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LM50/LM50-Q1 SOT-23 Single-Supply Centigrade Temperature Sensor

Check for Samples: LM50, LM50-Q1

FEATURES

- **Calibrated Directly in Degree Celsius (Centigrade)**
- **Linear + 10.0 mV/°C Scale Factor**
- **±2°C Accuracy Specified at +25°C**
- **Specified for Full −40° to +125°C range**
- **Suitable for Remote Applications**
- **Low Cost Due to Wafer-level Trimming**
- **Operates from 4.5V to 10V**
- **Less than 130 µA Current Drain**
- **Low Self-heating, Less than 0.2°C in Still Air**
- **Nonlinearity Less than 0.8°C Over Temp**
- **LM50Q is AEC-Q100 Grade 1 qualified and is manufactured on an Automotive Grade flow.**
- **UL Recognized Component**

APPLICATIONS

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

DESCRIPTION

The LM50/LM50-Q1 is a precision integrated-circuit temperature sensor that can sense a −40°C to +125°C temperature range using a single positive supply. The LM50/LM50-Q1's output voltage is linearly proportional to Celsius (Centigrade) temperature (+10 mV/°C) and has a DC offset of +500 mV. The offset allows reading negative temperatures without the need for a negative supply. The ideal output voltage of the LM50/LM50-Q1 ranges from +100 mV to +1.75V for a −40°C to +125°C temperature range. The LM50/LM50-Q1 does not require any external calibration or trimming to provide accuracies of ±3°C at room temperature and ±4°C over the full −40°C to +125°C temperature range. Trimming and calibration of the LM50/LM50-Q1 at the wafer level assure low cost and high accuracy. The LM50/LM50-Q1's linear output, +500 mV offset, and factory calibration simplify circuitry required in a single supply environment where reading negative temperatures is required. Because the LM50/LM50-Q1's quiescent current is less than 130 µA, self-heating is limited to a very low 0.2°C in still air.

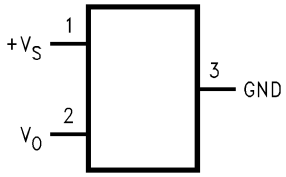


Figure 1. SOT-23 Pin Out
Top View
See Package Number DBZ0003A

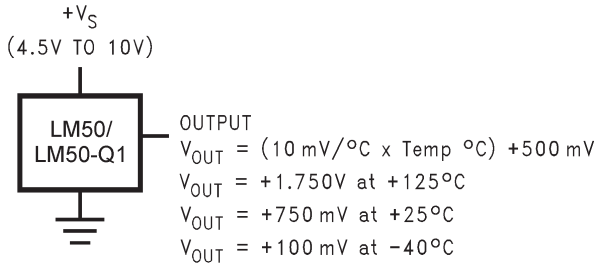


Figure 2. Full-Range Centigrade Temperature Sensor Application (−40°C to +125°C)

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PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of the Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

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

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

ABSOLUTE MAXIMUM RATINGS (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
T_{JMAX}, Maximum Junction Temperature	150°C
ESD Susceptibility (2): Human Body Model Machine Model (Does not apply for LM50-Q1) Charged Device Model	 2000V 250V 750V

(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.
(2) Human body model, 100 pF discharged through a 1.5 kΩ resistor. Machine model, 200 pF discharged directly into each pin.

OPERATING RATINGS (1)

Specified Temperature Range:	T_{MIN} to T_{MAX}
LM50C/LM50-Q1	−40°C to +125°C
LM50B	−25°C to +100°C
Operating Temperature Range	−40°C to +150°C
θ_{JA} (2)	450°C/W
Supply Voltage Range $(+V_S)$	+4.5V to +10V
Soldering process must comply with Reflow Temperature Profile specifications. Refer to http://www.ti.com/packaging. (3)	

(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.
(2) Thermal resistance of the SOT-23 package is specified without a heat sink, junction to ambient.
(3) Reflow temperature profiles are different for lead-free and non-lead-free packages.

