# LMT87 2.7V、SC70/TO-92/TO-92S、Class-AB出力のアナログ温度センサ

## 1 特長

- LMT87LPG (TO-92Sパッケージ)は高速な熱時定数、標準値10s (気流1.2m/s)
- 非常に正確: ±0.4℃ (標準値)
- 低電圧2.7Vでの動作
- 平均センサ・ゲイン: -13.6mV/℃
- 低い静止電流: 5.4µA
- 広い温度範囲: -50℃～150℃
- 出力の短絡保護
- 駆動能力±50µAのプッシュプル出力
- 業界標準のLM20/19およびLM35温度センサとフットプリント互換
- コスト効率に優れたサーミスタの代替

## 2 アプリケーション

- 車載用
- インフォテインメントおよびクラスタ
- パワートレイン・システム
- 煙および熱感知器
- ドローン
- 家電製品

## 3 概要

LMT87デバイスは高精度のCMOS温度センサであり、標準精度が±0.4℃ (最大±2.7℃)で、リニアなアナログ出力電圧を持ち、この電圧は温度に反比例します。2.7Vの電源電圧で動作し、静止電流が5.4µA、パワーオン時間が0.7msで、効率的なパワーサイクリング・アーキテクチャを実現し、ドローンやセンサ・ノードなどバッテリ駆動のアプリケーションで消費電力を最小化できます。LMT87LPGスルーホールTO-92Sパッケージは熱時定数が高速で、煙および熱感知器など、オフボードで時間-温度の感度が高いアプリケーションに対応できます。広い動作範囲での精度や、その他の特長から、LMT87はサーミスタの優れた代替となります。

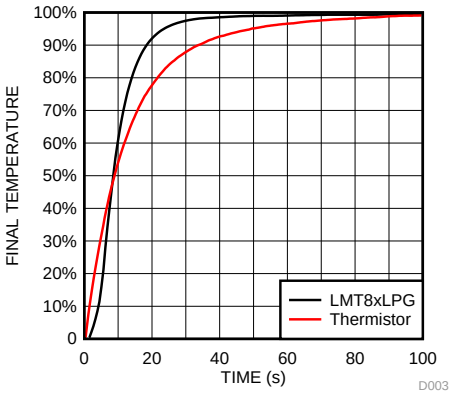
異なる平均センサ・ゲインおよび類似の精度を持つデバイスについては、*類似の代替デバイス*で、LMT8xファミリの他のデバイスを参照してください。

**製品情報(1)**

| 型番 | パッケージ | 本体サイズ(公称) |
|---|---|---|
| LMT87 | SOT (5) | 2.00mm×1.25mm |
| | TO-92 (3) | 4.30mm×3.50mm |
| | TO-92S (3) | 4.00mm×3.15mm |

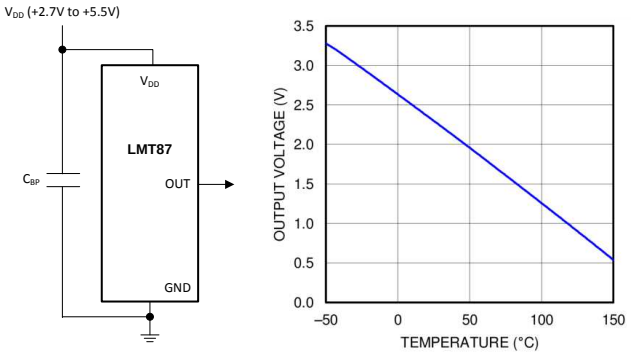
(1) 利用可能なすべてのパッケージについては、このデータシートの末尾にある注文情報を参照してください。

**熱時定数**




* 高速な熱応答NTC

**出力電圧と温度との関係**




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## 4 改訂履歴

資料番号末尾の英字は改訂を表しています。その改訂履歴は英語版に準じています。

**Revision D (June 2017)** から **Revision E** に変更 **Page**

- 車載用デバイスを単独のデータシート(SNIS202)に移動 ... 1
- Changed TO-92 GND pin number from: 1 to: 3 ... 4
- Changed TO-92 $V_{DD}$ pin number from: 3 to: 1 ... 4

**Revision C (October 2015)** から **Revision D** に変更 **Page**

- データシートのテキストを最新のドキュメントおよび翻訳標準に更新 ... 1
- 「*特長*」の箇条書きにAEC-Q100車載用認定の項目を追加 ... 1
- 時定数グラフを追加 ... 1
- 「*アプリケーション*」からディスク・ドライバ、ゲーム、ワイヤレス・トランシーバ、携帯電話を削除 ... 1
- Added LPG (TO-92S) package ... 4
- Added Figure 10 to *Typical Characteristics* ... 7

**Revision B (May 2014)** から **Revision C** に変更 **Page**

- TO-126パッケージへのすべての言及を 削除 ... 1
- Added TO-92 LPM pin configuration graphic ... 4
- Changed Handling Ratings to ESD Ratings and moved Storage Temperature to Absolute Maximum Ratings table ... 5
- Changed KV to V ... 5
- Added layout recommendation for TO-92 LP and LPM packages ... 15

**Revision A (June 2013)** から **Revision B** に変更 **Page**

- 新しいTIの標準に準拠するようデータシートのフローとレイアウトを追加。「アプリケーションと実装」、「電源に関する推奨事項」、「レイアウト」、「デバイスおよびドキュメントのサポート」、「メカニカル、パッケージ、および注文情報」の各セクションを 追加 ... 1
- TO-92およびTO-126のパッケージ情報を 追加 ... 1
- Changed from 450°C/W to 275 °C/W. New specification is derived using TI ' s latest methodology. ... 5


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- 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. ..... 6

# 5 Device Comparison Tables

**Table 1. Available Device Packages**

| ORDER NUMBER(1) | PACKAGE | PIN | BODY SIZE (NOM) | MOUNTING TYPE |
|---|---|---|---|---|
| LMT87DCK | SOT (AKA(2): SC70, DCK) | 5 | 2.00 mm × 1.25 mm | Surface Mount |
| LMT87LP | TO-92 (AKA(2): LP) | 3 | 4.30 mm × 3.50 mm | Through-hole; straight leads |
| LMT87LPG | TO-92S (AKA(2): LPG) | 3 | 4.00 mm × 3.15 mm | Through-hole; straight leads |
| LMT87LPM | TO-92 (AKA(2): LPM) | 3 | 4.30 mm × 3.50 mm | Through-hole; formed leads |
| LMT87DCK-Q1 | SOT (AKA(2): SC70, DCK) | 5 | 2.00 mm × 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

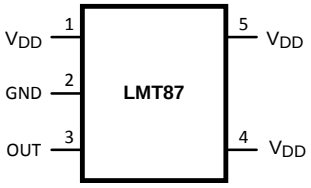
**Table 2. Comparable Alternative Devices**

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

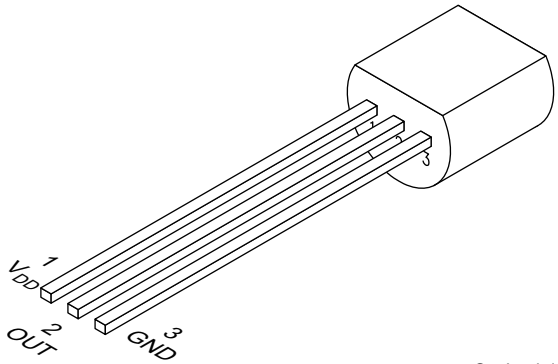
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# 6 Pin Configuration and Functions

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

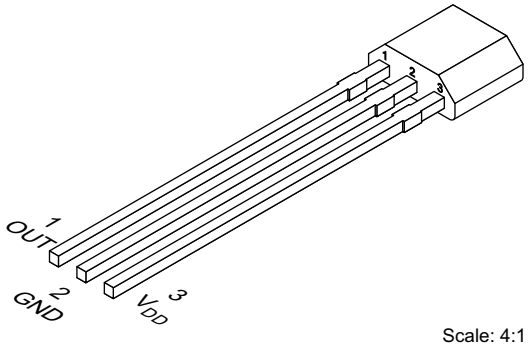



**LP Package**
**3-Pin TO-92**
**(Top View)**



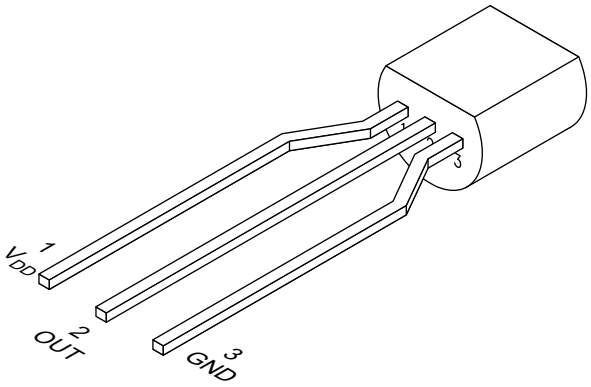

Scale: 4:1

**LPG Package**
**3-Pin TO-92S**
**(Top View)**



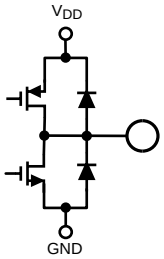

Scale: 4:1

**LPM Package**
**3-Pin TO-92**
**(Top View)**




Scale: 4:1

**Pin Functions**

| PIN | | | | TYPE | DESCRIPTION | |
|---|---|---|---|---|---|---|
| NAME | SOT (SC70) | TO-92 | TO-92S | | EQUIVALENT CIRCUIT | FUNCTION |
| GND | 2 (1) | 3 | 2 | Ground | N/A | Power Supply Ground |
| OUT | 3 | 2 | 1 | Analog Output |   | Outputs a voltage that is inversely proportional to temperature |
| $V_{DD}$ | 1, 4, 5 | 1 | 3 | Power | N/A | Positive Supply Voltage |

