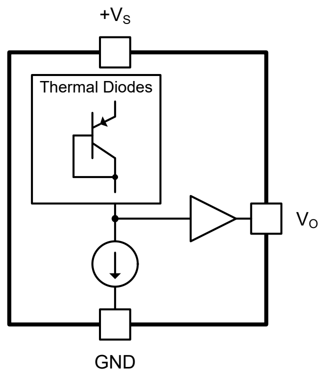
LM60 2.7V, SOT-23 or TO-92 Temperature Sensor

1 Features

- Industry-Standard Sensor Gain/Offset:
  - 6.25mV/°C, 424 mV at 0°C
- LM60B Temperature Accuracy:
  - ±2°C (Max) at 25°C
  - ±3°C (Max) over −25°C to +125°C (Legacy chip) and −40°C to +125°C (New chip)
- LM60C Temperature Accuracy:
  - ±3°C (Max) at 25°C
  - ±4°C (Max) over −40°C to +125°C
- Wide Supply Range: 2.7V to 10V
- Quiescent Current at 25°C: 110μA (Max/Legacy chip) and 70μA (Max/New chip)
- Available Package Options:
  - SOT-23 (3-pin)
  - TO-92 (3-pin, Straight Leads)
  - TO-92 (3-pin, Formed Leads)
- Nonlinearity: ±0.8°C (Maximum)
- DC Output Impedance: 120Ω/800Ω (typ/Max)
- Suitable for Remote Applications

2 Applications

- Mobile phones, PC & notebooks
- Power supply modules
- Battery management
- Home and Multifunction printers
- HVAC and Solid state drive
- Appliances



Simplified Schematic

3 Description

The LM60 device is a precision integrated-circuit temperature sensor that can sense a −40°C to +125°C temperature range while operating from a single 2.7V to 10V supply. The output voltage of the device is linearly proportional to Celsius (Centigrade) temperature (6.25mV/°C) and has a DC offset of 424mV. The offset allows reading negative temperatures without the need for a negative supply. The nominal output voltage of the device ranges from 174mV to 1205mV for a −40°C to +125°C temperature range. The device is calibrated to provide accuracies of ±2°C at room temperature and ±3°C over the full −25°C to +125°C (for Legacy chip) or −40°C to +125°C (for New chip) temperature range.

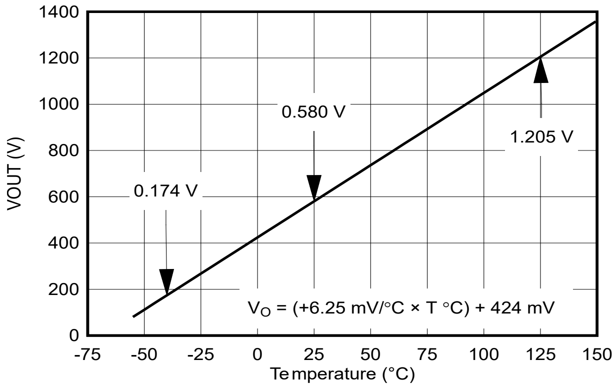
The linear output of the device, 424mV offset, and factory calibration simplify external circuitry required in a single supply environment where reading negative temperatures is required. Because the quiescent current of the device is less than 110μA (for Legacy chip) and 70μA (for New chip), self-heating is limited to a very low 0.1°C in still air in the SOT-23 package. Shutdown capability for the device is intrinsic because the inherent low power consumption allows the device to be powered directly from the output of many logic gates.

Package Information

PART NUMBER	PACKAGE(1)	PACKAGE SIZE(2)
LM60	LP (TO-92, 3)	4.83mm × 7.37mm
	DBZ (SOT-23, 3)	2.37mm × 2.92mm

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

(2) The package size (length × width) is a nominal value and includes pins, where applicable.



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

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4 Device Comparison

Table 4-1. Device Comparison

ORDER NUMBER	PACKAGE	ACCURACY OVER TEMPERATURE	SPECIFIED TEMPERATURE RANGE
LM60BIM3X/NOPB	SOT-23 (DBZ) 3-pin	±3°C	$–25°C \le T_A \le +125°C$(1) (Legacy chip)
			$–40°C \le T_A \le +125°C$ (New chip)
LM60CIM3X/NOPB		±4°C	$–40°C \le T_A \le +125°C$
LM60QIM3X/NOPB		±4°C	$–40°C \le T_A \le +125°C$
LM60BIZ/LFT3	TO-92 (LP) 3-pin Formed Leads	±3°C	$–25°C \le T_A \le +125°C$(1) (Legacy chip)
			$–40°C \le T_A \le +125°C$ (New chip)
LM60BIZ/NOPB	TO-92 (LP) 3-pin Straight Leads	±3°C	$–25°C \le T_A \le +125°C$(1) (Legacy chip)
			$–40°C \le T_A \le +125°C$ (New chip)
LM60CIZ/NOPB		±4°C	$–40°C \le T_A \le +125°C$

(1) LM60B (Legacy chip) operates down to –40°C without damage but the accuracy is only verified from –25°C to 125°C.

Table 4-2. Device Nomenclature

PRODUCT	OUT
LM60**xlyyy**/NOPB LM60**xlyyy**/LFT3	**x** indicates that the device has **B**, **C** or **Q** (grade-1 device in accordance with the AEC-Q100 standard) variant. These devices can ship with the legacy chip (CSO: GF6 or SHE) or the new chip (CSO: RFB) with different *date code*. The reel packaging label provides date code information to distinguish which chip is being used. Device performance for new and legacy chips is denoted throughout the document. **yyy** indicates that the package type of the device which can be **M3X/NOPB** (SOT-23 3-pin) or **Z/LFT3** (TO-92 3-pin Formed Leads) or **Z/NOPB** (TO-92 3-pin Straight Leads). For more information on TO-92 package options please see: *TO-92 Packing Options / Ordering Instructions*

5 Pin Configuration and Functions

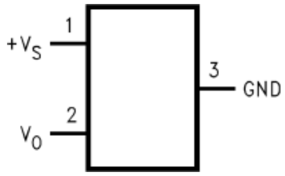


Figure 5-1. DBZ Package
3-Pin SOT-23
Top View

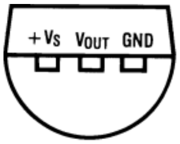


Figure 5-2. LP Package
3-Pin TO-92
(Formed Leads and Straight Leads)
Bottom View

Table 5-1. Pin Functions

PIN			TYPE	DESCRIPTION
NAME	SOT-23	TO-92		
GND	3	3	GND	Device ground, connected to power supply negative terminal
V_{OUT}	2	2	O	Temperature sensor analog output
$+V_S$	1	1	POWER	Positive power supply pin

6 Specifications

6.1 Absolute Maximum Ratings

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

		MIN	MAX	UNIT
Supply voltage, $+V_S$	LM60	-0.2	12	V
Output voltage, V_O		-0.6	$+V_S + 0.6$	V
Output current, I_{OUT}			10	mA
Input current at any pin(2)			5	mA
Maximum junction temperature, T_{JMAX}			125	°C
Storage temperature, T_{stg}		-65	150	°C

(1) Operation outside the *Absolute Maximum Ratings* may cause permanent device damage. *Absolute Maximum Ratings* do not imply functional operation of the device at these or any other conditions beyond those listed under *Recommended Operating Conditions*. If used outside the *Recommended Operating Conditions* but within the *Absolute Maximum Ratings*, the device may not be fully functional, and this may affect device reliability, functionality, performance, and shorten the device lifetime.

(2) When the input voltage (V_I) at any pin exceeds power supplies (V_I < GND or $V_I > +V_S$), the current at that pin must be limited to 5mA.

6.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$, Electrostatic discharge	LM60 (DBZ Package)	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001(1)	±2500	V
		Charged-device model (CDM), per JEDEC specification JESD22-C101(2)	±1000	
	LM60 (LP Package)	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001(1)	±2500	
		Charged-device model (CDM), per JEDEC specification JESD22-C101(2)	±1000	

(1) JEDEC document JEP155 states that 500V HBM allows safe manufacturing with a standard ESD control process.

(2) JEDEC document JEP157 states that 250V CDM allows safe manufacturing with a standard ESD control process.

6.3 Recommended Operating Conditions

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

				MIN	MAX	UNIT
$+V_S$	Supply voltage	LM60		2.7	10	V
T_A, ($T_{MIN} \le T_A \le T_{MAX}$)	Specified temperature	LM60B	Legacy chip	-25(2)	125	°C
		LM60B	New chip	-40	125	°C
		LM60C		-40	125	°C

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

(2) LM60B (Legacy chip) operates down to –40°C without damage but the accuracy is only ensured from –25°C to 125°C.

6.4 Thermal Information

THERMAL METRIC(1)		LM60				UNIT
		DBZ (SOT-23) 3 PINS		LP (TO-92) 3 PINS		
		Legacy chip	New chip	Legacy chip	New chip	
$R_{\theta JA}$ (2)	Junction-to-ambient thermal resistance	266	240.6	162	135.9	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	135	144.5	85	109.1	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	59	72.3	-	108.9	°C/W
Ψ_{JT}	Junction-to-top characterization parameter	18	28.7	29	24.6	°C/W
Ψ_{JB}	Junction-to-board characterization parameter	58	71.7	142	108.9	°C/W

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

(2) The junction to ambient thermal resistance ($R_{\theta JA}$) is specified without a heat sink in still air.

6.5 Electrical Characteristics

Unless otherwise noted, these specifications apply for $+V_S = 3V$ (DC) and $I_{LOAD} = 1\mu A$. All limits $T_A = T_J = 25°C$ unless otherwise noted.

