National Semiconductor

February 9, 2010

LM61

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

General Description

The LM61 is a precision integrated-circuit temperature sensor that can sense a −30°C to +100°C temperature range while operating from a single +2.7V supply. The LM61's output voltage is linearly proportional to Celsius (Centigrade) temperature (+10 mV/°C) and has a DC offset of +600 mV. The offset allows reading negative temperatures without the need for a negative supply. The nominal output voltage of the LM61 ranges from +300 mV to +1600 mV for a −30°C to +100°C temperature range. The LM61 is calibrated to provide accuracies of ±2.0°C at room temperature and ±3°C over the full −25°C to +85°C temperature range.

The LM61's linear output, +600 mV offset, and factory calibration simplify external circuitry required in a single supply environment where reading negative temperatures is required. Because the LM61's quiescent current is less than 125 µA, self-heating is limited to a very low 0.2°C in still air. Shutdown capability for the LM61 is intrinsic because its inherent low power consumption allows it to be powered directly from the output of many logic gates.

Features

- Calibrated linear scale factor of +10 mV/°C
- Rated for full −30° to +100°C range
- Suitable for remote applications
- UL Recognized Component ®

Applications

- Cellular Phones
- Computers
- Power Supply Modules
- Battery Management
- FAX Machines
- Printers
- HVAC
- Disk Drives
- Appliances

Key Specifications

■ Accuracy at 25°C	±2.0 or ±3.0°C (max)
■ Accuracy for −30°C to +100°C	±4.0°C (max)
■ Accuracy for −25°C to +85°C	±3.0°C (max)
■ Temperature Slope	+10 mV/°C
■ Power Supply Voltage Range	+2.7V to +10V
■ Current Drain @ 25°C	125 µA (max)
■ Nonlinearity	±0.8°C (max)
■ Output Impedance	800 Ω (max)

Typical Application
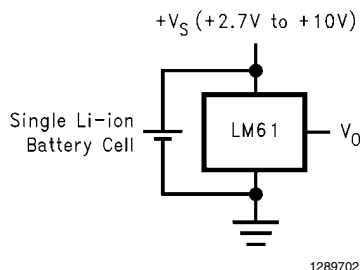
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$V_O = (+10\ mV/°C \times T\ °C) + 600\ mV$

Temperature (T)	Typical V_O
+100°C	+1600 mV
+85°C	+1450 mV
+25°C	+850 mV
0°C	+600 mV
−25°C	+350 mV
−30°C	+300 mV

FIGURE 1. Full-Range Centigrade Temperature Sensor (−30°C to +100°C) Operating from a Single Li-Ion Battery Cell

Connection Diagrams

SOT-23

+V$_S$ —[1
V$_O$ —[2
3]— GND

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Top View
See NS Package Number mf03a

TO-92

+V$_S$ V$_{OUT}$ GND

BOTTOM VIEW

1289725

See NS Package Number Z03A
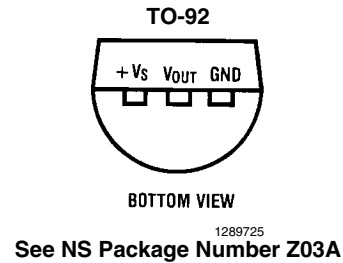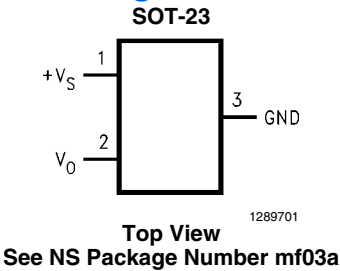
Ordering Information

Order Number	Device Top Mark	Supplied In	Accuracy Over Specified Temperature Range (°C)	Specified Temperature Range	Package Type
LM61BIM3	T1B	1000 Units on Tape and Reel	± 3	−25°C to +85°C	SOT-23
LM61BIM3X	T1B	3000 Units on Tape and Reel			
LM61CIM3	T1C	1000 Units on Tape and Reel	± 4	−30°C to +100°C	
LM61CIM3X	T1C	3000 Units on Tape and Reel			
LM61BIZ	LM61BIZ	Bulk	± 3	−25°C to +85°C	TO-92
LM61CIZ	LM61CIZ	Bulk	± 4	−30°C to +100°C	

