LM45

LM45 SOT-23 Precision Centigrade Temperature Sensors

Literature Number: SNIS117B

National Semiconductor

August 2005

LM45
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

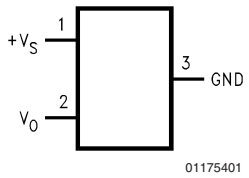
- Battery Management
- FAX Machines
- Printers
- Portable Medical Instruments
- HVAC
- Power Supply Modules
- Disk Drives
- Computers
- Automotive

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 mf03a

Order Number	Device Top Mark	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

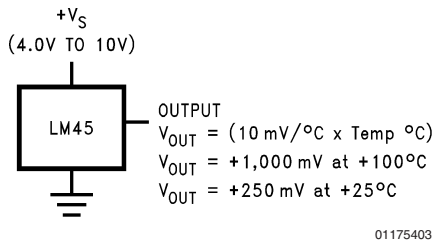
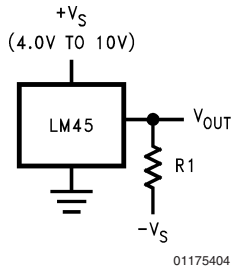


FIGURE 1. Basic Centigrade Temperature Sensor (+2.5˚C to +100˚C)



Choose $R_1 = -V_S/50\ \mu A$

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
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

Soldering process must comply with National Semiconductor's Reflow Temperature Profile specifications. Refer to www.national.com/packaging. (Note 2)

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

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.

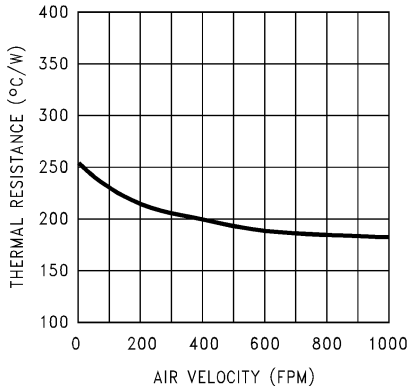
Note 9: Quiescent current is measured using the circuit of *Figure 1*.

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

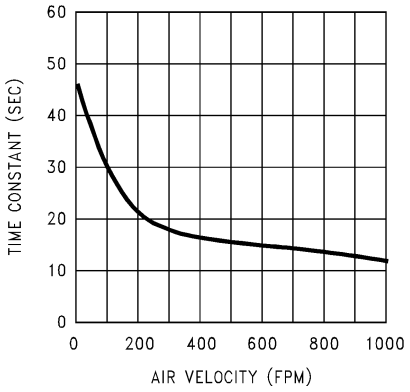
To generate these curves the LM45 was mounted to a printed circuit board as shown in *Figure 3*.

