LMT90 SOT-23 Single-Supply Centigrade Temperature Sensor

1 Features

- Cost-Effective Alternative to Thermistors
- Calibrated Directly in Degree Celsius (Centigrade)
- Linear + 10.0 mV/°C Scale Factor
- ±3°C Accuracy Guaranteed at 25°C
- Specified for Full −40° to 125°C range
- Suitable for Remote Applications
- Operates from 4.5 V to 10 V
- Less than 130-µA Current Drain
- Low Self-heating, Less Than 0.2°C in Still Air
- Non-linearity Less Than 0.8°C Over Temp

2 Applications

- Industrial
- HVAC
- Disk Drives
- Automotive
- Portable Medical Instruments
- Computers
- Battery Management
- Printers
- Power Supply Modules
- FAX Machines

3 Description

The LMT90 device is a precision integrated-circuit temperature sensor that can sense a −40°C to +125°C temperature range using a single positive supply. The output voltage of LMT90 is linearly proportional to Celsius (Centigrade) temperature (10 mV/°C) and has a DC offset of 500 mV. The offset allows reading negative temperatures without the need for a negative supply. The ideal output voltage of the LMT90 ranges from 100 mV to 1.75 V for a −40°C to 125°C temperature range. The LMT90 does not require any external calibration or trimming to provide accuracies of ±3°C at room temperature and ±4°C over the full −40°C to +125°C temperature range. Trimming and calibration of the LMT90 at the wafer level assure low cost and high accuracy. The linear output, 500-mV offset, and factory calibration of LMT90 simplify circuitry required in a single-supply environment where reading negative temperatures is required. The LMT90's quiescent current is less than 130 µA, thus self-heating is limited to a very low 0.2°C in still air.

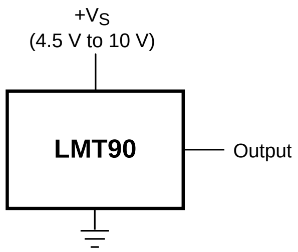
The LMT90 is a cost-competitive alternative to thermistors.

Device Information(1)

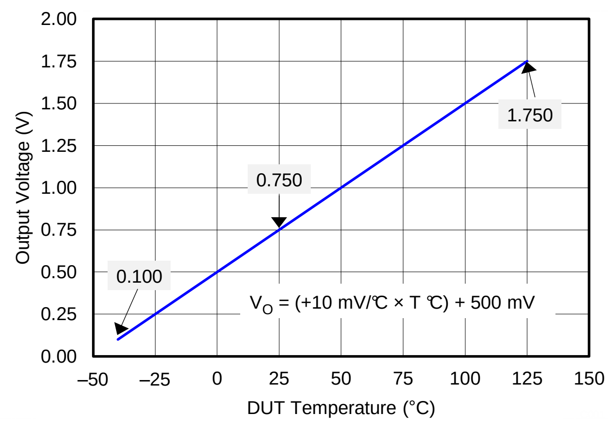
PART NUMBER	PACKAGE	BODY SIZE (NOM)
LMT90	SOT-23 (3)	2.92 mm × 1.30 mm

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

Simplified Schematic



Full-Range Centigrade Temperature Sensor (–40°C to +125°C)



An IMPORTANT NOTICE at the end of this data sheet addresses availability, warranty, changes, use in safety-critical applications, intellectual property matters and other important disclaimers. PRODUCTION DATA.

Table of Contents

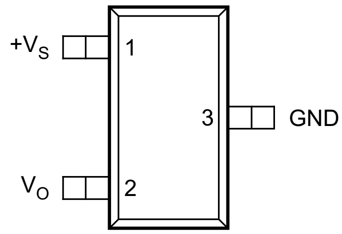
4 Revision History

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

Changes from Revision A (March 2013) to Revision B	Page
• Added *Pin Configuration and Functions* section, *ESD Ratings* table, *Feature Description* section, *Device Functional Modes*, *Application and Implementation* section, *Power Supply Recommendations* section, *Layout* section, *Device and Documentation Support* section, and *Mechanical, Packaging, and Orderable Information* section	1

5 Pin Configuration and Functions

DBZ Package
3-Pin SOT-23
Top View



Pin Functions

PIN		TYPE	DESCRIPTION
NO.	NAME		
1	$+V_S$	POWER	Positive power supply pin
2	V_O	OUTPUT	Temperature sensor analog output
3	GND	GND	Device ground pin, connected to power supply negative terminal

6 Specifications

6.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)(1)

	MIN	MAX	UNIT
Supply Voltage	–0.2	12	V
Output Voltage	−1	$(+V_S + 0.6)$	V
Output Current		10	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.

6.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human body model (HBM)(1)	2000	V
		Machine Model(1)	250	

(1) The human body model is a 100-pF capacitor discharged through a 1.5-kΩ resistor into each pin. Machine model is a 200-pF capacitor discharged directly into each pin.

6.3 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)(1)

	MIN	MAX	UNIT
LMT90 ($T_{MIN} \leq T_A \leq T_{MAX}$)	−40	125	°C
Operating Temperature Range (Device is functional but performance is not specified)	−40	150	°C
Supply Voltage Range ($+V_S$)	4.5	10	V

(1) Soldering process must comply with the Reflow Temperature Profile specifications. Reflow temperature profiles are different for lead-free and non-lead-free packages. Refer to www.ti.com/packaging.

