LM60 and LM60-Q1 2.7-V, SOT-23 or TO-92 Temperature Sensor

1 Features

- Calibrated Linear Scale Factor of 6.25 mV/°C
- Rated for Full −40°C to +125°C Range
- Suitable for Remote Applications
- Available in SOT-23 and TO-92 Packages
- LM60-Q1 is AEC-Q100 Grade 1 Qualified and is Manufactured on an Automotive Grade Flow.
- Key Specifications
  - Accuracy at 25°C: ± 2°C and ± 3°C (Maximum)
  - Accuracy for −40°C to +125°C: ±4°C (Maximum)
  - Accuracy for −25°C to +125°C: ±3°C (Maximum)
  - Temperature Slope: 6.25 mV/°C
  - Power-Supply Voltage Range: 2.7 V to 10 V
  - Current Drain at 25°C: 110 μA (Maximum)
  - Nonlinearity: ±0.8°C (Maximum)
  - Output Impedance: 800 Ω (Maximum)

2 Applications

- Automotive
- Cell Phones and Computers
- Power Supply Modules
- Battery Management
- Fax Machines and Printers
- HVAC and Disk Drives
- Appliances

3 Description

The LM60 and LM60-Q1 devices are precision integrated-circuit temperature sensors that can sense a −40°C to +125°C temperature range while operating from a single 2.7-V supply. The output voltage of the device is linearly proportional to Celsius (Centigrade) temperature (6.25 mV/°C) and has a DC offset of 424 mV. The offset allows reading negative temperatures without the need for a negative supply. The nominal output voltage of the device ranges from 174 mV to 1205 mV 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 temperature range.

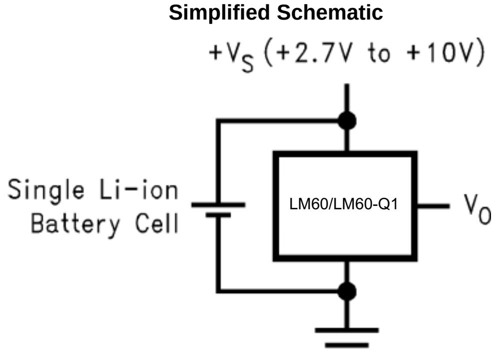
The linear output of the device, 424-mV offset, and factory calibration simplify external circuitry required in a single supply environment where reading negative temperatures is required. Because the quiescent current of the device is less than 110 μA, self-heating is limited to a very low 0.1°C in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

Device Information[1]

PART NUMBER	PACKAGE	BODY SIZE (NOM)
LM60	TO-92 (3)	4.30 mm × 4.30 mm
	SOT-23 (3)	2.92 mm × 1.30 mm
LM60 LM60-Q1	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)

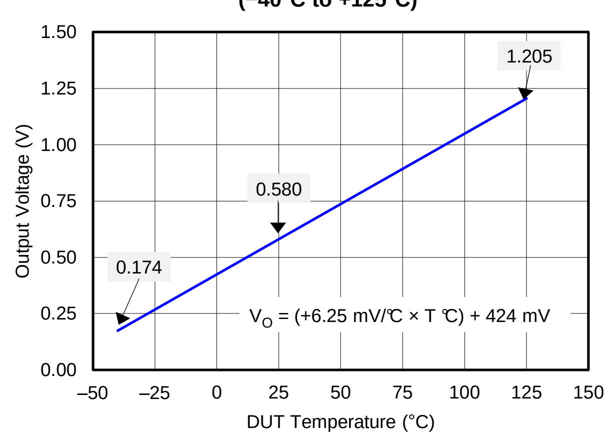


Table of Contents

1 **Features** 1
2 **Applications** 1
3 **Description** 1
4 **Revision History** 2
5 **Device Comparison Table** 3
6 **Pin Configuration and Functions** 4
7 **Specifications** 4
- 7.1 Absolute Maximum Ratings 4
- 7.2 ESD Ratings 4
- 7.3 Recommended Operating Conditions 5
- 7.4 Thermal Information 5
- 7.5 Electrical Characteristics 5
- 7.6 Typical Characteristics 7

8 **Detailed Description** 9
- 8.1 Overview 9
- 8.2 Functional Block Diagram 9
- 8.3 Feature Description 9
- 8.4 Device Functional Modes 9

9 **Application and Implementation** 10
- 9.1 Application Information 10
- 9.2 Typical Applications 11
- 9.3 System Examples 13

10 **Power Supply Recommendations** 13
11 **Layout** 13
- 11.1 Layout Guidelines 13
- 11.2 Layout Example 14
- 11.3 Thermal Considerations 14

12 **Device and Documentation Support** 16
- 12.1 Related Links 16
- 12.2 Community Resources 16
- 12.3 Trademarks 16
- 12.4 Electrostatic Discharge Caution 16
- 12.5 Glossary 16

13 **Mechanical, Packaging, and Orderable Information** 16

4 Revision History

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

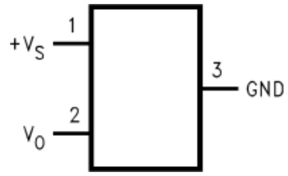
- Added *Pin Configuration and Functions* section, *ESD Ratings* table, *Feature Description* section, *Device Functional Modes*, *Application and Implementation* section, *Power Supply Recommendations* section, *Layout* section, *Device and Documentation Support* section, and *Mechanical, Packaging, and Orderable Information* section 1

5 Device Comparison Table

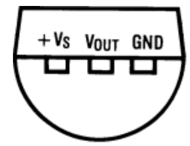
ORDER NUMBER	ACCURACY OVER SPECIFIED TEMPERATURE RANGE	SPECIFIED TEMPERATURE RANGE
LM60BIM3	±3	$-25°C \le T_A \le +125°C$
LM60BIM3X		
LM60CIM3	±4	$-40°C \le T_A \le +125°C$
LM60CIM3X		
LM60QIM3	±4	$-40°C \le T_A \le +125°C$
LM60QIM3X		
LM60BIZ	±3	$-25°C \le T_A \le +125°C$
LM60CIZ	±4	$-40°C \le T_A \le +125°C$

6 Pin Configuration and Functions

DBZ Package
3-Pin SOT-23
Top View



LP Package
3-Pin TO-92
Bottom View



Pin Functions

PIN			TYPE	DESCRIPTION
NAME	SOT-23 NO.	TO92 NO.		
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

7 Specifications

7.1 Absolute Maximum Ratings

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

	MIN	MAX	UNIT
Supply voltage	−0.2	12	V
Output voltage	−0.6	V_S + 0.6	V
Output current		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) 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) 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 should be limited to 5 mA.

7.2 ESD Ratings

			VALUE	UNIT
LM60 in DBZ Package				
$V_{(ESD)}$	Electrostatic discharge(1)	Human-body model (HBM)	±2500	V
		Machine Model (MM)	±250	
LM60 in LP Package				
$V_{(ESD)}$	Electrostatic discharge(1)	Human-body model (HBM)	±2500	V
		Machine Model (MM)	±200	

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

7.3 Recommended Operating Conditions

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

	MIN	MAX	UNIT
LM60B ($T_{MIN} \le T_A \le T_{MAX}$)	–25	125	°C
LM60C/LM60-Q1 ($T_{MIN} \le T_A \le T_{MAX}$)	–40	125	°C
Supply Voltage ($+V_S$)	2.7	10	V

(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.