(1) Direct connection to the back side of the die


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# 7 Specifications

## 7.1 Absolute Maximum Ratings

See (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 |
| Storage temperature $T_{stg}$ | –65 | 150 | °C |

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
(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 ESD Ratings

| | | | VALUE | UNIT |
|---|---|---|---|---|
| LMT87LP in TO-92 package | | | | |
| $V_{(ESD)}$ | Electrostatic discharge | Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001(1)(2) | ±2500 | V |
| | | Charged-device model (CDM), per JEDEC specification JESD22-C101(3) | ±1000 | |
| LMT87DCK in SC70 package | | | | |
| $V_{(ESD)}$ | Electrostatic discharge | Human-body model (HBM), per JESD22-A114(2) | ±2500 | V |
| | | Charged-device model (CDM), per JEDEC specification JESD22-C101(3) | ±1000 | |

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
(2) The human-body model is a 100-pF capacitor discharged through a 1.5-kΩ resistor 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 | $T_{MIN} \le T_A \le T_{MAX}$ | | °C |
| | $-50 \le T_A \le 150$ | | °C |
| Supply voltage ($V_{DD}$) | 2.7 | 5.5 | V |

## 7.4 Thermal Information(1)

| THERMAL METRIC(2) | | LMT87 DCK (SOT/SC70) 5 PINS | LMT87LP LP/LPM (TO-92) 3 PINS | LMT87LPG LPG (TO-92S) 3 PINS | UNIT |
|---|---|---|---|---|---|
| $R_{\theta JA}$ | Junction-to-ambient thermal resistance (3)(4) | 275 | 167 | 130.4 | °C/W |
| $R_{\theta JC(top)}$ | Junction-to-case (top) thermal resistance | 84 | 90 | 64.2 | °C/W |
| $R_{\theta JB}$ | Junction-to-board thermal resistance | 56 | 146 | 106.2 | °C/W |
| $\psi_{JT}$ | Junction-to-top characterization parameter | 1.2 | 35 | 14.6 | °C/W |
| $\psi_{JB}$ | Junction-to-board characterization parameter | 55 | 146 | 106.2 | °C/W |

(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.
(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.

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## 7.5 Accuracy Characteristics

These limits do not include DC load regulation. These stated accuracy limits are with reference to the values in Table 3.

| PARAMETER | CONDITIONS | MIN(1) | TYP | MAX(1) | UNIT |
|---|---|---|---|---|---|
| Temperature accuracy(2) | 70°C to 150°C; $V_{DD}$ = 3.0 V to 5.5 V | –2.7 | ±0.4 | 2.7 | °C |
| | 20°C to 40°C; $V_{DD}$ = 2.7 V to 5.5 V | | ±0.6 | | °C |
| | 20°C to 40°C; $V_{DD}$ = 3.4 V to 5.5 V | | ±0.3 | | °C |
| | 0°C; $V_{DD}$ = 3.0 V to 5.5 V | –2.7 | ±0.6 | 2.7 | °C |
| | 0°C; $V_{DD}$ = 3.6 V to 5.5 V | | ±0.3 | | °C |
| | –50°C; $V_{DD}$ = 3.6 V to 5.5 V | –2.7 | ±0.6 | 2.7 | °C |
| | –50°C; $V_{DD}$ = 4.2 V to 5.5 V | | ±0.3 | | °C |

(1) Limits are specific to TI's AOQL (Average Outgoing Quality Level).
(2) 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 +$V_{DD}$ = 2.7 V to 5.5 V. MIN and MAX limits apply for $T_A$ = $T_J$ = $T_{MIN}$ to $T_{MAX}$ ; typical limits apply for $T_A$ = $T_J$ = 25°C.

| PARAMETER | | TEST CONDITIONS | MIN(1) | TYP (2) | MAX (1) | UNIT |
|---|---|---|---|---|---|---|
| | Sensor gain (output transfer function slope) | | | –13.6 | | 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 | $T_A$ = $T_J$ = 25°C | –50 | | 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 LMT87. Sink currents are flowing into the LMT87.
(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.


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## 7.7 Typical Characteristics

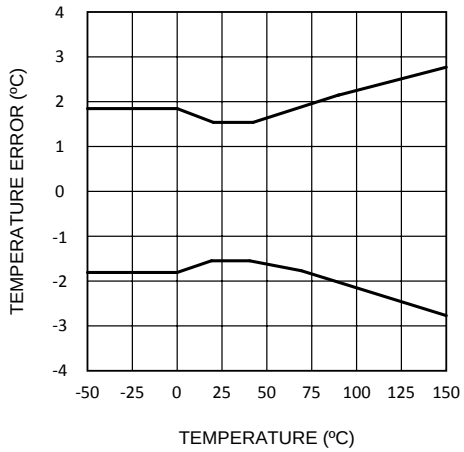



**Figure 1. Temperature Error vs Temperature**

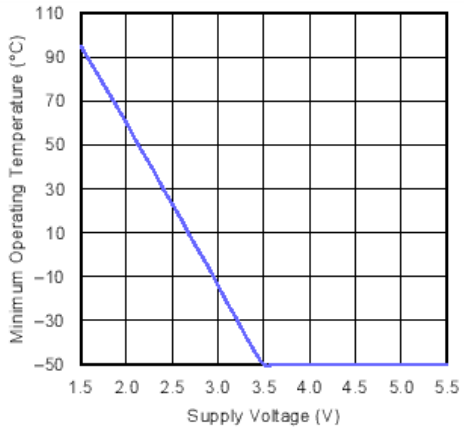



**Figure 2. Minimum Operating Temperature vs Supply Voltage**

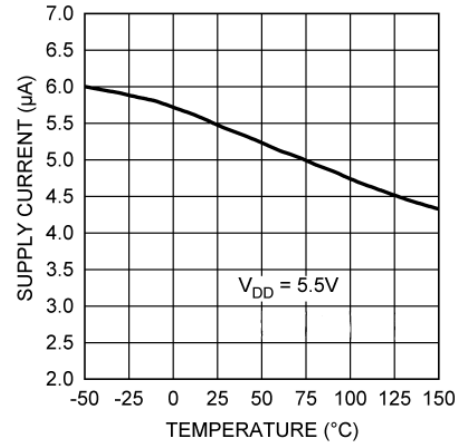



**Figure 3. Supply Current vs Temperature**

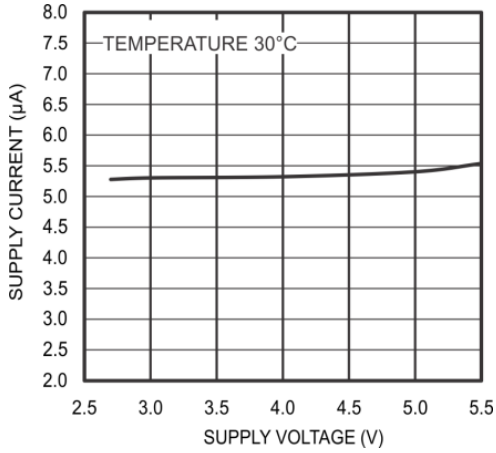



**Figure 4. Supply Current vs Supply Voltage**

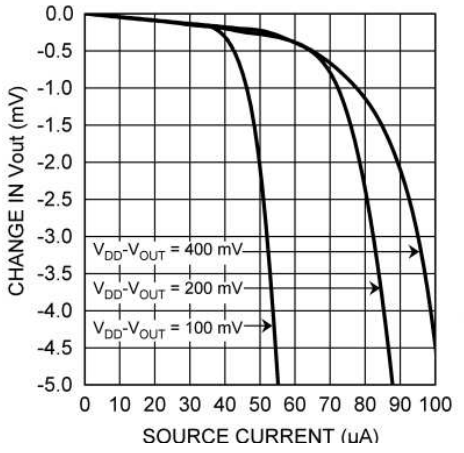



**Figure 5. Load Regulation, Sourcing Current**

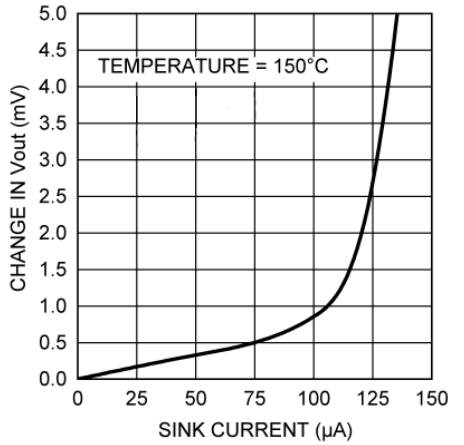



**Figure 6. Load Regulation, Sinking Current**

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## Typical Characteristics (continued)