6.4 Thermal Information

THERMAL METRIC[(1)]		LMT90 DBZ (SOT-23) 3 PINS	UNIT
$R_{\theta JA}$	Junction-to-ambient thermal resistance	450	°C/W

(1) For more information about traditional and new thermal metrics, see the *Semiconductor and IC Package Thermal Metrics* application report, SPRA953.

6.5 Electrical Characteristics

Unless otherwise noted, these specifications apply for V_S = 5 V_{DC} and I_{LOAD} = 0.5 µA, in the circuit of Figure 14. All limits T_A = T_J = 25°C, unless otherwise noted.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX[(1)]	UNIT
Accuracy[(2)]		–3		3	°C
	$T_A = T_{MAX}$	–4		4	°C
	$T_A = T_{MIN}$	–4		4	°C
Non-linearity[(3)]	$T_A = T_J = T_{MIN}$ to T_{MAX}	–0.8		0.8	°C
Sensor Gain (Average Slope)	$T_A = T_J = T_{MIN}$ to T_{MAX}	9.7		10.3	mV/°C
Output Resistance			2000		Ω
	$T_A = T_J = T_{MIN}$ to T_{MAX}			4000	Ω
Line Regulation[(4)]	4.5 V ≤ V_S ≤ 10 V	–0.8		0.8	mV/V
	$T_A = T_J = T_{MIN}$ to T_{MAX}	–1.2		1.2	mV/V
Quiescent Current[(5)]	4.5 V ≤ V_S ≤ 10 V			130	µA
	4.5 V ≤ V_S ≤ 10 V $T_A = T_J = T_{MIN}$ to T_{MAX}			180	µA
Change of Quiescent Current[(5)]	4.5 V ≤ V_S ≤ 10 V $T_A = T_J = T_{MIN}$ to T_{MAX}			2	µA
Temperature Coefficient of Quiescent Current	$T_A = T_J = T_{MIN}$ to T_{MAX}		2		µA/°C
Long Term Stability[(6)]	T_J = 125°C, for 1000 hours		±0.08		°C

(1) Limits are specific to TI's AOQL (Average Outgoing Quality Level).
(2) Accuracy is defined as the error between the output voltage and 10 mv/°C times the device's case temperature plus 500 mV, at specified conditions of voltage, current, and temperature (expressed in °C).
(3) Non-linearity is defined as the deviation of the output-voltage-versus-temperature curve from the best-fit straight line, over the device's rated temperature range.
(4) Regulation is measured at constant junction temperature, using pulse testing with a low duty cycle. Changes in output due to heating effects can be computed by multiplying the internal dissipation by the thermal resistance.
(5) Quiescent current is defined in the circuit of Figure 14.
(6) For best long-term stability, any precision circuit will give best results if the unit is aged at a warm temperature, and/or temperature cycled for at least 46 hours before long-term life test begins. This is especially true when a small (Surface-Mount) part is wave-soldered; allow time for stress relaxation to occur. The majority of the drift will occur in the first 1000 hours at elevated temperatures. The drift after 1000 hours will not continue at the first 1000 hour rate.

6.6 Typical Characteristics

To generate these curves the LMT90 was mounted to a printed circuit board as shown in Figure 19.

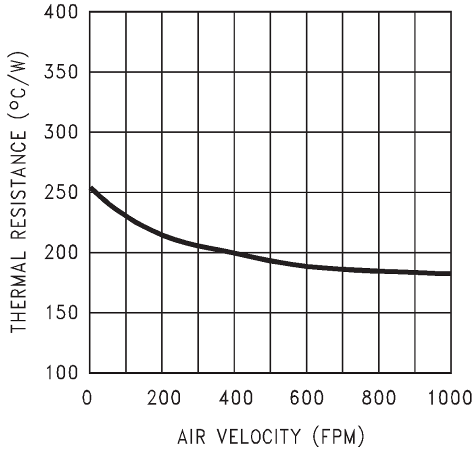


Figure 1. Thermal Resistance Junction to Air

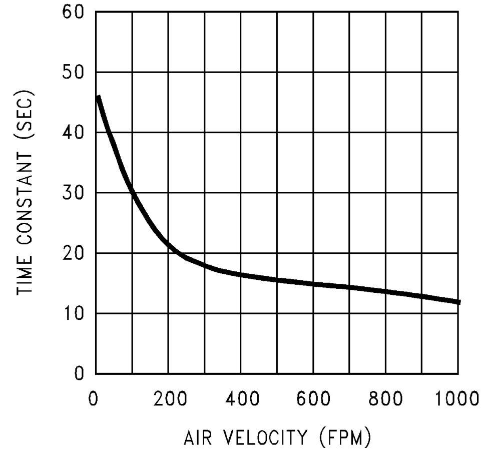


Figure 2. Thermal Time Constant

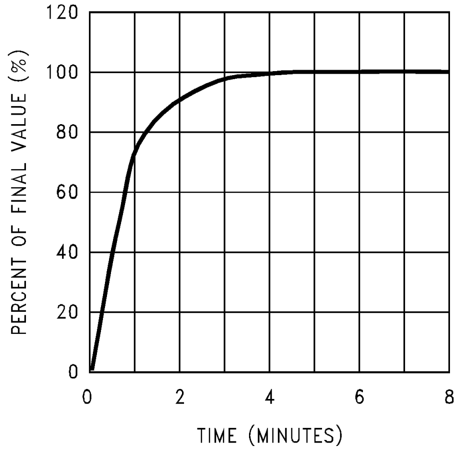


Figure 3. Thermal Response in Still Air With Heat Sink (Figure 19)