ELECTRICAL CHARACTERISTICS

Unless otherwise noted, these specifications apply for V_S = +5 V_{DC} and I_{LOAD} = +0.5 µA, in the circuit of Figure 2. **Boldface limits apply for the specified $T_A = T_J = T_{MIN}$ to T_{MAX}**; all other limits $T_A = T_J$ = +25°C, unless otherwise noted.

Parameter	Conditions	LM50B		LM50C/LM50-Q1		Units (Limit)
		Typical	Limit (1)	Typical	Limit (1)	
Accuracy (2)	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, −3.5		±4.0	°C (max)
Nonlinearity (3)			**±0.8**		**±0.8**	°C (max)
Sensor Gain(Average Slope)			**+9.7**		**+9.7**	mV/°C (min)
			+10.3		**+10.3**	mV/°C (max)
Output Resistance		2000	**4000**	2000	**4000**	Ω (max)
Line Regulation (4)	+4.5V ≤ V_S ≤ +10V		±0.8		±0.8	mV/V (max)
			±1.2		**±1.2**	mV/V (max)

(1) Limits are specified to TI's AOQL (Average Outgoing Quality Level).
(2) Accuracy is defined as the error between the output voltage and 10mv/°C times the device's case temperature plus 500 mV, at specified conditions of voltage, current, and temperature (expressed in °C).
(3) 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.
(4) 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.

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ELECTRICAL CHARACTERISTICS (continued)

Unless otherwise noted, these specifications apply for V_S = +5 V_{DC} and I_{LOAD} = +0.5 µA, in the circuit of Figure 2. **Boldface limits apply for the specified $T_A = T_J = T_{MIN}$ to T_{MAX}**; all other limits $T_A = T_J$ = +25°C, unless otherwise noted.

Parameter	Conditions	LM50B		LM50C/LM50-Q1		Units (Limit)
		Typical	Limit (1)	Typical	Limit (1)	
Quiescent Current (5)	+4.5V ≤ V_S ≤ +10V		130		130	µA (max)
			180		**180**	µA (max)
Change of Quiescent Current	+4.5V ≤ V_S ≤ +10V		**2.0**		**2.0**	µA (max)
Temperature Coefficient of Quiescent Current		**+1.0**		**+2.0**		µA/°C
Long Term Stability (6)	T_J = 125°C, for 1000 hours	±0.08		±0.08		°C

(5) Quiescent current is defined in the circuit of Figure 2.
(6) 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 CHARACTERISTICS

To generate these curves the LM50/LM50-Q1 was mounted to a printed circuit board as shown in Figure 14.

Thermal Resistance Junction to Air

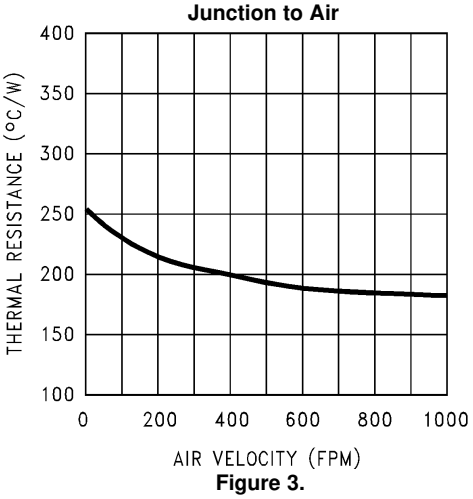


Figure 3.