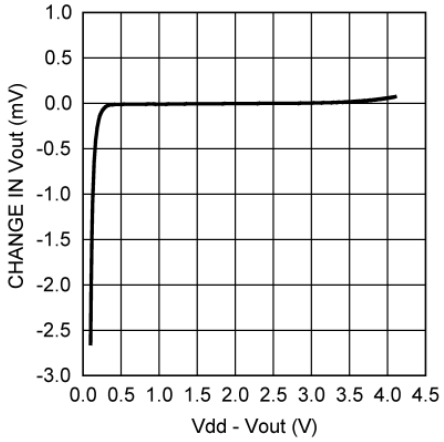



**Figure 7. Change in $V_{OUT}$ vs Overhead Voltage**

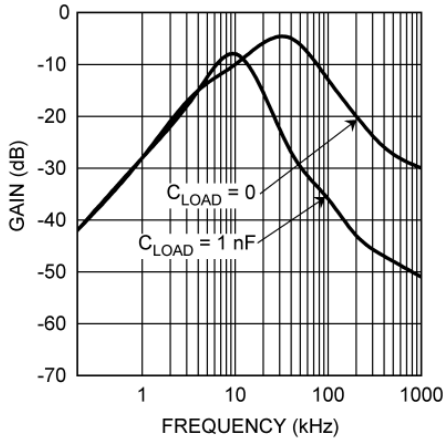



**Figure 8. Supply-Noise Gain vs Frequency**

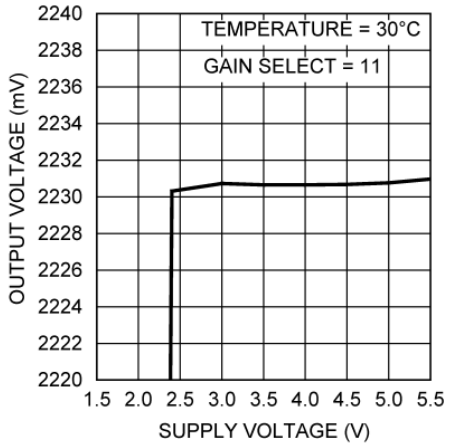



**Figure 9. Output Voltage vs Supply Voltage**

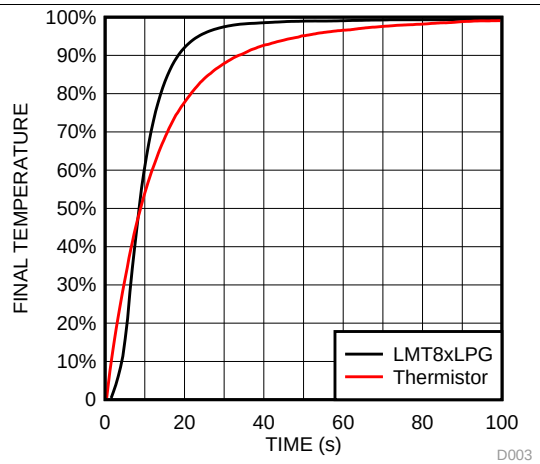



**Figure 10. LMT87LPG Thermal Response vs Common Leaded Thermistor With 1.2-m/s Airflow**


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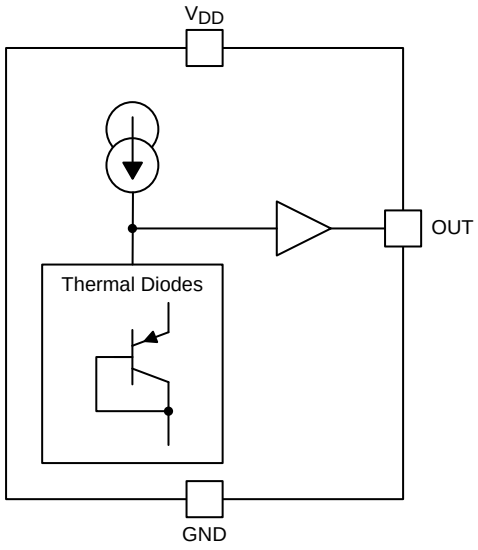
# 8 Detailed Description

## 8.1 Overview

The LMT87 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 LMT87 Transfer Function

The output voltage of the LMT87, across the complete operating temperature range, is shown in Table 3. This table is the reference from which the LMT87 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 LMT87 product folder under *Tools and Software Models*.

**Table 3. LMT87 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 | 3277 | –10 | 2767 | 30 | 2231 | 70 | 1679 | 110 | 1115 |
| –49 | 3266 | –9 | 2754 | 31 | 2217 | 71 | 1665 | 111 | 1101 |
| –48 | 3254 | –8 | 2740 | 32 | 2204 | 72 | 1651 | 112 | 1087 |
| –47 | 3243 | –7 | 2727 | 33 | 2190 | 73 | 1637 | 113 | 1073 |
| –46 | 3232 | –6 | 2714 | 34 | 2176 | 74 | 1623 | 114 | 1058 |
| –45 | 3221 | –5 | 2700 | 35 | 2163 | 75 | 1609 | 115 | 1044 |
| –44 | 3210 | –4 | 2687 | 36 | 2149 | 76 | 1595 | 116 | 1030 |
| –43 | 3199 | –3 | 2674 | 37 | 2136 | 77 | 1581 | 117 | 1015 |
| –42 | 3186 | –2 | 2660 | 38 | 2122 | 78 | 1567 | 118 | 1001 |
| –41 | 3173 | –1 | 2647 | 39 | 2108 | 79 | 1553 | 119 | 987 |
| –40 | 3160 | 0 | 2633 | 40 | 2095 | 80 | 1539 | 120 | 973 |
| –39 | 3147 | 1 | 2620 | 41 | 2081 | 81 | 1525 | 121 | 958 |
| –38 | 3134 | 2 | 2607 | 42 | 2067 | 82 | 1511 | 122 | 944 |

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## Feature Description (continued)

**Table 3. LMT87 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) |
|---|---|---|---|---|---|---|---|---|---|
| –37 | 3121 | 3 | 2593 | 43 | 2054 | 83 | 1497 | 123 | 929 |
| –36 | 3108 | 4 | 2580 | 44 | 2040 | 84 | 1483 | 124 | 915 |
| –35 | 3095 | 5 | 2567 | 45 | 2026 | 85 | 1469 | 125 | 901 |
| –34 | 3082 | 6 | 2553 | 46 | 2012 | 86 | 1455 | 126 | 886 |
| –33 | 3069 | 7 | 2540 | 47 | 1999 | 87 | 1441 | 127 | 872 |
| –32 | 3056 | 8 | 2527 | 48 | 1985 | 88 | 1427 | 128 | 858 |
| –31 | 3043 | 9 | 2513 | 49 | 1971 | 89 | 1413 | 129 | 843 |
| –30 | 3030 | 10 | 2500 | 50 | 1958 | 90 | 1399 | 130 | 829 |
| –29 | 3017 | 11 | 2486 | 51 | 1944 | 91 | 1385 | 131 | 814 |
| –28 | 3004 | 12 | 2473 | 52 | 1930 | 92 | 1371 | 132 | 800 |
| –27 | 2991 | 13 | 2459 | 53 | 1916 | 93 | 1356 | 133 | 786 |
| –26 | 2978 | 14 | 2446 | 54 | 1902 | 94 | 1342 | 134 | 771 |
| –25 | 2965 | 15 | 2433 | 55 | 1888 | 95 | 1328 | 135 | 757 |
| –24 | 2952 | 16 | 2419 | 56 | 1875 | 96 | 1314 | 136 | 742 |
| –23 | 2938 | 17 | 2406 | 57 | 1861 | 97 | 1300 | 137 | 728 |
| –22 | 2925 | 18 | 2392 | 58 | 1847 | 98 | 1286 | 138 | 713 |
| –21 | 2912 | 19 | 2379 | 59 | 1833 | 99 | 1272 | 139 | 699 |
| –20 | 2899 | 20 | 2365 | 60 | 1819 | 100 | 1257 | 140 | 684 |
| –19 | 2886 | 21 | 2352 | 61 | 1805 | 101 | 1243 | 141 | 670 |
| –18 | 2873 | 22 | 2338 | 62 | 1791 | 102 | 1229 | 142 | 655 |
| –17 | 2859 | 23 | 2325 | 63 | 1777 | 103 | 1215 | 143 | 640 |
| –16 | 2846 | 24 | 2311 | 64 | 1763 | 104 | 1201 | 144 | 626 |
| –15 | 2833 | 25 | 2298 | 65 | 1749 | 105 | 1186 | 145 | 611 |
| –14 | 2820 | 26 | 2285 | 66 | 1735 | 106 | 1172 | 146 | 597 |
| –13 | 2807 | 27 | 2271 | 67 | 1721 | 107 | 1158 | 147 | 582 |
| –12 | 2793 | 28 | 2258 | 68 | 1707 | 108 | 1144 | 148 | 568 |
| –11 | 2780 | 29 | 2244 | 69 | 1693 | 109 | 1130 | 149 | 553 |
| | | | | | | | | 150 | 538 |

Although the LMT87 is very linear, the response does have a slight umbrella parabolic shape. This shape is very accurately reflected in Table 3. The transfer table can be calculated by using the parabolic equation (Equation 1).

$$V_{TEMP}(mV) = 2230.8mV - \left[13.582\frac{mV}{°C}(T - 30°C)\right] - \left[0.00433\frac{mV}{°C^2}(T - 30°C)^2\right] \quad (1)$$

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:

$$T = \frac{13.582 - \sqrt{(-13.582)^2 + 4 \times 0.00433 \times (2230.8 - V_{TEMP}(mV))}}{2 \times (-0.00433)} + 30 \quad (2)$$

For an even less accurate linear transfer function approximation, a line can easily be calculated over the desired temperature range from Table 3 using the two-point equation (Equation 3):

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

where

- V is in mV,
- T is in °C,
- $T_1$ and $V_1$ are the coordinates of the lowest temperature,
- and $T_2$ and $V_2$ are the coordinates of the highest temperature. (3)


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For example, if the user wanted to resolve this equation, over a temperature range of 20°C to 50°C, they would proceed as follows:

$$V - 2365\ mV = \left(\frac{1958\ mV - 2365\ mV}{50^oC - 20^oC}\right) \times (T - 20^oC) \quad (4)$$

$$V - 2365\ mV = (-13.6\ mV / {}^oC) \times (T - 20^oC) \quad (5)$$

$$V = (-13.6\ mV / {}^oC) \times T + 2637\ mV \quad (6)$$

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 LMT87 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 LMT87 die is directly attached to the GND pin. The temperatures of the lands and traces to the other leads of the LMT87 will also affect the temperature reading.