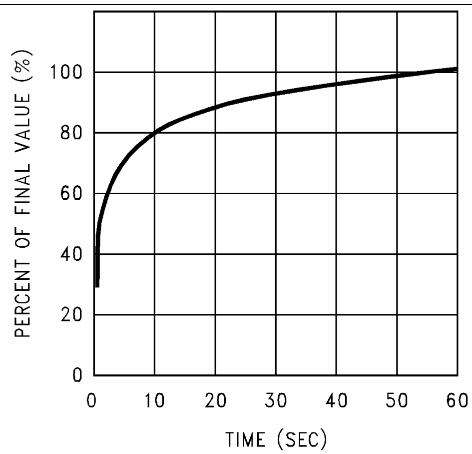


Figure 4. Thermal Response in Stirred Oil Bath With Heat Sink

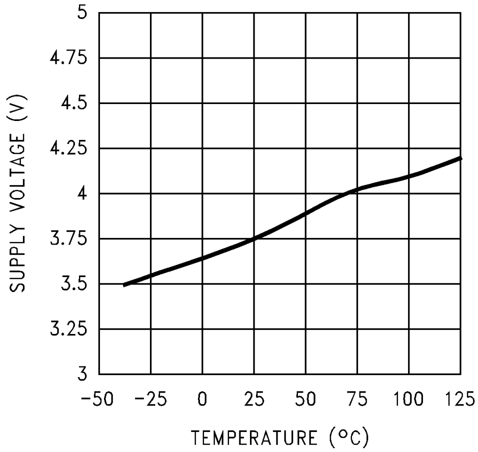


Figure 5. Startup Voltage vs Temperature

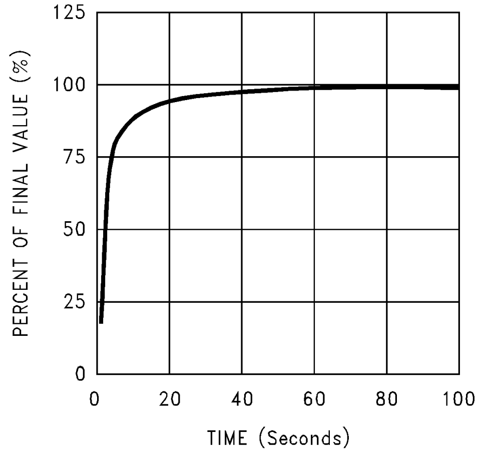


Figure 6. Thermal Response in Still Air Without a Heat Sink

Typical Characteristics (continued)

To generate these curves the LMT90 was mounted to a printed circuit board as shown in Figure 19.

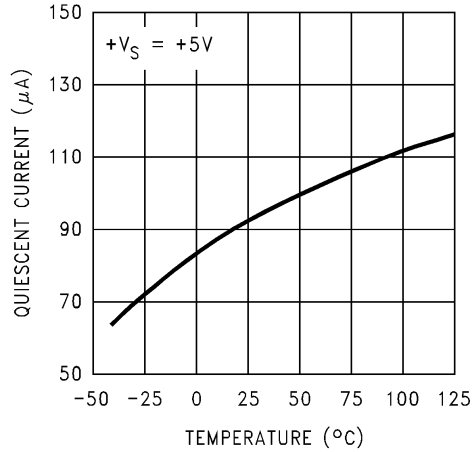


Figure 7. Quiescent Current vs Temperature (Figure 14)