7.4 Thermal Information

THERMAL METRIC(1)		LM60/LM60-Q1	LM60	UNIT
		DBZ (SOT-23)	LP (TO-92)	
		3 PINS	3 PINS	
$R_{\theta JA}$(2)	Junction-to-ambient thermal resistance	266	162	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	135	85	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	59	—	°C/W
ψ_{JT}	Junction-to-top characterization parameter	18	29	°C/W
ψ_{JB}	Junction-to-board characterization parameter	58	142	°C/W

(1) For more information about traditional and new thermal metrics, see the *Semiconductor or IC Package Thermal Metrics* application report, SPRA953.
(2) The junction to ambient thermal resistance ($R_{\theta JA}$) is specified without a heat sink in still air.

7.5 Electrical Characteristics

Unless otherwise noted, these specifications apply for $+V_S = 3\ V_{DC}$ 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
Accuracy(3)	LM60B		–2		2	°C
		$T_A = T_J = T_{MIN}$ to T_{MAX}	–3		3	
	LM60C/LM60-Q1		–3		3	°C
		$T_A = T_J = T_{MIN}$ to T_{MAX}	–4		4	
Output Voltage at 0°C				424		mV
Nonlinearity(4)	LM60B	$T_A = T_J = T_{MIN}$ to T_{MAX}	–0.6		±0.6	°C
	LM60C/LM60-Q1	$T_A = T_J = T_{MIN}$ to T_{MAX}	–0.8		±0.8	
Sensor Gain (Average Slope)				6.25		mV/°C
	LM60B	$T_A = T_J = T_{MIN}$ to T_{MAX}	6.06		6.44	
	LM60C/LM60-Q1	$T_A = T_J = T_{MIN}$ to T_{MAX}	6		6.5	
Output Impedance	$T_A = T_J = T_{MIN}$ to T_{MAX}				800	Ω
Line Regulation(5)	$3\ V \le +V_S \le 10\ V$	$T_A = T_J = T_{MIN}$ to T_{MAX}	–0.3		0.3	mV/V
	$2.7\ V \le +V_S \le 3.3\ V$	$T_A = T_J = T_{MIN}$ to T_{MAX}	–2.3		2.3	mV

(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 6.25 mV/°C times the case temperature of the device plus 424 mV, at specified conditions of voltage, current, and temperature (expressed in °C).
(4) Nonlinearity is defined as the deviation of the output-voltage-versus-temperature curve from the best-fit straight line, over the rated temperature range of the device.
(5) 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.

Electrical Characteristics (continued)

Unless otherwise noted, these specifications apply for $+V_S$ = 3 V_{DC} and I_{LOAD} = 1 µA. All limits T_A = T_J = 25°C unless otherwise noted.

PARAMETER	TEST CONDITIONS		MIN[1]	TYP[2]	MAX[1]	UNIT
Quiescent Current	2.7 V ≤ $+V_S$ ≤ 10 V			82	110	µA
		T_A = T_J = T_{MIN} to T_{MAX}			125	µA
Change of Quiescent Current	2.7 V ≤ $+V_S$ ≤ 10 V			±5		µA
Temperature Coefficient of Quiescent Current				0.2		µA/°C
Long Term Stability[6]	T_J = T_{MAX} = 125°C for 1000 hours			±0.2		°C

(6) For best long-term stability, any precision circuit will give 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.

7.6 Typical Characteristics

To generate these curves, the device was mounted to a printed-circuit-board as shown in Figure 20.

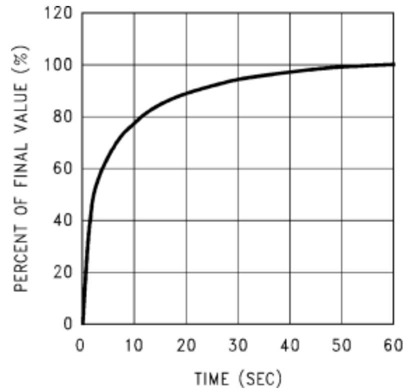


Figure 1. Thermal Resistance Junction to Air

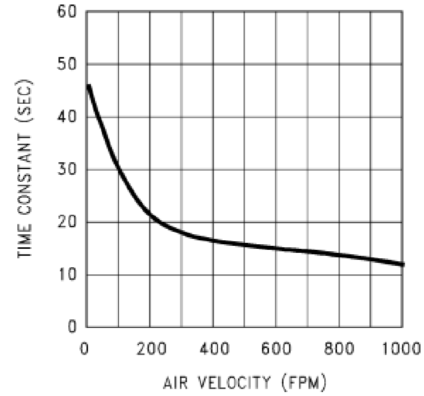


Figure 2. Thermal Time Constant

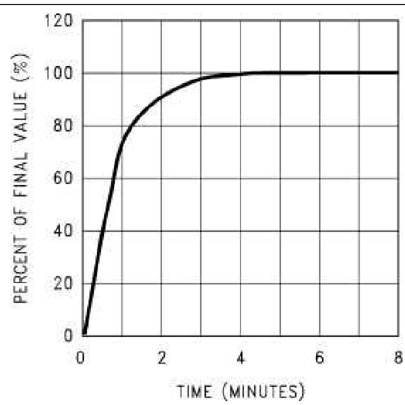


Figure 3. Thermal Response in Still Air With Heat Sink

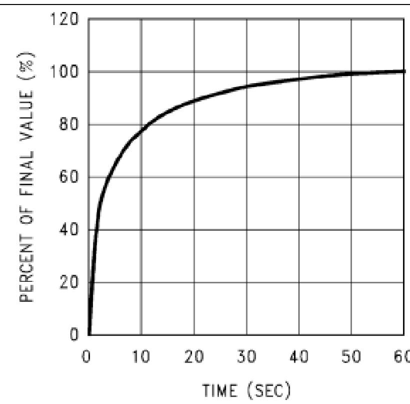


Figure 4. Thermal Response in Stirred Oil Bath With Heat Sink

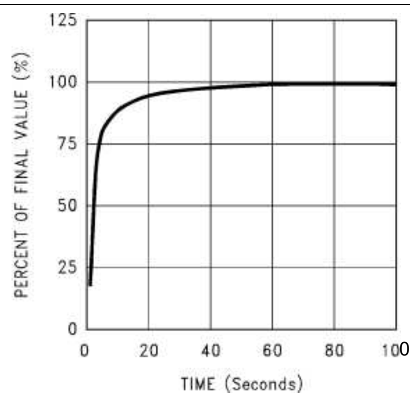


Figure 5. Thermal Response in Still Air Without a Heat Sink

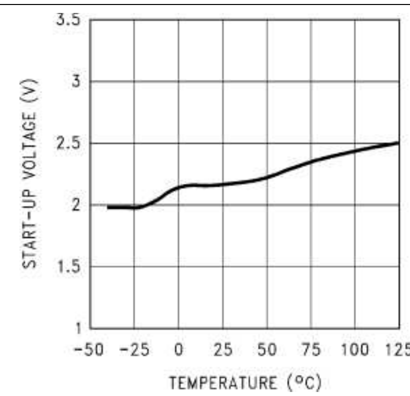


Figure 6. Start-Up Voltage vs Temperature

Typical Characteristics (continued)

To generate these curves, the device was mounted to a printed-circuit-board as shown in Figure 20.