Thermal Resistance Junction to Air



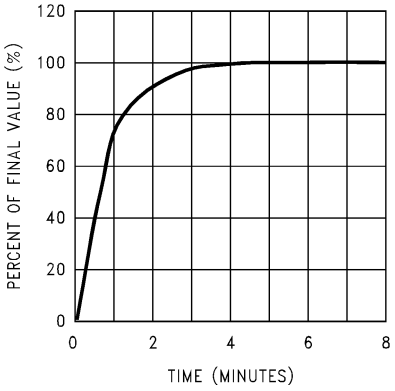
01175424

Thermal Time Constant



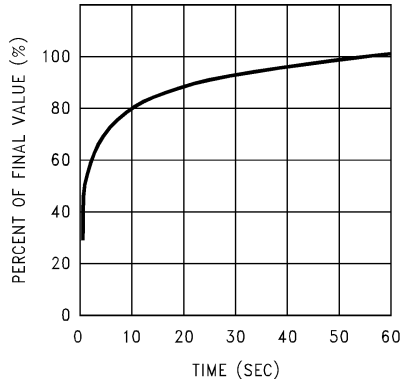
01175425

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



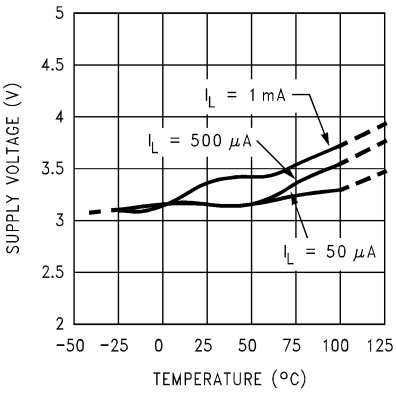
01175426

Thermal Response in Stirred Oil Bath with Heat Sink



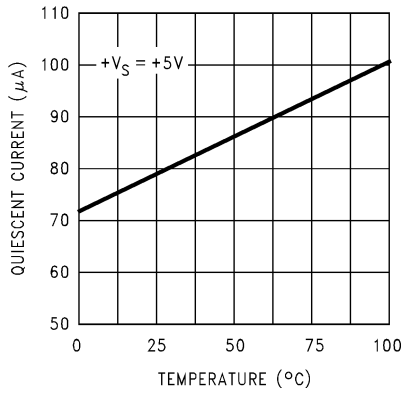
01175427

Start-Up Voltage vs Temperature



01175428

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

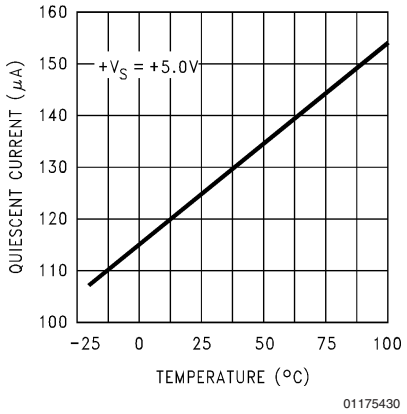


01175429

Typical Performance Characteristics

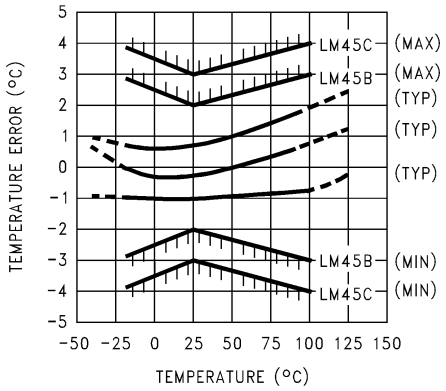
To generate these curves the LM45 was mounted to a printed circuit board as shown in *Figure 3*. (Continued)

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



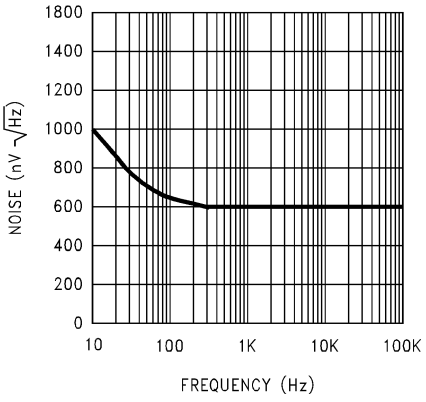
01175430

Accuracy vs Temperature (Guaranteed)



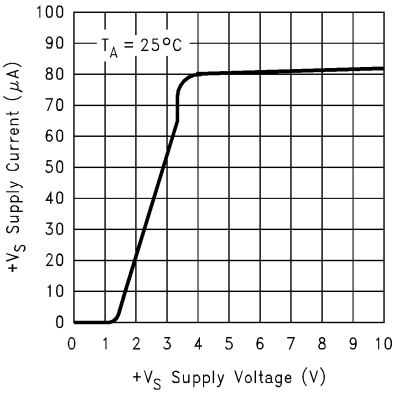
01175431

Noise Voltage



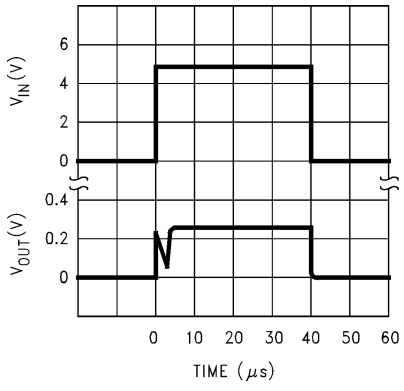
01175432

Supply Voltage vs Supply Current



01175433

Start-Up Response



01175434

Printed Circuit Board

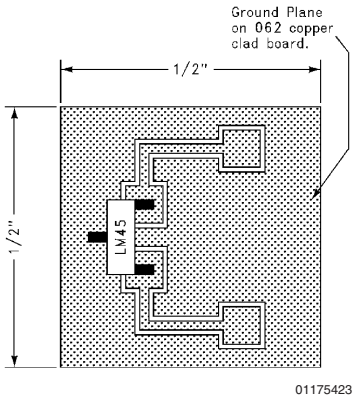


FIGURE 3. Printed Circuit Board Used for Heat Sink to Generate All Curves.
½" Square Printed Circuit Board with 2 oz. Foil or Similar

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.