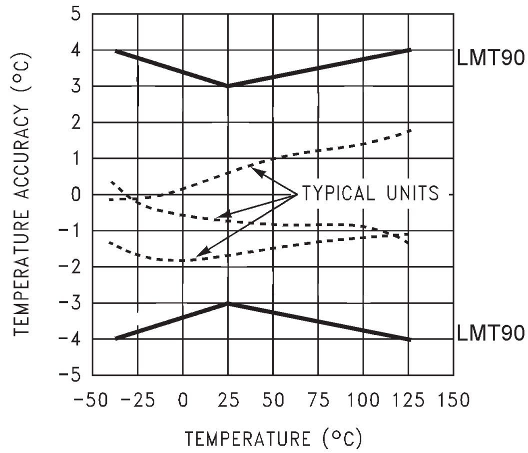


Figure 8. Accuracy vs Temperature

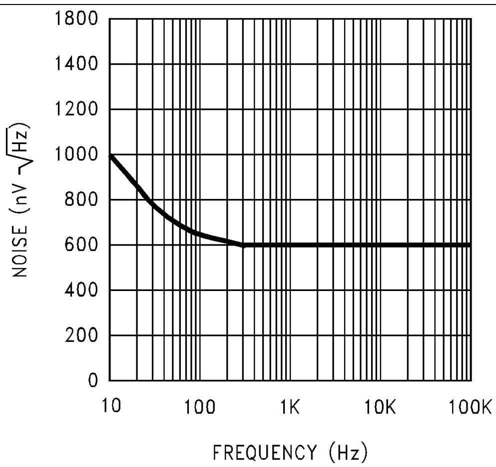


Figure 9. Noise Voltage

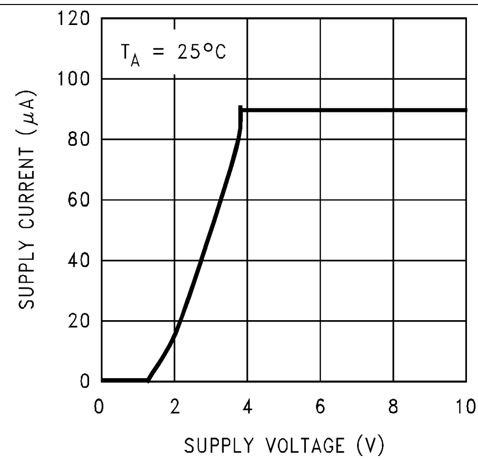


Figure 10. Supply Voltage vs Supply Current

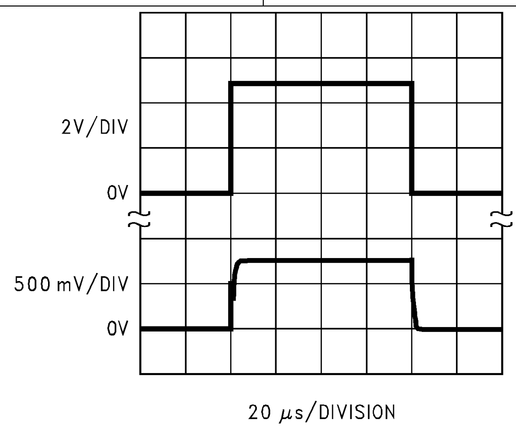


Figure 11. Start-Up Response

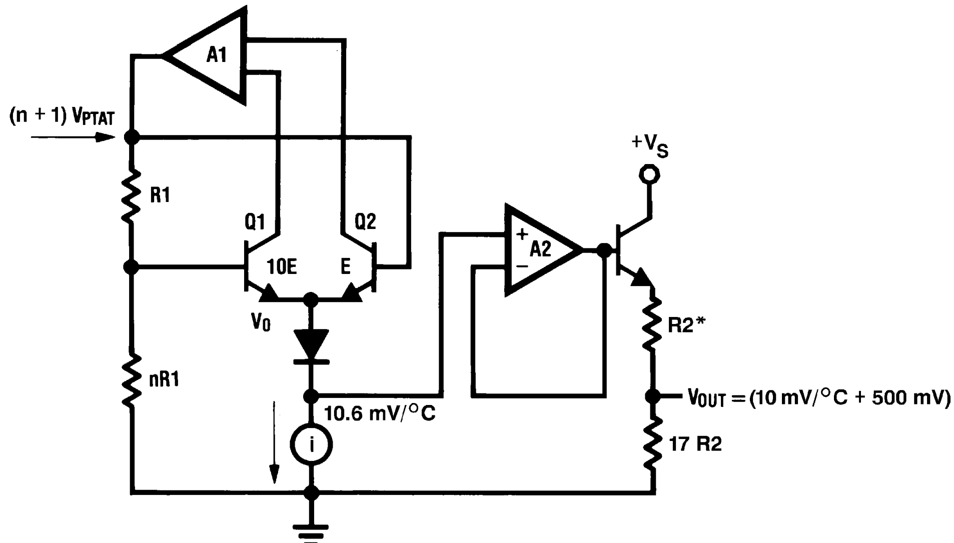
7 Detailed Description

7.1 Overview

The LMT90 is a precision integrated-circuit temperature sensor that can sense a −40°C to 125°C temperature range using a single positive supply. The output voltage of the LMT90 has a positive temperature slope of 10 mV/°C. A 500-mV offset is included enabling negative temperature sensing when biased by a single supply.

The temperature-sensing element is comprised of a delta-V_{BE} architecture. The temperature-sensing element is then buffered by an amplifier and provided to the V_O pin. The amplifier has a simple class A output stage with typical 2-kΩ output impedance as shown in the *Functional Block Diagram*. The output impedance has a temperature coefficient of approximately 1300 ppm/°C. Over temperature the output impedance will max out at 4 kΩ.

7.2 Functional Block Diagram



*R2 ≈ 2k With a typical 1300 ppm/°C Drift.

7.3 Feature Description

7.3.1 LMT90 Transfer Function

The LM60 follows a simple linear transfer function in order to achieve the accuracy as listed in *Electrical Characteristics*:

$$V_{OUT} = 10\ mV/°C \times T\ °C + 500\ mV$$

where

- T is the temperature in °C
- V_{OUT} is the LMT90 output voltage (1)

7.4 Device Functional Modes

The LMT90's only functional mode is that it has an analog output directly proportional to temperature.

8 Application and Implementation

NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

8.1 Application Information

The LMT90 has a wide supply range and a 10 mV/°C output slope with a 500-mV DC offset at 25 °C. Therefore, it can easily be applied in many temperature-sensing applications where a single supply is required for positive and negative temperatures.

8.1.1 Capacitive Loads

The LMT90 handles capacitive loading very well. Without any special precautions, the LMT90 can drive any capacitive load. The LMT90 has a nominal 2-kΩ output impedance (as can be seen in the *Functional Block Diagram*). The temperature coefficient of the output resistors is around 1300 ppm/°C. Taking into account this temperature coefficient and the initial tolerance of the resistors the output impedance of the LMT90 will not exceed 4 kΩ. In an extremely noisy environment it may be necessary to add some filtering to minimize noise pickup. TI recommends that 0.1 µF be added from V_{IN} to GND to bypass the power supply voltage, as shown in Figure 13. In a noisy environment, it may be necessary to add a capacitor from the output to ground. A 1-µF output capacitor with the 4-kΩ output impedance will form a 40-Hz lowpass filter. Because the thermal time constant of the LMT90 is much slower than the 25-ms time constant formed by the RC, the overall response time of the LMT90 will not be significantly affected. For much larger capacitors this additional time lag will increase the overall response time of the LMT90.