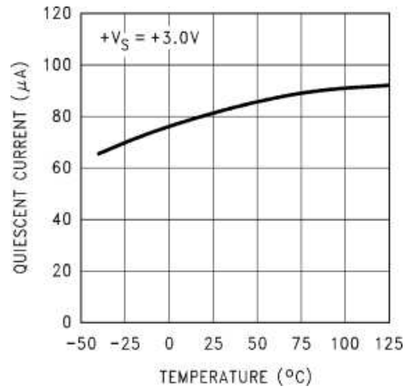


Figure 7. Quiescent Current vs Temperature

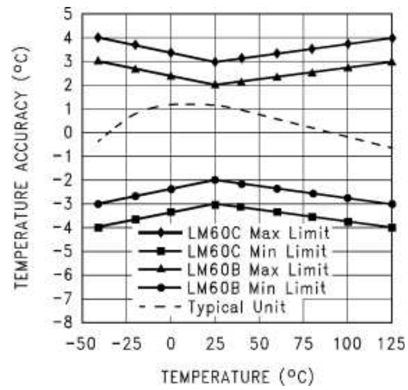


Figure 8. Accuracy vs Temperature

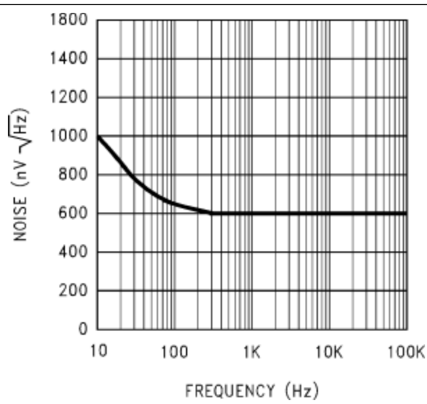


Figure 9. Noise Voltage

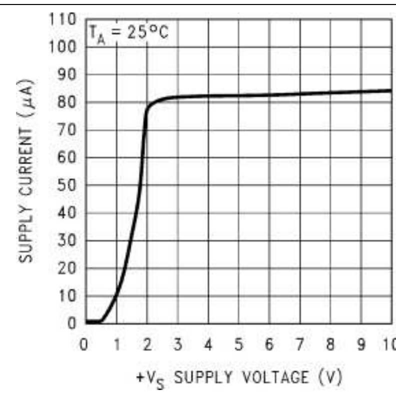


Figure 10. Supply Voltage vs Supply Current

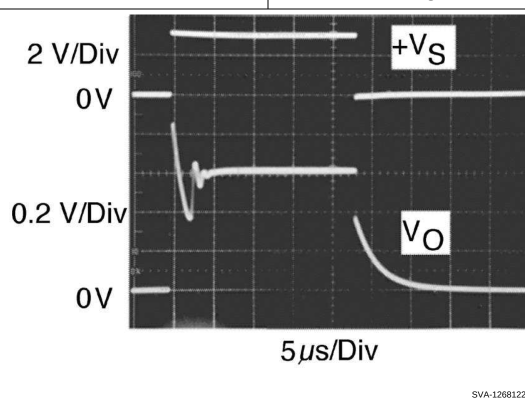


Figure 11. Start-Up Response

8 Detailed Description

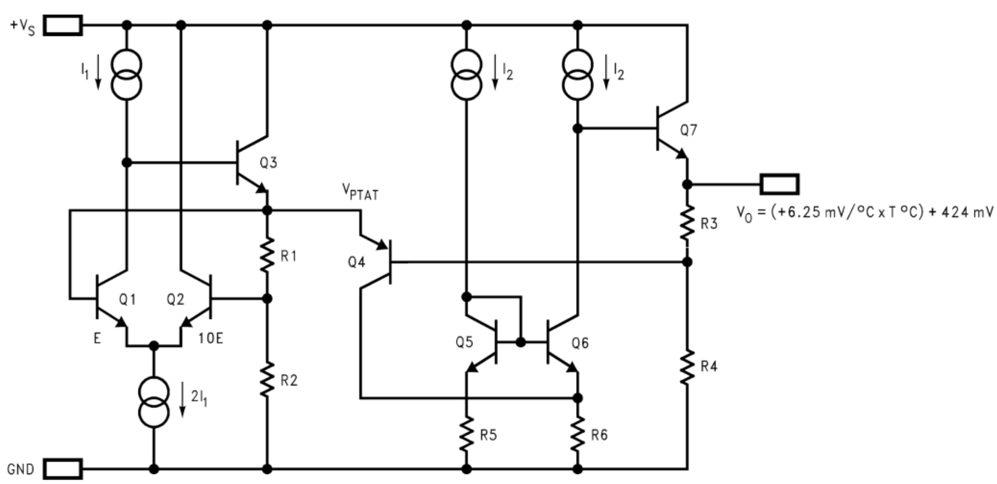
8.1 Overview

The LM60 and LM60-Q1 devices are precision analog bipolar temperature sensors that can sense a −40°C to +125°C temperature range while operating from a single 2.7-V supply. The output voltage of the LM60 and LM60-Q1 is linearly proportional to Celsius (Centigrade) temperature (6.25 mV/°C) and has a DC offset of 424 mV. The offset allows reading negative temperatures with a single positive supply. The nominal output voltage of the device ranges from 174 mV to 1205 mV 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 temperature range.

With a quiescent current of the device is less than 110 µA, 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 its inherent low power consumption allows it to be powered directly from the output of many logic gates.

The output of the LM60 and LM60-Q1 is a Class A base emitter follower, thus the LM60 and LM60-Q1 can source quite a bit of current while sinking less than 1 µA. In any event load current should be minimized in order to limit it's contribution to the total temperature error. The temperature-sensing element is based on a delta V_{BE} topology of two transistors (Q1 and Q2 in *Functional Block Diagram*) that are sized with a 10:1 area ratio.

8.2 Functional Block Diagram



8.3 Feature Description

8.3.1 LM60 Transfer Function

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

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

where

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

8.4 Device Functional Modes

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

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

9.1.1 Capacitive Loads

The device handles capacitive loading well. Without any special precautions, the device can drive any capacitive load as shown in Figure 12. Over the specified temperature range the device has a maximum output impedance of 800 Ω. In an extremely noisy environment adding some filtering to minimize noise pick-up could be required. TI recommends that 0.1 µF be added from $+V_S$ to GND to bypass the power supply voltage, as shown in Figure 13. In a noisy environment, adding a capacitor from the output to ground. A 1-µF output capacitor with the 800-Ω output impedance will form a 199-Hz lowpass filter. Because the thermal time constant of the device is much slower than the 6.3-ms 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.

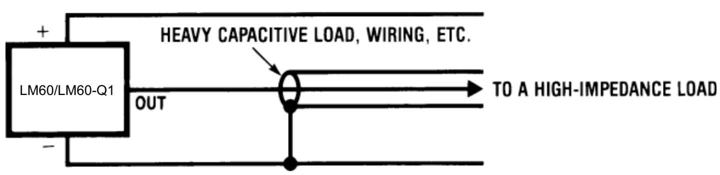


Figure 12. No Decoupling Required for Capacitive Load

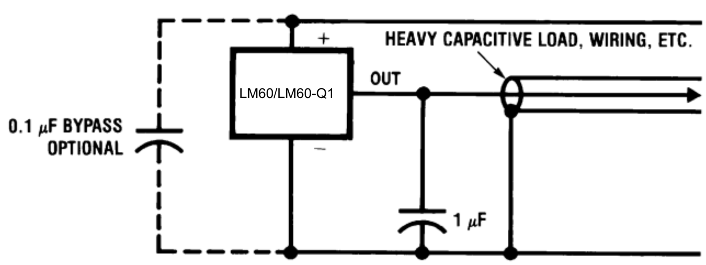
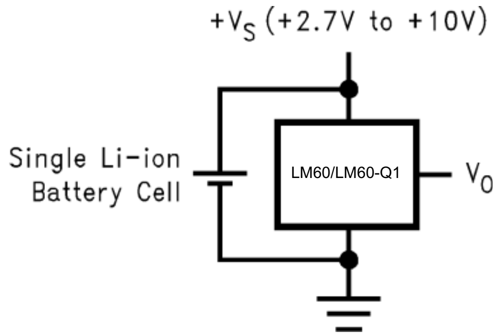


Figure 13. Filter Added for Noisy Environment

9.2 Typical Applications

9.2.1 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 *Layout* for details.



