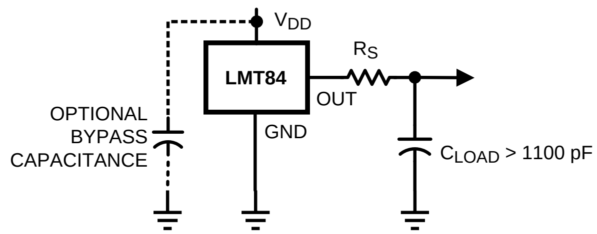



**Figure 11. LMT84 with Series Resistor for Capacitive Loading Greater than 1100 pF**

| $C_{LOAD}$ | Minimum $R_S$ |
|---|---|
| 1.1 nF to 99 nF | 3 kΩ |
| 100 nF to 999 nF | 1.5 kΩ |
| 1 µF | 800 Ω |

### 8.4.4 Output Voltage Shift

The LMT84/LMT84-Q1 is very linear over temperature and supply voltage range. Due to the intrinsic behavior of an NMOS/PMOS rail-to-rail buffer, a slight shift in the output can occur when the supply voltage is ramped over the operating range of the device. The location of the shift is determined by the relative levels of $V_{DD}$ and $V_{OUT}$. The shift typically occurs when $V_{DD}$- $V_{OUT}$ = 1.0V.

This slight shift (a few millivolts) takes place over a wide change (approximately 200 mV) in $V_{DD}$ or $V_{OUT}$. Since the shift takes place over a wide temperature change of 5°C to 20°C, $V_{OUT}$ is always monotonic. The accuracy specifications in the Accuracy Characteristics table already include this possible shift.

# 9 Application and Implementation

## 9.1 Applications Information

The LMT84/LMT84-Q1 features make it suitable for many general temperature sensing applications. It can operate down to 1.5V supply with 5.4 uA power consumption making it ideal for battery powered devices. Multiple package options including through-hole TO-92 and TO-126 packages also allow the LMT84 to be mounted on-board, off-board, to a heat sink, or on multiple unique locations in the same application.

## 9.2 Typical Applications

### 9.2.1 Connection to an ADC

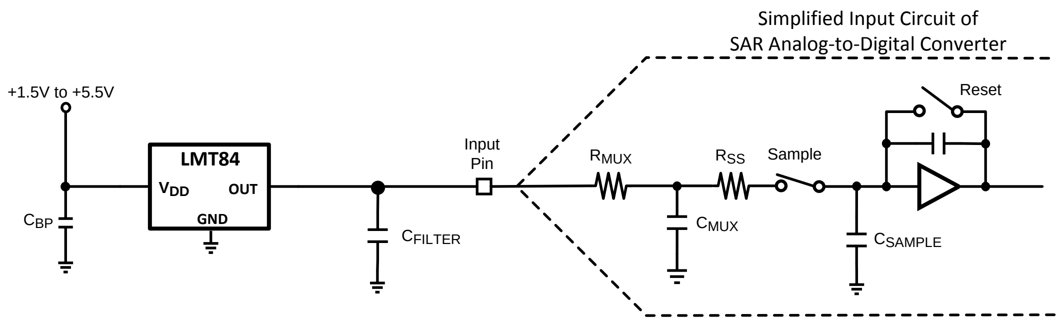



**Figure 12. Suggested Connection to a Sampling Analog-to-Digital Converter Input Stage**

#### *9.2.1.1 Design Requirements*

Most CMOS ADCs found in microcontrollers and ASICs have a sampled data comparator input structure. When the ADC charges the sampling cap, it requires instantaneous charge from the output of the analog source such as the LMT84/LMT84-Q1 temperature sensor and many op amps. This requirement is easily accommodated by the addition of a capacitor ($C_{FILTER}$).

#### *9.2.1.2 Detailed Design Procedure*

The size of $C_{FILTER}$ depends on the size of the sampling capacitor and the sampling frequency. Since not all ADCs have identical input stages, the charge requirements will vary. This general ADC application is shown as an example only.