Alternatively, the LMT87 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 LMT87 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 LMT87 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. Use Equation 7 to calculate the rise in the LMT87 die temperature:

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

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, $V_{OUT}$ = 2231 mV, and $I_L$ = 2 μA, the junction temperature would be 30.014°C, showing a self-heating error of only 0.014°C. Because the junction temperature of the LMT87 is the actual temperature being measured, take care to minimize the load current that the LMT87 is required to drive. *Thermal Information*(1) shows the thermal resistance of the LMT87.

### 8.4.2 Output Noise Considerations

A push-pull output gives the LMT87 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. The LMT87 is ideal for this and other applications which require strong source or sink current.

The LMT87 supply-noise gain (the ratio of the AC signal on $V_{OUT}$ to the AC signal on $V_{DD}$) was measured during bench tests. The 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 LMT87.

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

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## Device Functional Modes (continued)

### 8.4.3 Capacitive Loads

The LMT87 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 LMT87 can drive a capacitive load less than or equal to 1100 pF, as shown in Figure 11. For capacitive loads greater than 1100 pF, a series resistor may be required on the output, as shown in Figure 12.

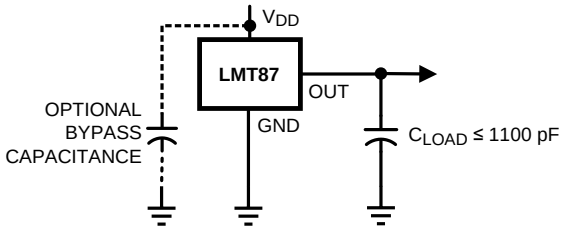



**Figure 11. LMT87 No Decoupling Required for Capacitive Loads Less Than 1100 pF**

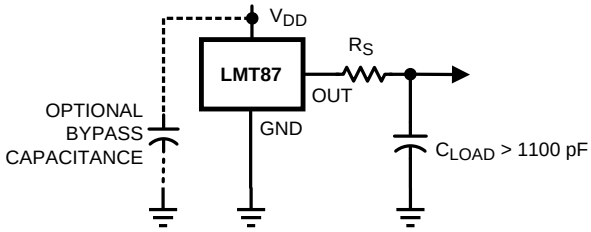



**Figure 12. LMT87 with Series Resistor for Capacitive Loading Greater Than 1100 pF**

**Table 4. Recommended Series Resistor Values**

| $C_{LOAD}$ | 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 LMT87 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 V.

This slight shift (a few millivolts) takes place over a wide change (approximately 200 mV) in $V_{DD}$ or $V_{OUT}$. Because 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.


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# 9 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.

## 9.1 Application Information

The LMT87 features make it suitable for many general temperature-sensing applications. It can operate down to 2.7-V supply with 5.4-µA power consumption. Package options like the through-hole TO-92 package also allow the LMT87 to be mounted onboard, off-board, to a heat sink, or on multiple unique locations in the same application.

## 9.2 Typical Applications

### 9.2.1 Connection to ADC

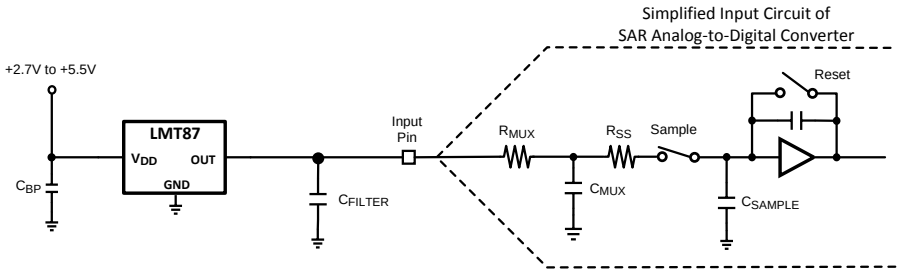



**Figure 13. Suggested Connection to a Sampling Analog-to-Digital Converter Input Stage**

#### *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 LMT87 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. Because 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 Curve*

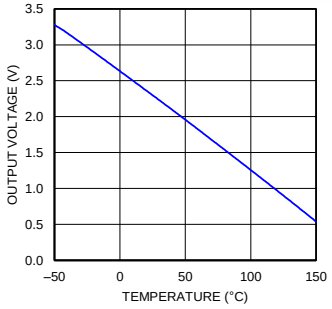



**Figure 14. Analog Output Transfer Function**

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## Typical Applications (continued)

### 9.2.2 Conserving Power Dissipation With Shutdown

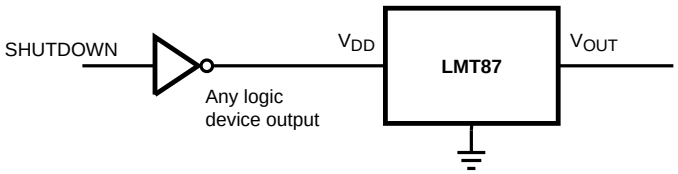



**Figure 15. Simple Shutdown Connection of the LMT87**

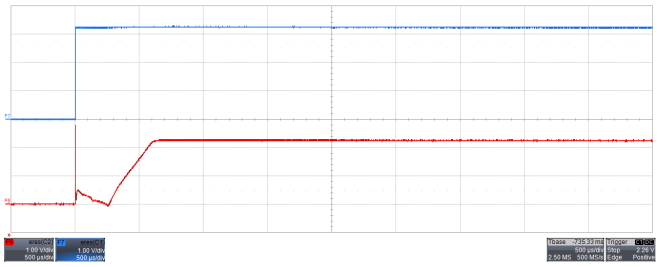
#### *9.2.2.1 Design Requirements*

Because the power consumption of the LMT87 is less than 9 µA, it can simply be powered directly from any logic gate output and therefore not require a specific shutdown pin. The device can even be powered directly from a microcontroller GPIO. In this way, it can easily be turned off for cases such as battery-powered systems where power savings are critical.

#### *9.2.2.2 Detailed Design Procedure*

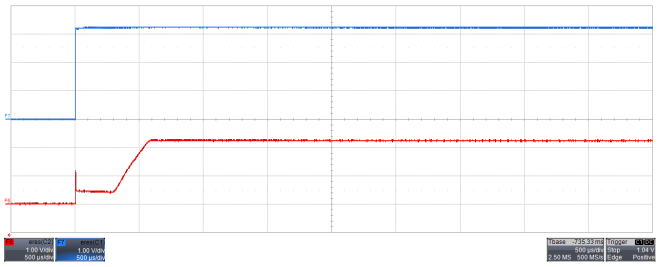
Simply connect the $V_{DD}$ pin of the LMT87 directly to the logic shutdown signal from a microcontroller.

#### *9.2.2.3 Application Curves*



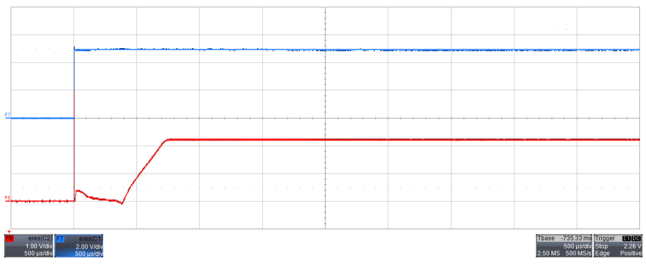
Time: 500 µs/div; Top trace: $V_{DD}$ 1 V/div;
Bottom trace: OUT 1 V/div

**Figure 16. Output Turnon Response Time Without a Capacitive Load and $V_{DD}$ = 3.3 V**



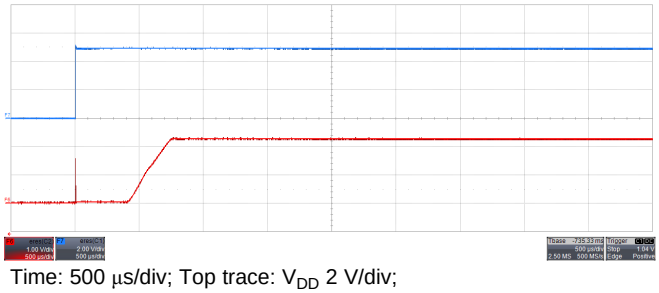
Time: 500 µs/div; Top trace: $V_{DD}$ 1 V/div;
Bottom trace: OUT 1 V/div

**Figure 17. Output Turnon Response Time With a 1.1-nF Capacitive Load and $V_{DD}$ = 3.3 V**



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

**Figure 18. Output Turnon Response Time Without a Capacitive Load and $V_{DD}$ = 5 V**



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

**Figure 19. Output Turnon Response Time With a 1.1-nF Capacitive Load and $V_{DD}$ = 5 V**

## 10 Power Supply Recommendations

The low supply current and supply range (2.7 V to 5.5 V) of the LMT87 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 output of the LMT87.


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# 11 Layout

## 11.1 Layout Guidelines

The LMT87 is extremely simple to layout. If a power-supply bypass capacitor is used, it should be connected as shown in the *Layout Example*.