Absolute Maximum Ratings (*Note 1*)

Supply Voltage	+12V to −0.2V
Output Voltage	(+V_S + 0.6V) to −0.6V
Output Current	10 mA
Input Current at any pin (*Note 2*)	5 mA
Storage Temperature	−65°C to +150°C
Maximum Junction Temperature (T_{JMAX})	+125°C
ESD Susceptibility (*Note 3*) :	
Human Body Model	2500V
Machine Model	250V

Operating Ratings (*Note 1*)

Specified Temperature Range:	$T_{MIN} \leq T_A \leq T_{MAX}$
LM61C	−30°C ≤ T_A ≤ +100°C
LM61B	−25°C ≤ T_A ≤ +85°C
Supply Voltage Range (+V_S)	+2.7V to +10V
Thermal Resistance, θ_{JA}(*Note 5*)	
SOT-23	450°C/W
TO-92	180°C/W

Soldering process must comply with National Semiconductor's Reflow Temperature Profile specifications. Refer to www.national.com/packaging. (Note 4)

Electrical Characteristics

Unless otherwise noted, these specifications apply for +V_S = +3.0 V_{DC}. **Boldface limits apply for $T_A = T_J = T_{MIN}$ to T_{MAX}** ; all other limits $T_A = T_J = 25°C$.

Parameter	Conditions	Typical (*Note 6*)	LM61B Limits (*Note 7*)	LM61C Limits (*Note 7*)	Units (Limit)
Accuracy (*Note 8*)			±2.0	±3.0	°C (max)
			±3.0	**±4.0**	°C (max)
Output Voltage at 0°C		+600			mV
Nonlinearity (*Note 9*)			**±0.6**	**±0.8**	°C (max)
Sensor Gain (Average Slope)		+10	**+9.7**	**+9.6**	mV/°C (min)
			+10.3	**+10.4**	mV/°C (max)
Output Impedance	+3.0V ≤ +V_S ≤ +10V		**0.8**	**0.8**	kΩ (max)
	−30°C ≤ T_A ≤ +85°C, +V_S= +2.7V		**2.3**	**2.3**	kΩ (max)
	+85°C ≤ T_A ≤ +100°C, +V_S= +2.7V		**5**	**5**	kΩ (max)
Line Regulation (*Note 10*)	+3.0V ≤ +V_S ≤ +10V		**±0.7**	**±0.7**	mV/V (max)
	+2.7V ≤ +V_S ≤ +3.3V		**±5.7**	**±5.7**	mV (max)
Quiescent Current	+2.7V ≤ +V_S ≤ +10V	82	125	125	µA (max)
			155	**155**	µA (max)
Change of Quiescent Current	+2.7V ≤ +V_S ≤ +10V	±5			µA
Temperature Coefficient of Quiescent Current		0.2			µA/°C
Long Term Stability (*Note 11*)	T_J=T_{MAX}=+100°C, for 1000 hours	±0.2			°C

Note 1: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not guarantee specific performance limits. For guaranteed specifications and test conditions, see the Electrical Characteristics. The guaranteed specifications apply only for the test conditions listed. Some performance characteristics may degrade when the device is not operated under the listed test conditions.

Note 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.

Note 3: 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.

Note 4: Reflow temperature profiles are different for lead-free and non-lead-free packages.

Note 5: The junction to ambient thermal resistance (θ_{JA}) is specified without a heat sink in still air.

Note 6: Typicals are at $T_J = T_A = 25°C$ and represent most likely parametric norm.

Note 7: Limits are guaranteed to National's AOQL (Average Outgoing Quality Level).