#### *9.2.1.3 Application Curves*

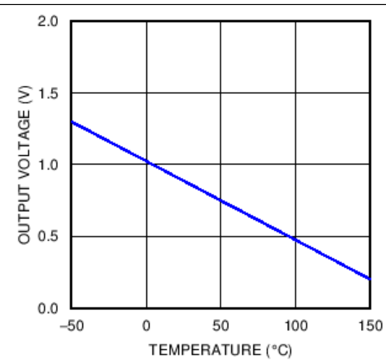



**Figure 13. Analog Output Transfer Function**

### 9.2.2 Conserving Power Dissipation with Shutdown

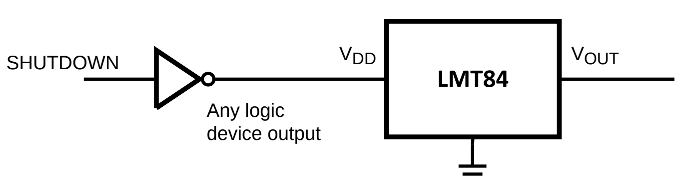



**Figure 14. Simple Shutdown Connection of the LMT84**

## Typical Applications (continued)

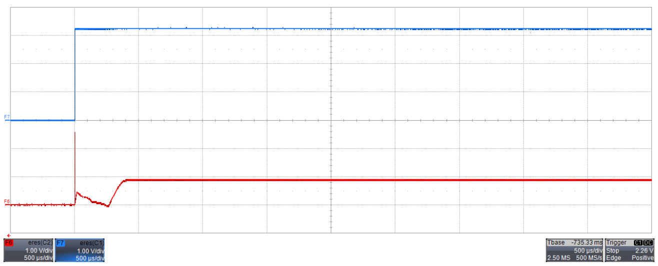
#### 9.2.2.1 Design Requirements

Since the power consumption of the LMT84 is less than 9 µA it can simply be powered directly from any logic gate output, thus not requiring a specific shutdown pin. The device can even be powered directly from a micro controller GPIO. In this way it can easily be turned off for cases such as battery powered systems where power savings is critical.

#### 9.2.2.2 Detailed Design Procedure

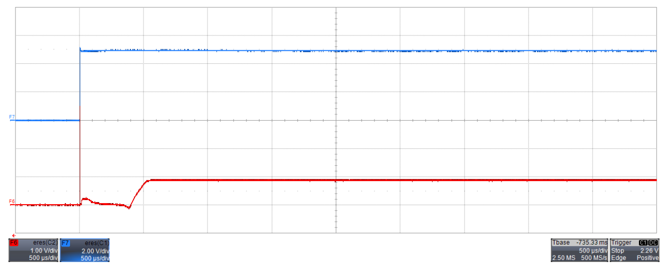
Simply connect the $V_{DD}$ pin of the LMT84 directly to the logic shutdown signal from a microcontroller.

#### 9.2.2.3 Application Curves



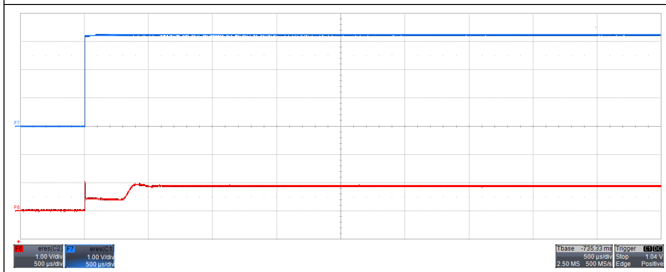
Time: 500 µsec/div; Top trace: $V_{DD}$ 1 V/div;
Bottom trace: OUT 1 V/div

**Figure 15. Output Turn-on Response Time Without a Capacitive Load and $V_{DD}$= 3.3V**



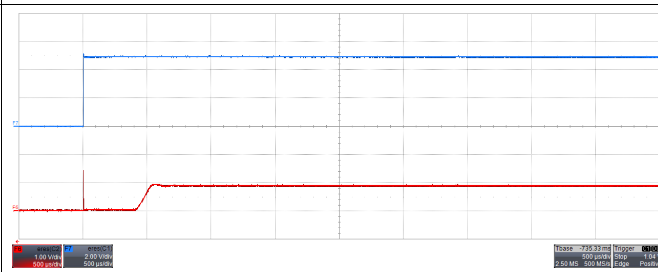
Time: 500 µsec/div; Top trace: $V_{DD}$ 2 V/div;
Bottom trace: OUT 1 V/div

**Figure 16. Output Turn-on Response Time Without a Capacitive Load and $V_{DD}$= 5V**



Time: 500 µsec/div; Top trace: $V_{DD}$ 1 V/div;
Bottom trace: OUT 1 V/div

**Figure 17. Output Turn-on Response Time With 1.1 Nf Capacitive Load and $V_{DD}$= 3.3V**



Time: 500 µsec/div; Top trace: $V_{DD}$ 2 V/div;
Bottom trace: OUT 1 V/div

**Figure 18. Output Turn-on Response Time With 1.1 Nf Capacitive Load and $V_{DD}$= 5V**

## 10 Power Supply Recommendations

The LMT84's low supply current and supply range of 1.5V to 5.5V allow the device to easily be powered from many sources.