V_O = (6.25 mV/°C × T°C) + 424 mV

Figure 14. Full-Range Centigrade Temperature Sensor (−40°C to +125°C) Operating from a Single Li-Ion Battery Cell

9.2.1.1 Design Requirements

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

Table 1. Temperature and Typical V_O Values of Figure 14

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

9.2.1.2 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.

9.2.1.3 Application Curve

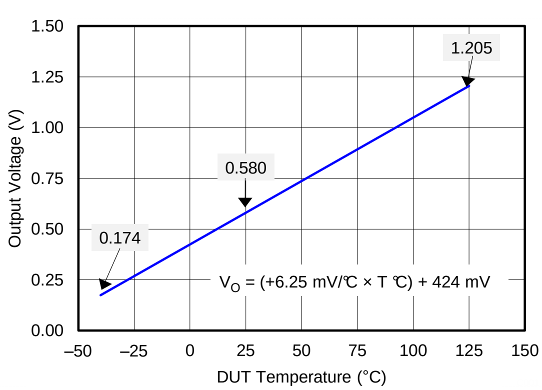


Figure 15. LMT60 and LMT60-Q1 Output Transfer Function

9.2.2 Centigrade Thermostat Application

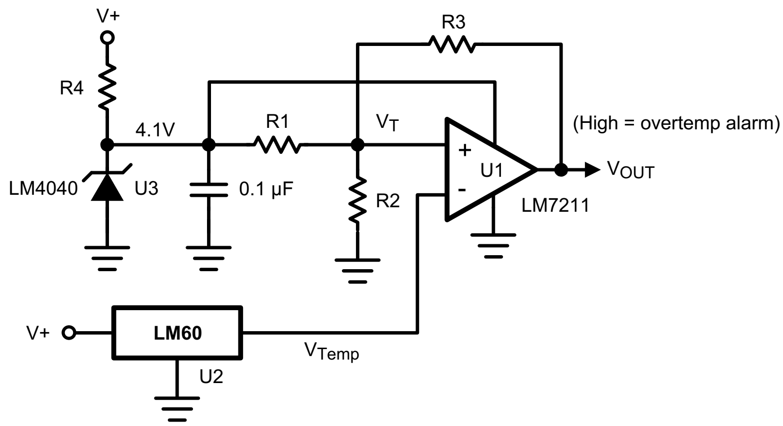


Figure 16. Centigrade Thermostat

9.2.2.1 *Design Requirements*

A simple thermostat can be created by using a reference (LM4040) and a comparator (LM7211) as shown in Figure 16.

9.2.2.2 *Detailed Design Procedure*

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

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

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

9.2.2.3 *Application Curve*

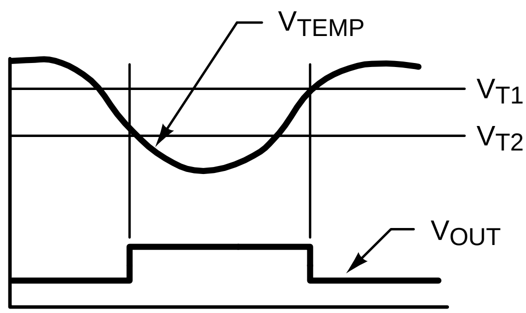


Figure 17. Thermostat Output Waveform

9.3 System Examples

9.3.1 Conserving Power Dissipation With Shutdown

The LMT89 draws very little power therefore it can simply be shutdown by driving the LMT89 supply pin with the output of a logic gate as shown in Figure 18.

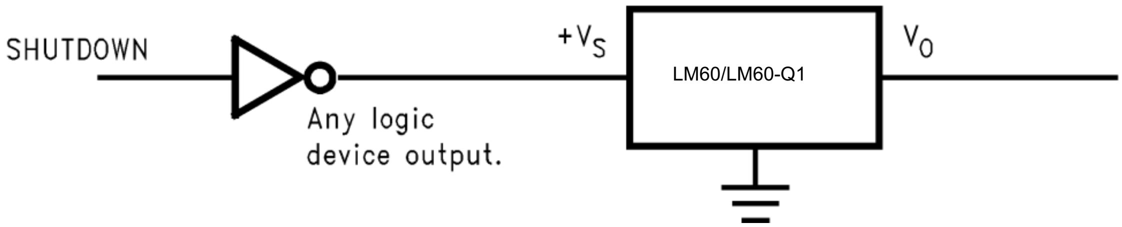


Figure 18. Conserving Power Dissipation With Shutdown

10 Power Supply Recommendations

In an extremely noisy environment, adding some filtering to minimize noise pick-up. Adding 0.1 µF from $+V_S$ to GND is recommended to bypass the power supply voltage, as shown in Figure 13. In a noisy environment adding a capacitor from the output to ground.

11 Layout

11.1 Layout Guidelines

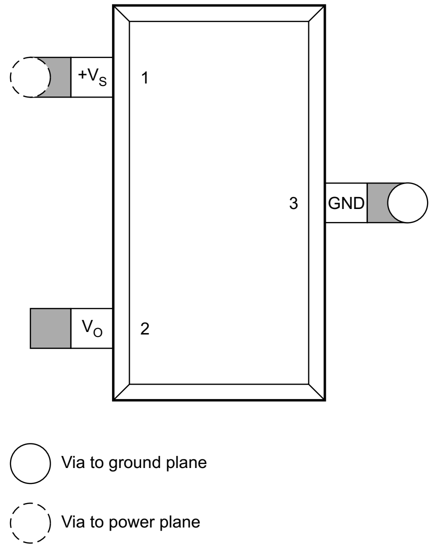
The LM60 and LM60-Q1 can be applied easily in the same way as other integrated-circuit temperature sensors. It can be glued or cemented to a surface. The temperature that the LM60 and LM60-Q1 is sensing will be within about +0.1°C of the surface temperature that the leads of th LM60 and LM60-Q1 are attached to.

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 device die would be at an intermediate temperature between the surface temperature and the air temperature.

To ensure good thermal conductivity the backside of the device die is directly attached to the GND pin. The lands and traces to the device 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 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 ensure that moisture cannot corrode the device or connections.

11.2 Layout Example



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

Figure 19. PCB Layout

11.3 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.