PARAMETER		TEST CONDITIONS		MIN(1)	TYP(2)	MAX(1)	UNIT
SENSOR ACCURACY							
T_{ACY}	Temperature accuracy(3)	LM60B(4)		-2		2	°C
			$T_A = T_J = T_{MIN}$ to T_{MAX}	-3		3	
		LM60C		-3		3	
			$T_A = T_J = T_{MIN}$ to T_{MAX}	-4		4	
SENSOR OUTPUT							
$V_{0°C}$	Output voltage offset at 0°C				424		mV
T_C	Temperature coefficient (sensor gain)				6.25		mV/°C
		LM60B	$T_A = T_J = T_{MIN}$ to T_{MAX}	6.06		6.44	
		LM60C	$T_A = T_J = T_{MIN}$ to T_{MAX}	6		6.5	
V_{ONL}	Output Nonlinearity(5)	LM60B	$T_A = T_J = T_{MIN}$ to T_{MAX}	-0.6		0.6	°C
		LM60C	$T_A = T_J = T_{MIN}$ to T_{MAX}	-0.8		0.8	
Z_{OUT}	Output impedance					800	Ω
T_{LTD}	Long-term stability and drift(6)	$T_J = T_{MAX} = 125°C$ for 1000 hours			±0.2		°C
POWER SUPPLY							
I_{DD}	Operating current	LM60, $2.7V \le +V_S \le 10V$	Legacy chip		82	110	µA
			New chip		52	70	
			$T_A = T_J = T_{MIN}$ to T_{MAX} Legacy chip			125	
			$T_A = T_J = T_{MIN}$ to T_{MAX} New chip			90	
PSR	Line regulation(7)	LM60, $2.7V \le +V_S \le 3.3V$	$T_A = T_J = T_{MIN}$ to T_{MAX}	-2.3		2.3	mV
		LM60, $3V \le +V_S \le 10V$	$T_A = T_J = T_{MIN}$ to T_{MAX}	-0.3		0.3	mV/V
ΔI_{DD}	Change of quiescent current	LM60, $2.7V \le +V_S \le 10V$	Legacy chip		±5		µA
			New chip		±6.5		
I_{DD_TEMP}	Temperature coefficient of quiescent current				0.2		µA/°C

(1) Limits are specified to TI's AOQL (Average Outgoing Quality Level).
(2) Typicals are at $T_J = T_A = 25°C$ and represent most likely parametric norm.
(3) Accuracy is defined as the error between the output voltage and 6.25mV/°C times the case temperature of the device plus 424mV, at specified conditions of voltage, current, and temperature (expressed in °C).
(4) LM60B (Legacy chip) operates down to –40°C without damage but the accuracy is only verified from –25°C to 125°C. However, LM60B (New chip) specs are verified from –40°C to 125°C.
(5) Nonlinearity is defined as the deviation of the output-voltage-versus-temperature curve from the best-fit straight line, over the rated temperature rating of the device
(6) For best long-term stability, any precision circuit provides the best results if the unit is aged at a warm temperature, temperature cycled for at least 46 hours before long-term life test begins for both temperatures. 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.
(7) 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

6.6 Typical Characteristics

To generate these curves, the device is mounted to a printed-circuit board as shown in Figure 8-9 or Figure 8-10.

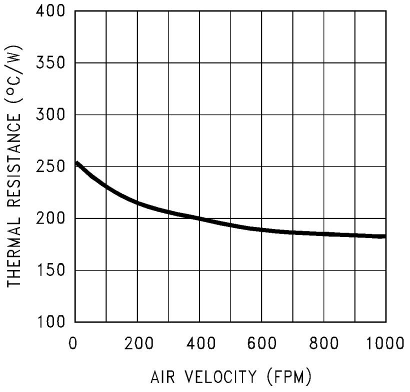


Figure 6-1. Thermal Resistance Junction to Air (Legacy chip)

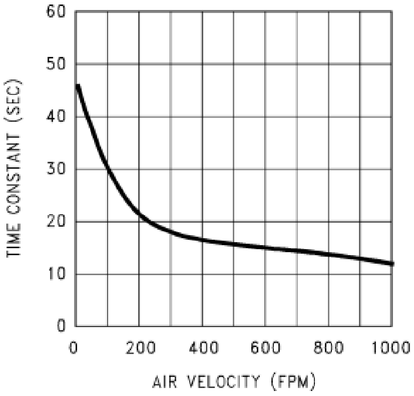


Figure 6-2. Thermal Time Constant (Legacy chip)

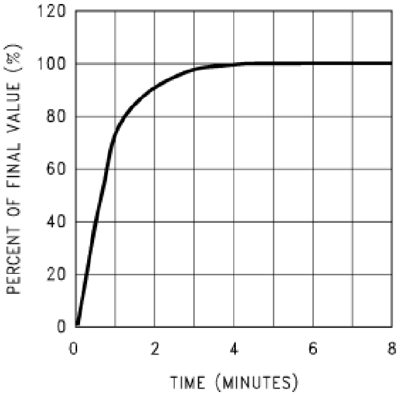


Figure 6-3. Thermal Response in Still Air With Heat Sink (Legacy chip)

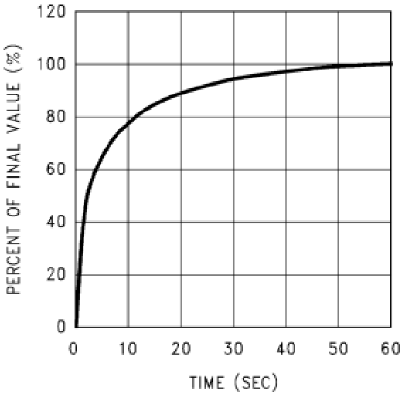


Figure 6-4. Thermal Response in Stirred Oil Bath With Heat Sink (Legacy chip)

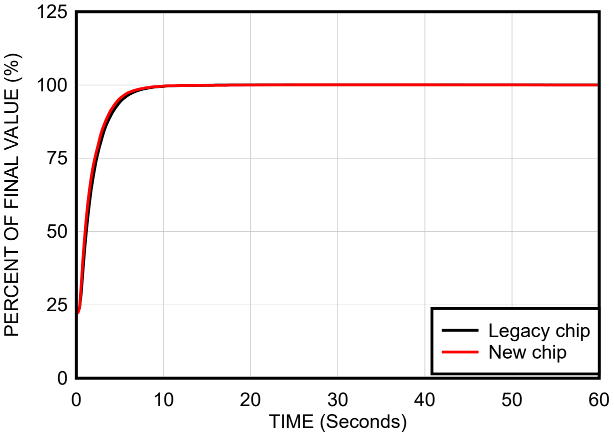


Figure 6-5. Thermal Response in Stirred Oil Bath With Heat Sink (0.5 inches × 0.5 inches PCB board)

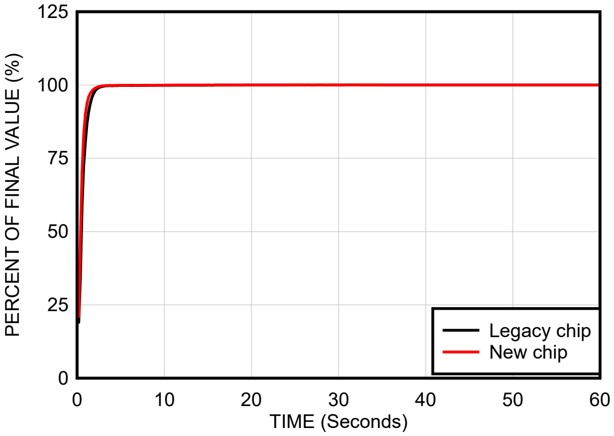


Figure 6-6. Thermal Response in Stirred Oil Bath Without Heat Sink

6.6 Typical Characteristics (continued)

To generate these curves, the device is mounted to a printed-circuit board as shown in Figure 8-9 or Figure 8-10.

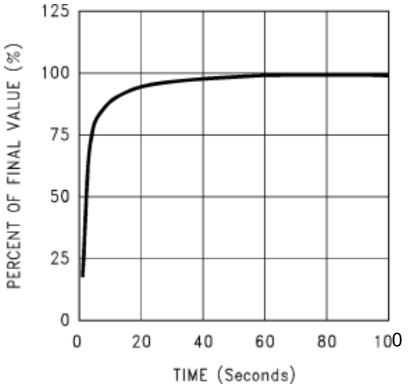


Figure 6-7. Thermal Response in Still Air Without a Heat Sink (Legacy chip)

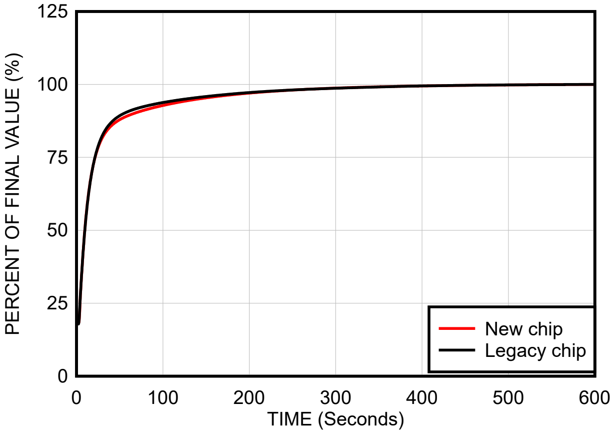


Figure 6-8. Thermal Response in Still Air Without a Heat Sink (Both Legacy and New chip in the new test setup)