## 11.2 Layout Example

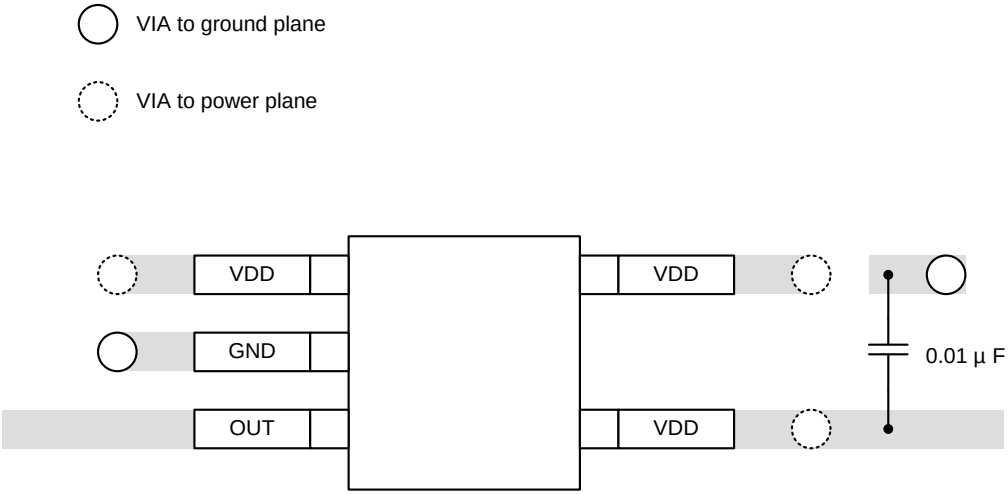



**Figure 20. SC70 Package Recommended Layout**

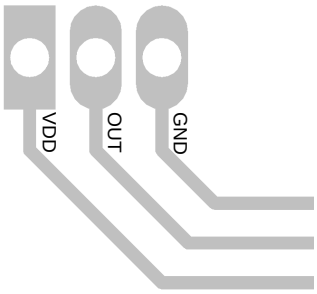



**Figure 21. TO-92 LP Package Recommended Layout**

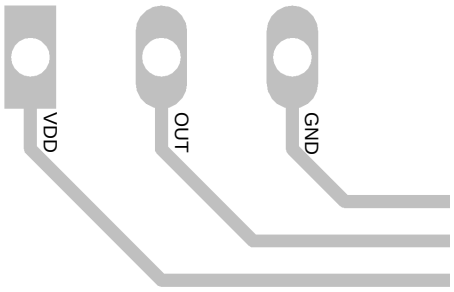



**Figure 22. TO-92 LPM Package Recommended Layout**

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# 12 デバイスおよびドキュメントのサポート

## 12.1 ドキュメントの更新通知を受け取る方法

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## 12.2 コミュニティ・リソース

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**設計サポート** ***TIの設計サポート*** **役に立つE2Eフォーラムや、設計サポート・ツールをすばやく見つけることができます。技術サポート用の連絡先情報も参照できます。**

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## 12.5 Glossary

SLYZ022 — *TI Glossary*.

This glossary lists and explains terms, acronyms, and definitions.

# 13 メカニカル、パッケージ、および注文情報

以降のページには、メカニカル、パッケージ、および注文に関する情報が記載されています。この情報は、そのデバイスについて利用可能な最新のデータです。このデータは予告なく変更されることがあり、ドキュメントが改訂される場合もあります。本データシートのブラウザ版を使用されている場合は、画面左側の説明をご覧ください。


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## PACKAGING INFORMATION

| Orderable part number | Status (1) | Material type (2) | Package \| Pins | Package qty \| Carrier | RoHS (3) | Lead finish/ Ball material (4) | MSL rating/ Peak reflow (5) | Op temp (°C) | Part marking (6) |
|---|---|---|---|---|---|---|---|---|---|
| LMT87DCKR | Active | Production | SC70 (DCK) \| 5 | 3000 \| LARGE T&R | Yes | SN | Level-1-260C-UNLIM | -50 to 150 | BUA |
| LMT87DCKR.A | Active | Production | SC70 (DCK) \| 5 | 3000 \| LARGE T&R | Yes | SN | Level-1-260C-UNLIM | -50 to 150 | BUA |
| LMT87DCKR.B | Active | Production | SC70 (DCK) \| 5 | 3000 \| LARGE T&R | Yes | SN | Level-1-260C-UNLIM | -50 to 150 | BUA |
| LMT87DCKT | Obsolete | Production | SC70 (DCK) \| 5 | - | - | Call TI | Call TI | -50 to 150 | BUA |
| LMT87LP | Active | Production | TO-92 (LP) \| 3 | 1800 \| LARGE T&R | Yes | SN | N/A for Pkg Type | -50 to 150 | LMT87 |
| LMT87LP.A | Active | Production | TO-92 (LP) \| 3 | 1800 \| LARGE T&R | Yes | SN | N/A for Pkg Type | -50 to 150 | LMT87 |
| LMT87LP.B | Active | Production | TO-92 (LP) \| 3 | 1800 \| LARGE T&R | Yes | SN | N/A for Pkg Type | -50 to 150 | LMT87 |
| LMT87LPG | Active | Production | TO-92 (LPG) \| 3 | 1000 \| BULK | Yes | SN | N/A for Pkg Type | -50 to 150 | LMT87 |
| LMT87LPG.A | Active | Production | TO-92 (LPG) \| 3 | 1000 \| BULK | Yes | SN | N/A for Pkg Type | -50 to 150 | LMT87 |
| LMT87LPG.B | Active | Production | TO-92 (LPG) \| 3 | 1000 \| BULK | Yes | SN | N/A for Pkg Type | -50 to 150 | LMT87 |
| LMT87LPGM | Active | Production | TO-92 (LPG) \| 3 | 3000 \| AMMO | Yes | SN | N/A for Pkg Type | -50 to 150 | LMT87 |
| LMT87LPGM.A | Active | Production | TO-92 (LPG) \| 3 | 3000 \| AMMO | Yes | SN | N/A for Pkg Type | -50 to 150 | LMT87 |
| LMT87LPGM.B | Active | Production | TO-92 (LPG) \| 3 | 3000 \| AMMO | Yes | SN | N/A for Pkg Type | -50 to 150 | LMT87 |
| LMT87LPM | Active | Production | TO-92 (LP) \| 3 | 2000 \| LARGE T&R | Yes | SN | N/A for Pkg Type | -50 to 150 | LMT87 |
| LMT87LPM.A | Active | Production | TO-92 (LP) \| 3 | 2000 \| LARGE T&R | Yes | SN | N/A for Pkg Type | -50 to 150 | LMT87 |
| LMT87LPM.B | Active | Production | TO-92 (LP) \| 3 | 2000 \| LARGE T&R | Yes | SN | N/A for Pkg Type | -50 to 150 | LMT87 |

(1) **Status:** For more details on status, see our product life cycle.

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

(3) **RoHS values:** Yes, No, RoHS Exempt. See the TI RoHS Statement for additional information and value definition.

(4) **Lead finish/Ball material:** Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

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

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

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

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**OTHER QUALIFIED VERSIONS OF LMT87 :**

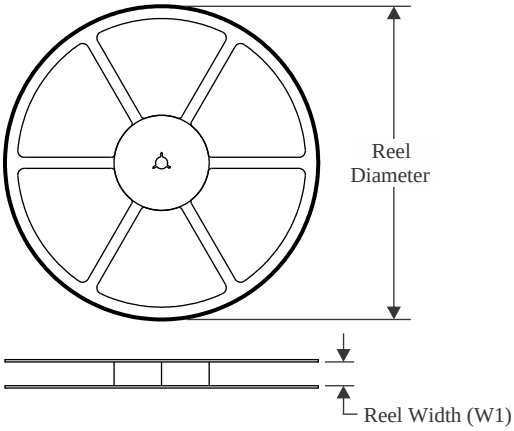
- Automotive : LMT87-Q1

NOTE: Qualified Version Definitions:

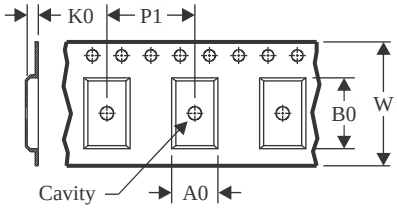
- Automotive - Q100 devices qualified for high-reliability automotive applications targeting zero defects

## TAPE AND REEL INFORMATION

**REEL DIMENSIONS**

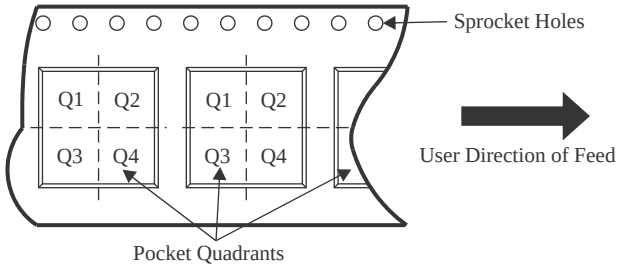



**TAPE DIMENSIONS**




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

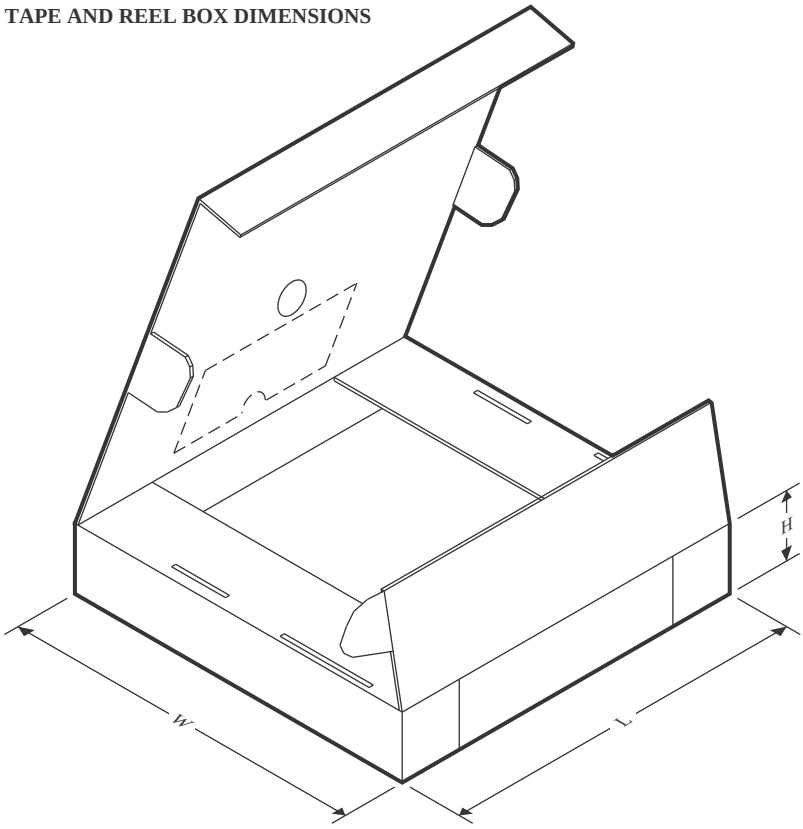
**QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE**