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

where

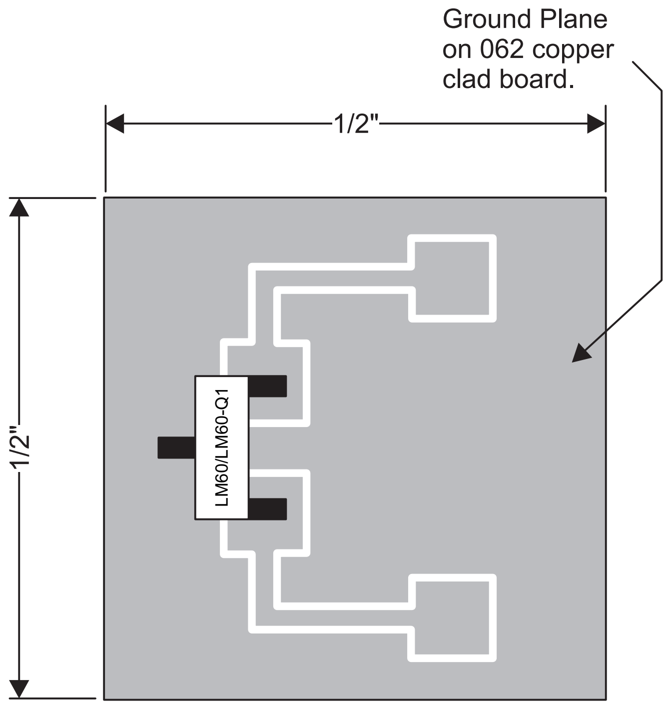
- I_Q is the quiescent current
- I_L is the load current on the output (4)

Table 2 summarizes the rise in die temperature of the LM60 and LM60-Q1 without any loading, and the thermal resistance for different conditions. The values in Table 2 were actually measured where as the values shown in Thermal Information where calculated using modeling methods as described in the *Semiconductor and IC Package Thermal Metrics* application report, SPRA953.

Table 2. Temperature Rise of LM60/LM60-Q1 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	450	0.17	260	0.1	180	0.07	140	0.05
Moving air			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 20.
(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 2-oz. Copper Foil or Similar.

Figure 20. Printed-Circuit-Board Used for Heat Sink to Generate Thermal Response Curves

12 Device and Documentation Support

12.1 Related Links

The table below lists quick access links. Categories include technical documents, support and community resources, tools and software, and quick access to sample or buy.

Table 3. Related Links

PARTS	PRODUCT FOLDER	SAMPLE & BUY	TECHNICAL DOCUMENTS	TOOLS & SOFTWARE	SUPPORT & COMMUNITY
LM60	Click here	Click here	Click here	Click here	Click here
LM60-Q1	Click here	Click here	Click here	Click here	Click here

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.
All other trademarks are the property of their respective owners.

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.

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
LM60BIM3	NRND	SOT-23	DBZ	3	1000	TBD	Call TI	Call TI	-25 to 125	T6B	
LM60BIM3/NOPB	ACTIVE	SOT-23	DBZ	3	1000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-25 to 125	T6B	Samples
LM60BIM3X	NRND	SOT-23	DBZ	3	3000	TBD	Call TI	Call TI	-25 to 125	T6B	
LM60BIM3X/NOPB	ACTIVE	SOT-23	DBZ	3	3000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-25 to 125	T6B	Samples
LM60BIZ/LFT3	ACTIVE	TO-92	LP	3	2000	Green (RoHS & no Sb/Br)	CU SN	N / A for Pkg Type		LM60 BIZ	Samples
LM60BIZ/NOPB	ACTIVE	TO-92	LP	3	1800	Green (RoHS & no Sb/Br)	CU SN	N / A for Pkg Type	-25 to 125	LM60 BIZ	Samples
LM60CIM3	NRND	SOT-23	DBZ	3	1000	TBD	Call TI	Call TI	-40 to 125	T6C	
LM60CIM3/NOPB	ACTIVE	SOT-23	DBZ	3	1000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 125	T6C	Samples
LM60CIM3X	NRND	SOT-23	DBZ	3	3000	TBD	Call TI	Call TI	-40 to 125	T6C	
LM60CIM3X/NOPB	ACTIVE	SOT-23	DBZ	3	3000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 125	T6C	Samples
LM60CIZ/NOPB	ACTIVE	TO-92	LP	3	1800	Green (RoHS & no Sb/Br)	CU SN	N / A for Pkg Type	-40 to 125	LM60 CIZ	Samples
LM60QIM3/NOPB	ACTIVE	SOT-23	DBZ	3	1000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 125	L60Q	Samples
LM60QIM3X/NOPB	ACTIVE	SOT-23	DBZ	3	3000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 125	L60Q	Samples

(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
TBD: The Pb-Free/Green conversion plan has not been defined.
Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

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

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OTHER QUALIFIED VERSIONS OF LM60, LM60-Q1 :

- Catalog: LM60

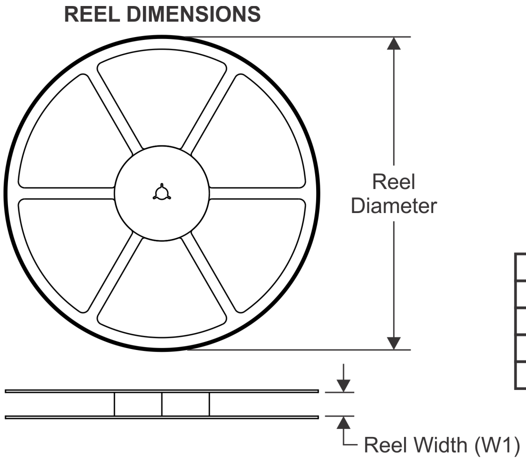
- Automotive: LM60-Q1

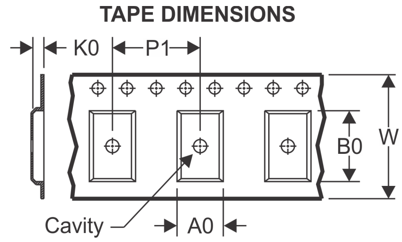
NOTE: Qualified Version Definitions:

- Catalog - TI's standard catalog product

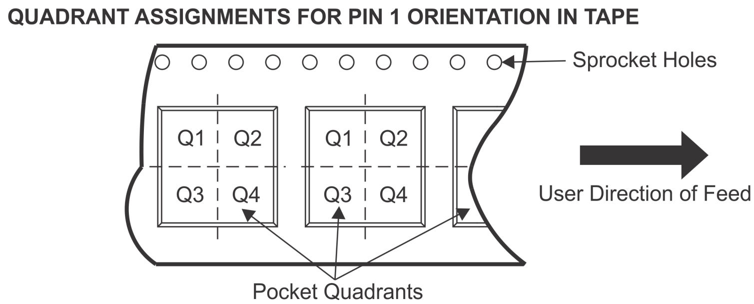
- Automotive - Q100 devices qualified for high-reliability automotive applications targeting zero defects

TAPE AND REEL INFORMATION





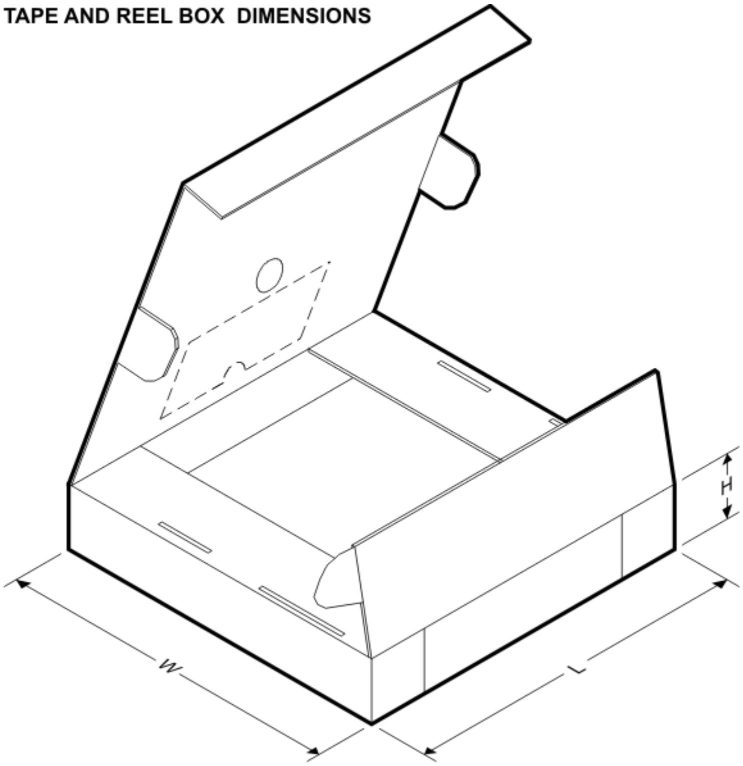
A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers



*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
LM60BIM3	SOT-23	DBZ	3	1000	178.0	8.4	3.3	2.9	1.22	4.0	8.0	Q3
LM60BIM3/NOPB	SOT-23	DBZ	3	1000	178.0	8.4	3.3	2.9	1.22	4.0	8.0	Q3
LM60BIM3X	SOT-23	DBZ	3	3000	178.0	8.4	3.3	2.9	1.22	4.0	8.0	Q3
LM60BIM3X/NOPB	SOT-23	DBZ	3	3000	178.0	8.4	3.3	2.9	1.22	4.0	8.0	Q3
LM60CIM3	SOT-23	DBZ	3	1000	178.0	8.4	3.3	2.9	1.22	4.0	8.0	Q3
LM60CIM3/NOPB	SOT-23	DBZ	3	1000	178.0	8.4	3.3	2.9	1.22	4.0	8.0	Q3
LM60CIM3X	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
LM60QIM3/NOPB	SOT-23	DBZ	3	1000	178.0	8.4	3.3	2.9	1.22	4.0	8.0	Q3
LM60QIM3X/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)
LM60BIM3	SOT-23	DBZ	3	1000	210.0	185.0	35.0
LM60BIM3/NOPB	SOT-23	DBZ	3	1000	210.0	185.0	35.0
LM60BIM3X	SOT-23	DBZ	3	3000	210.0	185.0	35.0
LM60BIM3X/NOPB	SOT-23	DBZ	3	3000	210.0	185.0	35.0
LM60CIM3	SOT-23	DBZ	3	1000	210.0	185.0	35.0
LM60CIM3/NOPB	SOT-23	DBZ	3	1000	210.0	185.0	35.0
LM60CIM3X	SOT-23	DBZ	3	3000	210.0	185.0	35.0
LM60CIM3X/NOPB	SOT-23	DBZ	3	3000	210.0	185.0	35.0
LM60QIM3/NOPB	SOT-23	DBZ	3	1000	210.0	185.0	35.0
LM60QIM3X/NOPB	SOT-23	DBZ	3	3000	210.0	185.0	35.0

LP 3 — TO-92 - 5.34 mm max height

TRANSISTOR OUTLINE

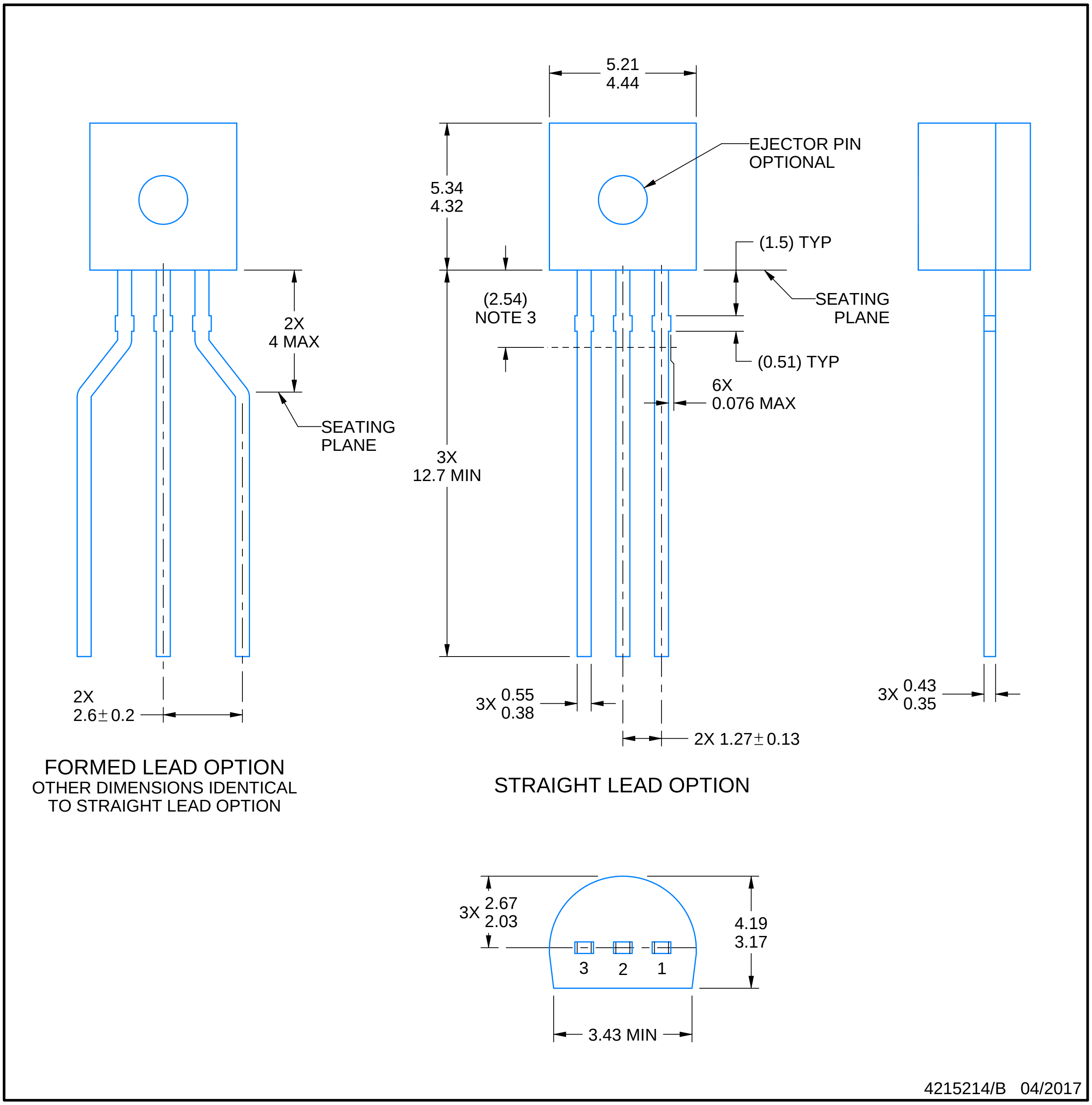
Images above are just a representation of the package family, actual package may vary.
Refer to the product data sheet for package details.