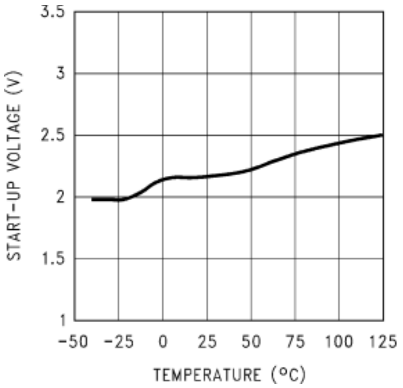


Figure 6-9. Start-Up Voltage vs Temperature (Legacy chip)

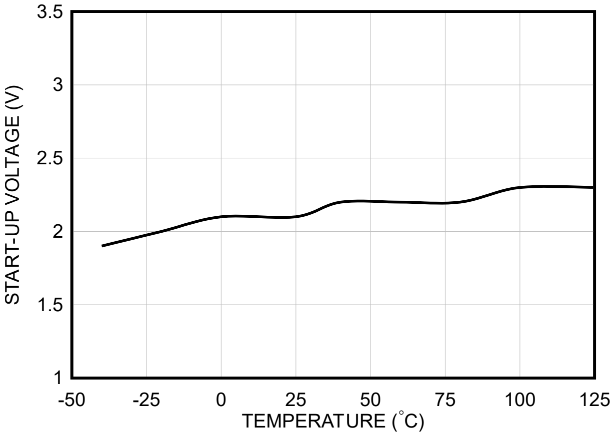


Figure 6-10. Start-Up Voltage vs Temperature (New chip)

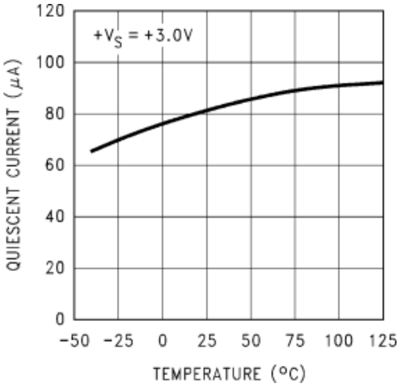


Figure 6-11. Quiescent Current vs Temperature (Legacy chip)

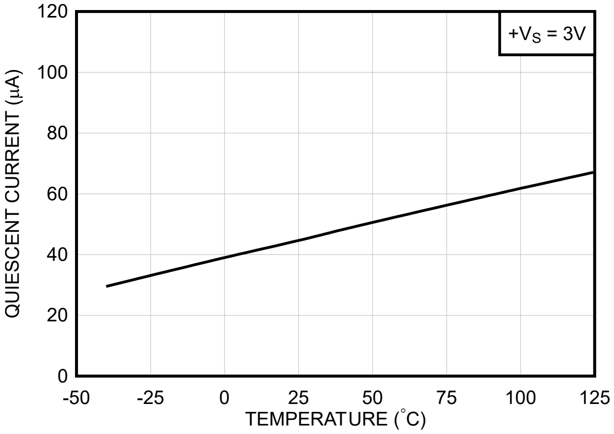


Figure 6-12. Quiescent Current vs Temperature (New chip)

6.6 Typical Characteristics (continued)

To generate these curves, the device is mounted to a printed-circuit board as shown in Figure 8-9 or Figure 8-10.

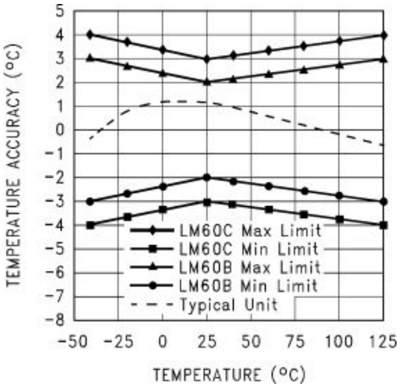


Figure 6-13. Accuracy vs Temperature (Legacy chip)

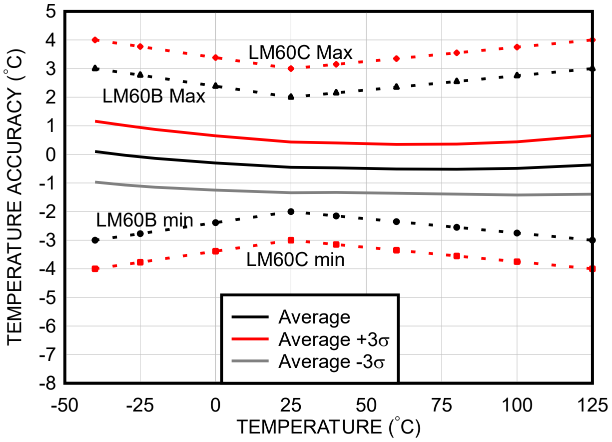


Figure 6-14. Accuracy vs Temperature (New chip)

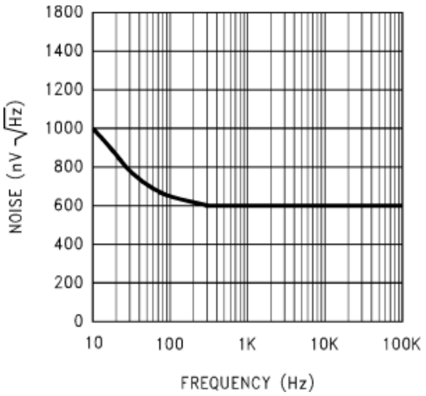


Figure 6-15. Noise Voltage (Legacy chip)

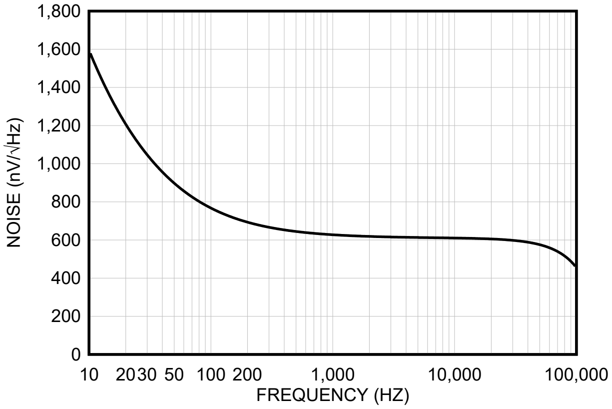


Figure 6-16. Noise Voltage (New chip)

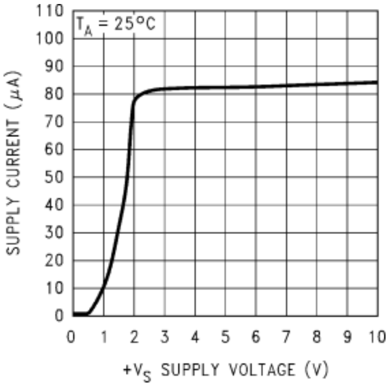


Figure 6-17. Supply Current vs Supply Voltage (Legacy chip)

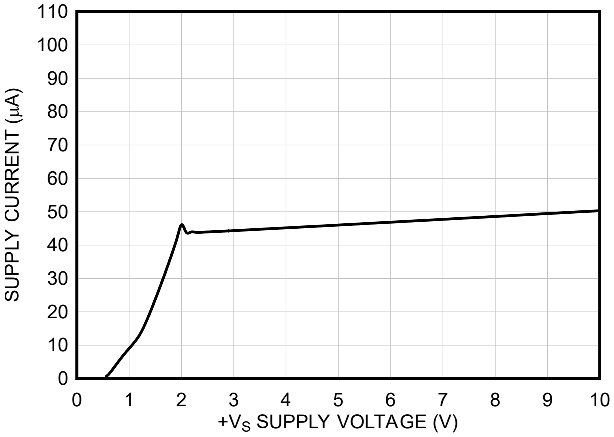


Figure 6-18. Supply Current vs Supply Voltage (New chip)

6.6 Typical Characteristics (continued)

To generate these curves, the device is mounted to a printed-circuit board as shown in Figure 8-9 or Figure 8-10.

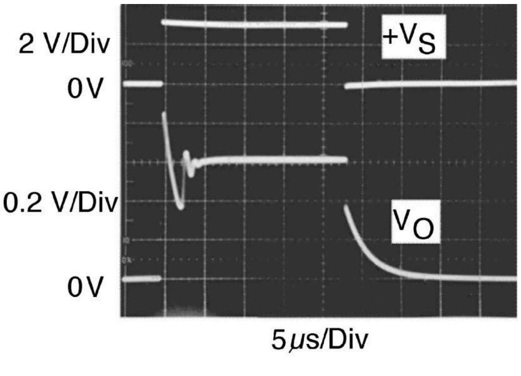


Figure 6-19. Start-Up Response (Legacy chip)

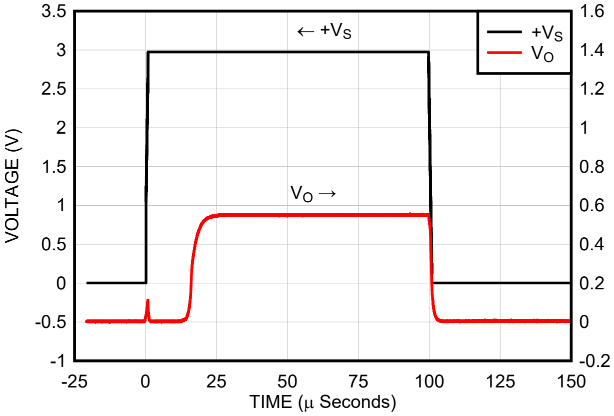


Figure 6-20. Start-Up Response (New chip)