Thermal Time Constant

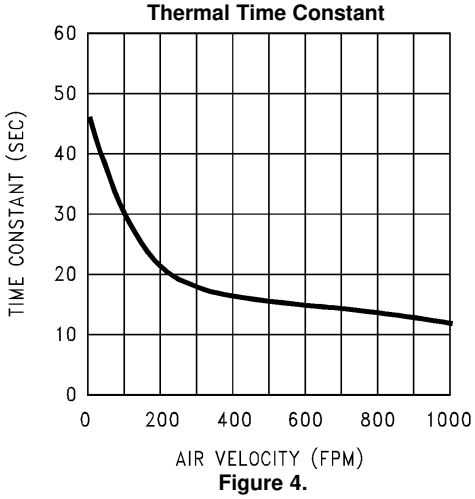


Figure 4.

Thermal Response in Still Air with Heat Sink (Figure 14)

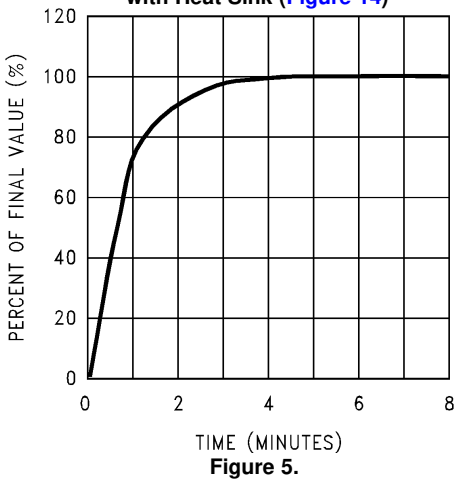


Figure 5.

Thermal Response in Stirred Oil Bath with Heat Sink

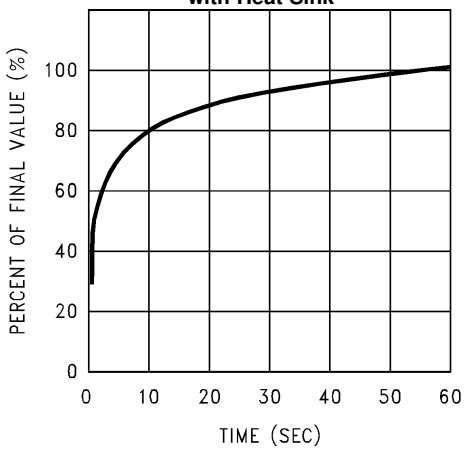


Figure 6.

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TYPICAL CHARACTERISTICS (continued)

To generate these curves the LM50/LM50-Q1 was mounted to a printed circuit board as shown in Figure 14.

Start-Up Voltage vs Temperature

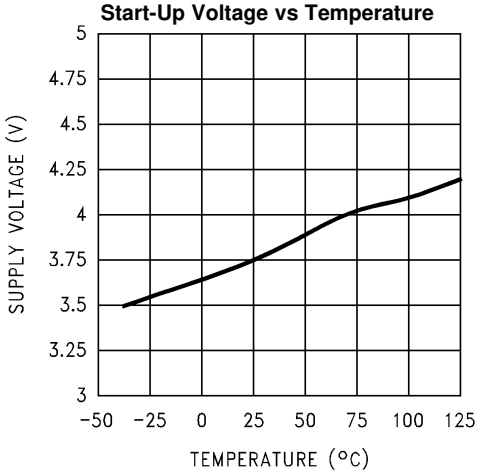


Figure 7.

Thermal Response in Still Air without a Heat Sink

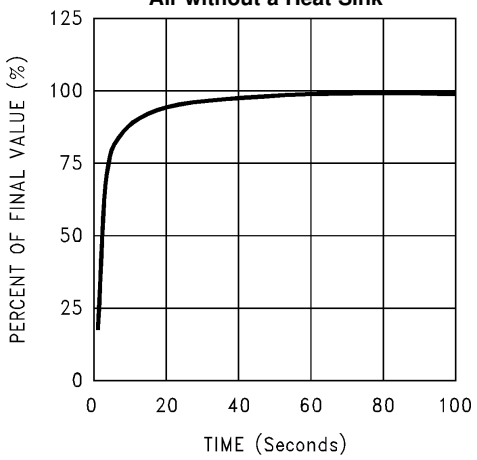


Figure 8.