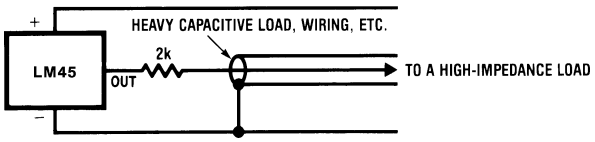


FIGURE 4. LM45 with Decoupling from Capacitive Load

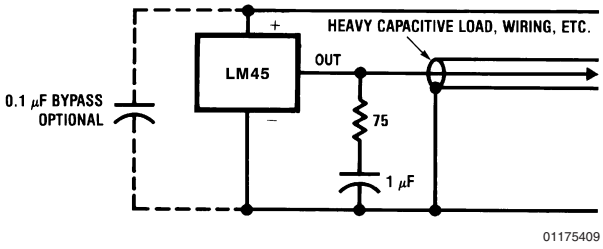


FIGURE 5. LM45 with R-C Damper

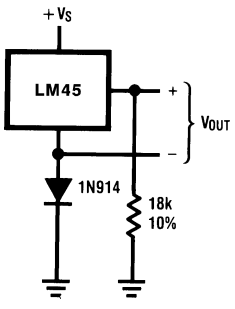


FIGURE 6. Temperature Sensor, Single Supply, –20˚C to +100˚C

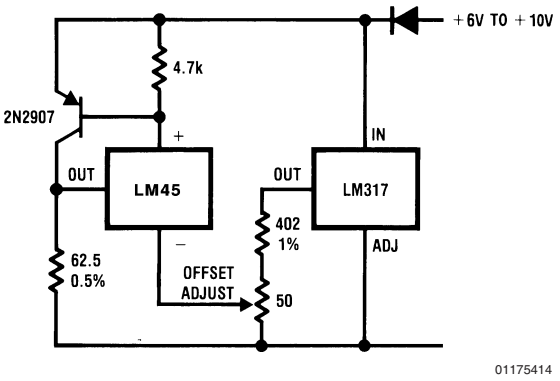


FIGURE 7. 4-to-20 mA Current Source (0˚C to +100˚C)

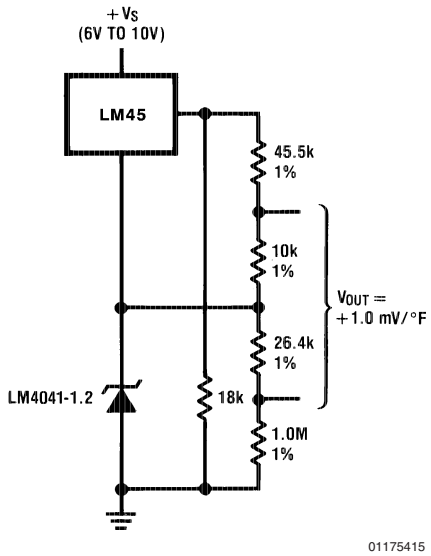


FIGURE 8. Fahrenheit Thermometer

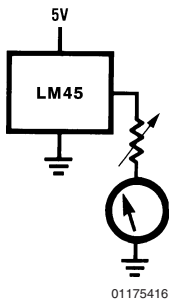


FIGURE 9. Centigrade Thermometer (Analog Meter)

Typical Applications (Continued)

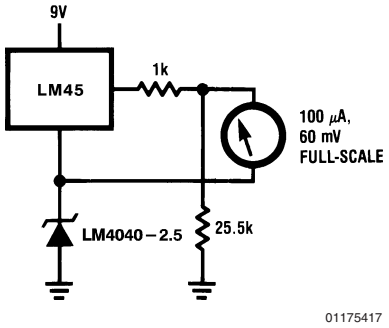


FIGURE 10. Expanded Scale Thermometer (50˚ to 80˚ Fahrenheit, for Example Shown)

