



LMT87

SNIS170E - JANUARY 2014-REVISED OCTOBER 2017

# LMT87 2.7-V, SC70/TO-92/TO-92S, Analog Temperature Sensors With Class-AB Output

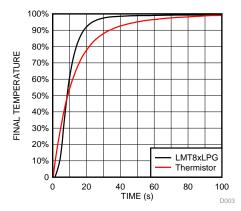
#### 1 Features

- LMT87LPG (TO-92S package) has a Fast Thermal Time Constant, 10-s Typical (1.2 m/s Airflow)
- Very Accurate: ±0.4°C Typical
- Low 2.7-V Operation
- Average Sensor Gain of -13.6 mV/°C
- Low 5.4-µA Quiescent Current
- Wide Temperature Range: -50°C to 150°C
- · 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
- Infotainment and Cluster
- Powertrain Systems
- Smoke and Heat Detectors
- Drones
- Appliances

#### Thermal Time Constant



<sup>\*</sup> Fast thermal response NTC

## 3 Description

The LMT87 device is a precision CMOS temperature sensor with  $\pm 0.4^{\circ}\text{C}$  typical accuracy ( $\pm 2.7^{\circ}\text{C}$  maximum) and a linear analog output voltage that is inversely proportional to temperature. The 2.7-V supply voltage operation, 5.4- $\mu$ A quiescent current, and 0.7-ms power-on time enable effective power-cycling architectures to minimize power consumption for battery-powered applications such as drones and sensor nodes. The LMT87LPG through-hole TO-92S package fast thermal time constant supports off-board time-temperature sensitive applications such as smoke and heat detectors. The accuracy over the wide operating range and other features make the LMT87 an excellent alternative to thermistors.

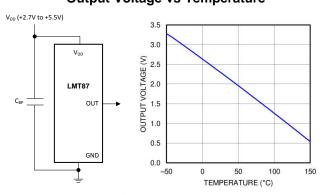
For devices with different average sensor gains and comparable accuracy, refer to *Comparable Alternative Devices* for alternative devices in the LMT8x family.

## Device Information<sup>(1)</sup>

PART NUMBER PACKAGE		BODY SIZE (NOM)
LMT87	SOT (5)	2.00 mm × 1.25 mm
	TO-92 (3)	4.30 mm × 3.50 mm
	TO-92S (3)	4.00 mm × 3.15 mm

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

## **Output Voltage vs Temperature**



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## 4 Revision History

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

C	hanges from Revision D (June 2017) to Revision E	Page
•	Moved the automotive device to a standalone data sheet (SNIS202)	1
•	Changed TO-92 GND pin number from: 1 to: 3	4
•	Changed TO-92 V <sub>DD</sub> pin number from: 3 to: 1	4
C	hanges from Revision C (October 2015) to Revision D	Page
•	Updated data sheet text to the latest documentation and translations standards	1
•	Added AEC-Q100 automotive qualification bullets to Features	1
•	Added Time Constant graph	1
•	Removed disk drivers, games, wireless transceivers, and cell phones from Applications	1
•	Added LPG (TO-92S) package	4
<u>•</u>	Added Figure 10 to Typical Characteristics	7
C	hanges from Revision B (May 2014) to Revision C	Page
•	Deleted all mentions of TO-126 package	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

## Changes from Revision A (June 2013) to Revision B

**Page** 

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•	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	6

## 5 Device Comparison Tables

## **Table 1. Available Device Packages**

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

<sup>(1)</sup> For all available packages and complete order numbers, see the Package Option addendum at the end of the data sheet.