Quiescent Current vs Temperature (Figure 2)

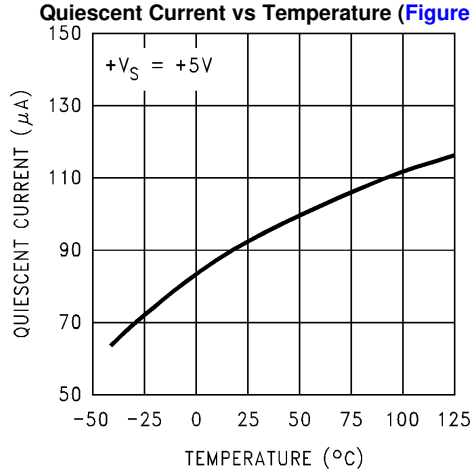


Figure 9.

Accuracy vs Temperature

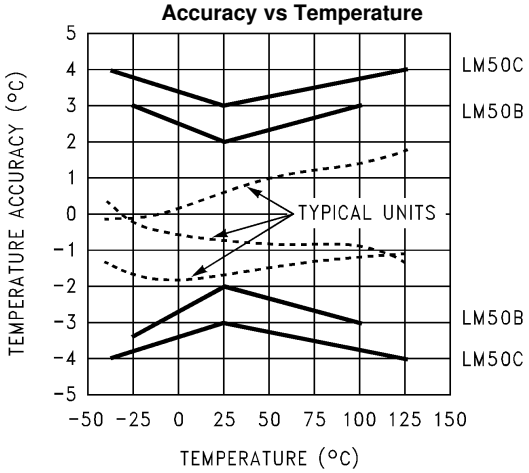


Figure 10.

Noise Voltage

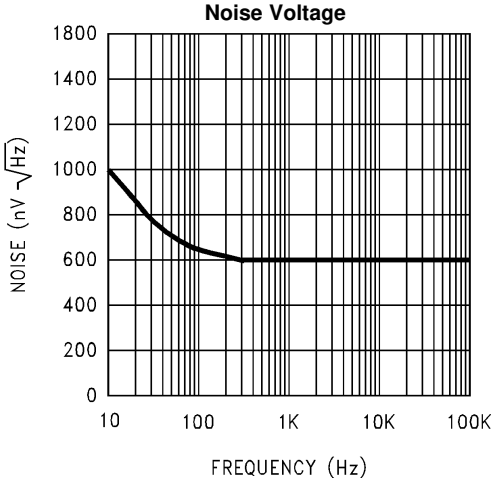


Figure 11.

Supply Voltage vs Supply Current

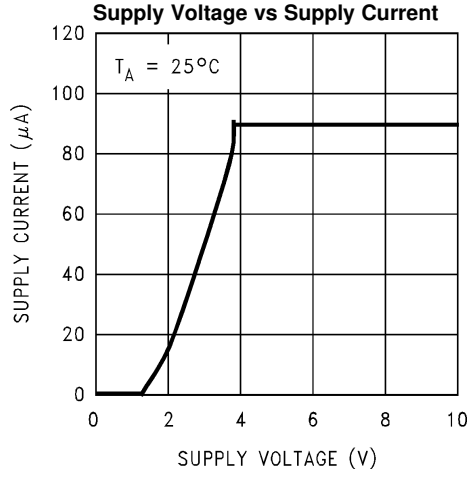


Figure 12.

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TYPICAL CHARACTERISTICS (continued)

To generate these curves the LM50/LM50-Q1 was mounted to a printed circuit board as shown in Figure 14.