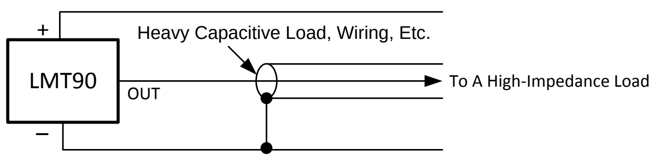


Figure 12. LMT90 No Decoupling Required for Capacitive Load

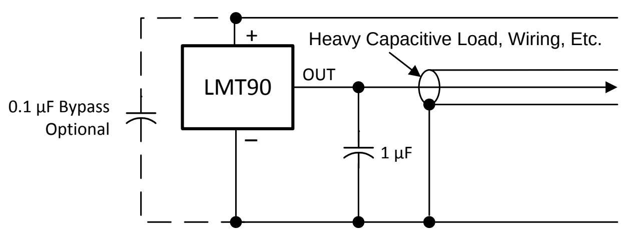


Figure 13. LMT90 With Filter for Noisy Environment

8.2 Typical Application

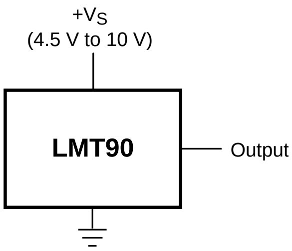


Figure 14. Full-Range Centigrade Temperature Sensor (−40°C to 125°C)

8.2.1 Design Requirements

For this design example, use the following design parameters in Table 1.

Table 1. Design Parameters

PARAMETER	VALUE	UNIT
Accuracy at 25°C	±3.0 (maximum)	°C
Accuracy Over –40°C to 125°C	±4.0 (maximum)	°C
Temperature slope	10	mV/°C
Power Supply Voltage Range	4.5 to 10	V
Output Impedance	4 (maximum)	kΩ

8.2.2 Detailed Design Procedure

The LMT90 is a simple temperature sensor that provides an analog output. Therefore design requirements related to layout out weigh other requirements in importance, refer to *Layout* for a detailed description.

8.2.3 Application Curve

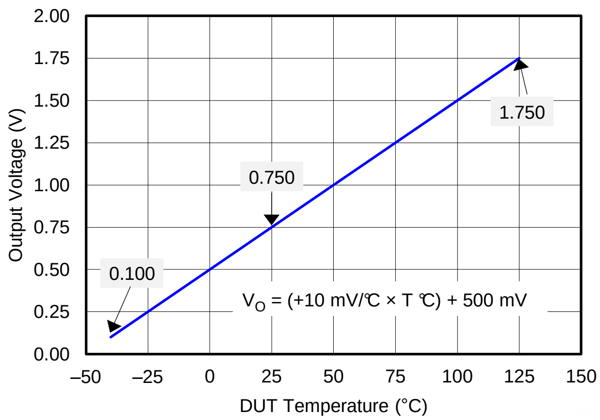


Figure 15. Plot of Output Transfer Function

8.3 System Examples

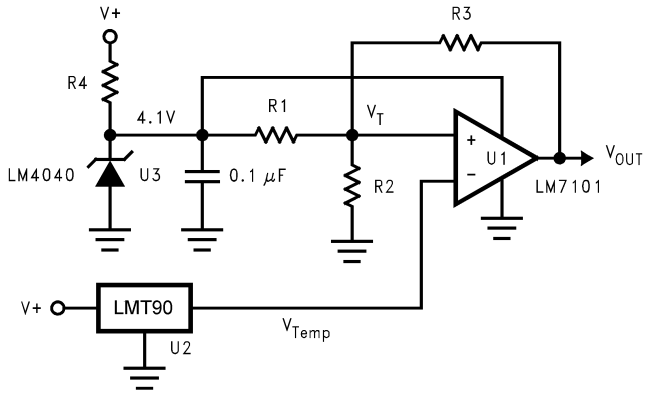


Figure 16. Centigrade Thermostat / Fan Controller

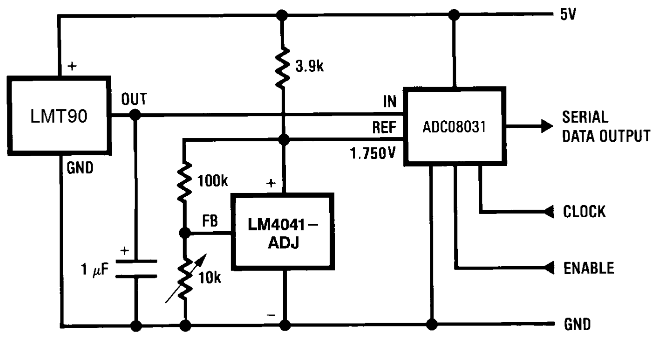


Figure 17. Temperature to Digital Converter (Serial Output) (125°C Full Scale)

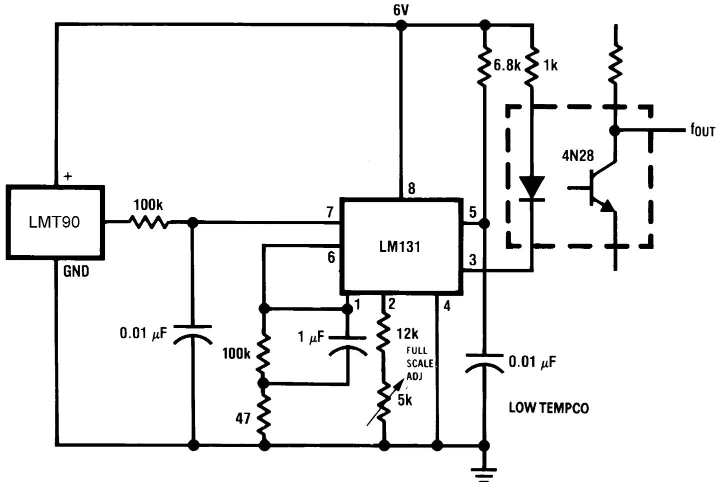


Figure 18. LMT90 With Voltage-To-Frequency Converter and Isolated Output (−40°C to 125°C; 100 Hz to 1750 Hz)

9 Power Supply Recommendations

In an extremely noisy environment, it may be necessary to add some filtering to minimize noise pickup. TI recommends that 0.1 µF be added from V_{IN} to GND to bypass the power supply voltage, as shown in Figure 13.

