National Semiconductor

January 1999

LM45B/LM45C
SOT-23 Precision Centigrade Temperature Sensors

General Description

The LM45 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. The LM45 does not require any external calibration or trimming to provide accuracies of ±2˚C at room temperature and ±3˚C over a full −20 to +100˚C temperature range. Low cost is assured by trimming and calibration at the wafer level. The LM45's low output impedance, linear output, and precise inherent calibration make interfacing to readout or control circuitry especially easy. It can be used with a single power supply, or with plus and minus supplies. As it draws only 120 µA from its supply, it has very low self-heating, less than 0.2˚C in still air. The LM45 is rated to operate over a −20˚ to +100˚C temperature range.

Applications

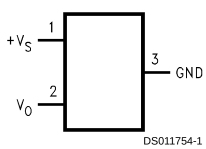
- Battery Management
- FAX Machines
- Printers
- Portable Medical Instruments
- HVAC
- Power Supply Modules
- Disk Drives
- Computers
- Automotive

Features

- Calibrated directly in ˚ Celsius (Centigrade)
- Linear + 10.0 mV/˚C scale factor
- ±3˚C accuracy guaranteed
- Rated for full −20˚ to +100˚C range
- Suitable for remote applications
- Low cost due to wafer-level trimming
- Operates from 4.0V to 10V
- Less than 120 µA current drain
- Low self-heating, 0.20˚C in still air
- Nonlinearity only ±0.8˚C max over temp
- Low impedance output, 20Ω for 1 mA load

Connection Diagram

SOT-23



Top View
See NS Package Number MA03B

Order Number	SOT-23 Device Marking	Supplied As
LM45BIM3	T4B	1000 Units on Tape and Reel
LM45BIM3X	T4B	3000 Units on Tape and Reel
LM45CIM3	T4C	1000 Units on Tape and Reel
LM45CIM3X	T4C	3000 Units on Tape and Reel

Typical Applications

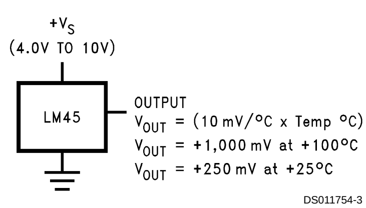
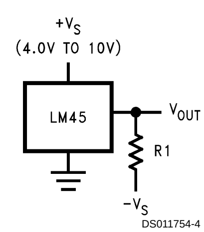


FIGURE 1. Basic Centigrade Temperature Sensor (+2.5˚C to +100˚C)



Choose $R_1 = -V_S/50$ µA
V_{OUT}= (10 mV/˚C x Temp ˚C)
V_{OUT} = +1,000 mV at +100˚C
= +250 mV at +25˚C
= −200 mV at −20˚C

FIGURE 2. Full-Range Centigrade Temperature Sensor (−20˚C to +100˚C)

Absolute Maximum Ratings (Note 1)

Supply Voltage	+12V to −0.2V
Output Voltage	$+V_S$ + 0.6V to −1.0V
Output Current	10 mA
Storage Temperature	−65˚C to +150˚C
Lead Temperature:	
SOT Package (Note 2):	
Vapor Phase (60 seconds)	215˚C
Infrared (15 seconds)	220˚C
ESD Susceptibility (Note 3):	
Human Body Model	2000V
Machine Model	250V

Operating Ratings (Note 1)

Specified Temperature Range	
(Note 4)	T_{MIN} to T_{MAX}
LM45B, LM45C	−20˚C to +100˚C
Operating Temperature Range	
LM45B, LM45C	−40˚C to +125˚C
Supply Voltage Range ($+V_S$)	+4.0V to +10V

Electrical Characteristics

Unless otherwise noted, these specifications apply for $+V_S$ = +5Vdc and I_{LOAD} = +50 µA, in the circuit of *Figure 2*. These specifications also apply from +2.5˚C to T_{MAX} in the circuit of *Figure 1* for $+V_S$ = +5Vdc. **Boldface limits apply for $T_A = T_J = T_{MIN}$ to T_{MAX}** ; all other limits $T_A = T_J$ = +25˚C, unless otherwise noted.