*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LMT87DCKR | SC70 | DCK | 5 | 3000 | 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) |
|---|---|---|---|---|---|---|---|
| LMT87DCKR | SC70 | DCK | 5 | 3000 | 208.0 | 191.0 | 35.0 |

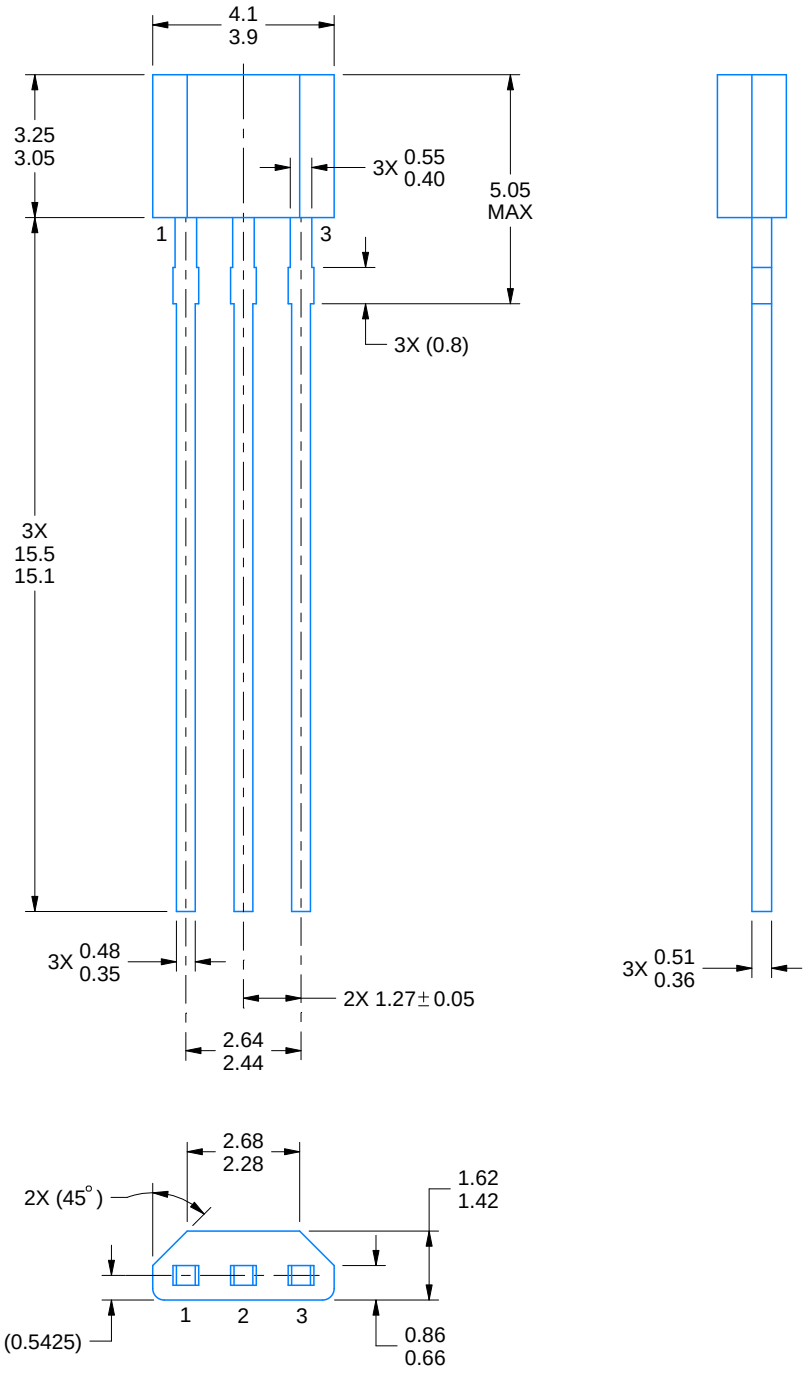


# PACKAGE OUTLINE

## LPG0003A

## TO-92 - 5.05 mm max height

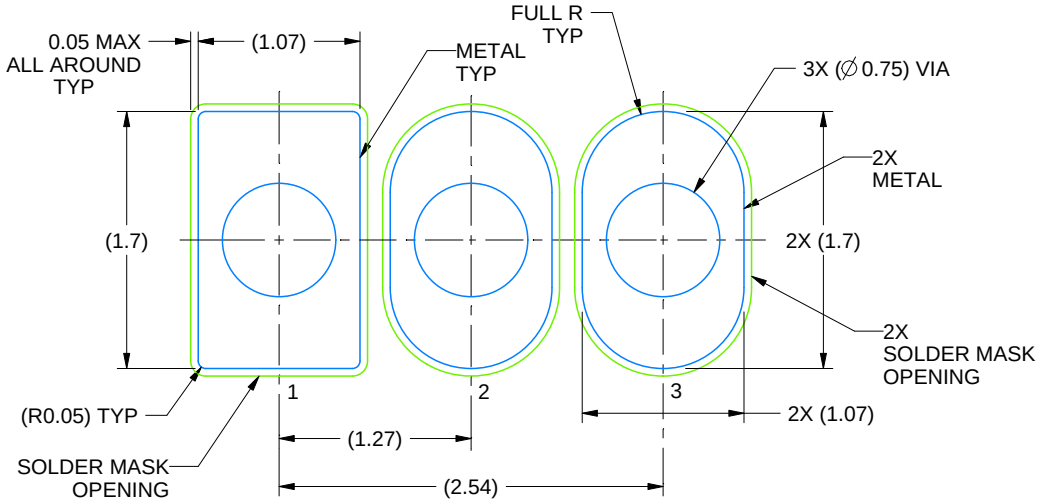
TRANSISTOR OUTLINE




4221343/C 01/2018

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.