7 Detailed Description

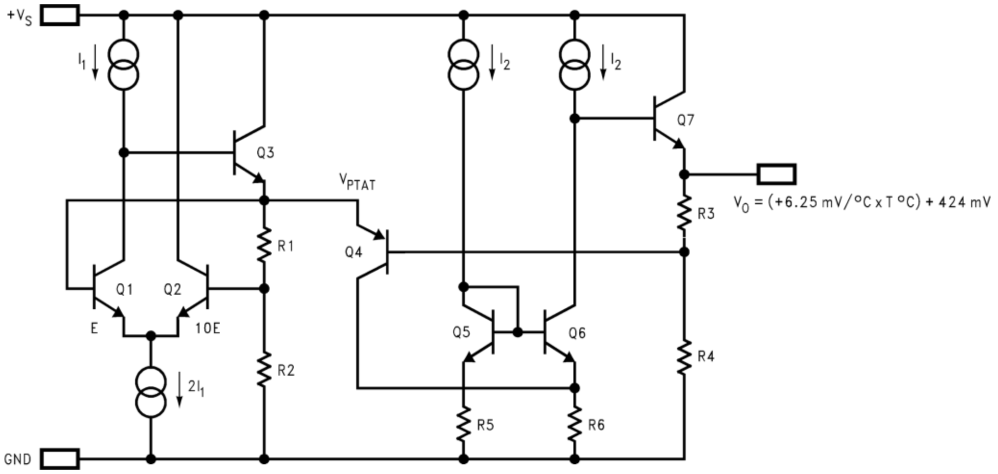
7.1 Overview

The LM60 device is a precision analog bipolar temperature sensor that can sense a −40°C to +125°C temperature range while operating from a single 2.7V supply. The output voltage of the LM60 is linearly proportional to Celsius (Centigrade) temperature (6.25mV/°C) and has a DC offset of 424mV. The offset allows reading negative temperatures with a single positive supply. The nominal output voltage of the device ranges from 174mV to 1205mV for a −40°C to +125°C temperature range. The device is calibrated to provide accuracies of ±2.0°C at room temperature and ±3°C over the full −25°C to +125°C (for Legacy chip) or −40°C to +125°C (for New chip)temperature range.

With a quiescent current of the device is less than 110µA (for Legacy chip) and 70µA (for New chip), self-heating is limited to a very low 0.1°C in still air in the SOT-23 package. Shutdown capability for the device is intrinsic because the inherent low power consumption allows the device to be powered directly from the output of many logic gates.

The output of the LM60 is a Class A base emitter follower, thus the LM60 can source quite a bit of current while sinking less than 1µA. In any event load current must be minimized to limit the contribution to the total temperature error.

7.2 Functional Block Diagram



7.3 Feature Description

7.3.1 LM60 Transfer Function

The LM60 follows a simple linear transfer function to achieve the accuracy as listed in *Section 6.5* as given:

$$V_O = (6.25\text{mV/°C} \times T\ \text{°C}) + 424\text{mV} \quad (1)$$

where

- T is the temperature
- V_O is the LM60 output voltage

7.4 Device Functional Modes

The only functional mode for this device is 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, as well as validating and testing their design implementation to confirm system functionality.

8.1 Application Information

The device has a low supply current and a wide supply range, therefore it can easily be driven by a battery.

8.1.1 Capacitive Loads

The device handles capacitive loading well. Without any special precautions, the device can drive any capacitive load as shown in Figure 8-1. Over the specified temperature range the device has a maximum output impedance of 800Ω. In an extremely noisy environment, adding some filtering to minimize noise pick-up can be required. TI recommends that 0.1µF be added from +V_S to GND to bypass the power supply voltage, as shown in Figure 8-2. In a noisy environment, adding a capacitor from the output to ground can be required. A 1µF output capacitor with the 800Ω output impedance forms a 199Hz, low-pass filter. Because the thermal time constant of the device is much slower than the 6.3ms time constant formed by the RC, the overall response time of the device is not be significantly affected. For much larger capacitors, this additional time lag increases the overall response time of the device.

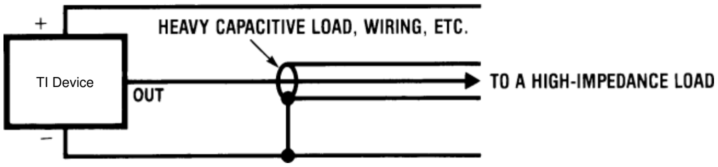


Figure 8-1. No Decoupling Required for Capacitive Load

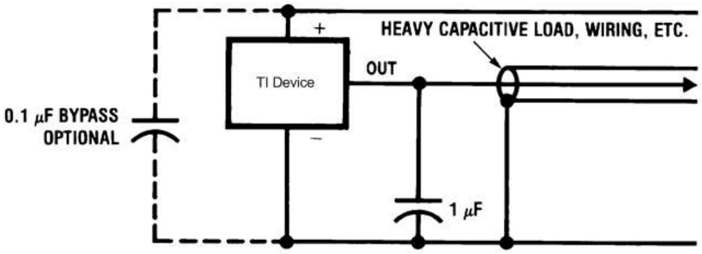
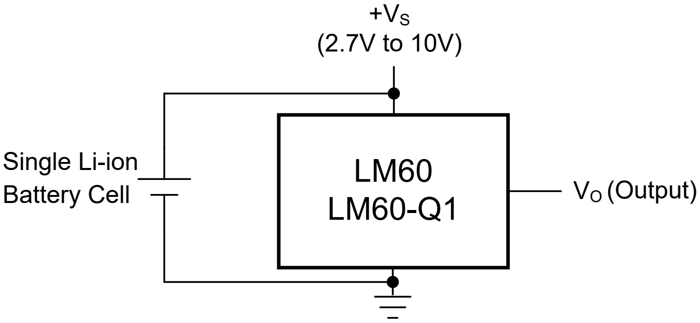


Figure 8-2. Filter Added for Noisy Environment

8.2 Typical Applications

8.2.1 Full-Range Centigrade Temperature Sensor

Because the LM60 is a simple temperature sensor that provides an analog output, design requirements related to the layout are also important. Refer to *Section 8.5* for details.



$V_O = (6.25mV/°C \times T°C) + 424mV$

Figure 8-3. Full-Range Centigrade Temperature Sensor (−40°C to +125°C) Operating From a Single Li-Ion Battery Cell

8.2.1.1 Design Requirements

For this design example, use the design parameters listed in Table 8-1.

Table 8-1. Temperature and Typical V_O Values of Figure 8-3

TEMPERATURE (T)	TYPICAL V_O
125°C	1205mV
100°C	1049mV
25°C	580mV
0°C	424mV
–25°C	268mV
–40°C	174mV

8.2.1.2 Detailed Design Procedure

Selection of the LM60 is based on the output voltage transfer function being able to meet the needs of the rest of the system.

8.2.1.3 Application Curve

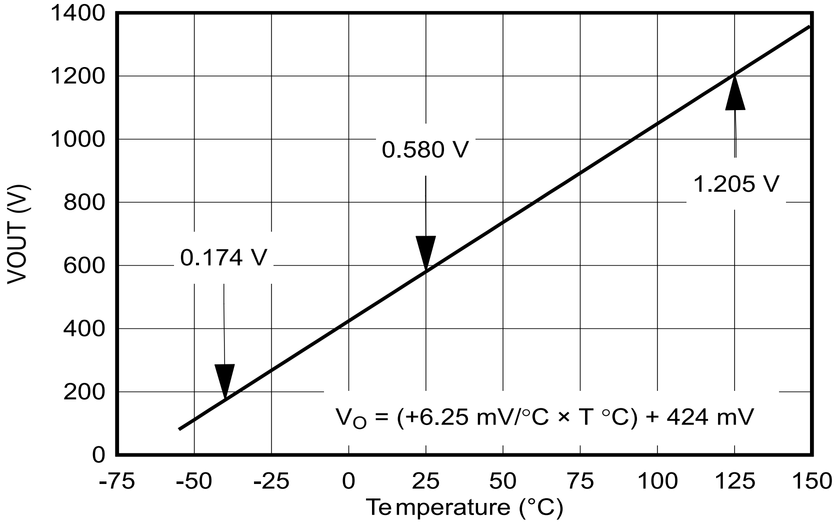


Figure 8-4. LM60 Output Transfer Function

8.2.2 Centigrade Thermostat Application

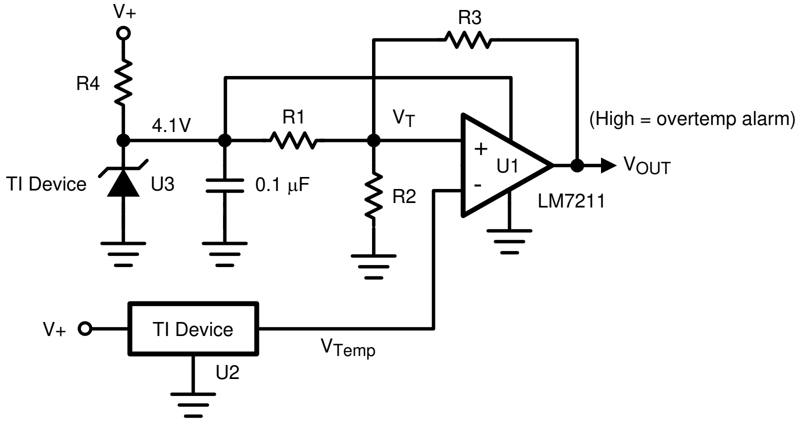


Figure 8-5. Centigrade Thermostat

8.2.2.1 Design Requirements

A simple thermostat can be created by using a reference (LM4040) and a comparator (LM7211 or LMC7211-N) as shown in Figure 8-5.