Note 8: Accuracy is defined as the error between the output voltage and +10 mV/°C times the device's case temperature plus 600 mV, at specified conditions of voltage, current, and temperature (expressed in °C).
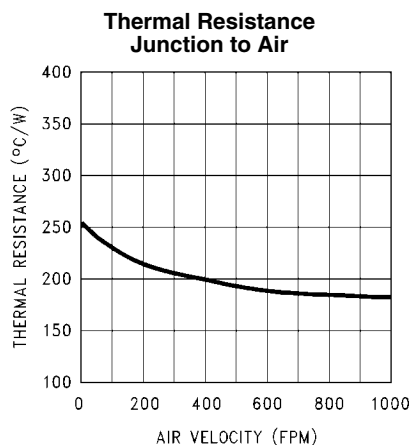
Note 9: Nonlinearity is defined as the deviation of the output-voltage-versus-temperature curve from the best-fit straight line, over the device's rated temperature range.

Note 10: 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.
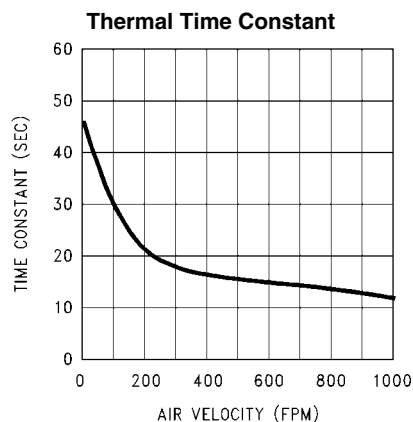
www.national.com

Note 11: 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.

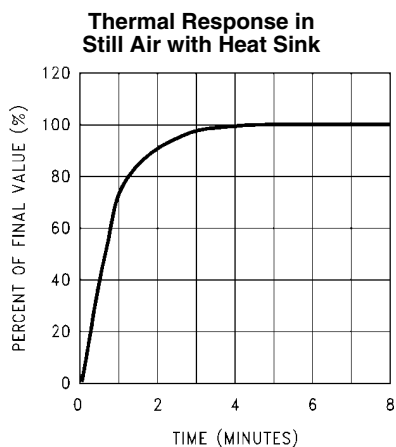## Typical Performance Characteristics

The LM61 in the SOT-23 package mounted to a printed circuit board as shown in *Figure 2* was used to generate the following thermal curves.
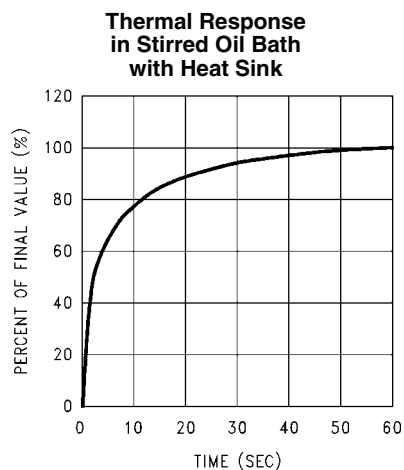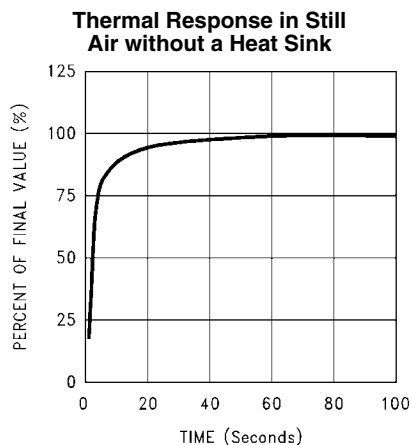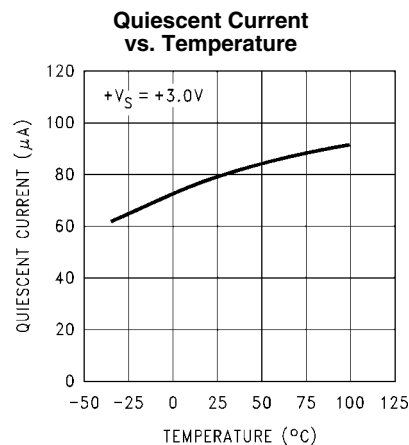
Thermal Resistance Junction to Air