Power supply bypassing is optional and is mainly dependent on the noise on the power supply used. In noisy systems it may be necessary to add bypass capacitors to lower the noise that is coupled to the LMT84's output.

## 11 Layout

### 11.1 Layout Guidelines

The LMT84 is extremely simple to layout. If a power supply bypass capacitor is used is should be connected as shown in the Layout Example.

## 11.2 Layout Example

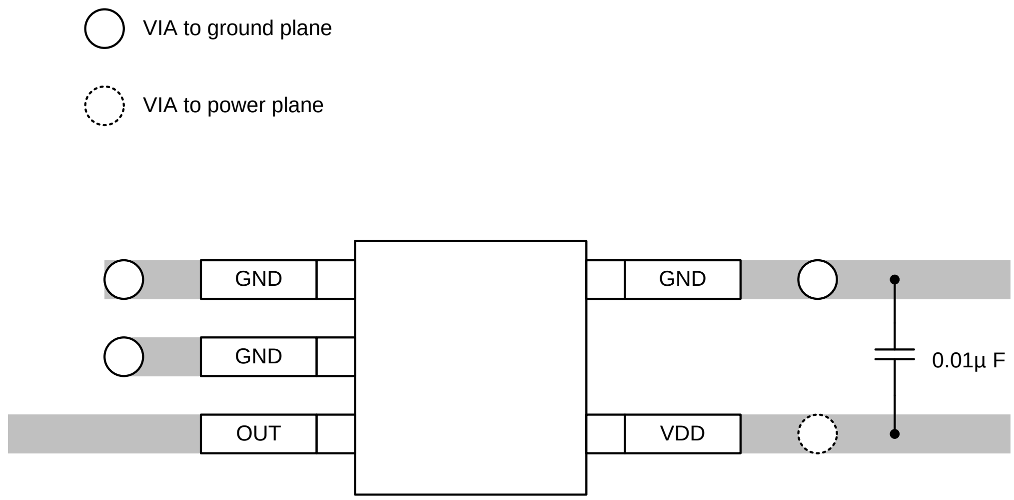



**Figure 19. SC70 Package Recommended Layout**

# 12 Device and Documentation Support

## 12.1 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 3. Related Links**

| PARTS | PRODUCT FOLDER | SAMPLE & BUY | TECHNICAL DOCUMENTS | TOOLS & SOFTWARE | SUPPORT & COMMUNITY |
|---|---|---|---|---|---|
| LMT84 | Click here | Click here | Click here | Click here | Click here |
| LMT84-Q1 | Click here | Click here | Click here | Click here | Click here |

## 12.2 Trademarks

All trademarks are the property of their respective owners.

## 12.3 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.

## 12.4 Glossary

SLYZ022 — *TI Glossary*.

This glossary lists and explains terms, acronyms and definitions.

## 13 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| LMT84DCKR | ACTIVE | SC70 | DCK | 5 | 3000 | Green (RoHS & no Sb/Br) | CU SN | Level-1-260C-UNLIM | -50 to 150 | BNA | Samples |
| LMT84DCKT | ACTIVE | SC70 | DCK | 5 | 250 | Green (RoHS & no Sb/Br) | CU SN | Level-1-260C-UNLIM | -50 to 150 | BNA | Samples |
| LMT84LP | ACTIVE | TO-92 | LP | 3 | 1800 | Green (RoHS & no Sb/Br) | CU SN | N / A for Pkg Type | -50 to 150 | LMT84 | Samples |
| LMT84LPC | PREVIEW | TO-126 | LPD | 3 | 60 | TBD | Call TI | Call TI | -50 to 150 | | |
| LMT84LPM | ACTIVE | TO-92 | LP | 3 | 2000 | Green (RoHS & no Sb/Br) | CU SN | N / A for Pkg Type | -50 to 150 | LMT84 | Samples |
| LMT84QDCKRQ1 | ACTIVE | SC70 | DCK | 5 | 3000 | Green (RoHS & no Sb/Br) | CU SN | Level-1-260C-UNLIM | -50 to 150 | BOA | Samples |
| LMT84QDCKTQ1 | ACTIVE | SC70 | DCK | 5 | 250 | Green (RoHS & no Sb/Br) | CU SN | Level-1-260C-UNLIM | -50 to 150 | BOA | 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) 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.

(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.