8.2.2.2 Detailed Design Procedure

Use Equation 2 and Equation 3 to calculate the threshold values for T1 and T2.

$$V_{T1} = \frac{(4.1)R2}{R2 + R1||R3} \tag{2}$$

$$V_{T2} = \frac{(4.1)R2||R3}{R1 + R2||R3} \tag{3}$$

8.2.2.3 Application Curve

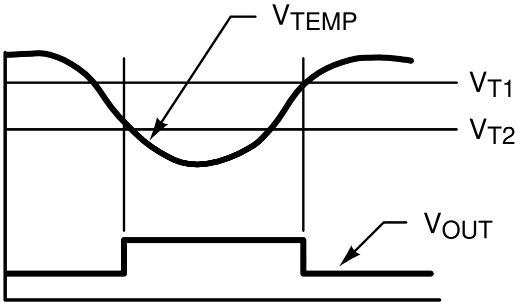


Figure 8-6. Thermostat Output Waveform

8.3 System Examples

8.3.1 Conserving Power Dissipation With Shutdown

The LM60 draws very little power, therefore the device can simply be shutdown by driving the LM60 supply pin with the output of a logic gate as shown in Figure 8-7.

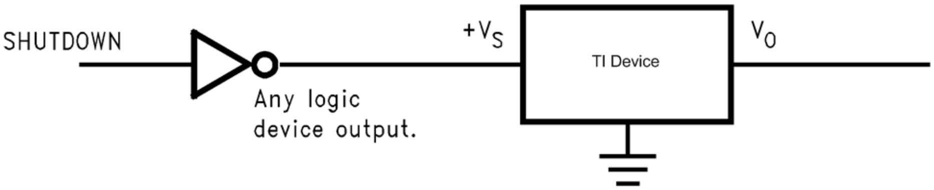


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Figure 8-7. Conserving Power Dissipation With Shutdown

8.4 Power Supply Recommendations

In an extremely noisy environment, add some filtering to minimize noise pick-up. Adding 0.1µF from $+V_S$ to GND is recommended to bypass the power supply voltage, as shown in Figure 8-2. In a noisy environment, add a capacitor from the output to ground.

8.5 Layout

8.5.1 Layout Guidelines

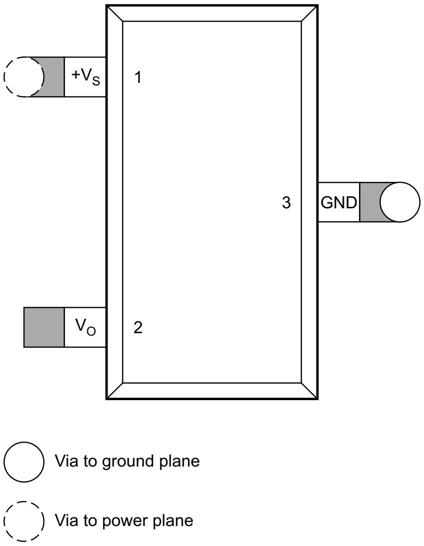
The LM60 can be applied easily in the same way as other integrated-circuit temperature sensors. The device can be glued or cemented to a surface. The temperature that the LM60 is sensing is within approximately +0.1°C of the surface temperature that the leads of the LM60 are attached to.

This presumes that the ambient air temperature is almost the same as the surface temperature. If the air temperature is much higher or lower than the surface temperature, the actual temperature of the device die is at an intermediate temperature between the surface temperature and the air temperature.

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

Alternatively, the device 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 device and accompanying wiring and circuits must be kept insulated and dry to avoid leakage and corrosion. Specifically when the device operates 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 verify that moisture cannot corrode the device or connections.

8.5.2 Layout Example



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

Figure 8-8. PCB Layout

8.5.3 Thermal Considerations

The thermal resistance junction to ambient ($R_{θJA}$) is the parameter used to calculate the rise of a device junction temperature due to the device power dissipation. Use Equation 4 to calculate the rise in the die temperature of the device.

$$T_J = T_A + R_{θJA} [(+V_S I_Q) + (+V_S − V_O) I_L] \quad (4)$$

where

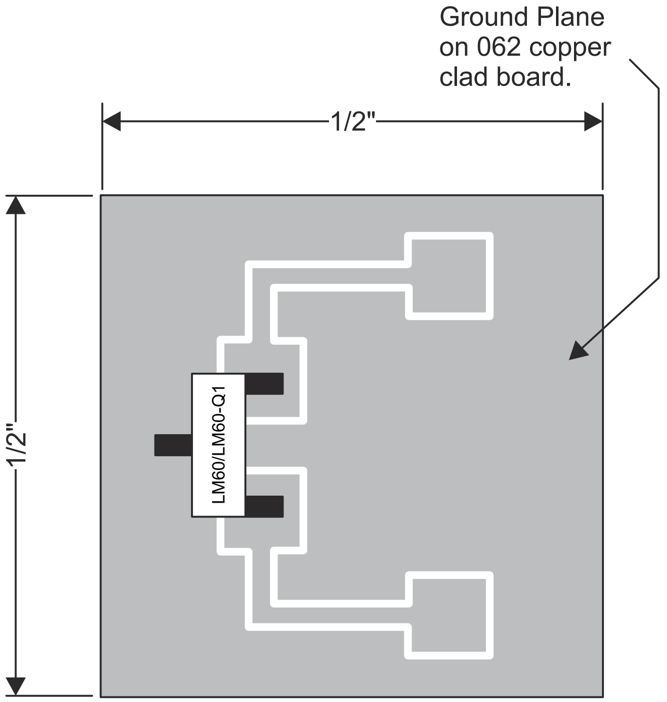
- I_Q is the quiescent current
- I_L is the load current on the output

Table 8-2 summarizes the rise in die temperature of the LM60 without any loading, and the thermal resistance for different conditions. The values in Table 8-2 were actually measured where as the values shown in Section 6.4 where calculated using modeling methods as described in the *Semiconductor and IC Package Thermal Metrics* (SPRA953) application report.

Table 8-2. Temperature Rise of LM60 Due to Self-Heating and Thermal Resistance ($R_{θJA}$)

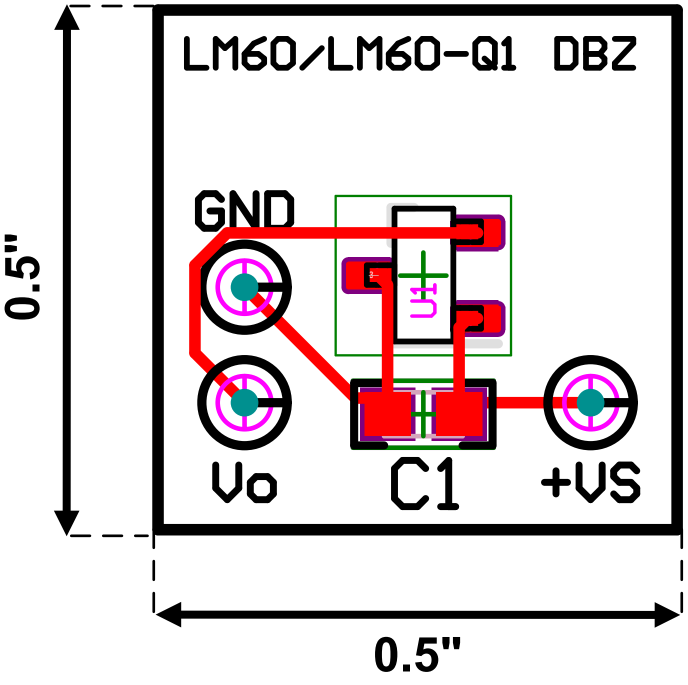
	SOT-23[1] NO HEAT SINK		SOT-23[2] SMALL HEAT FIN		TO-92[1] NO HEAT FIN		TO-92[3] SMALL HEAT FIN	
	$R_{θJA}$ (°C/W)	$T_J − T_A$ (°C)	$R_{θJA}$ (°C/W)	$T_J − T_A$ (°C)	$R_{θJA}$ (°C/W)	$T_J − T_A$ (°C)	$R_{θJA}$ (°C/W)	$T_J − T_A$ (°C)
Still air Legacy chip	450	0.17	260	0.1	180	0.07	140	0.05
Moving air Legacy chip	—	—	180	0.07	90	0.034	70	0.026

(1) Part soldered to 30 gauge wire.
(2) Heat sink used is 1/2-in square printed-circuit board with 2-oz. foil with part attached as shown in Figure 8-9.
(3) Part glued or leads soldered to 1-in square of 1/16-in printed-circuit board with 2-oz. foil or similar.



1/2-in Square Printed-Circuit Board with 2oz. Copper Foil or Similar.

Figure 8-9. Printed-Circuit Board Used for Heat Sink to Generate Thermal Response Curves (Legacy chip)



1/2in Square Printed-Circuit Board with FR-4 material.

Figure 8-10. Printed-Circuit Board Used to Generate Thermal Response Curves (New Test Setup for Both New Chip and Legacy Chip)

9 Device and Documentation Support

9.1 Documentation Support

9.1.1 Related Documentation

For related documentation see the following:

- Texas Instruments, *LM50 and LM50-Q1 SOT-23 Single-Supply Centigrade Temperature Sensor*, data sheet
- Texas Instruments, *TMP23x Low-Power, High-Accuracy Analog Output Temperature Sensors*, data sheet
- Texas Instruments, *LM60 Evaluation Module*, EVM user's guide
- Texas Instruments, *LM60-Q1 Functional Safety FIT Rate and FMD*, Functional safety information.

9.2 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. Click on *Notifications* 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.