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Thermal Time Constant

1289704

Thermal Response in Still Air with Heat Sink

1289705

Thermal Response in Stirred Oil Bath with Heat Sink

1289706

Thermal Response in Still Air without a Heat Sink

1289708

Quiescent Current vs. Temperature

1289709

Accuracy vs Temperature

1289710

Noise Voltage

1289711

**Supply Voltage
vs Supply Current**

1289712

Start-Up Response

2 V/Div

0V

0.2 V/Div

0V

$+V_S$

V_O

5µs/Div

1289722

Ground Plane
on 062 copper
clad board.
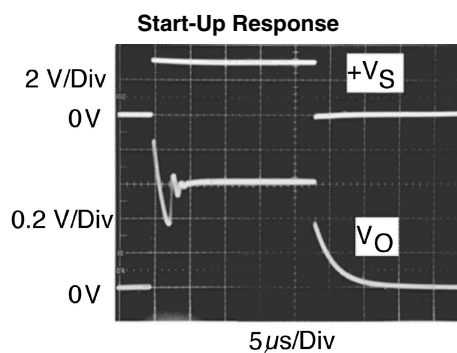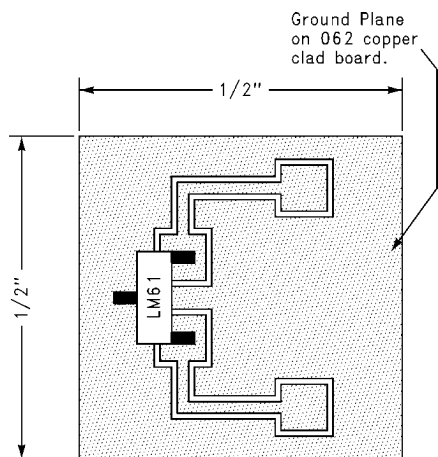
1/2"

1/2"
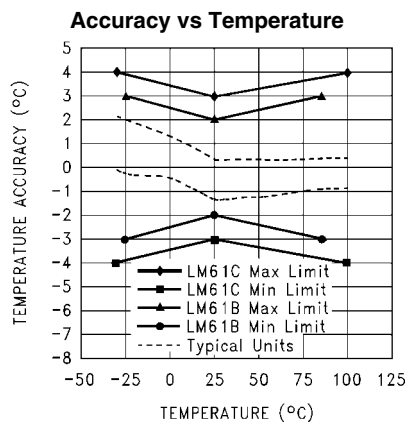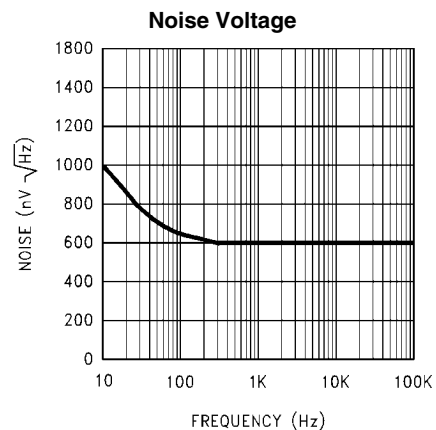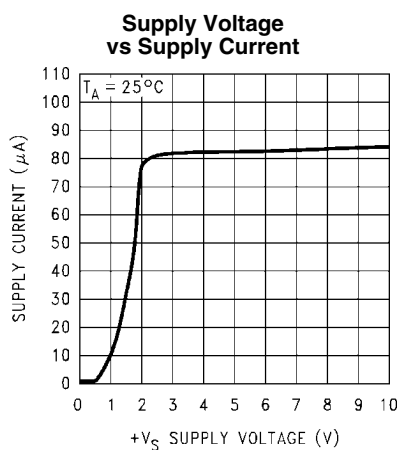
LM61

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**FIGURE 2. Printed Circuit Board Used
for Heat Sink to Generate All Curves.
½ Square Printed Circuit Board
with 2 oz. Copper Foil or Similar.**

1.0 Mounting

The LM61 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 LM61 is sensing will be within about +0.2°C of the surface temperature that LM61's leads 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 measured would be at an intermediate temperature between the surface temperature and the air temperature.

To ensure good thermal conductivity the backside of the LM61 die is directly attached to the GND pin. The lands and traces to the LM61 will, of course, be part of the printed circuit board, which is the object whose temperature is being measured.