Parameter	Conditions	LM45B		LM45C		Units (Limit)
		Typical	Limit (Note 5)	Typical	Limit (Note 5)	
Accuracy (Note 6)	T_A=+25˚C		±2.0		±3.0	˚C (max)
	$T_A=T_{MAX}$		±3.0		±4.0	˚C (max)
	$T_A=T_{MIN}$		±3.0		±4.0	˚C (max)
Nonlinearity (Note 7)	$T_{MIN} \leq T_A \leq T_{MAX}$		**±0.8**		**±0.8**	˚C (max)
Sensor Gain (Average Slope)	$T_{MIN} \leq T_A \leq T_{MAX}$		**+9.7**		**+9.7**	mV/˚C (min)
			+10.3		**+10.3**	mV/˚C (max)
Load Regulation (Note 8)	$0 \leq I_L \leq$ +1 mA		**±35**		**±35**	mV/mA (max)
Line Regulation (Note 8)	$+4.0V \leq +V_S \leq +10V$		±0.80		±0.80	mV/V (max)
			±1.2		**±1.2**	mV/V (max)
Quiescent Current (Note 9)	$+4.0V \leq +V_S \leq +10V$, +25˚C		120		120	µA (max)
	$+4.0V \leq +V_S \leq +10V$		**160**		**160**	µA (max)
Change of Quiescent Current (Note 9)	$4.0V \leq +V_S \leq 10V$		**2.0**		**2.0**	µA (max)
Temperature Coefficient of Quiescent Current		**+2.0**		**+2.0**		µA/˚C
Minimum Temperature for Rated Accuracy	In circuit of *Figure 1*, I_L=0		+2.5		+2.5	˚C (min)
Long Term Stability (Note 10)	$T_J=T_{MAX}$, for 1000 hours	±0.12		±0.12		˚C

Note 1: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. DC and AC electrical specifications do not apply when operating the device beyond its rated operating conditions.

Note 2: See AN-450 "Surface Mounting Methods and Their Effect on Product Reliability" or the section titled "Surface Mount" found in a current National Semiconductor Linear Data Book for other methods of soldering surface mount devices.

Note 3: Human body model, 100 pF discharged through a 1.5 kΩ resistor. Machine model, 200 pF discharged directly into each pin.

Note 4: Thermal resistance of the SOT-23 package is 260˚C/W, junction to ambient when attached to a printed circuit board with 2 oz. foil as shown in *Figure 3*.

Note 5: Limits are guaranteed to National's AOQL (Average Outgoing Quality Level).

Note 6: Accuracy is defined as the error between the output voltage and 10 mv/˚C times the device's case temperature, at specified conditions of voltage, current, and temperature (expressed in ˚C).

Note 7: 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 8: 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.

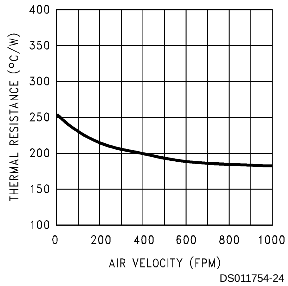
Note 9: Quiescent current is measured using the circuit of *Figure 1*.

Note 10: 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.

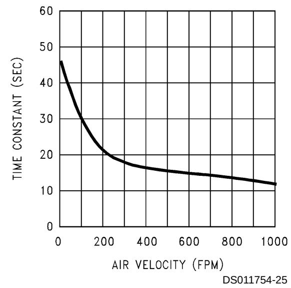
Typical Performance Characteristics

To generate these curves the LM45 was mounted to a printed circuit board as shown in *Figure 3*.

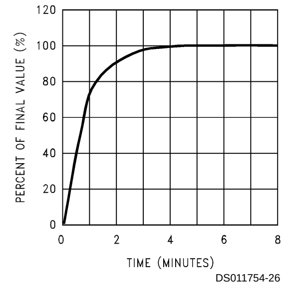
Thermal Resistance Junction to Air



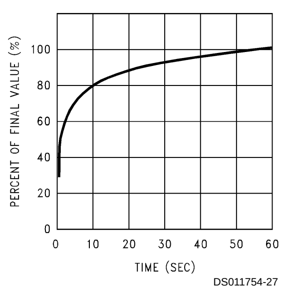
Thermal Time Constant



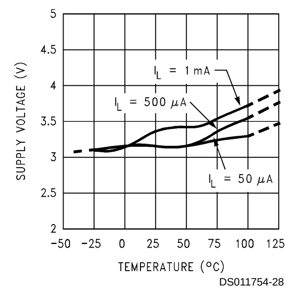
Thermal Response in Still Air with Heat Sink (*Figure 3*)