10 Layout

10.1 Layout Guidelines

The LMT90 can be applied easily in the same way as other integrated-circuit temperature sensors. It can be glued or cemented to a surface and its temperature will be within about 0.2°C of the surface temperature.

This presumes that the ambient air temperature is almost the same as the surface temperature; if the air temperature were much higher or lower than the surface temperature, the actual temperature of the LMT90 die would be at an intermediate temperature between the surface temperature and the air temperature.

To ensure good thermal conductivity the backside of the LMT90 die is directly attached to the GND pin. The lands and traces to the LMT90 will, of course, be part of the printed-circuit-board, which is the object whose temperature is being measured. These printed-circuit-board lands and traces will not cause the LMT90 temperature to deviate from the desired temperature.

Layout Guidelines (continued)

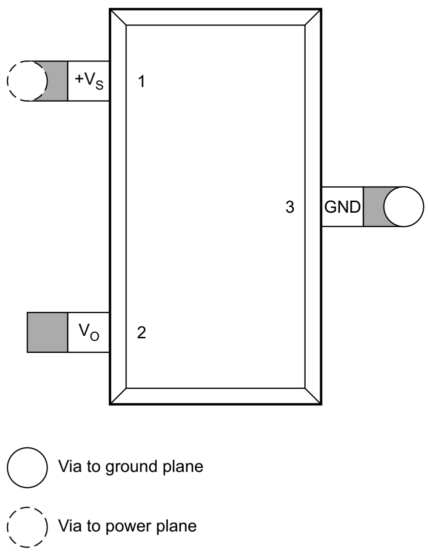
Alternatively, the LMT90 can be mounted inside a sealed-end metal tube, and can then be dipped into a bath or screwed into a threaded hole in a tank. As with any IC, the LMT90 and accompanying wiring and circuits must be kept insulated and dry, to avoid leakage and corrosion. This is especially true if the circuit may operate at cold temperatures where condensation can occur. Printed-circuit coatings and varnishes such as a conformal coating and epoxy paints or dips are often used to ensure that moisture cannot corrode the LMT90 or its connections.

Table 2. Temperature Rise of LMT90 Due to Self-Heating (Thermal Resistance, $R_{\Theta JA}$)

	SOT-23 no heat sink (1)	SOT-23 small heat fin (2)
Still air	450°C/W	260°C/W
Moving air	—	180°C/W

(1) Part soldered to 30 gauge wire.
(2) Heat sink used is 1/2-inch square printed circuit board with 2-oz. foil with part attached as shown in Figure 19.

10.2 Layout Examples



1/2-inch square printed-circuit-board with 2-oz. foil or similar

Figure 19. PCB Layout

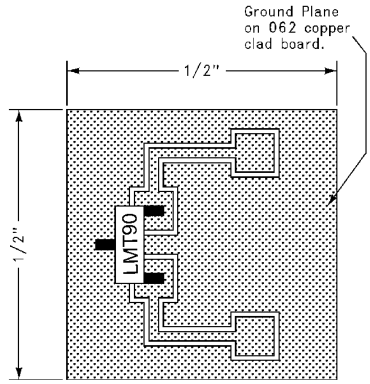


Figure 20. PCB Used for Heat Sink to Generate Thermal Response Curves

11 Device and Documentation Support

11.1 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.

11.2 Trademarks

E2E is a trademark of Texas Instruments.
All other trademarks are the property of their respective owners.

11.3 Electrostatic Discharge Caution

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

11.4 Glossary

SLYZ022 — *TI Glossary*.
This glossary lists and explains terms, acronyms, and definitions.

12 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

PACKAGING INFORMATION

Orderable 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)
LMT90DBZR	Active	Production	SOT-23 (DBZ) | 3	3000 | LARGE T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 125	T8C
LMT90DBZR.Z	Active	Production	SOT-23 (DBZ) | 3	3000 | LARGE T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 125	T8C
LMT90DBZT	Obsolete	Production	SOT-23 (DBZ) | 3	-	-	Call TI	Call TI	-40 to 125	T8C

(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.