## **Table 2. Comparable Alternative Devices**

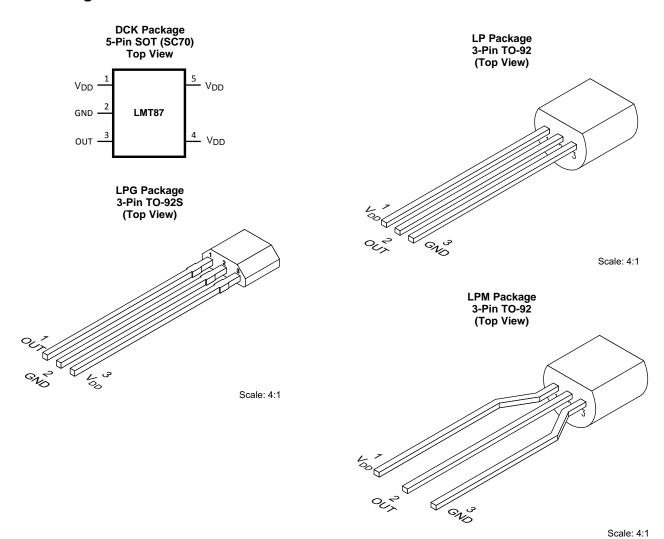
DEVICE NAME	AVERAGE OUTPUT SENSOR GAIN	POWER SUPPLY RANGE
LMT84	−5.5 mV/°C	1.5 V to 5.5 V
LMT85	−8.2 mV/°C	1.8 V to 5.5 V
LMT86	−10.9 mV/°C	2.2 V to 5.5 V
LMT87	−13.6 mV/°C	2.7 V to 5.5 V

Product Folder Links: LMT87

<sup>(2)</sup> AKA = Also Known As

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## 6 Pin Configuration and Functions



## **Pin Functions**

	PI	N		TYPE	DESCRIPTION	
NAME	SOT (SC70)	TO-92	TO-92S	ITPE	EQUIVALENT CIRCUIT	FUNCTION
GND	2 <sup>(1)</sup>	3	2	Ground	N/A	Power Supply Ground
OUT	3	2	1	Analog Output	V <sub>DD</sub> GND	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



## 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 <sup>(3)</sup>	<b>-</b> 5	5	mA
Maximum junction temperature (T <sub>JMAX</sub> )		150	°C
Storage temperature T <sub>stg</sub>	-65	150	°C

<sup>(1)</sup> 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.

## 7.2 ESD Ratings

			VALUE	UNIT			
LMT87L	LMT87LP in TO-92 package						
V	Electrostatic	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 (1)(2)	±2500	V			
V <sub>(ESD)</sub>	discharge	Charged-device model (CDM), per JEDEC specification JESD22-C101 (3)	±1000	V			
LMT87D	LMT87DCK in SC70 package						
V	Electrostatic	Human-body model (HBM), per JESD22-A114 <sup>(2)</sup>	±2500	\ <u>/</u>			
V <sub>(ESD)</sub>	discharge	Charged-device model (CDM), per JEDEC specification JESD22-C101 <sup>(3)</sup>	±1000	V			

<sup>(1)</sup> 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-k $\Omega$  resistor into each pin.

## 7.3 Recommended Operating Conditions

	MIN	MAX	UNIT
Specified temperature	$T_{MIN} \le T_A \le T_{MAX}$		°C
Specified temperature	-50 ≤ T <sub>A</sub> ≤ 150		°C
Supply voltage (V <sub>DD</sub> )	2.7	5.5	V

## 7.4 Thermal Information (1)

THERMAL METRIC <sup>(2)</sup>		LMT87	LMT87LP	LMT87LPG	
		DCK (SOT/SC70)	LP/LPM (TO-92)	LPG (TO-92S)	UNIT
		5 PINS	3 PINS	3 PINS	
$R_{\theta JA}$	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
ΨЈТ	Junction-to-top characterization parameter	1.2	35	14.6	°C/W
ΨЈВ	Junction-to-board characterization parameter	55	146	106.2	°C/W

<sup>1)</sup> 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.

(4) Changes in output due to self-heating can be computed by multiplying the internal dissipation by the thermal resistance.

Product Folder Links: LMT87

<sup>3)</sup> When the input voltage  $(V_1)$  at any pin exceeds power supplies  $(V_1 < GND \text{ or } V_1 > V)$ , the current at that pin should be limited to 5 mA.

<sup>(3)</sup> JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

<sup>(3)</sup> The junction to ambient thermal resistance (R<sub>0,JA</sub>) 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.