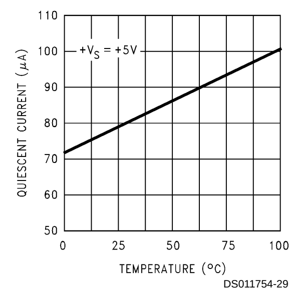
Thermal Response in Stirred Oil Bath with Heat Sink



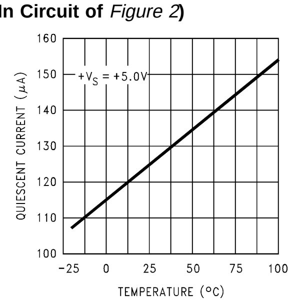
Start-Up Voltage vs Temperature



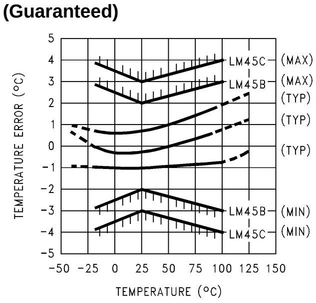
Quiescent Current vs Temperature (In Circuit of *Figure 1*)



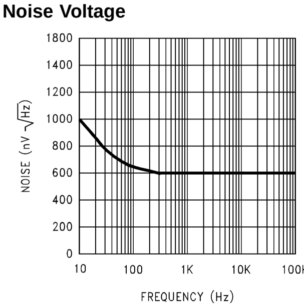
Quiescent Current vs Temperature (In Circuit of *Figure 2*)



Accuracy vs Temperature (Guaranteed)

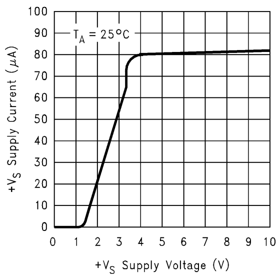


Noise Voltage



Typical Performance Characteristics To generate these curves the LM45 was mounted to a printed circuit board as shown in *Figure 3*. (Continued)

Supply Voltage vs Supply Current



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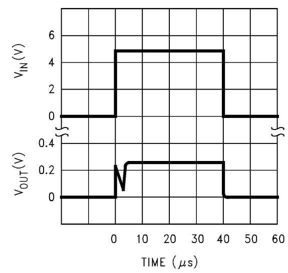
Start-Up Response



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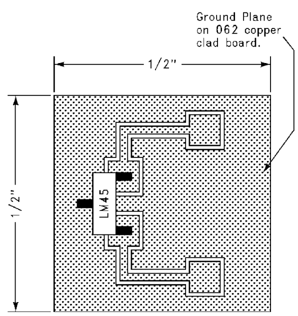

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FIGURE 3. Printed Circuit Board Used for Heat Sink to Generate All Curves. ½" Square Printed Circuit Board with 2 oz. Foil or Similar

Applications

The LM45 can be applied easily in the same way as other integrated-circuit temperature sensors. It can be glued or cemented to a surface and its temperature will be within about 0.2˚C of the surface temperature.

This presumes that the ambient air temperature is almost the same as the surface temperature; if the air temperature were much higher or lower than the surface temperature, the actual temperature of the LM45 die would be at an intermediate temperature between the surface temperature and the air temperature.

To ensure good thermal conductivity the backside of the LM45 die is directly attached to the GND pin. The lands and traces to the LM45 will, of course, be part of the printed circuit board, which is the object whose temperature is being measured. These printed circuit board lands and traces will not cause the LM45s temperature to deviate from the desired temperature.

Alternatively, the LM45 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 LM45 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 insure that moisture cannot corrode the LM45 or its connections.

Temperature Rise of LM45 Due to Self-Heating (Thermal Resistance)

	SOT-23 no heat sink*	SOT-23 small heat fin**
Still air	450˚C/W	260˚C/W
Moving air		180˚C/W

* 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 3*.