**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 LMT84, LMT84-Q1 :**

- Catalog: LMT84

- Automotive: LMT84-Q1

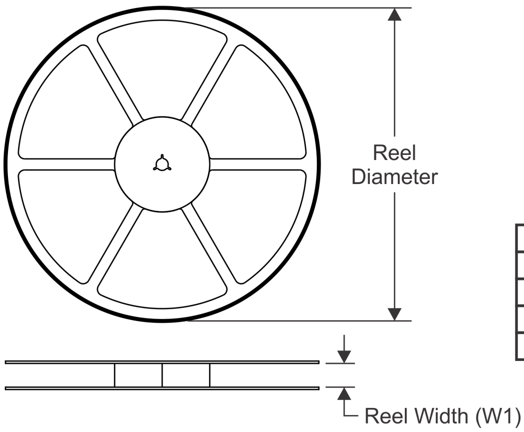
NOTE: Qualified Version Definitions:

- Catalog - TI's standard catalog product

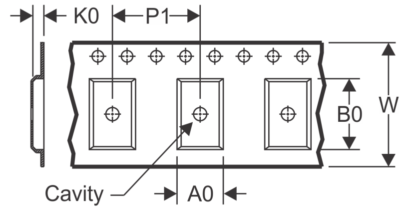
- Automotive - Q100 devices qualified for high-reliability automotive applications targeting zero defects

## TAPE AND REEL INFORMATION

**REEL DIMENSIONS**

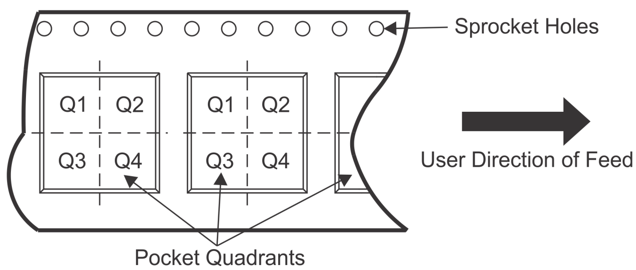



**TAPE DIMENSIONS**




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

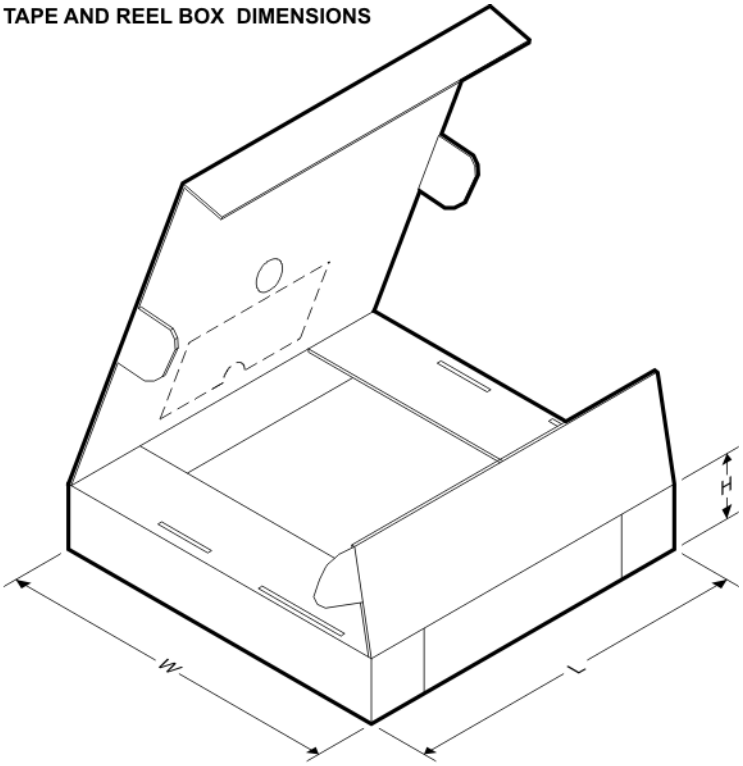
**QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE**




*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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LMT84DCKR | SC70 | DCK | 5 | 3000 | 178.0 | 8.4 | 2.25 | 2.45 | 1.2 | 4.0 | 8.0 | Q3 |
| LMT84DCKT | SC70 | DCK | 5 | 250 | 178.0 | 8.4 | 2.25 | 2.45 | 1.2 | 4.0 | 8.0 | Q3 |
| LMT84QDCKRQ1 | SC70 | DCK | 5 | 3000 | 178.0 | 8.4 | 2.25 | 2.45 | 1.2 | 4.0 | 8.0 | Q3 |
| LMT84QDCKTQ1 | SC70 | DCK | 5 | 250 | 178.0 | 8.4 | 2.25 | 2.45 | 1.2 | 4.0 | 8.0 | Q3 |