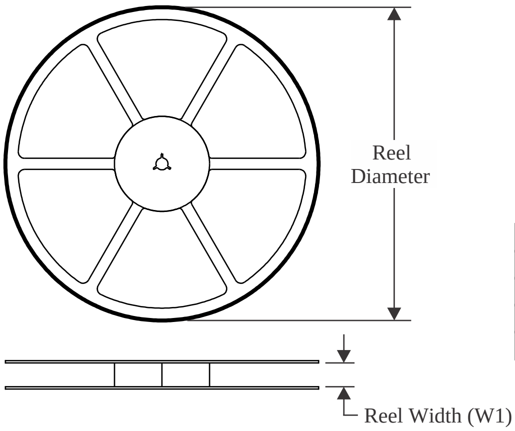
Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

Important Information and Disclaimer: The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

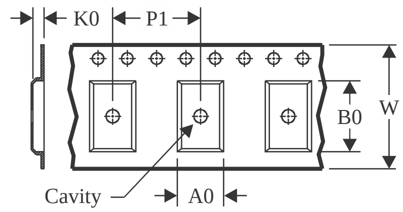
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

TAPE AND REEL INFORMATION

REEL DIMENSIONS

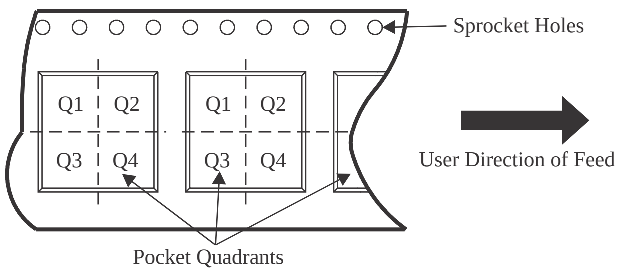


TAPE DIMENSIONS



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

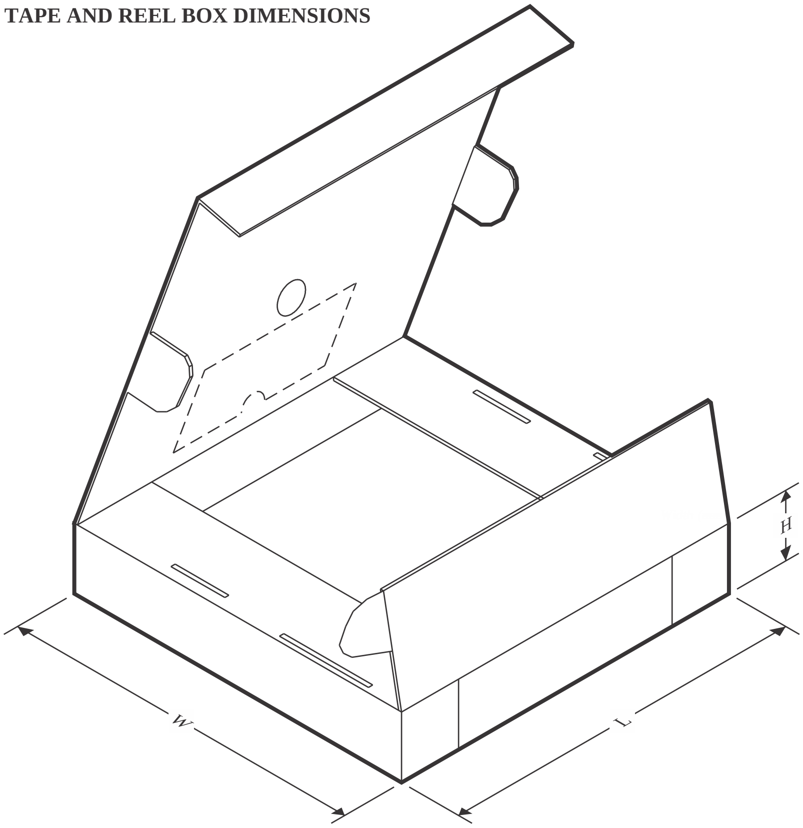
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

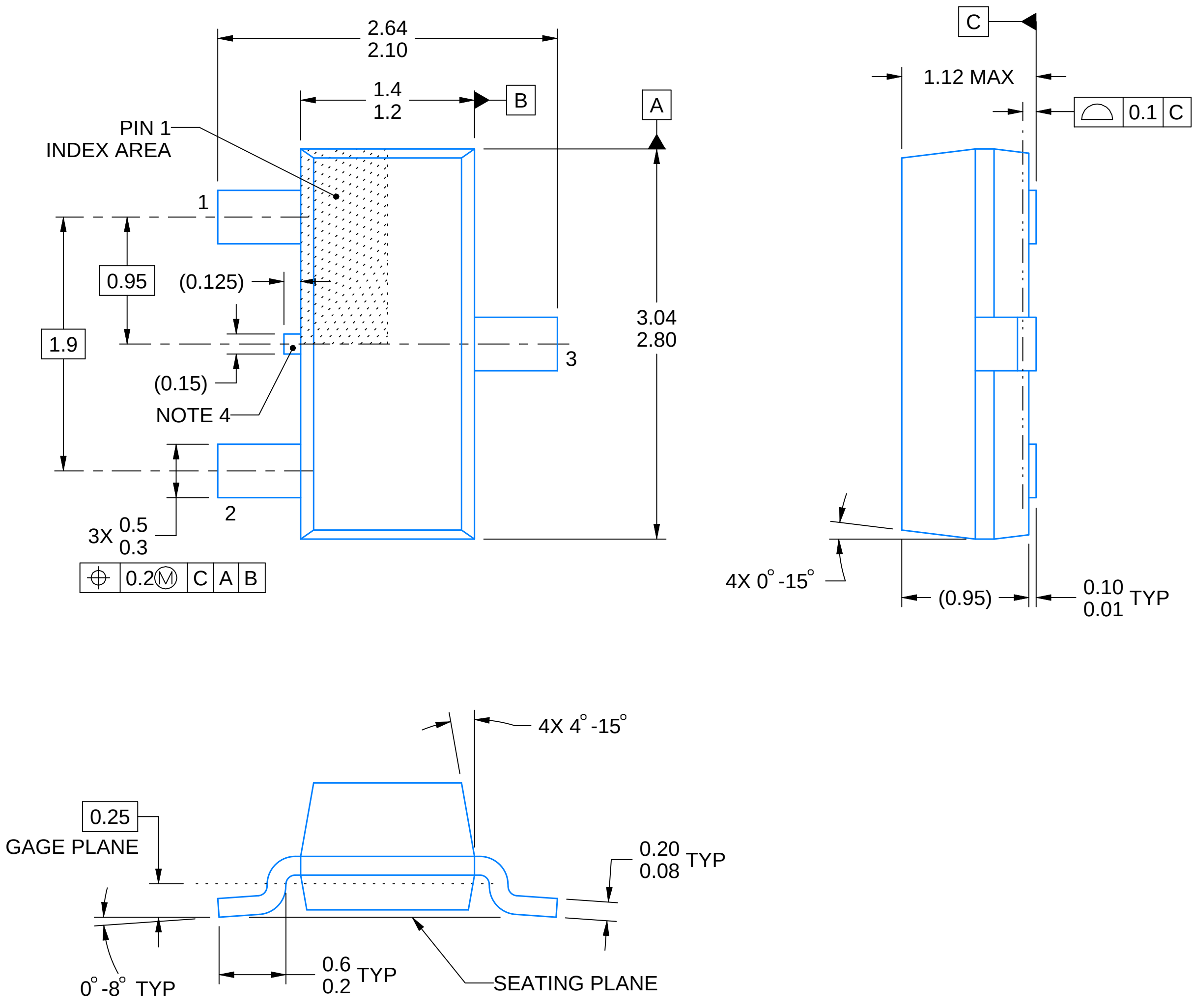
Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
LMT90DBZR	SOT-23	DBZ	3	3000	178.0	8.4	3.3	2.9	1.22	4.0	8.0	Q3