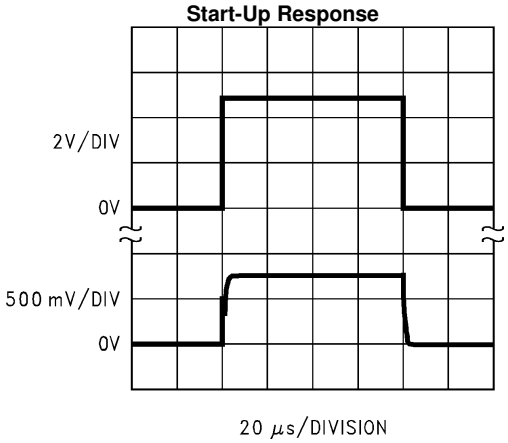
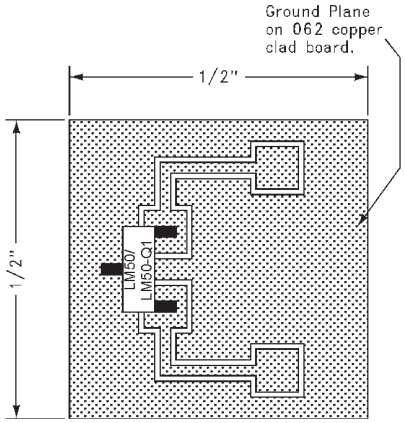


Figure 13.

PRINTED CIRCUIT BOARD



A. ½″ Square Printed Circuit Board with 2 oz. Foil or Similar

Figure 14. Printed Circuit Board Used for Heat Sink to Generate All Curves

Mounting

The LM50/LM50-Q1 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 LM50/LM50-Q1 die would be at an intermediate temperature between the surface temperature and the air temperature.

To ensure good thermal conductivity the backside of the LM50/LM50-Q1 die is directly attached to the GND pin. The lands and traces to the LM50/LM50-Q1 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 LM50/LM50-Q1s temperature to deviate from the desired temperature.

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Alternatively, the LM50/LM50-Q1 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 LM50/LM50-Q1 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 LM50/LM50-Q1 or its connections.

Table 1. Temperature Rise of LM50/LM50-Q1 Due to Self-Heating (Thermal Resistance, θ_{JA})

	SOT-23	SOT-23
	no heat sink(1)	**small heat fin**(2)
Still air	450°C/W	260°C/W
Moving air		180°C/W

(1) Part soldered to 30 gauge wire.
(2) Heat sink used is ½″ square printed circuit board with 2 oz. foil with part attached as shown in Figure 14.

Capacitive Loads

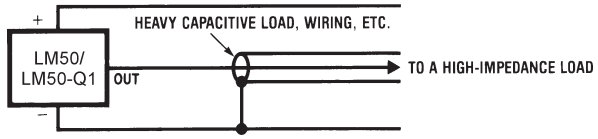


Figure 15. LM50/LM50-Q1 No Decoupling Required for Capacitive Load

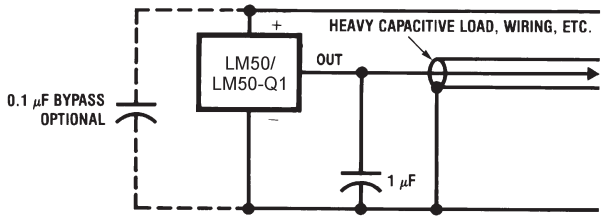
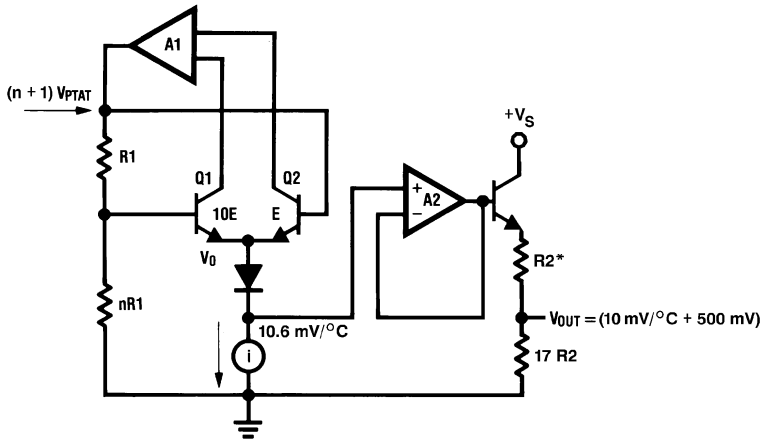