Alternatively, the LM61 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 LM61 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 Humiseal and epoxy paints or dips are often used to ensure that moisture cannot corrode the LM61 or its connections.

The thermal resistance junction to ambient (θ_{JA}) is the parameter used to calculate the rise of a device junction temperature due to its power dissipation. For the LM61 the equation used to calculate the rise in the die temperature is as follows:

$$T_J = T_A + \theta_{JA} [(+V_S I_Q) + (+V_S - V_O) I_L]$$

where I_Q is the quiescent current and I_L is the load current on the output. Since the LM61's junction temperature is the actual temperature being measured care should be taken to minimize the load current that the LM61 is required to drive.

The table shown in *Figure 3* summarizes the rise in die temperature of the LM61 without any loading with a 3.3V supply, and the thermal resistance for different conditions.

	SOT-23* no heat sink		SOT-23** small heat fin		TO-92* no heat sink		TO-92*** small heat fin	
	θ_{JA} (°C/W)	$T_J - T_A$ (°C)	θ_{JA} (°C/W)	$T_J - T_A$ (°C)	θ_{JA} (°C/W)	$T_J - T_A$ (°C)	θ_{JA} (°C/W)	$T_J - T_A$ (°C)
Still air	450	0.26	260	0.13	180	0.09	140	0.07
Moving air			180	0.09	90	0.05	70	0.03

*Part soldered to 30 gauge wire.
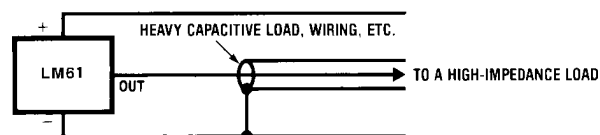
**Heat sink used is ½ square printed circuit board with 2 oz. foil with part attached as shown in *Figure 2*.

***Part glued and leads soldered to 1" square of 1/16" printed circuit board with 2oz. foil or similar.

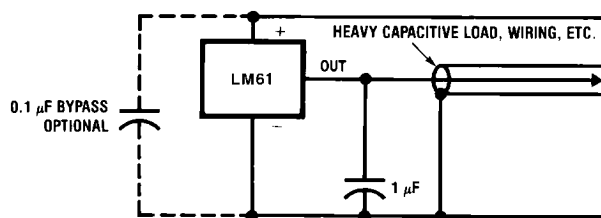**FIGURE 3. Temperature Rise of LM61 Due to Self-Heating and Thermal Resistance (θ_{JA})**

2.0 Capacitive Loads

The LM61 handles capacitive loading well. Without any special precautions, the LM61 can drive any capacitive load as shown in *Figure 4*. Over the specified temperature range the LM61 has a maximum output impedance of 5 kΩ. In an extremely noisy environment it may be necessary to add some filtering to minimize noise pickup. It is recommended that 0.1 μF be added from $+V_S$ to GND to bypass the power supply voltage, as shown in *Figure 5*. In a noisy environment it may be necessary to add a capacitor from the output to ground. A 1 μF output capacitor with the 5 kΩ maximum output impedance will form a 32 Hz lowpass filter. Since the thermal time constant of the LM61 is much slower than the 5 ms time constant formed by the RC, the overall response time of the LM61 will not be significantly affected. For much larger capacitors this additional time lag will increase the overall response time of the LM61.

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FIGURE 5. LM61 with Filter for Noisy Environment

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FIGURE 4. LM61 No Decoupling Required for Capacitive Load