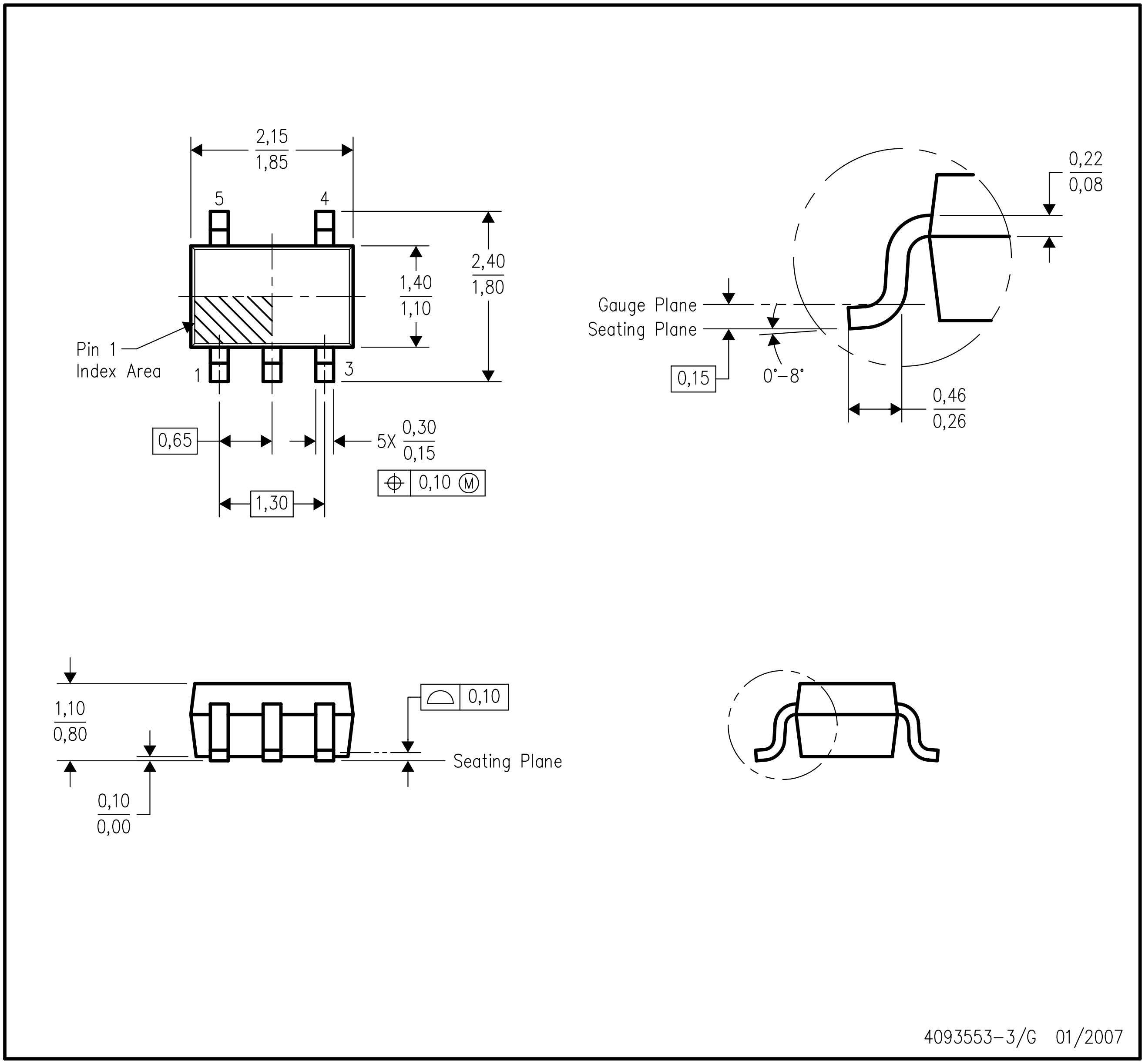
TAPE AND REEL BOX DIMENSIONS




*All dimensions are nominal

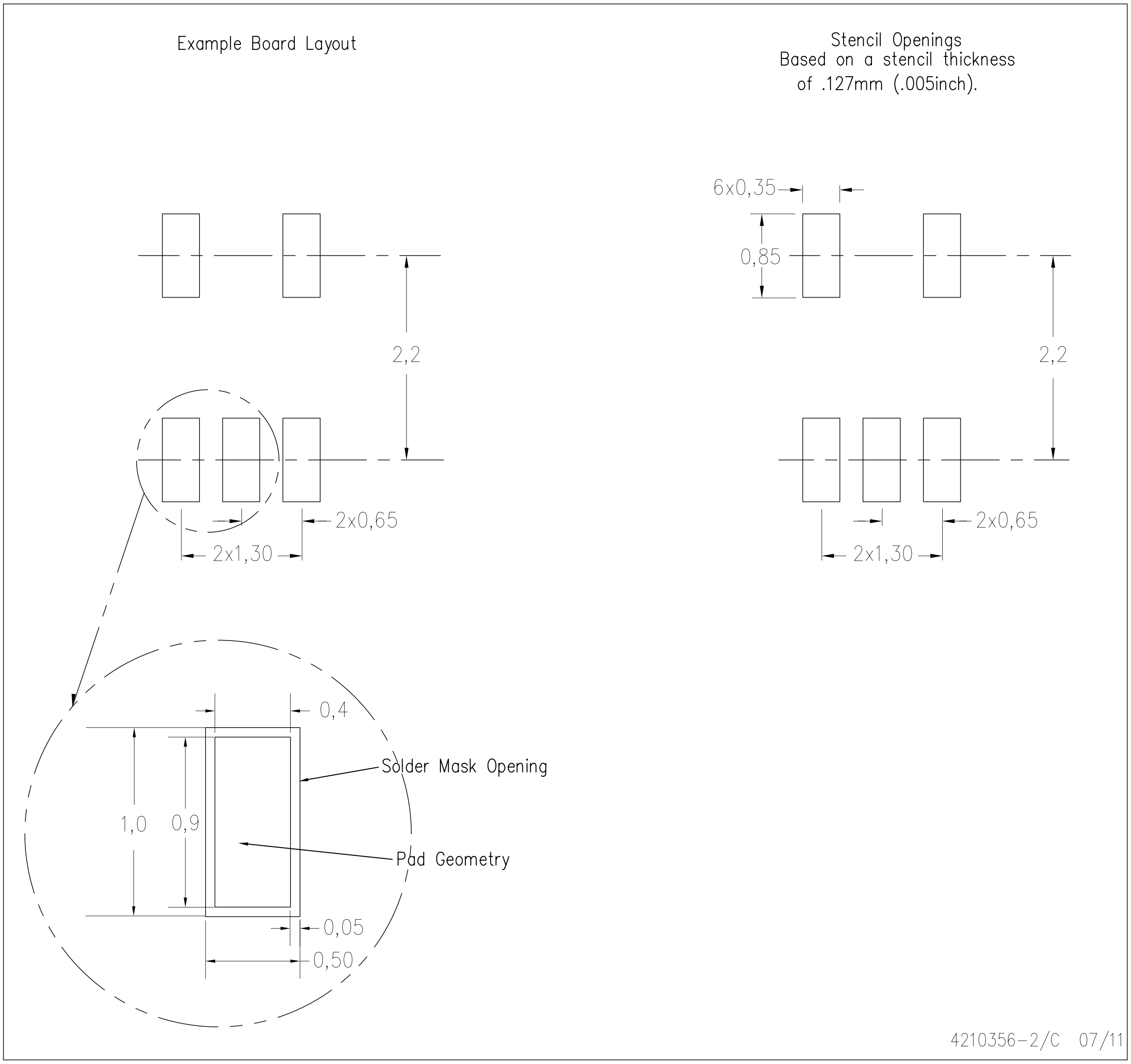
| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|---|---|---|---|---|---|---|---|
| LMT84DCKR | SC70 | DCK | 5 | 3000 | 210.0 | 185.0 | 35.0 |
| LMT84DCKT | SC70 | DCK | 5 | 250 | 210.0 | 185.0 | 35.0 |
| LMT84QDCKRQ1 | SC70 | DCK | 5 | 3000 | 210.0 | 185.0 | 35.0 |
| LMT84QDCKTQ1 | SC70 | DCK | 5 | 250 | 210.0 | 185.0 | 35.0 |