Typical Applications

CAPACITIVE LOADS

Like most micropower circuits, the LM45 has a limited ability to drive heavy capacitive loads. The LM45 by itself is able to drive 500 pF without special precautions. If heavier loads are anticipated, it is easy to isolate or decouple the load with a resistor; see *Figure 4*. Or you can improve the tolerance of capacitance with a series R-C damper from output to ground; see *Figure 5*.

Any linear circuit connected to wires in a hostile environment can have its performance affected adversely by intense electromagnetic sources such as relays, radio transmitters, motors with arcing brushes, SCR transients, etc, as its wiring can act as a receiving antenna and its internal junctions can act as rectifiers. For best results in such cases, a bypass capacitor from V_{IN} to ground and a series R-C damper such as 75Ω in series with 0.2 or 1 µF from output to ground, as shown in *Figure 5*, are often useful.

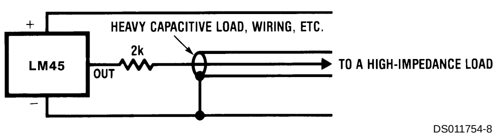


FIGURE 4. LM45 with Decoupling from Capacitive Load

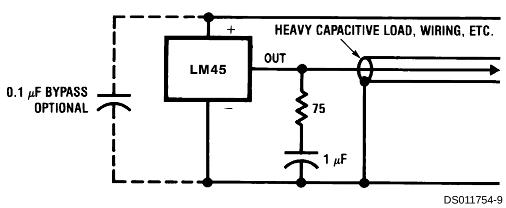


FIGURE 5. LM45 with R-C Damper

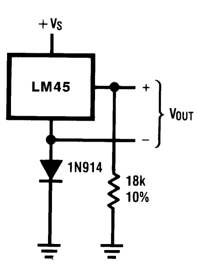


FIGURE 6. Temperature Sensor, Single Supply, −20˚C to +100˚C

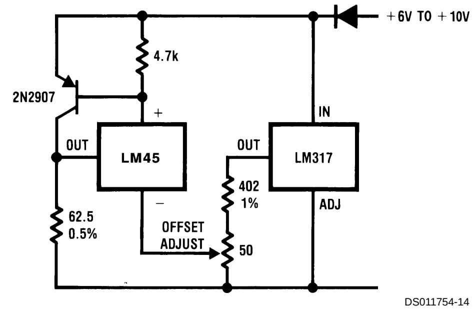


FIGURE 7. 4-to-20 mA Current Source (0˚C to +100˚C)

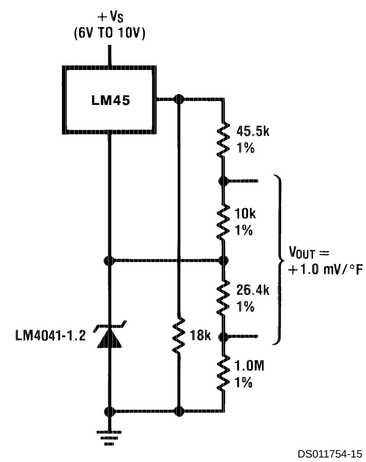


FIGURE 8. Fahrenheit Thermometer

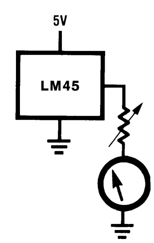


FIGURE 9. Centigrade Thermometer (Analog Meter)

Typical Applications (Continued)

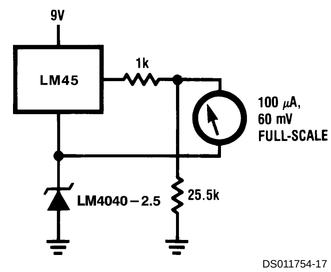


FIGURE 10. Expanded Scale Thermometer (50˚ to 80˚ Fahrenheit, for Example Shown)