9.3 Support Resources

TI E2E™ support forums are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

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9.4 Trademarks

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9.5 Electrostatic Discharge Caution

This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

9.6 Glossary

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

10 Revision History

Changes from Revision F (August 2017) to Revision G (February 2025) **Page**

- Updated the numbering format for tables, figures, and cross-references throughout the document 1
- Updated the *Device Comparison* section with existing OPNs and adding *Device Nomenclature* table............ 3
- Changed Machine model (MM) Electrostatic discharge to Charged-device model (CDM).............................. 4
- Changed minimum specified temperature for LM60B from -25°C to -40°C in the New chip............................ 4
- Changed DBZ and LP packages Thermal Information section. in the New chip.. 4
- Added “operating current” and “Change of quiescent current” for the New chip.. 5
- Added graphs for new chip, reordered and corrected the graphs for legacy chip... 6
- Added corrections to the *Thermal Resistance Junction to Air (Legacy chip)* graph.. 6
- Added *Thermal Response in Stirred Oil Bath With Heat Sink (0.5 inches × 0.5 inches PCB board)* graph for both Legacy and New chips.. 6
- Added *Thermal Response in Still Air Without a Heat Sink (Both Legacy and New chip together in a new test setup)* graph for both Legacy and New chips.. 6

- Added the *Start-Up Voltage vs Temperature*, *Quiescent Current vs Temperature*, *Accuracy vs Temperature*, *Noise Voltage*, *Supply Current vs Supply Voltage* and *Start-Up Response* graphs for New chip...................... 6

Changes from Revision E (September 2015) to Revision F (August 2017) **Page**

- Moved the automotive device to a standalone data sheet (SNIS197)...1
- Added table note for the LM60B...3

Changes from Revision D (November 2012) to Revision E (November 2014) **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

11 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)
LM60BIM3	NRND	Production	SOT-23 (DBZ) | 3	1000 | SMALL T&R	No	Call TI	Level-1-260C-UNLIM	-25 to 125	T6B
LM60BIM3.B	NRND	Production	SOT-23 (DBZ) | 3	1000 | SMALL T&R	No	Call TI	Level-1-260C-UNLIM	-25 to 125	T6B
LM60BIM3/NOPB	Obsolete	Production	SOT-23 (DBZ) | 3	-	-	Call TI	Call TI	-25 to 125	T6B
LM60BIM3X	NRND	Production	SOT-23 (DBZ) | 3	3000 | LARGE T&R	No	Call TI	Level-1-260C-UNLIM	-25 to 125	T6B
LM60BIM3X.B	NRND	Production	SOT-23 (DBZ) | 3	3000 | LARGE T&R	No	Call TI	Level-1-260C-UNLIM	-25 to 125	T6B
LM60BIM3X/NOPB	Active	Production	SOT-23 (DBZ) | 3	3000 | LARGE T&R	Yes	SN	Level-1-260C-UNLIM	-25 to 125	T6B
LM60BIM3X/NOPB.A	Active	Production	SOT-23 (DBZ) | 3	3000 | LARGE T&R	Yes	SN	Level-1-260C-UNLIM	-25 to 125	T6B
LM60BIM3X/NOPB.B	Active	Production	SOT-23 (DBZ) | 3	3000 | LARGE T&R	Yes	SN	Level-1-260C-UNLIM	-25 to 125	T6B
LM60BIZ/LFT3	Active	Production	TO-92 (LP) | 3	2000 | LARGE T&R	Yes	SN	N/A for Pkg Type	-25 to 125	(LM60, LM60BIZ) BIZ
LM60BIZ/LFT3.A	Active	Production	TO-92 (LP) | 3	2000 | LARGE T&R	Yes	SN	N/A for Pkg Type	-25 to 125	(LM60, LM60BIZ) BIZ
LM60BIZ/LFT3.B	Active	Production	TO-92 (LP) | 3	2000 | LARGE T&R	Yes	SN	N/A for Pkg Type	-25 to 125	(LM60, LM60BIZ) BIZ
LM60BIZ/NOPB	Active	Production	TO-92 (LP) | 3	1800 | SMALL T&R	-	SN	N/A for Pkg Type	-25 to 125	(LM60, LM60BIZ) BIZ
LM60BIZ/NOPB.A	Active	Production	TO-92 (LP) | 3	1800 | SMALL T&R	-	SN	N/A for Pkg Type	-25 to 125	(LM60, LM60BIZ) BIZ
LM60BIZ/NOPB.B	Active	Production	TO-92 (LP) | 3	1800 | SMALL T&R	-	Call TI	Call TI	-25 to 125	
LM60CIM3	NRND	Production	SOT-23 (DBZ) | 3	1000 | SMALL T&R	No	Call TI	Level-1-260C-UNLIM	-40 to 125	T6C
LM60CIM3.B	NRND	Production	SOT-23 (DBZ) | 3	1000 | SMALL T&R	No	Call TI	Level-1-260C-UNLIM	-40 to 125	T6C
LM60CIM3/NOPB	Obsolete	Production	SOT-23 (DBZ) | 3	-	-	Call TI	Call TI	-40 to 125	T6C
LM60CIM3X	NRND	Production	SOT-23 (DBZ) | 3	3000 | LARGE T&R	No	Call TI	Level-1-260C-UNLIM	-40 to 125	T6C
LM60CIM3X.B	NRND	Production	SOT-23 (DBZ) | 3	3000 | LARGE T&R	No	Call TI	Level-1-260C-UNLIM	-40 to 125	T6C
LM60CIM3X/NOPB	Active	Production	SOT-23 (DBZ) | 3	3000 | LARGE T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 125	T6C
LM60CIM3X/NOPB.A	Active	Production	SOT-23 (DBZ) | 3	3000 | LARGE T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 125	T6C
LM60CIM3X/NOPB.B	Active	Production	SOT-23 (DBZ) | 3	3000 | LARGE T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 125	T6C
LM60CIZ/NOPB	Active	Production	TO-92 (LP) | 3	1800 | SMALL T&R	-	SN	N/A for Pkg Type	-40 to 125	(LM60, LM60CIZ) CIZ
LM60CIZ/NOPB.A	Active	Production	TO-92 (LP) | 3	1800 | SMALL T&R	-	SN	N/A for Pkg Type	-40 to 125	(LM60, LM60CIZ) CIZ

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)
LM60CIZ/NOPB.B	Active	Production	TO-92 (LP) | 3	1800 | SMALL T&R	-	Call TI	Call TI	-40 to 125	

(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 LM60 :

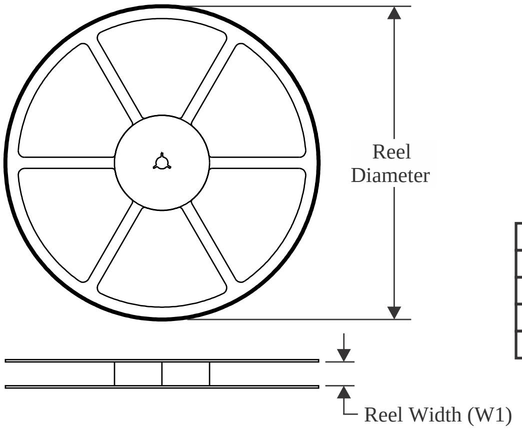
- Automotive : LM60-Q1

NOTE: Qualified Version Definitions:

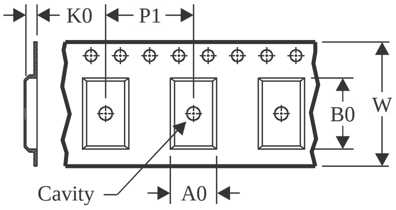
- Automotive - Q100 devices qualified for high-reliability automotive applications targeting zero defects

TAPE AND REEL INFORMATION

REEL DIMENSIONS

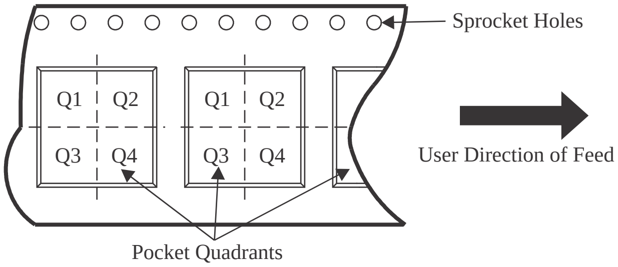


TAPE DIMENSIONS



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

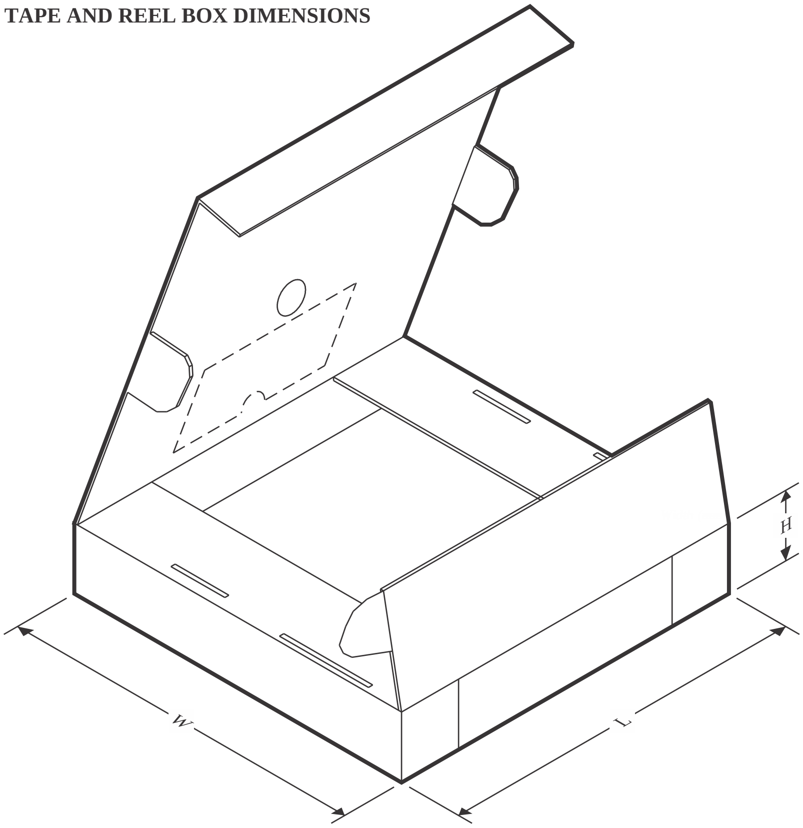
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