## 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 <sup>(1)</sup>	TYP	MAX <sup>(1)</sup>	UNIT
	70°C to 150°C; V <sub>DD</sub> = 3.0 V to 5.5 V	-2.7	±0.4	2.7	°C
	20°C to 40°C; V <sub>DD</sub> = 2.7 V to 5.5 V		±0.6		°C
	20°C to 40°C; V <sub>DD</sub> = 3.4 V to 5.5 V		±0.3		ů
Temperature accuracy (2)	0°C; V <sub>DD</sub> = 3.0 V to 5.5 V	-2.7	±0.6	2.7	ů
	0°C; V <sub>DD</sub> = 3.6 V to 5.5 V		±0.3		ů
	-50°C; V <sub>DD</sub> = 3.6 V to 5.5 V	-2.7	±0.6	2.7	ů
	$-50$ °C; $V_{DD} = 4.2 \text{ V to } 5.5 \text{ V}$		±0.3		°C

<sup>(1)</sup> Limits are specific to TI's AOQL (Average Outgoing Quality Level).

#### 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  $T_A=T_J=25^{\circ}C$ .

	PARAMETER	TEST CONDITIONS	MIN <sup>(1)</sup>	TYP (2)	MAX <sup>(1)</sup>	UNIT
	Sensor gain (output transfer function slope)			-13.6		mV/°C
	Load regulation (3)	Source ≤ 50 $\mu$ A, (V <sub>DD</sub> – V <sub>OUT</sub> ) ≥ 200 mV	-1	-0.22		mV
	Load regulation (*)	Sink ≤ 50 μA, V <sub>OUT</sub> ≥ 200 mV		0.26	1	mV
	Line regulation (4)			200		$\mu V/V$
	Cumply aurent	$T_A = 30^{\circ}C \text{ to } 150^{\circ}C, (V_{DD} - V_{OUT}) \ge 100 \text{ mV}$		5.4	8.1	μΑ
IS	Supply current	$T_A = -50$ °C to 150°C, $(V_{DD} - V_{OUT}) \ge 100 \text{ mV}$		5.4	9	μΑ
$C_L$	Output load capacitance			1100		pF
	Power-on time <sup>(5)</sup>	C <sub>L</sub> = 0 pF to 1100 pF		0.7	1.9	ms
	Output drive	$T_A = T_J = 25$ °C	-50		50	μΑ

<sup>(1)</sup> Limits are specific to TI's AOQL (Average Outgoing Quality Level).

(5) Specified by design and characterization.

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<sup>(2)</sup> 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.

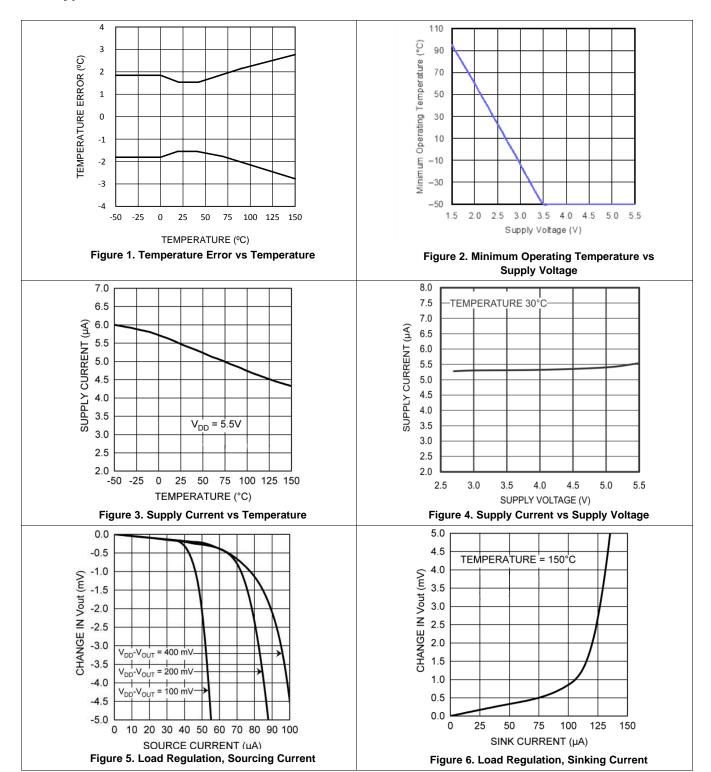
<sup>(2)</sup> Typicals are at  $T_J = T_A = 25^{\circ}$ C and represent most likely parametric norm.