$$V_O = (+10\,mV/°C \times T\,°C) + 600\,mV$$
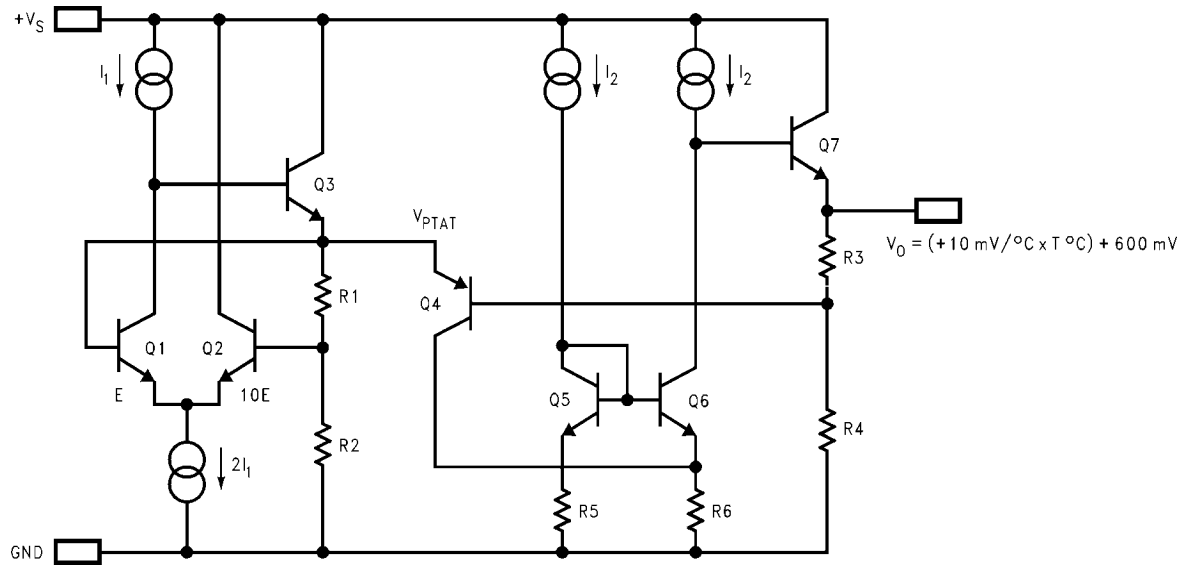
FIGURE 6. Simplified Schematic