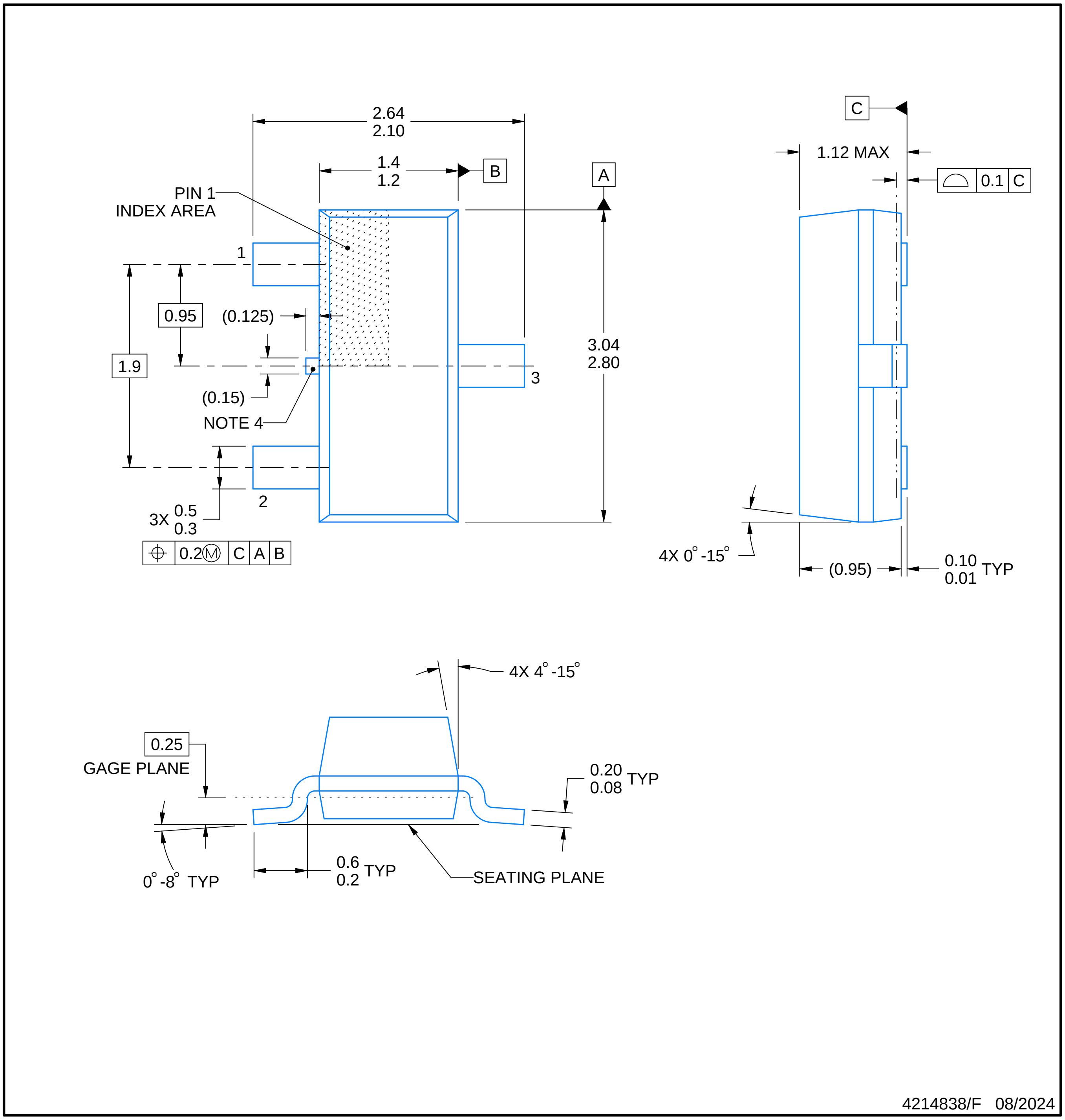
Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
LM60BIM3X/NOPB	SOT-23	DBZ	3	3000	178.0	8.4	3.3	2.9	1.22	4.0	8.0	Q3
LM60CIM3X/NOPB	SOT-23	DBZ	3	3000	178.0	8.4	3.3	2.9	1.22	4.0	8.0	Q3

TAPE AND REEL BOX DIMENSIONS



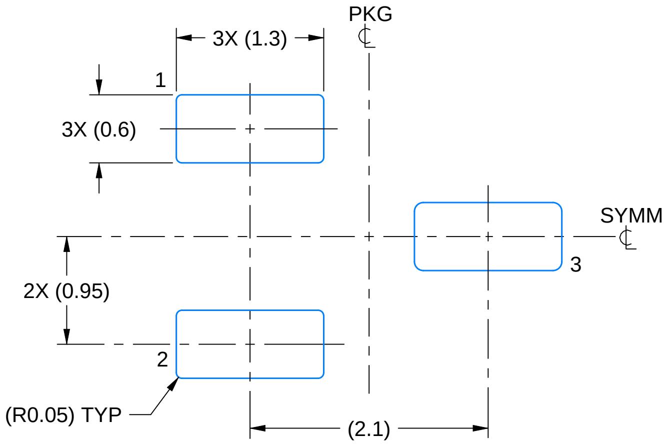
*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
LM60BIM3X/NOPB	SOT-23	DBZ	3	3000	208.0	191.0	35.0
LM60CIM3X/NOPB	SOT-23	DBZ	3	3000	208.0	191.0	35.0

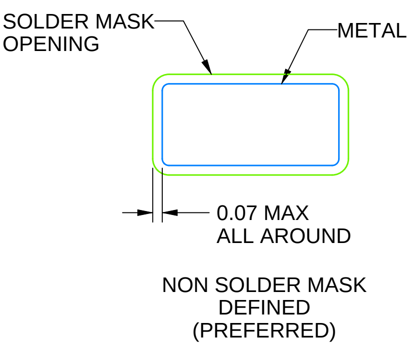


NOTES:

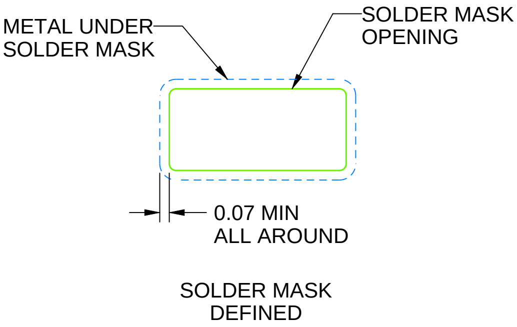
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. Reference JEDEC registration TO-236, except minimum foot length.
4. Support pin may differ or may not 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



NON SOLDER MASK
DEFINED
(PREFERRED)

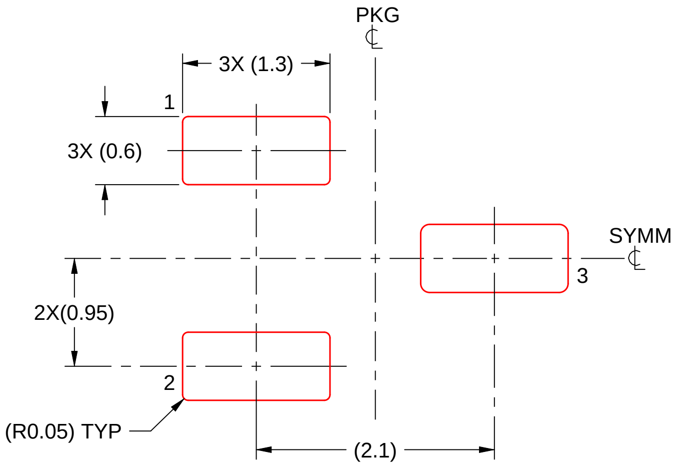


SOLDER MASK
DEFINED

SOLDER MASK DETAILS

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

NOTES: (continued)

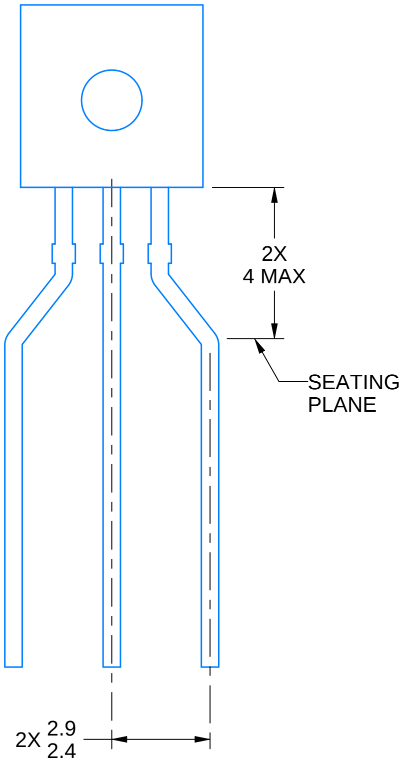
7. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
8. Board assembly site may have different recommendations for stencil design.