<sup>(3)</sup> Source currents are flowing out of the LMT87. Sink currents are flowing into the LMT87.

<sup>(4)</sup> 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.

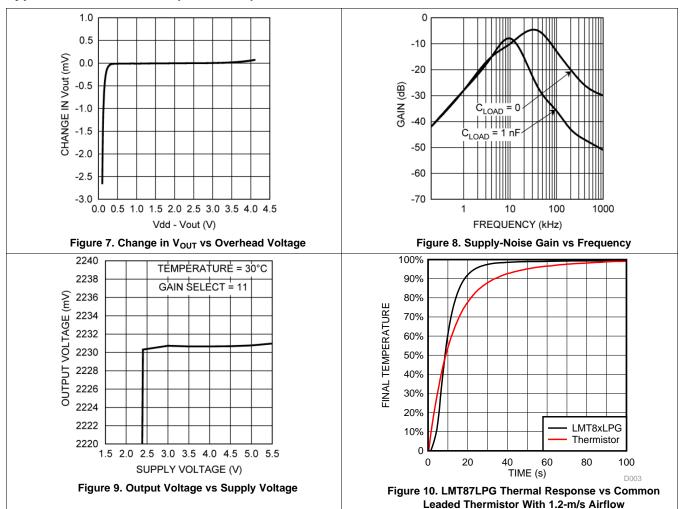


## 7.7 Typical Characteristics





## **Typical Characteristics (continued)**



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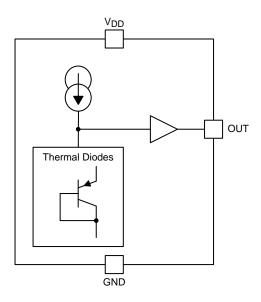
## 8 Detailed Description

#### 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 <sub>OUT</sub> (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

Product Folder Links: LMT87



## Feature Description (continued)

Table 3. LMT87 Transfer Table (continued)

CCD         VOLY         CCD         VOLY         CCD         VOLY         CCD         VOLY         CCD         COLY	TEMP	V	TEMP	V	TEMP		TEMP		TEMP	V
-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         1995         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 <td< th=""><th></th><th>V<sub>OUT</sub> (mV)</th><th></th><th>V<sub>OUT</sub> (mV)</th><th></th><th>V<sub>OUT</sub> (mV)</th><th></th><th>V<sub>OUT</sub> (mV)</th><th></th><th>V<sub>OUT</sub> (mV)</th></td<>		V <sub>OUT</sub> (mV)								
-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 <t< td=""><td>-37</td><td>3121</td><td>3</td><td>2593</td><td>43</td><td>2054</td><td>83</td><td>1497</td><td>123</td><td>929</td></t<>	-37	3121	3	2593	43	2054	83	1497	123	929
-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         <	-36	3108	4	2580	44	2040	84	1483	124	915
-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	-35	3095	5	2567	45	2026	85	1469	125	901
-32         3066         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	-34	3082	6	2553	46	2012	86	1455	126	886
-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	-33	3069	7	2540	47	1999	87	1441	127	872
-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	-32	3056	8	2527	48	1985	88	1427	128	858
-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	-31	3043	9	2513	49	1971	89	1413	129	843
-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	-30	3030	10	2500	50	1958	90	1399	130	829
-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	-29	3017	11	2486	51	1944	91	1385	131	814
-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	-28	3004	12	2473	52	1930	92	1371	132	800
-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	-27	2991	13	2459	53	1916	93	1356	133	786
-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	-26	2978	14	2446	54	1902	94	1342	134	771
-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	-25	2965	15	2433	55	1888	95	1328	135	757
-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 <td>-24</td> <td>2952</td> <td>16</td> <td>2419</td> <td>56</td> <td>1875</td> <td>96</td> <td>1314</td> <td>136</td> <td>742</td>	-24	2952	16	2419	56	1875	96	1314	136	742
-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 <td>-23</td> <td>2938</td> <td>17</td> <td>2406</td> <td>57</td> <td>1861</td> <td>97</td> <td>1300</td> <td>137</td> <td>728</td>	-23	2938	17	2406	57	1861	97	1300	137	728
-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 </td <td>-22</td> <td>2925</td> <td>18</td> <td>2392</td> <td>58</td> <td>1847</td> <td>98</td> <td>1286</td> <td>138</td> <td>713</td>	-22	2925	18	2392	58	1847	98	1286	138	713
-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 </td <td>-21</td> <td>2912</td> <td>19</td> <td>2379</td> <td>59</td> <td>1833</td> <td>99</td> <td>1272</td> <td>139</td> <td>699</td>	-21	2912	19	2379	59	1833	99	1272	139	699
-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	-20	2899	20	2365	60	1819	100	1257	140	684
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-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	-18	2873	22	2338	62	1791	102	1229	142	655
-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	-17	2859	23	2325	63	1777	103	1215	143	640
-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	-16	2846	24	2311	64	1763	104	1201	144	626
-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	-15	2833	25	2298	65	1749	105	1186	145	611
-12     2793     28     2258     68     1707     108     1144     148     568       -11     2780     29     2244     69     1693     109     1130     149     553	-14	2820	26	2285	66	1735	106	1172	146	597
-11     2780     29     2244     69     1693     109     1130     149     553	-13	2807	27	2271	67	1721	107	1158	147	582
	-12	2793	28	2258	68	1707	108	1144	148	568
150 538	-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).