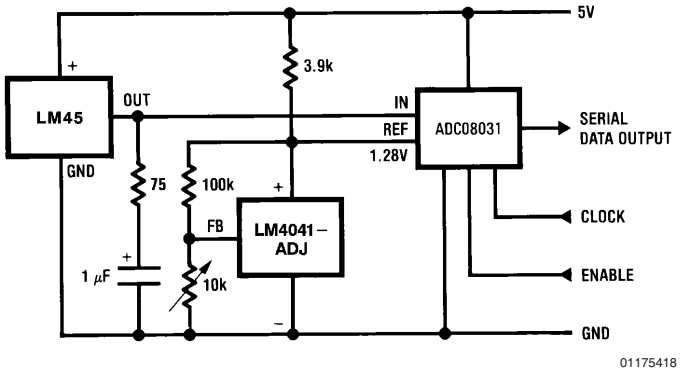


FIGURE 11. Temperature To Digital Converter (Serial Output) (+128˚C Full Scale)

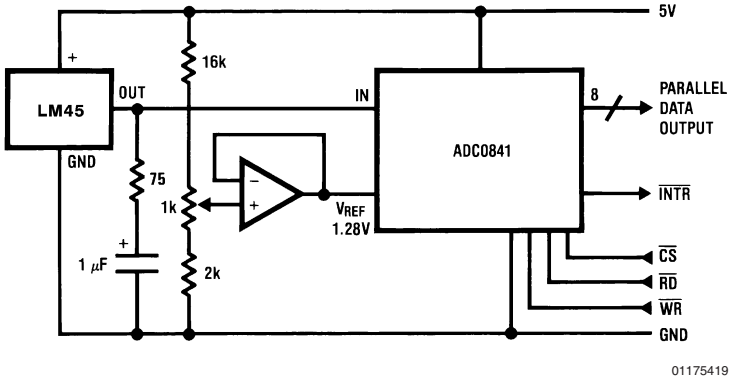
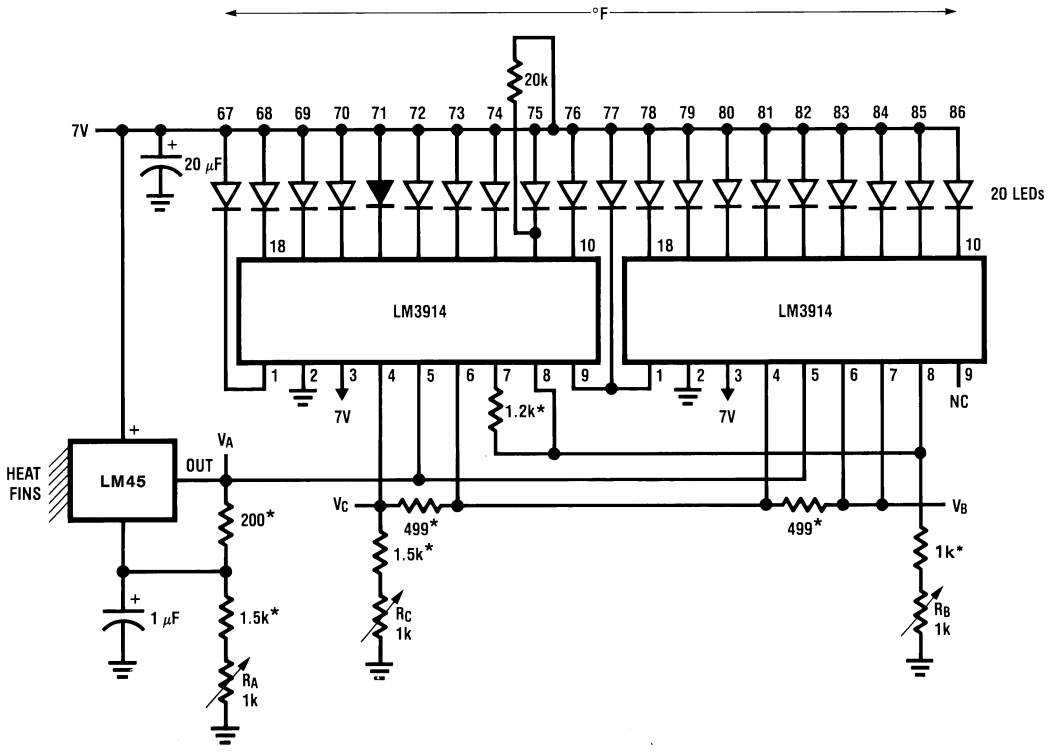