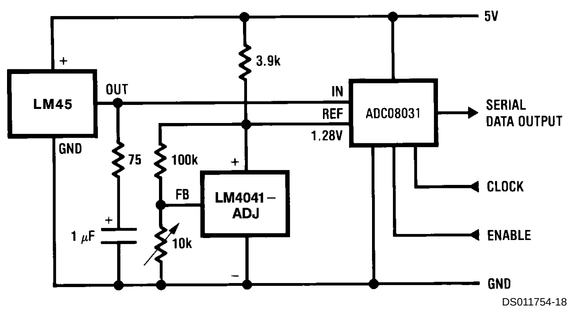


FIGURE 11. Temperature To Digital Converter (Serial Output) (+128˚C Full Scale)

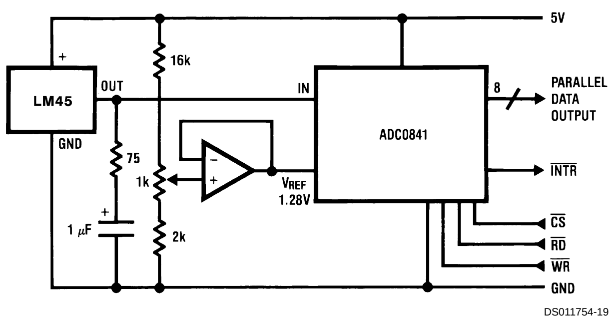
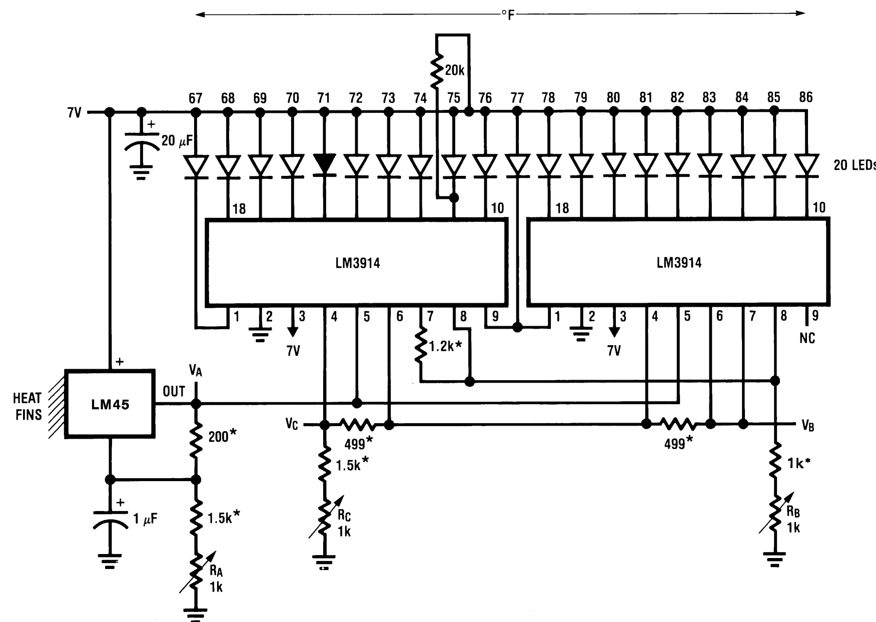


FIGURE 12. Temperature To Digital Converter (Parallel TRI-STATE® Outputs for Standard Data Bus to µP Interface) (128˚C Full Scale)

Typical Applications (Continued)



* =1% or 2% film resistor

-Trim R_B for V_B=3.075V

-Trim R_C for V_C=1.955V

-Trim R_A for V_A=0.075V + 100mV/˚C x $T_{ambient}$

-Example, V_A=2.275V at 22˚C

FIGURE 13. Bar-Graph Temperature Display (Dot Mode)