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
LMT90DBZR	SOT-23	DBZ	3	3000	208.0	191.0	35.0



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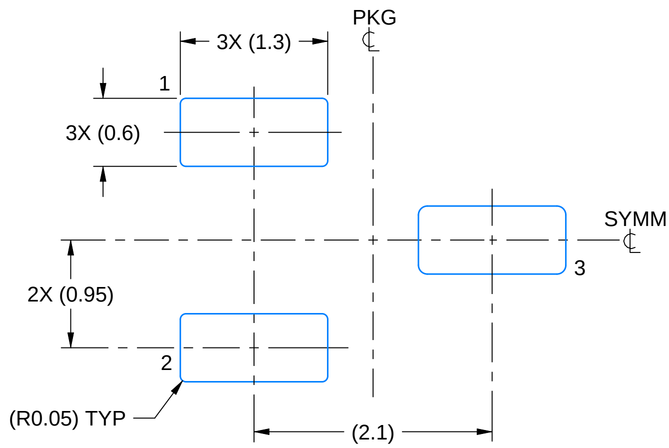
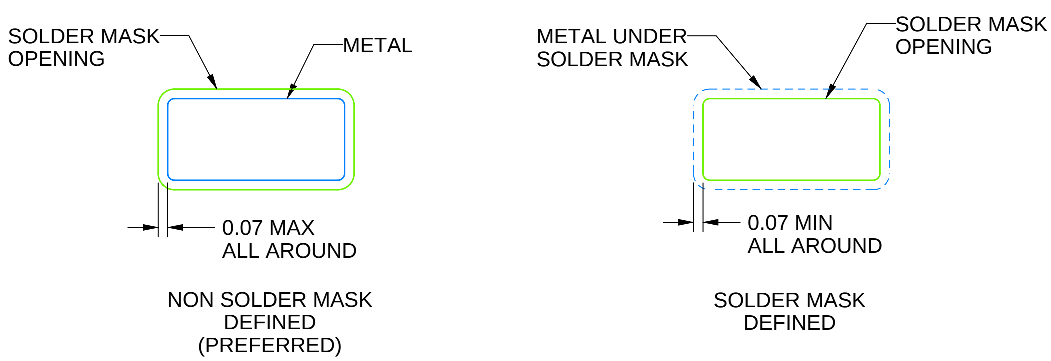
NOTES:

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 registration TO-236, except minimum foot length.
4. Support pin may differ or may not be present.
5. 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
SCALE:15X



SOLDER MASK DETAILS

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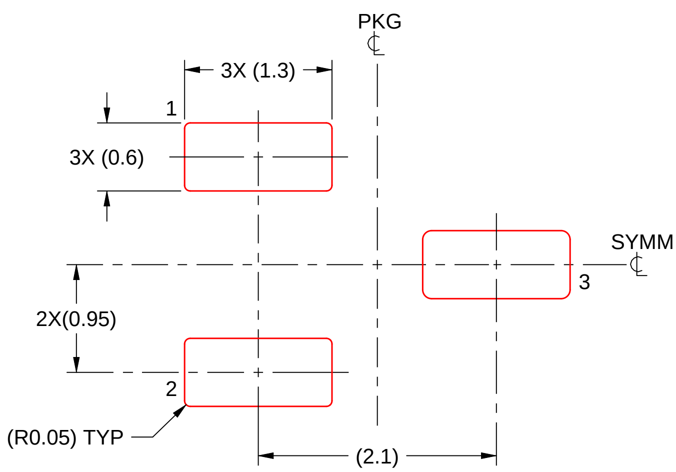
NOTES: (continued)

5. Publication IPC-7351 may have alternate designs.
6. 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:15X

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NOTES: (continued)

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