FIGURE 12. Temperature To Digital Converter (Parallel TRI-STATE® Outputs for Standard Data Bus to μP Interface) (128˚C Full Scale)

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)

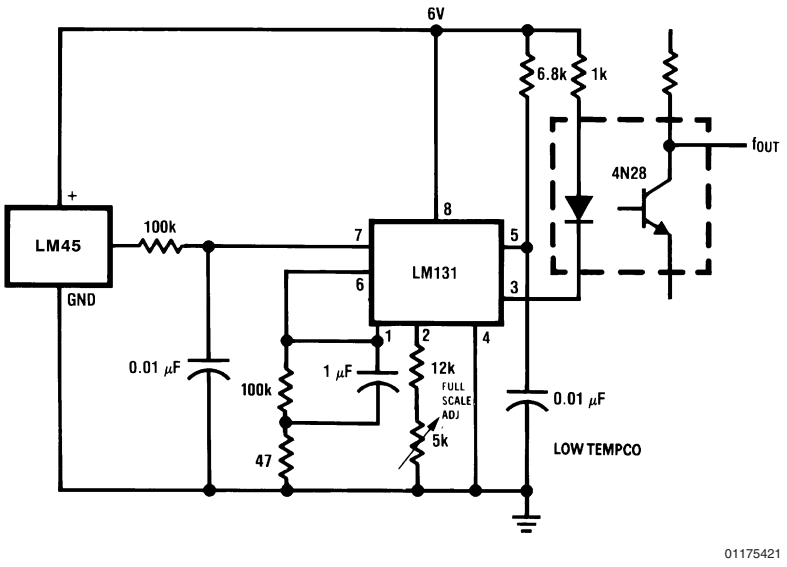
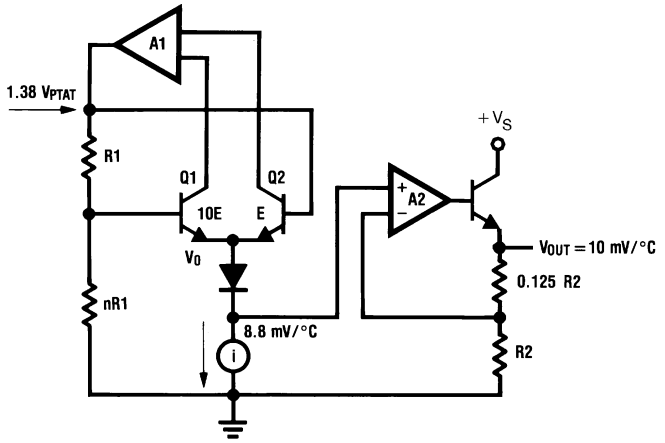


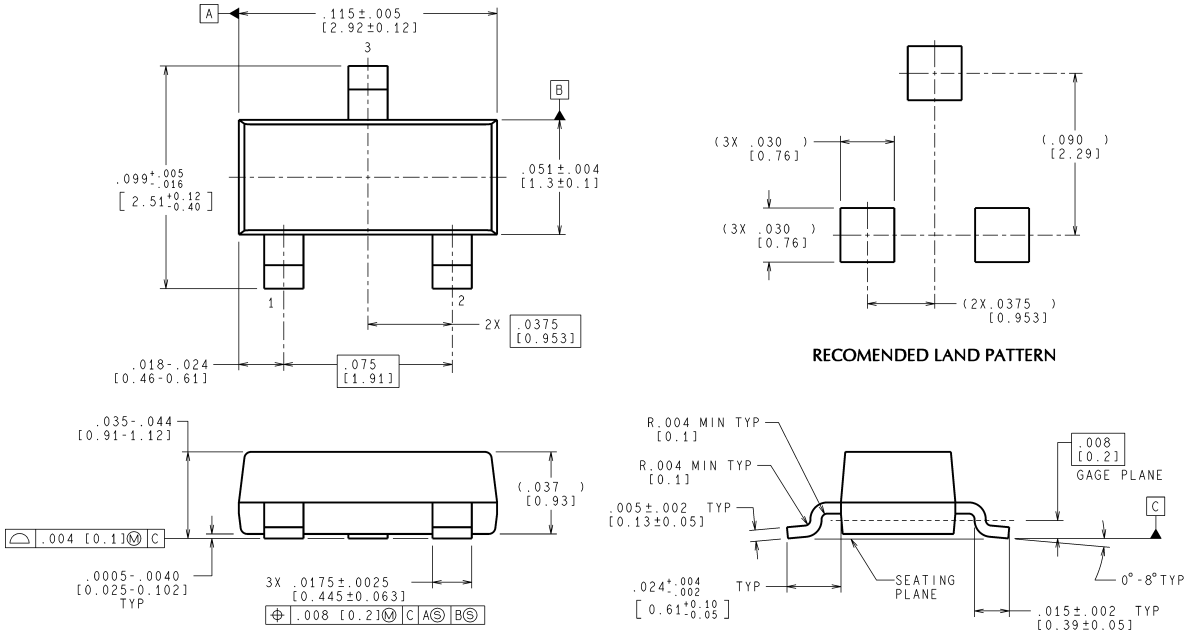
FIGURE 14. LM45 With Voltage-To-Frequency Converter And Isolated Output (2.5˚C to +100˚C; 25 Hz to 1000 Hz)