4040001-2/F

PACKAGE OUTLINE

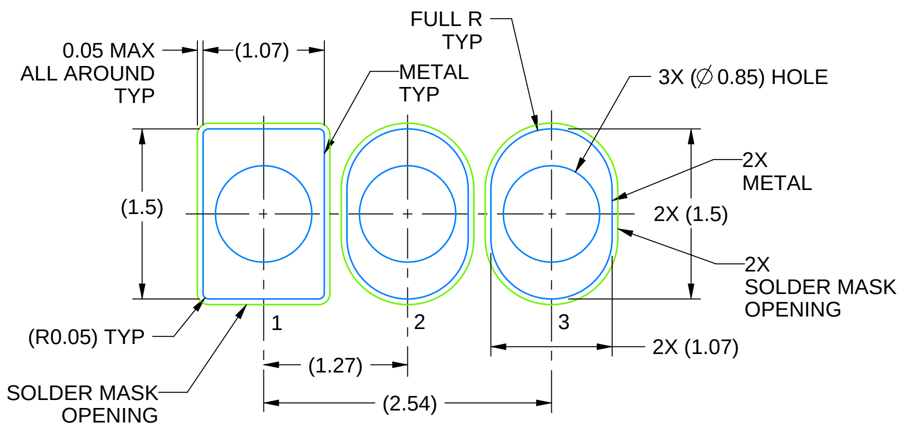
TO-92 - 5.34 mm max height

TO-92

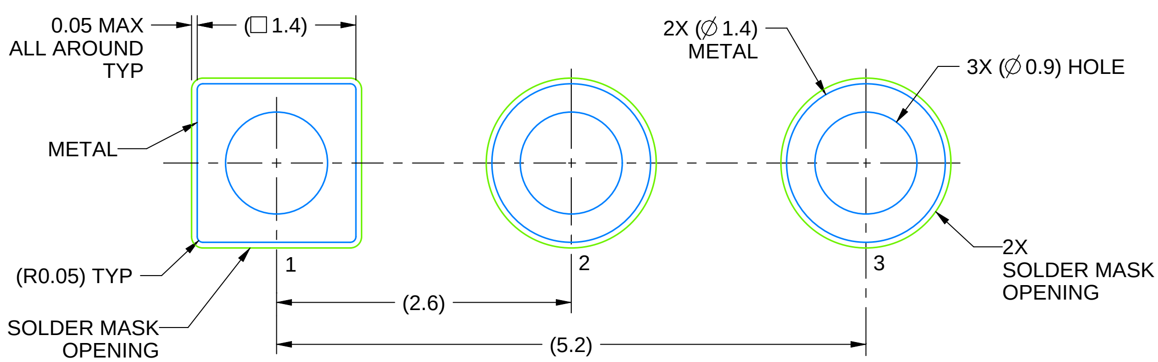


NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. Lead dimensions are not controlled within this area.
4. Reference JEDEC TO-226, variation AA.
5. Shipping method:
   a. Straight lead option available in bulk pack only.
   b. Formed lead option available in tape and reel or ammo pack.
   c. Specific products can be offered in limited combinations of shipping medium and lead options.
   d. Consult product folder for more information on available options.