LAND PATTERN EXAMPLE
NON-SOLDER MASK DEFINED
SCALE:20X

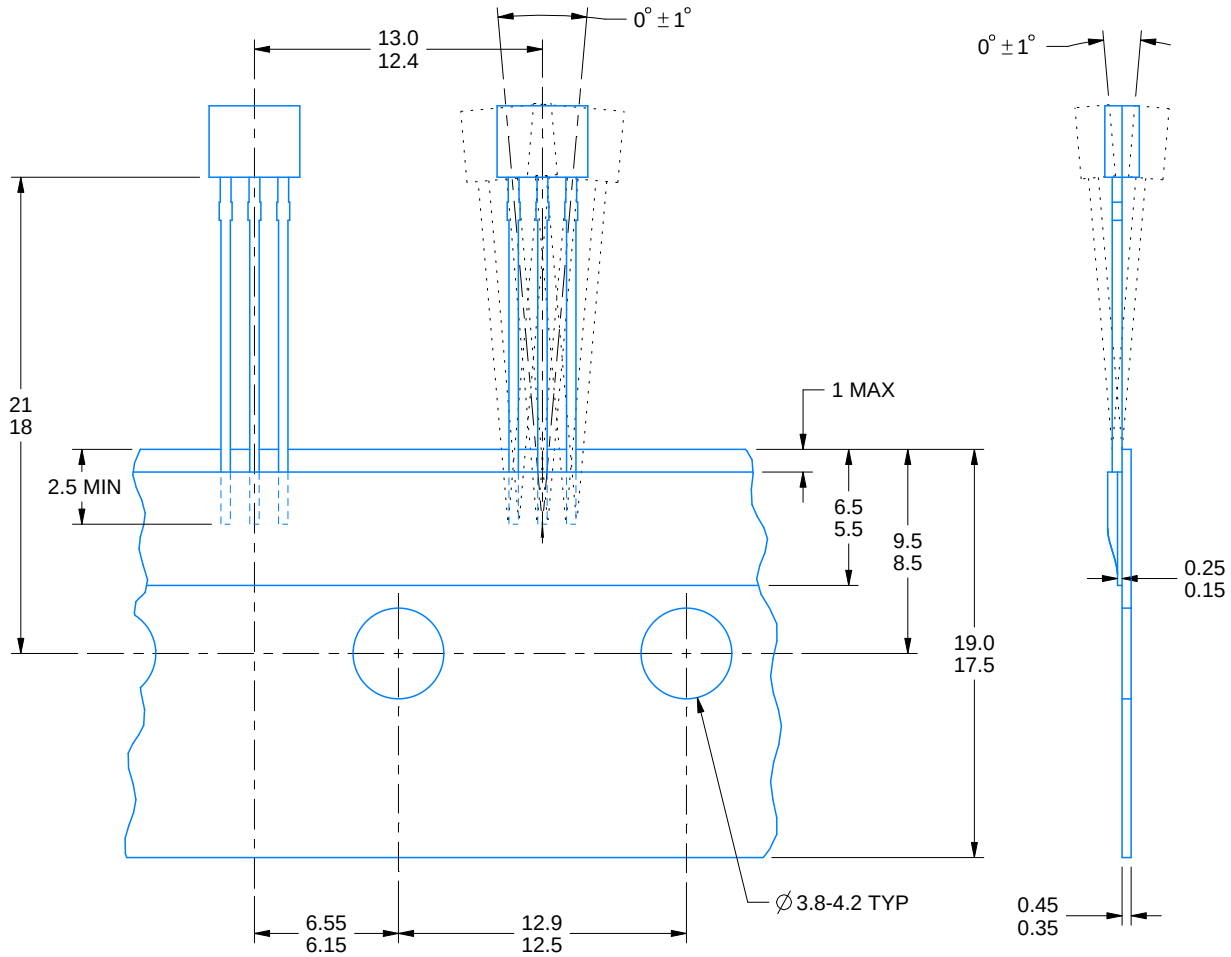
4221343/C 01/2018

# TAPE SPECIFICATIONS

## LPG0003A

## TO-92 - 5.05 mm max height

TRANSISTOR OUTLINE



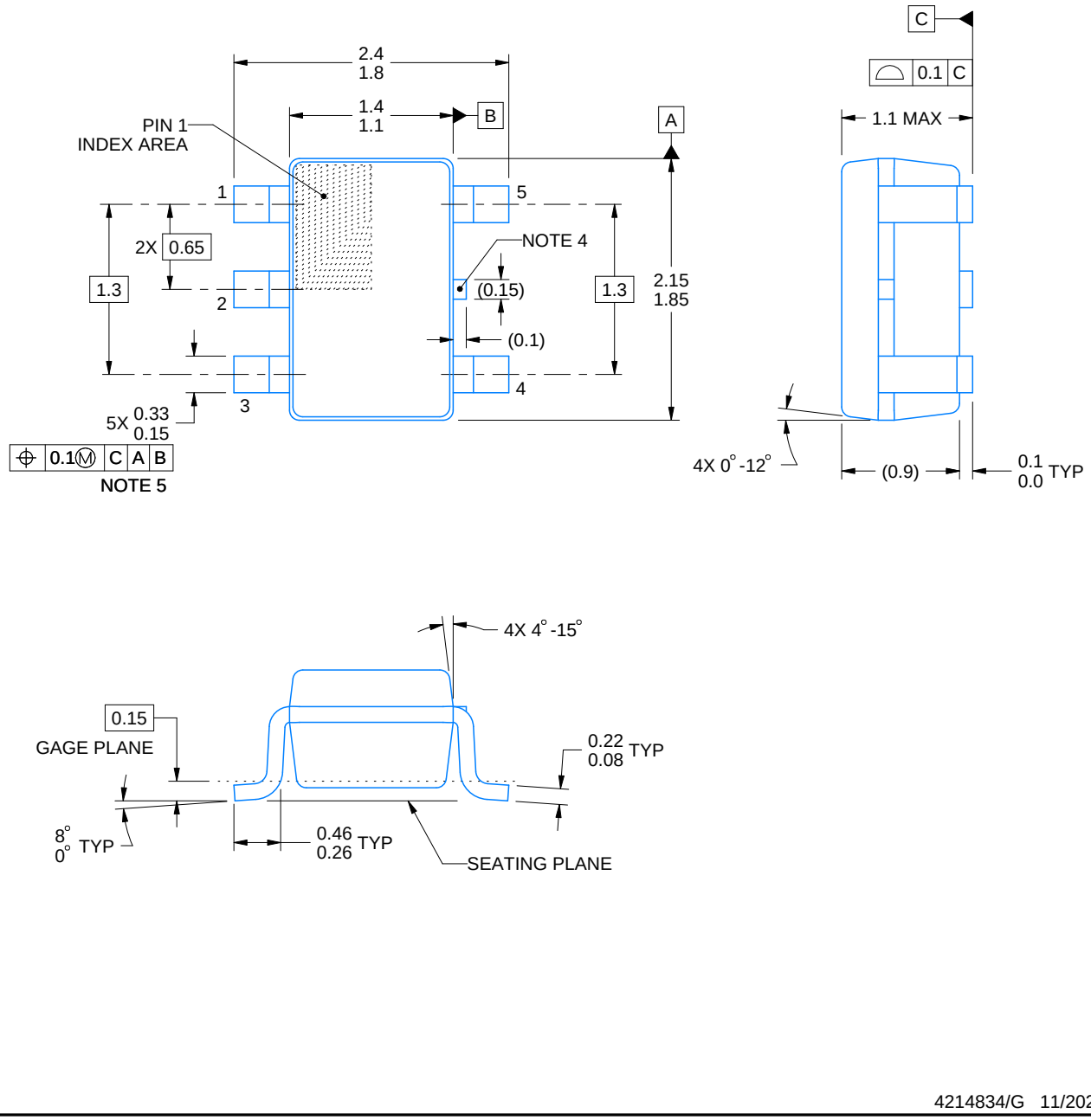

4221343/C 01/2018

# PACKAGE OUTLINE

## DCK0005A

## SOT - 1.1 max height

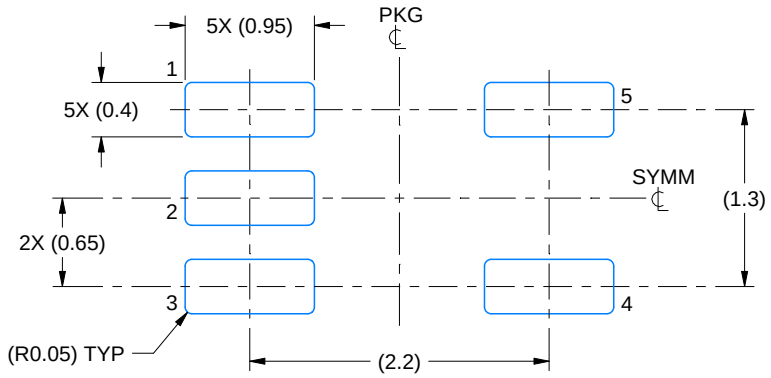
SMALL OUTLINE TRANSISTOR



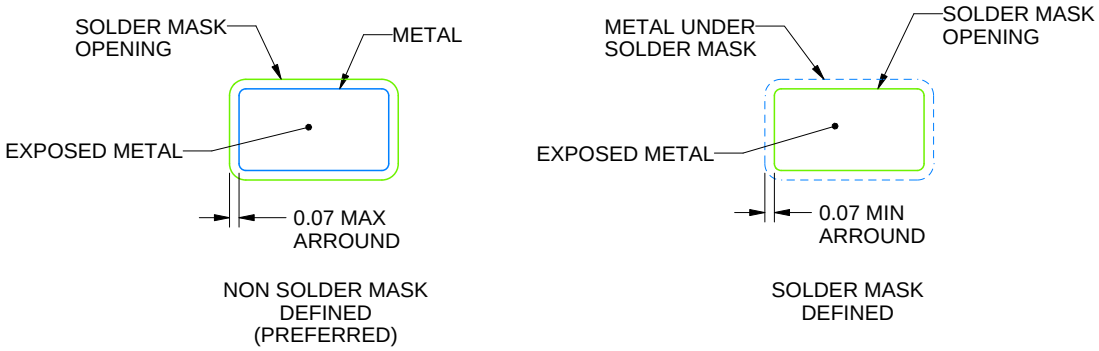

4214834/G 11/2024

NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. Refernce 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




LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:18X

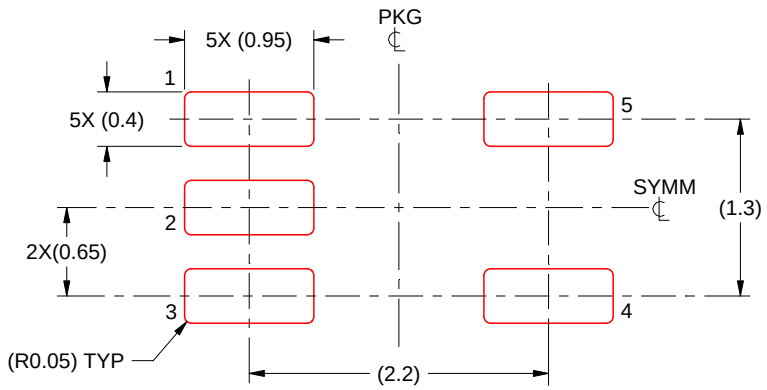



SOLDER MASK DETAILS

4214834/G 11/2024

NOTES: (continued)

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




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

4214834/G 11/2024

NOTES: (continued)