Figure 16. LM50C/LM50-Q1 with Filter for Noisy Environment

The LM50/LM50-Q1 handles capacitive loading very well. Without any special precautions, the LM50/LM50-Q1 can drive any capacitive load. The LM50/LM50-Q1 has a nominal 2 kΩ output impedance (as can be seen in Figure 17). The temperature coefficient of the output resistors is around 1300 ppm/°C. Taking into account this temperature coefficient and the initial tolerance of the resistors the output impedance of the LM50/LM50-Q1 will not exceed 4 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_{IN} to GND to bypass the power supply voltage, as shown in Figure 16. In a noisy environment it may be necessary to add a capacitor from the output to ground. A 1 µF output capacitor with the 4 kΩ output impedance will form a 40 Hz lowpass filter. Since the thermal time constant of the LM50/LM50-Q1 is much slower than the 25 ms time constant formed by the RC, the overall response time of the LM50/LM50-Q1 will not be significantly affected. For much larger capacitors this additional time lag will increase the overall response time of the LM50/LM50-Q1.

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*R2 ≈ 2k with a typical 1300 ppm/°C drift.

Figure 17. Block Diagram

TYPICAL APPLICATIONS

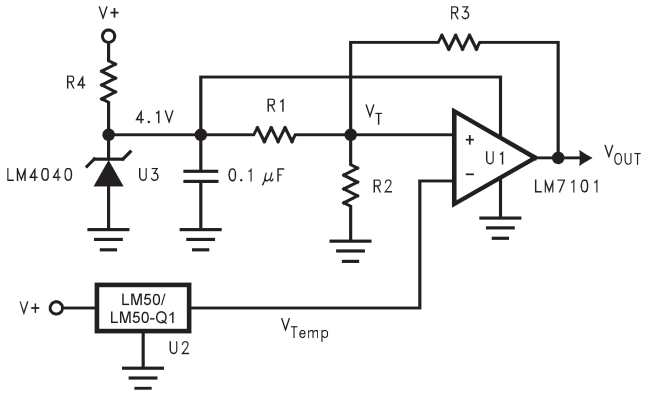


Figure 18. Centigrade Thermostat/Fan Controller

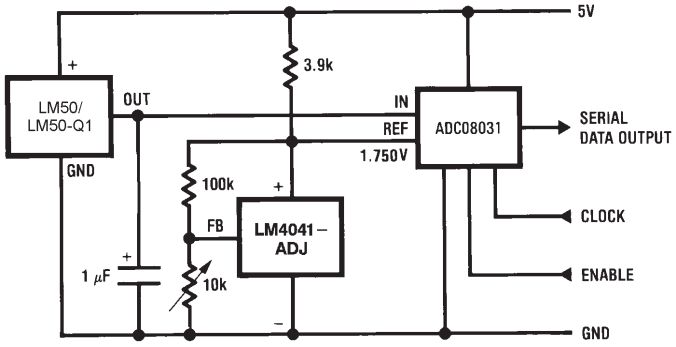


Figure 19. Temperature To Digital Converter (Serial Output) (+125°C Full Scale)