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



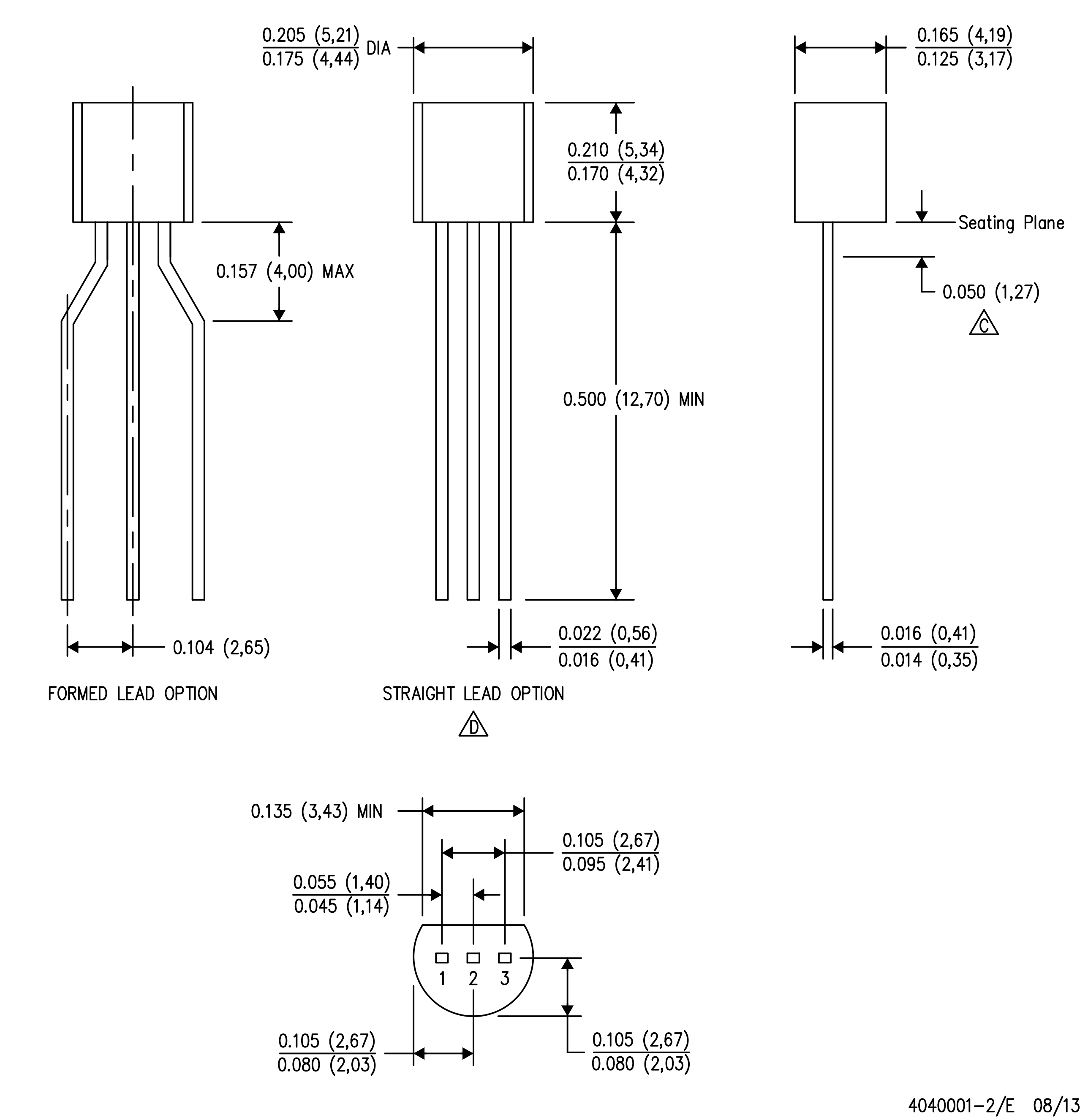

NOTES: A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion. Mold flash and protrusion shall not exceed 0.15 per side.
D. Falls within JEDEC MO-203 variation AA.