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

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



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:

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

$$V - 2365 \text{ mV} = (-13.6 \text{ mV} / {}^{\circ}\text{C}) \times (\text{T} - 20 {}^{\circ}\text{C})$$
 (5)

$$V = (-13.6 \text{ mV} / {}^{\circ}\text{C}) \times \text{T} + 2637 \text{ mV}$$
 (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  $V_{\rm DD}$ , 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:

$$T_J = T_A + \theta_{JA} \lceil (V_{DD}I_S) + (V_{DD} - V_{OUT}) I_L \rceil$$

#### where

- T<sub>A</sub> is the ambient temperature,
- Is is the supply current,
- ILis the load current on the output,
- and V<sub>O</sub> is the output voltage.

For example, in an application where  $T_A = 30^{\circ}\text{C}$ ,  $V_{DD} = 5$  V,  $I_S = 5.4$   $\mu\text{A}$ ,  $V_{OUT} = 2231$  mV, and  $I_L = 2$   $\mu\text{A}$ , the junction temperature would be  $30.014^{\circ}\text{C}$ , showing a self-heating error of only  $0.014^{\circ}\text{C}$ . 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.



## **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.

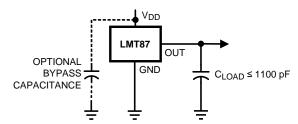


Figure 11. LMT87 No Decoupling Required for Capacitive Loads Less Than 1100 pF

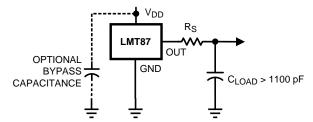


Figure 12. LMT87 with Series Resistor for Capacitive Loading Greater Than 1100 pF

**Table 4. Recommended Series Resistor Values** 

C <sub>LOAD</sub>	MINIMUM R <sub>s</sub>				
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.

Product Folder Links: LMT87



## 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

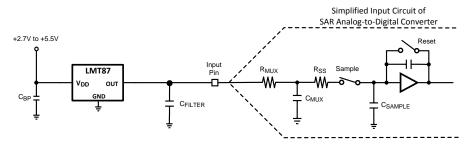


Figure 13. Suggested Connection to a Sampling Analog-to-Digital Converter Input Stage

## 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<sub>FILTER</sub>).

#### 9.2.1.2 Detailed Design Procedure

The size of  $C_{\text{FILTER}}$  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

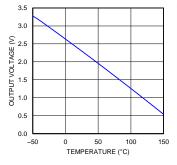


Figure 14. Analog Output Transfer Function

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## **Typical Applications (continued)**