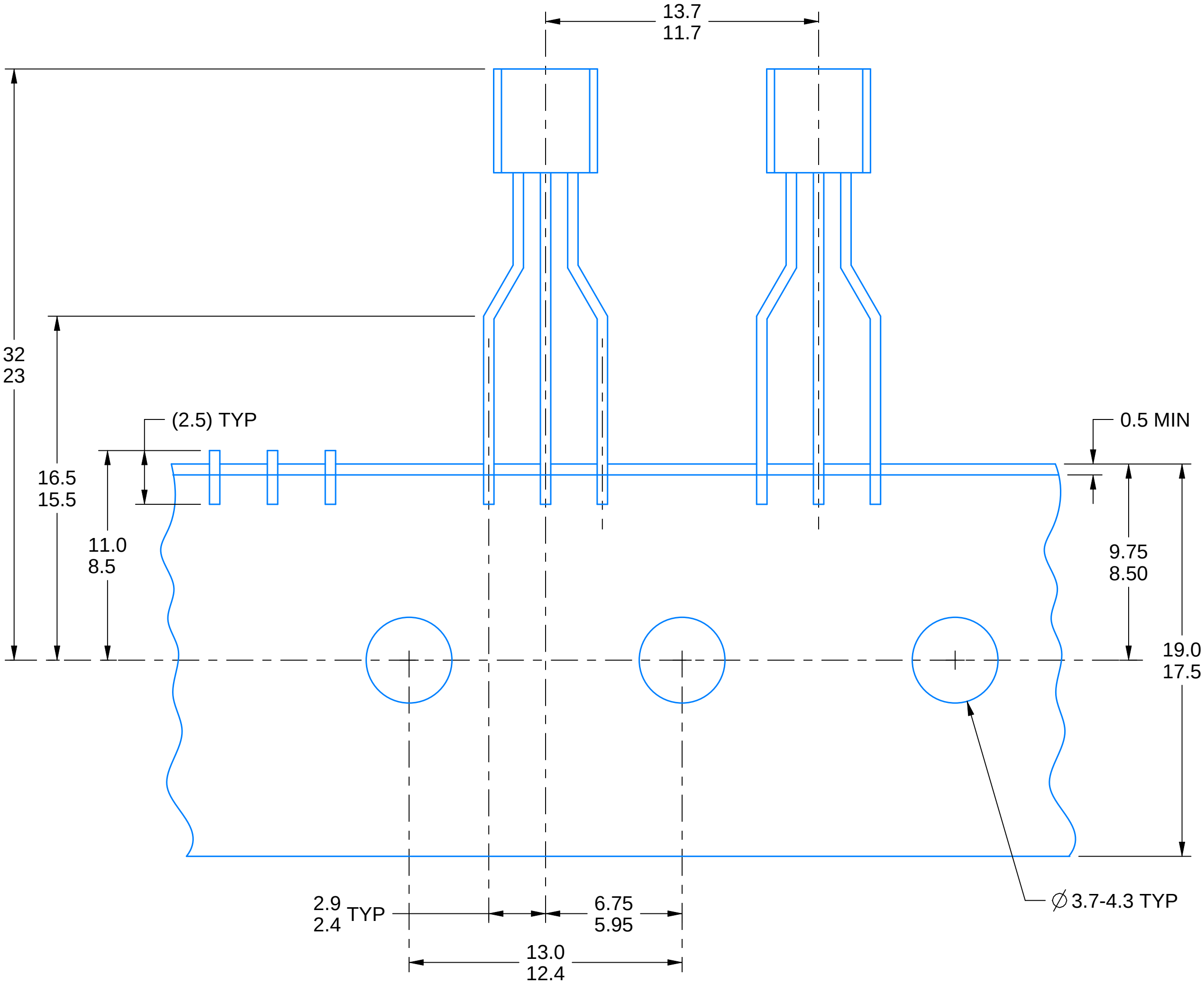


LAND PATTERN EXAMPLE
STRAIGHT LEAD OPTION
NON-SOLDER MASK DEFINED
SCALE:15X



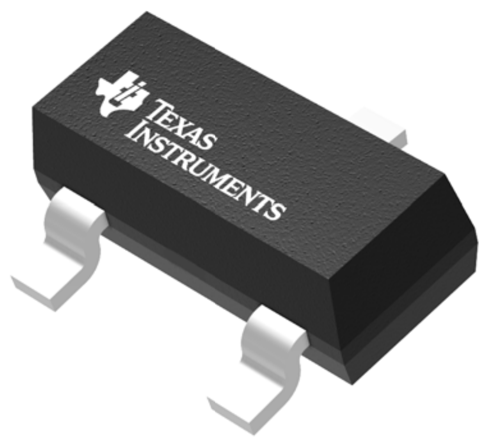
LAND PATTERN EXAMPLE
FORMED LEAD OPTION
NON-SOLDER MASK DEFINED
SCALE:15X

4215214/B 04/2017



FOR FORMED LEAD OPTION PACKAGE

4215214/B 04/2017



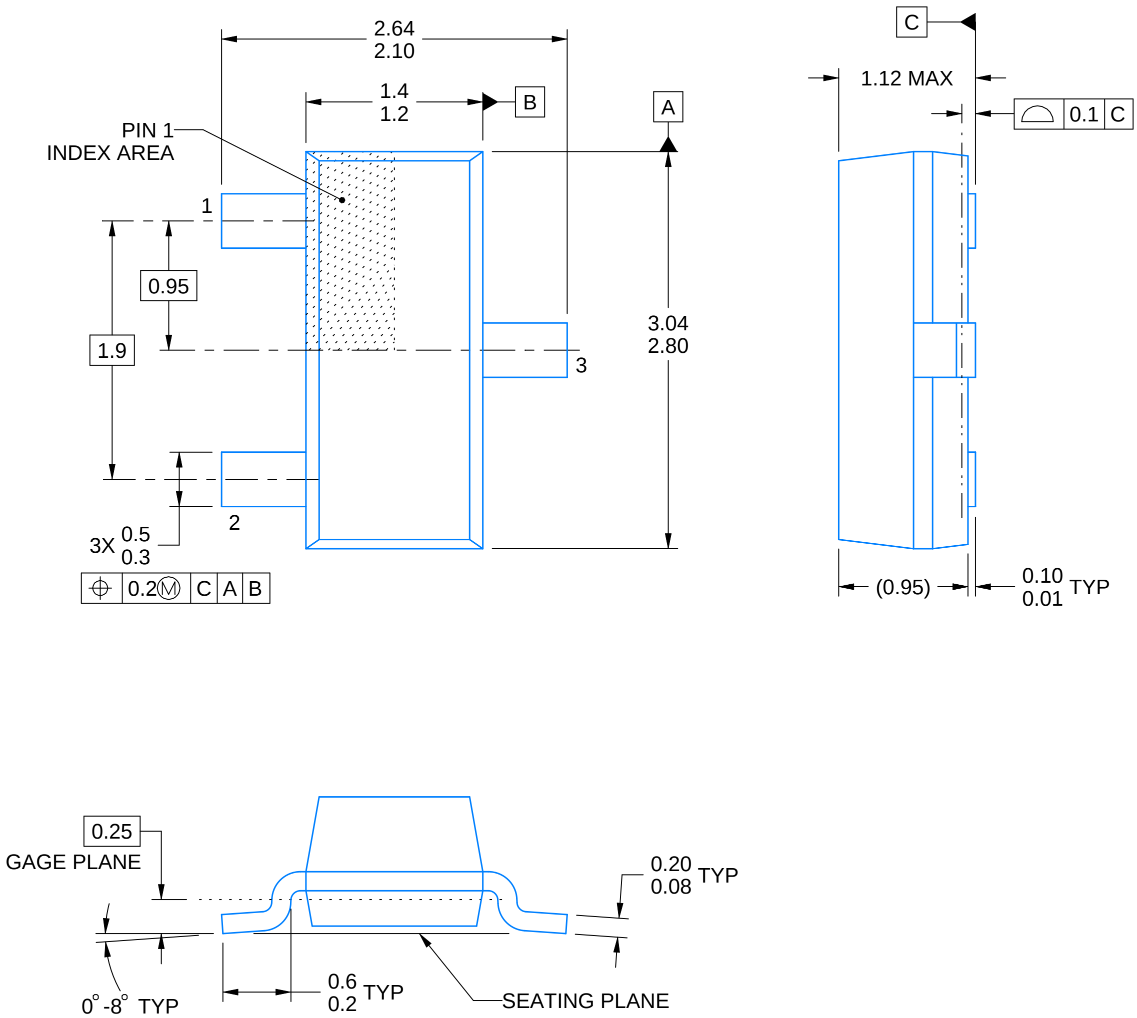
Images above are just a representation of the package family, actual package may vary.
Refer to the product data sheet for package details.

DBZ0003A

PACKAGE OUTLINE

SOT-23 - 1.12 mm max height

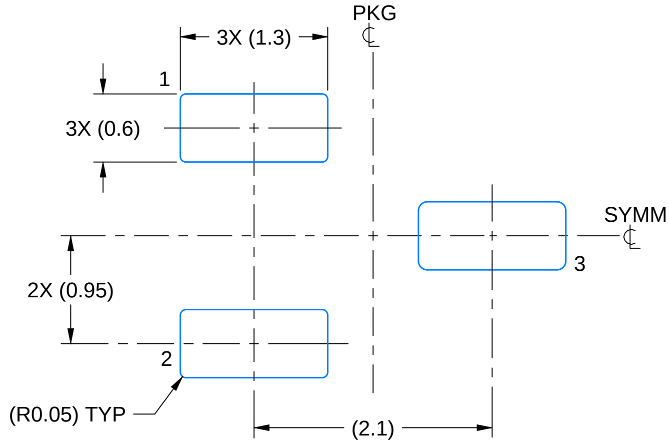
SMALL OUTLINE TRANSISTOR



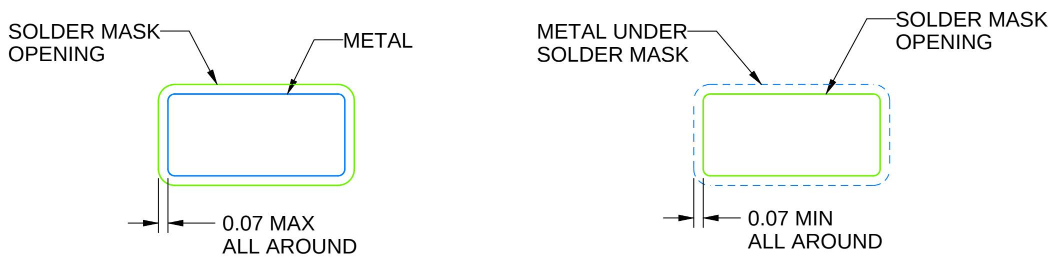
4214838/C 04/2017

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.



LAND PATTERN EXAMPLE
SCALE:15X



NON SOLDER MASK DEFINED (PREFERRED)

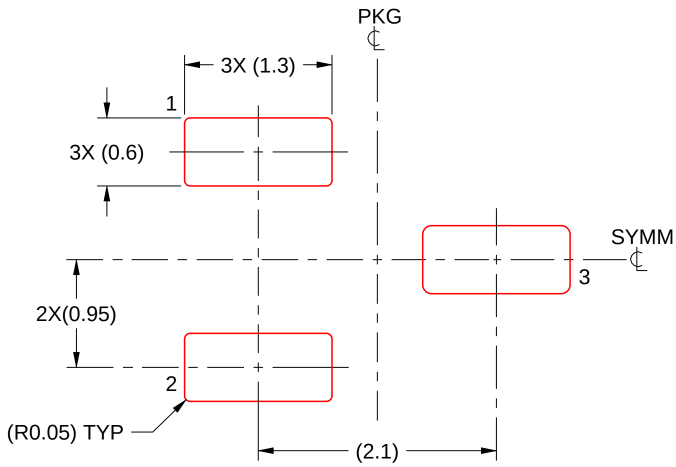
SOLDER MASK DEFINED

SOLDER MASK DETAILS

4214838/C 04/2017

NOTES: (continued)

4. Publication IPC-7351 may have alternate designs.
5. 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

4214838/C 04/2017

NOTES: (continued)

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

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