DCK (R-PDSO-G5) PLASTIC SMALL OUTLINE



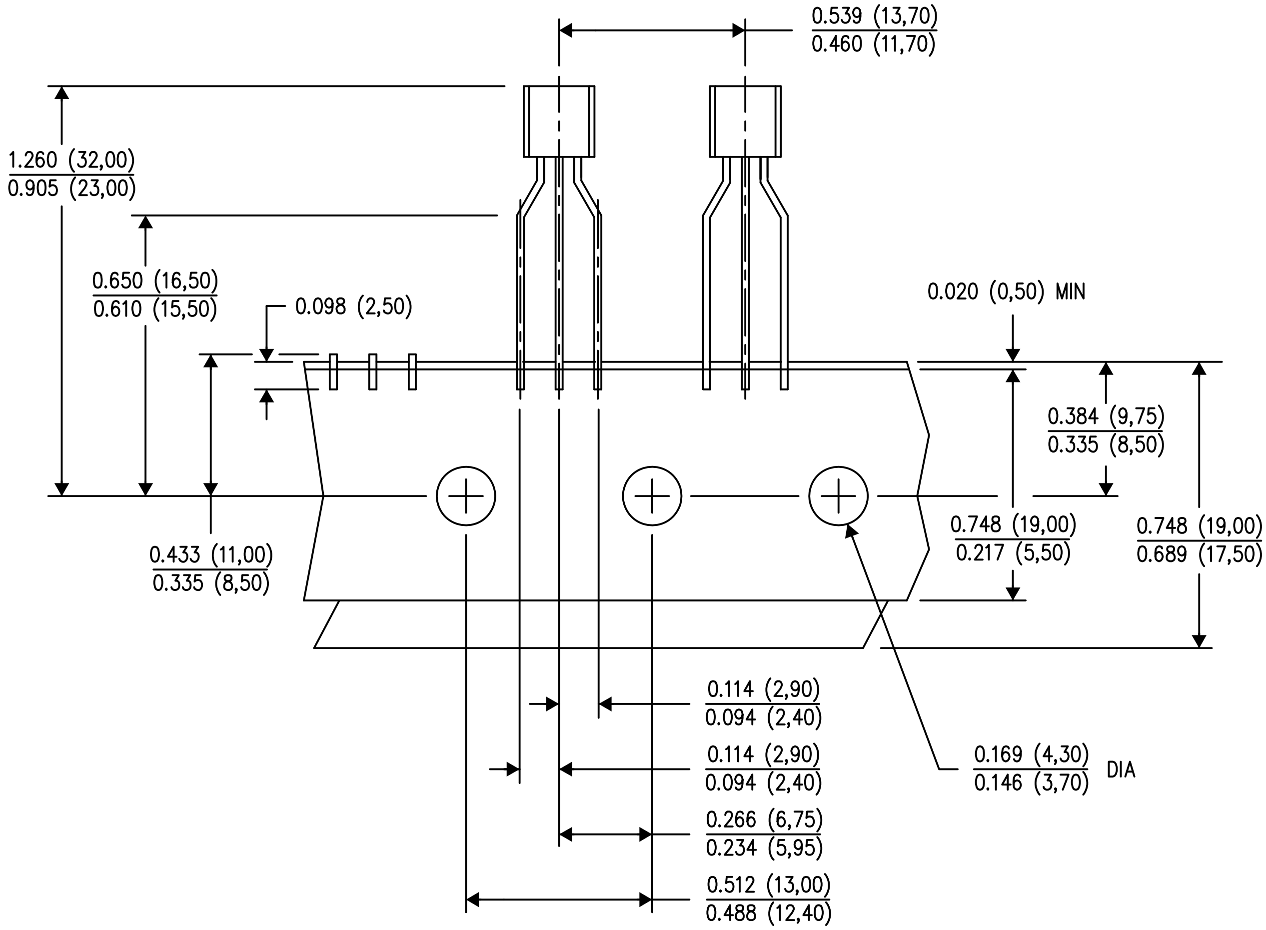

NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Customers should place a note on the circuit board fabrication drawing not to alter the center solder mask defined pad.
D. Publication IPC-7351 is recommended for alternate designs.
E. Laser cutting 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.

LP (O–PBCY–W3) PLASTIC CYLINDRICAL PACKAGE




NOTES:
A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Lead dimensions are not controlled within this area.
D. Falls within JEDEC TO–226 Variation AA (TO–226 replaces TO–92).
E. Shipping Method:
Straight lead option available in bulk pack only.
Formed lead option available in tape & reel or ammo pack.
Specific products can be offered in limited combinations of shipping mediums and lead options.
Consult product folder for more information on available options.

LP (O–PBCY–W3) PLASTIC CYLINDRICAL PACKAGE




4040001–3/E 08/13

NOTES:
- A. All linear dimensions are in inches (millimeters).
- B. This drawing is subject to change without notice.
- C. Tape and Reel information for the Formed Lead Option package.

# IMPORTANT NOTICE



| **Products** | | **Applications** | |
|---|---|---|---|
| Audio | www.ti.com/audio | Automotive and Transportation | www.ti.com/automotive |
| Amplifiers | amplifier.ti.com | Communications and Telecom | www.ti.com/communications |
| Data Converters | dataconverter.ti.com | Computers and Peripherals | www.ti.com/computers |
| DLP® Products | www.dlp.com | Consumer Electronics | www.ti.com/consumer-apps |
| DSP | dsp.ti.com | Energy and Lighting | www.ti.com/energy |
| Clocks and Timers | www.ti.com/clocks | Industrial | www.ti.com/industrial |
| Interface | interface.ti.com | Medical | www.ti.com/medical |
| Logic | logic.ti.com | Security | www.ti.com/security |
| Power Mgmt | power.ti.com | Space, Avionics and Defense | www.ti.com/space-avionics-defense |
| Microcontrollers | microcontroller.ti.com | Video and Imaging | www.ti.com/video |
| RFID | www.ti-rfid.com | | |
| OMAP Applications Processors | www.ti.com/omap | **TI E2E Community** | e2e.ti.com |
| Wireless Connectivity | www.ti.com/wirelessconnectivity | | |

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