#### 9.2.2 Conserving Power Dissipation With Shutdown

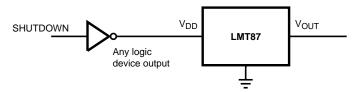


Figure 15. Simple Shutdown Connection of the LMT87

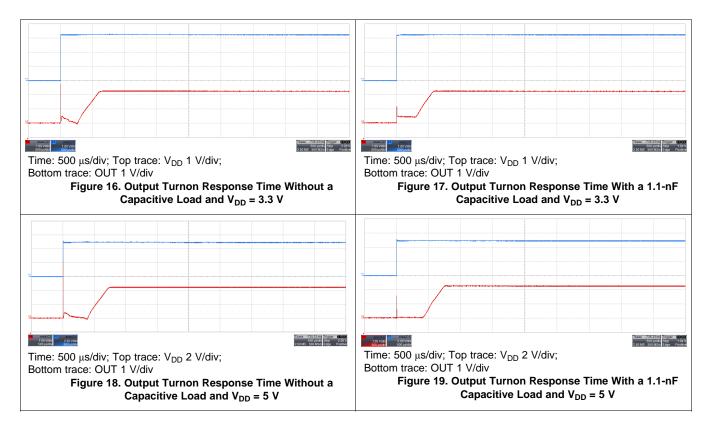
#### 9.2.2.1 Design Requirements

Because the power consumption of the LMT87 is less than  $9 \mu A$ , 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<sub>DD</sub> pin of the LMT87 directly to the logic shutdown signal from a microcontroller.

#### 9.2.2.3 Application Curves



## 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.

Product Folder Links: LMT87

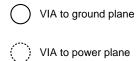


## 11 Layout

## 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



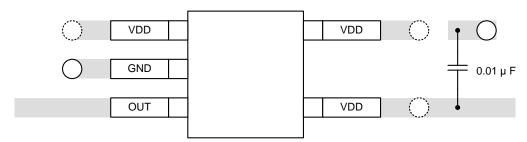


Figure 20. SC70 Package Recommended Layout

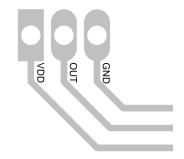


Figure 21. TO-92 LP Package Recommended Layout

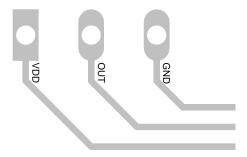


Figure 22. TO-92 LPM Package Recommended Layout

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## 12 Device and Documentation Support

## 12.1 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. In the upper right corner, click on *Alert me* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

## 12.2 Community Resources

The following links connect to TI community resources. Linked contents are provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

TI E2E™ Online Community *TI's Engineer-to-Engineer (E2E) Community.* Created to foster collaboration among engineers. At e2e.ti.com, you can ask questions, share knowledge, explore ideas and help solve problems with fellow engineers.

**Design Support** *TI's Design Support* Quickly find helpful E2E forums along with design support tools and contact information for technical support.

#### 12.3 Trademarks

E2E is a trademark of Texas Instruments.

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#### 12.4 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.

#### 12.5 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.

Product Folder Links: *LMT*87

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#### PACKAGING INFORMATION

Orderable part number	Status (1)	Material type	Package   Pins	Package qty   Carrier	RoHS (3)	Lead finish/ Ball material	MSL rating/ Peak reflow	Op temp (°C)	Part marking (6)
						(4)	(5)		
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
LMT87DCKT.B	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

<sup>(1)</sup> Status: For more details on status, see our product life cycle.

<sup>(2)</sup> 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.

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

<sup>(4)</sup> 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.

<sup>(5)</sup> 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.

## **PACKAGE OPTION ADDENDUM**

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(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

# **PACKAGE MATERIALS INFORMATION**

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## TAPE AND REEL INFORMATION





A0	Dimension designed to accommodate the component width
В0	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		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

# **PACKAGE MATERIALS INFORMATION**

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## \*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



TRANSISTOR OUTLINE



#### 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.



TRANSISTOR OUTLINE



TRANSISTOR OUTLINE





SMALL OUTLINE TRANSISTOR



#### NOTES:

- 1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
  2. This drawing is subject to change without notice.
  3. Reference JEDEC MO-203.

- 4. Support pin may differ or may not be present.5. Lead width does not comply with JEDEC.
- 6. Body dimensions do not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.25mm per side



SMALL OUTLINE TRANSISTOR



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.



SMALL OUTLINE TRANSISTOR



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.



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.



TO-92





TO-92





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