LP0003A

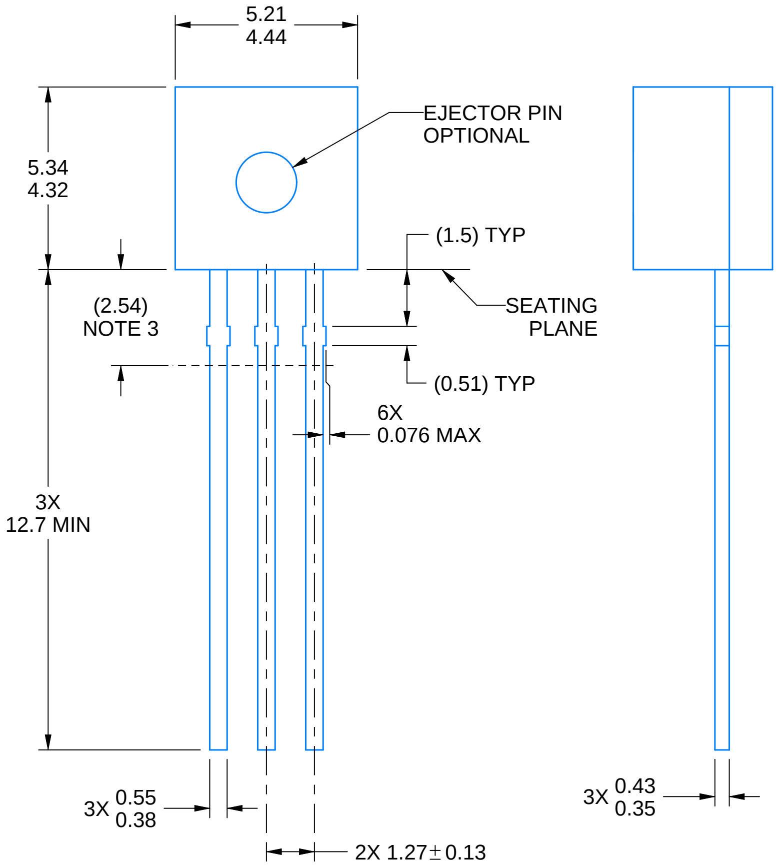
PACKAGE OUTLINE

TO-92 - 5.34 mm max height

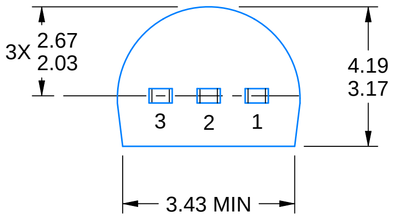
TO-92



FORMED LEAD OPTION
OTHER DIMENSIONS IDENTICAL
TO STRAIGHT LEAD OPTION



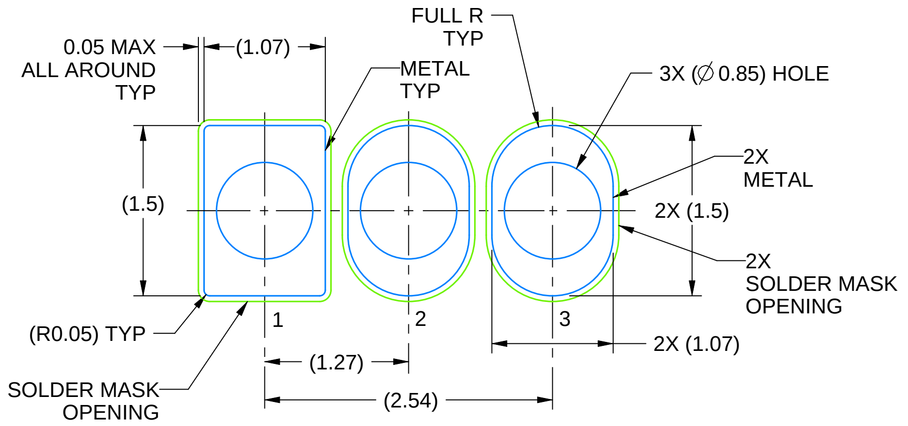
STRAIGHT LEAD OPTION



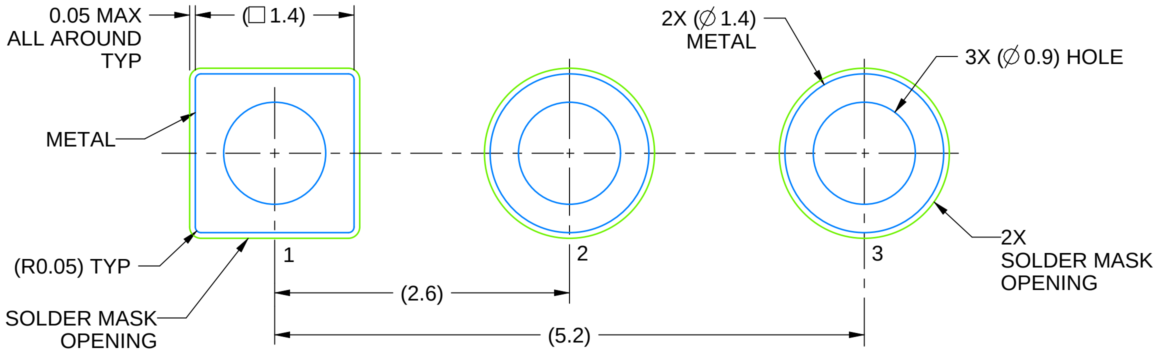
4215214/C 04/2025

NOTES:

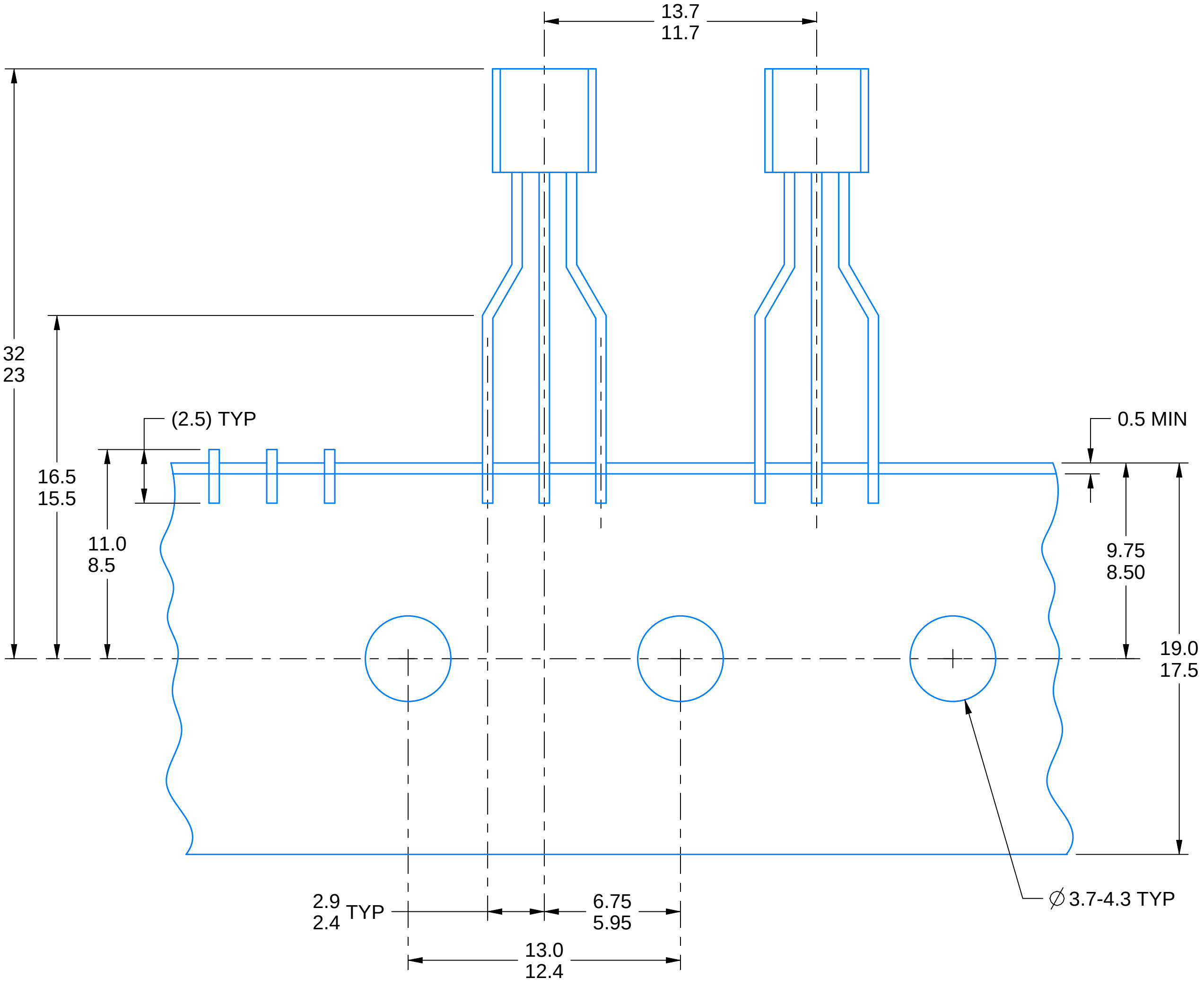
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. Lead dimensions are not controlled within this area.
4. Reference JEDEC TO-226, variation AA.
5. Shipping 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



FOR FORMED LEAD OPTION PACKAGE

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