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3.0 Applications Circuits

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

$$V_{T2} = \frac{(4.1)R2 \| R3}{R1 + R2 \| R3}$$
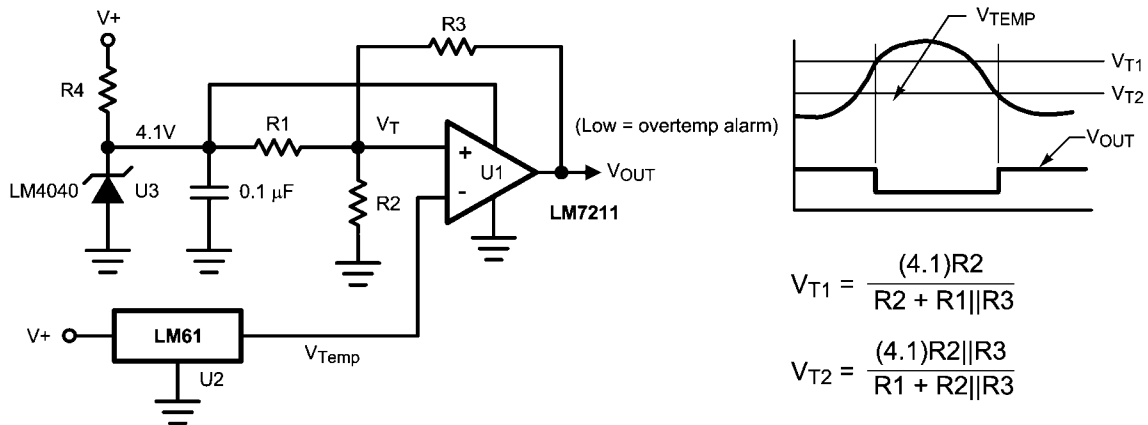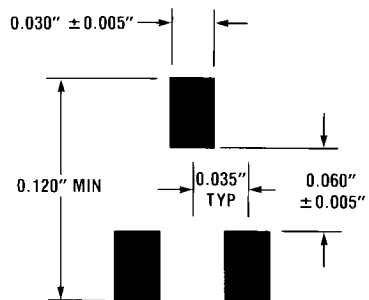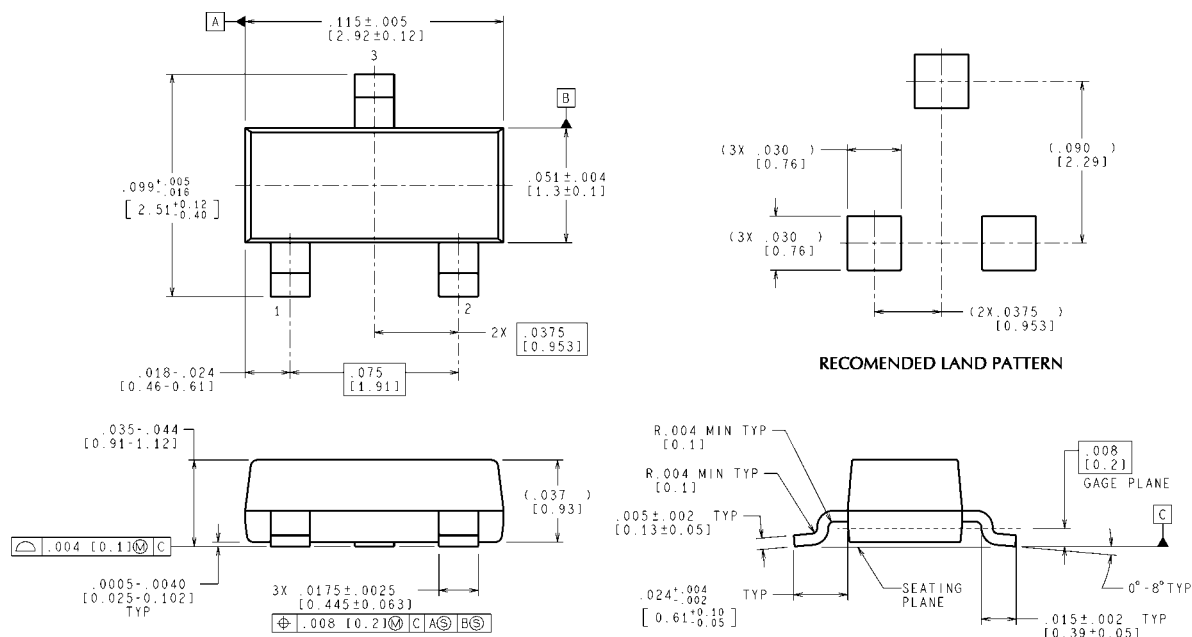
FIGURE 7. Centigrade Thermostat
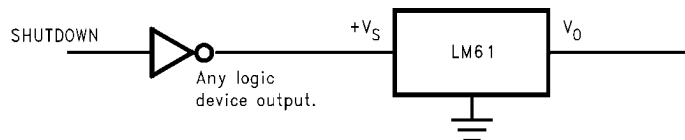
FIGURE 8. Conserving Power Dissipation with Shutdown
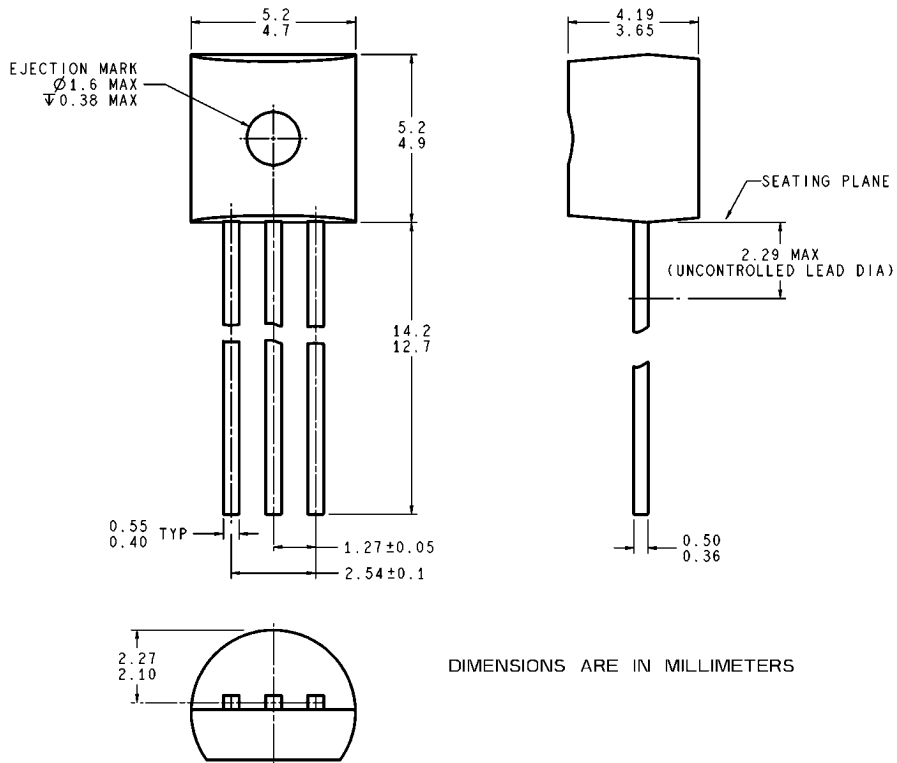
4.0 Recommended Solder Pads for SOT-23 Package