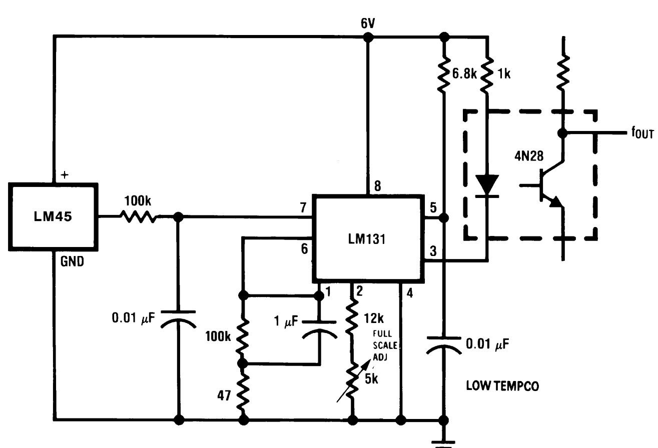
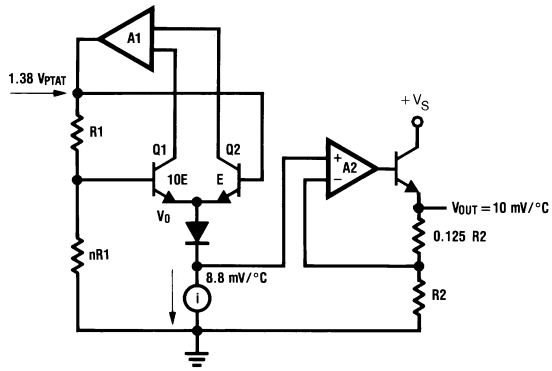


FIGURE 14. LM45 With Voltage-To-Frequency Converter And Isolated Output (2.5˚C to +100˚C; 25 Hz to 1000 Hz)

Block Diagram



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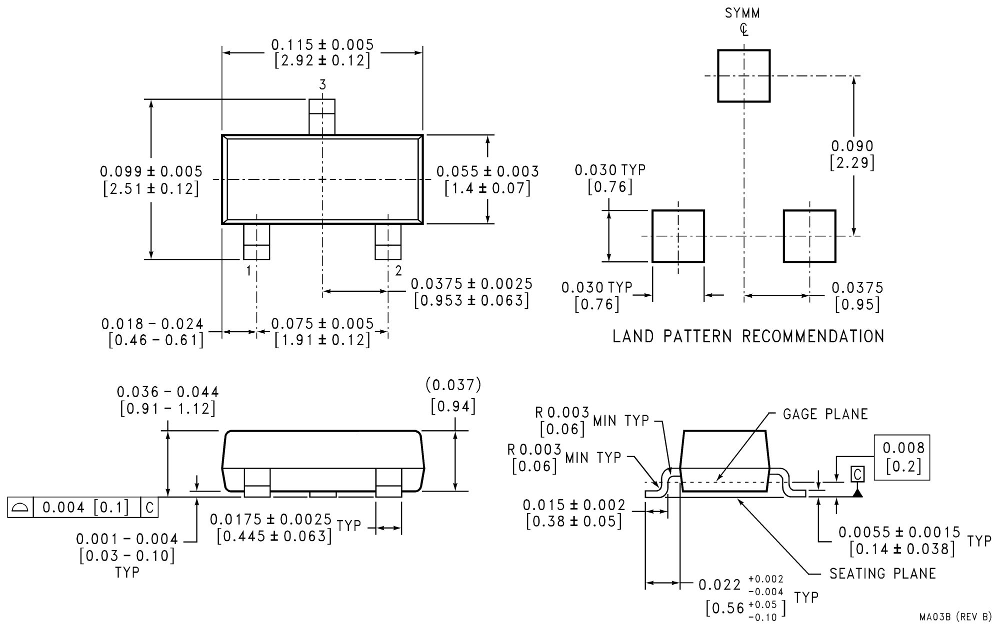
Physical Dimensions inches (millimeters) unless otherwise noted



SOT-23 Molded Small Outline Transistor Package (M3)
Order Number LM45BIM3, LM45BIM3X, LM45CIM3 or LM45CIM3X
NS Package Number MA03B

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National Semiconductor Corporation
Americas
Tel: 1-800-272-9959
Fax: 1-800-737-7018
Email: support@nsc.com

www.national.com

National Semiconductor Europe
Fax: +49 (0) 1 80-530 85 86
Email: europe.support@nsc.com
Deutsch Tel: +49 (0) 1 80-530 85 85
English Tel: +49 (0) 1 80-532 78 32
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National Semiconductor Asia Pacific Customer Response Group
Tel: 65-2544466
Fax: 65-2504466
Email: sea.support@nsc.com

National Semiconductor Japan Ltd.
Tel: 81-3-5639-7560
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