Block Diagram



01175422

Physical Dimensions inches (millimeters) unless otherwise noted



CONTROLLING DIMENSION IS INCH
VALUES IN [ ] ARE MILLIMETERS

MF03A (Rev B)

SOT-23 Molded Small Outline Transistor Package (M3)
Order Number LM45BIM3, LM45BIM3X, LM45CIM3 or LM45CIM3X
NS Package Number mf03a

National Semiconductor
Americas Customer
Support Center
Email: new.feedback@nsc.com
Tel: 1-800-272-9959

www.national.com

National Semiconductor
Europe Customer Support Center
Fax: +49 (0) 180-530 85 86
Email: europe.support@nsc.com
Deutsch Tel: +49 (0) 69 9508 6208
English Tel: +44 (0) 870 24 0 2171
Français Tel: +33 (0) 1 41 91 8790

National Semiconductor
Asia Pacific Customer
Support Center
Email: ap.support@nsc.com

National Semiconductor
Japan Customer Support Center
Fax: 81-3-5639-7507
Email: jpn.feedback@nsc.com
Tel: 81-3-5639-7560

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

TI products are not authorized for use in safety-critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, unless officers of the parties have executed an agreement specifically governing such use. Buyers represent that they have all necessary expertise in the safety and regulatory ramifications of their applications, and acknowledge and agree that they are solely responsible for all legal, regulatory and safety-related requirements concerning their products and any use of TI products in such safety-critical applications, notwithstanding any applications-related information or support that may be provided by TI. Further, Buyers must fully indemnify TI and its representatives against any damages arising out of the use of TI products in such safety-critical applications.

TI products are neither designed nor intended for use in military/aerospace applications or environments unless the TI products are specifically designated by TI as military-grade or "enhanced plastic." Only products designated by TI as military-grade meet military specifications. Buyers acknowledge and agree that any such use of TI products which TI has not designated as military-grade is solely at the Buyer's risk, and that they are solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI products are neither designed nor intended for use in automotive applications or environments unless the specific TI products are designated by TI as compliant with ISO/TS 16949 requirements. Buyers acknowledge and agree that, if they use any non-designated products in automotive applications, TI will not be responsible for any failure to meet such requirements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

Products		**Applications**	
Audio	www.ti.com/audio	Communications and Telecom	www.ti.com/communications
Amplifiers	amplifier.ti.com	Computers and Peripherals	www.ti.com/computers
Data Converters	dataconverter.ti.com	Consumer Electronics	www.ti.com/consumer-apps
DLP® Products	www.dlp.com	Energy and Lighting	www.ti.com/energy
DSP	dsp.ti.com	Industrial	www.ti.com/industrial
Clocks and Timers	www.ti.com/clocks	Medical	www.ti.com/medical
Interface	interface.ti.com	Security	www.ti.com/security
Logic	logic.ti.com	Space, Avionics and Defense	www.ti.com/space-avionics-defense
Power Mgmt	power.ti.com	Transportation and Automotive	www.ti.com/automotive
Microcontrollers	microcontroller.ti.com	Video and Imaging	www.ti.com/video
RFID	www.ti-rfid.com		
OMAP Mobile Processors	www.ti.com/omap		
Wireless Connectivity	www.ti.com/wirelessconnectivity		
	TI E2E Community Home Page		e2e.ti.com

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265