Physical Dimensions inches (millimeters) unless otherwise noted

.115±.005
[2.92±0.12]

A

3

B

.099 +.005 -.016
[2.51 +0.12 -0.40]

.051±.004
[1.3±0.1]

1   2

2X .0375
[0.953]

.018-.024
[0.46-0.61]

.075
[1.91]

RECOMENDED LAND PATTERN

(3X .030)
[0.76]

(3X .030)
[0.76]

(.090)
[2.29]

(2X .0375)
[0.953]

.035-.044
[0.91-1.12]

(.037)
[0.93]

.004 [0.1] Ⓜ C

.0005-.0040
[0.025-0.102]
TYP

3X .0175±.0025
[0.445±0.063]

⊕ .008 [0.2] Ⓜ C A Ⓢ B Ⓢ

R.004 MIN TYP
[0.1]

R.004 MIN TYP
[0.1]

.005±.002 TYP
[0.13±0.05]

.024 +.004 -.002 TYP
[0.61 +0.10 -0.05]

SEATING
PLANE

.008
[0.2]
GAGE PLANE

C

0°-8° TYP

.015±.002 TYP
[0.39±0.05]

CONTROLLING DIMENSION IS INCH
VALUES IN [ ] ARE MILLIMETERS

MF03A (Rev B)

SOT-23 Molded Small Outline Transistor Package (M3)
Order Number LM61BIM3, LM61BIM3X, LM61CIM3 or LM61CIM3X
NS Package Number mf03a

EJECTION MARK
Ø1.6 MAX
0.38 MAX

5.2
4.7

5.2
4.9

14.2
12.7

0.55
0.40 TYP

1.27±0.05

2.54±0.1

4.19
3.65

SEATING PLANE

2.29 MAX
(UNCONTROLLED LEAD DIA)

0.50
0.36

2.27
2.10

DIMENSIONS ARE IN MILLIMETERS

Z03A (Rev G)

TO-92 Plastic Package (Z)
Order Number LM61BIZ or LM61CIZ
NS Package Number Z03A

Notes

Notes

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LVDS	www.national.com/lvds	Packaging	www.national.com/packaging
Power Management	www.national.com/power	Green Compliance	www.national.com/quality/green
Switching Regulators	www.national.com/switchers	Distributors	www.national.com/contacts
LDOs	www.national.com/ldo	Quality and Reliability	www.national.com/quality
LED Lighting	www.national.com/led	Feedback/Support	www.national.com/feedback
Voltage References	www.national.com/vref	Design Made Easy	www.national.com/easy
PowerWise® Solutions	www.national.com/powerwise	Applications & Markets	www.national.com/solutions
Serial Digital Interface (SDI)	www.national.com/sdi	Mil/Aero	www.national.com/milaero
Temperature Sensors	www.national.com/tempsensors	SolarMagic™	www.national.com/solarmagic
PLL/VCO	www.national.com/wireless	PowerWise® Design University	www.national.com/training

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