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

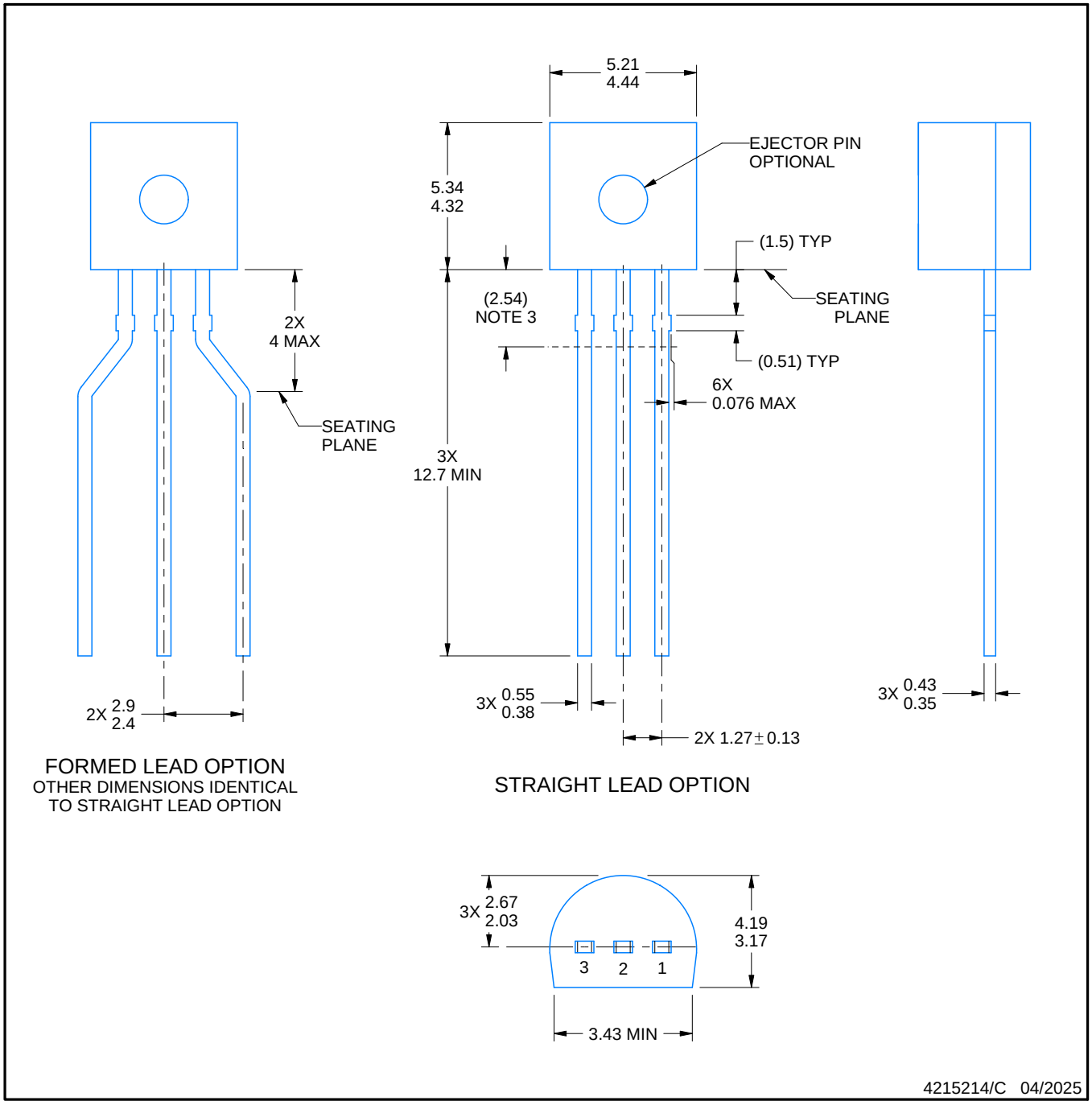
# LP0003A



## PACKAGE OUTLINE

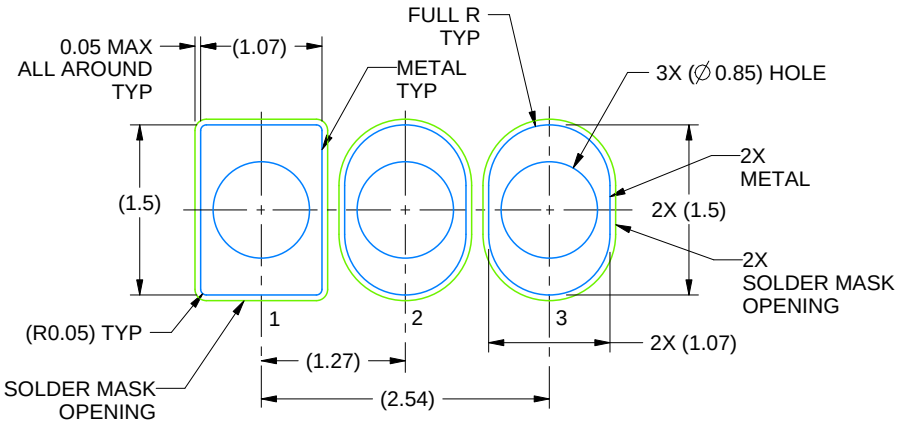
### TO-92 - 5.34 mm max height

TO-92

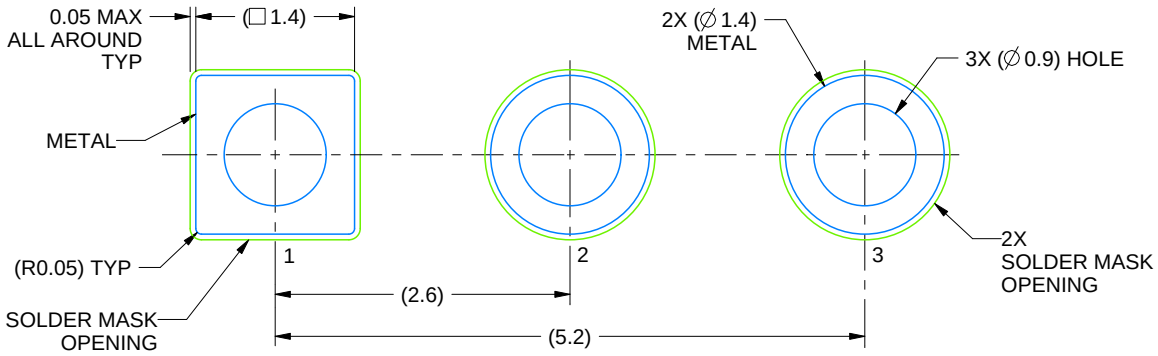



NOTES:

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. Lead dimensions are not controlled within this area.
4. Reference JEDEC TO-226, variation AA.
5. Shipping method:
   a. Straight lead option available in bulk pack only.
   b. Formed lead option available in tape and reel or ammo pack.
   c. Specific products can be offered in limited combinations of shipping medium and lead options.
   d. Consult product folder for more information on available options.




LAND PATTERN EXAMPLE
STRAIGHT LEAD OPTION
NON-SOLDER MASK DEFINED
SCALE:15X



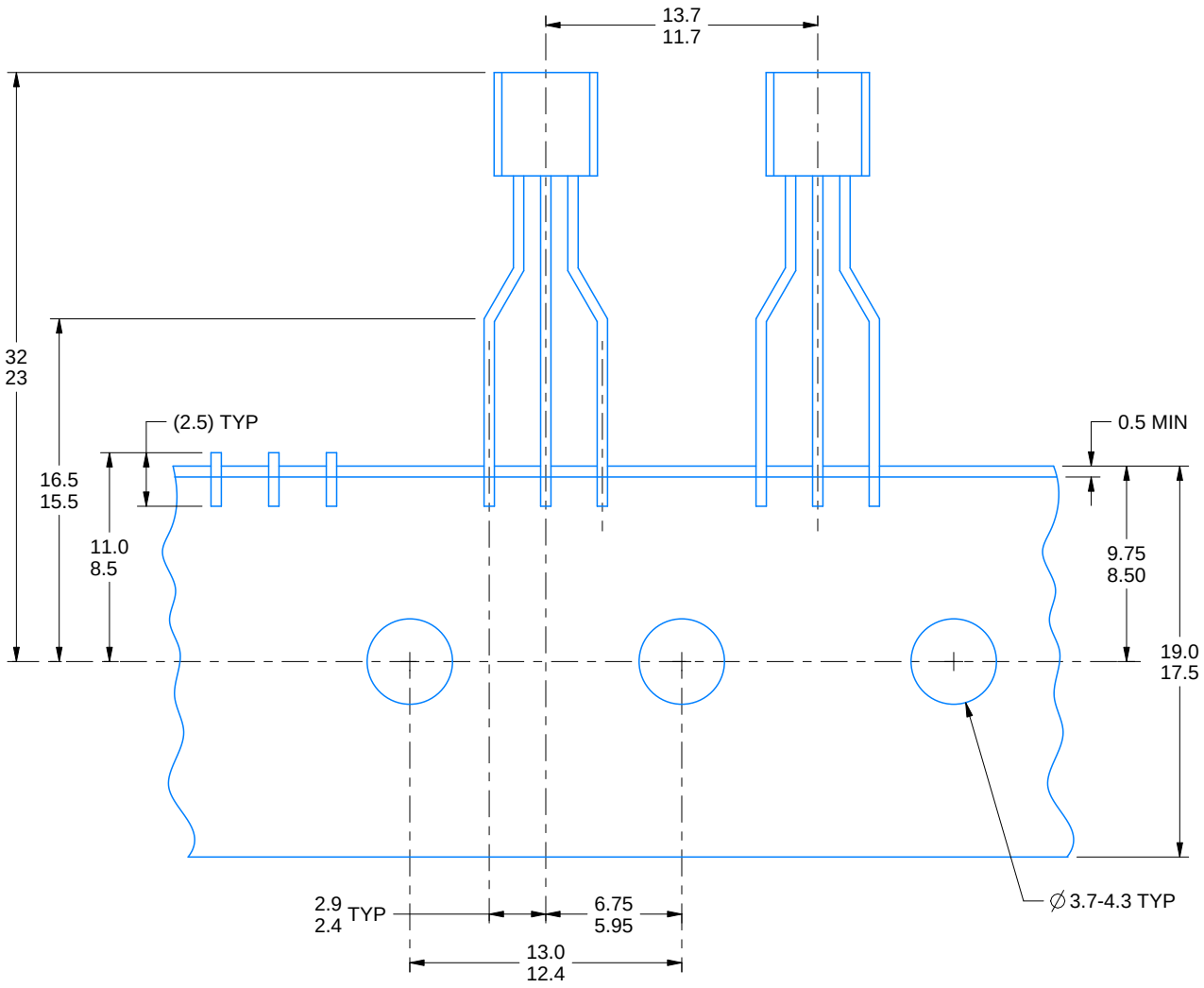

LAND PATTERN EXAMPLE
FORMED LEAD OPTION
NON-SOLDER MASK DEFINED
SCALE:15X

4215214/C 04/2025

# LP0003A

## TO-92 - 5.34 mm max height

TO-92




FOR FORMED LEAD OPTION PACKAGE

4215214/C 04/2025

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