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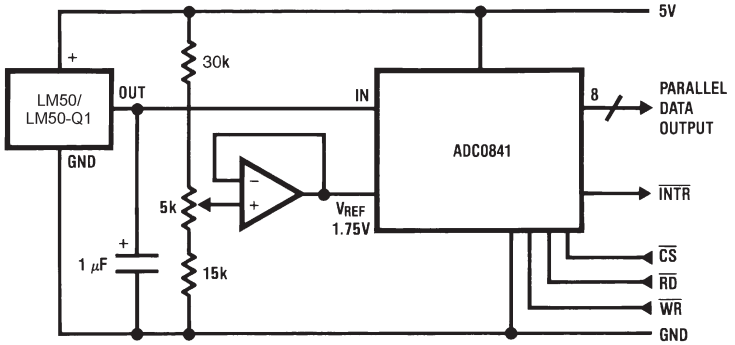


Figure 20. Temperature To Digital Converter (Parallel TRI-STATE Outputs for Standard Data Bus to μP Interface) (125°C Full Scale)

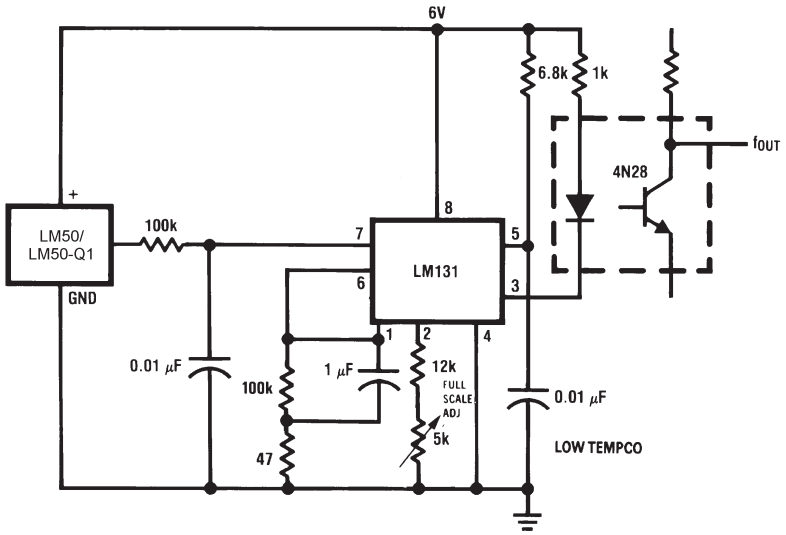


Figure 21. LM50/LM50-Q1 With Voltage-To-Frequency Converter And Isolated Output (−40°C to +125°C; 100 Hz to 1750 Hz)

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REVISION HISTORY

Changes from Revision C (February 2013) to Revision E **Page**

- Added LM50-Q1 option throughout document 1
- Added Charged Device Model ESD for LM50B and LM50C 2

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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
LM50BIM3	NRND	SOT-23	DBZ	3	1000	TBD	Call TI	Call TI	-25 to 100	T5B	
LM50BIM3/NOPB	ACTIVE	SOT-23	DBZ	3	1000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-25 to 100	T5B	Samples
LM50BIM3X	NRND	SOT-23	DBZ	3	3000	TBD	Call TI	Call TI	-25 to 100	T5B	
LM50BIM3X/NOPB	ACTIVE	SOT-23	DBZ	3	3000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-25 to 100	T5B	Samples
LM50CIM3	NRND	SOT-23	DBZ	3	1000	TBD	Call TI	Call TI	-40 to 125	T5C	
LM50CIM3/NOPB	ACTIVE	SOT-23	DBZ	3	1000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 125	T5C	Samples
LM50CIM3X	NRND	SOT-23	DBZ	3	3000	TBD	Call TI	Call TI	-40 to 125	T5C	
LM50CIM3X/NOPB	ACTIVE	SOT-23	DBZ	3	3000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 125	T5C	Samples
LM50QIM3/NOPB	ACTIVE	SOT-23	DBZ	3	1000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-25 to 100	T5Q	Samples
LM50QIM3X/NOPB	ACTIVE	SOT-23	DBZ	3	3000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-25 to 100	T5Q	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 LM50, LM50-Q1 :

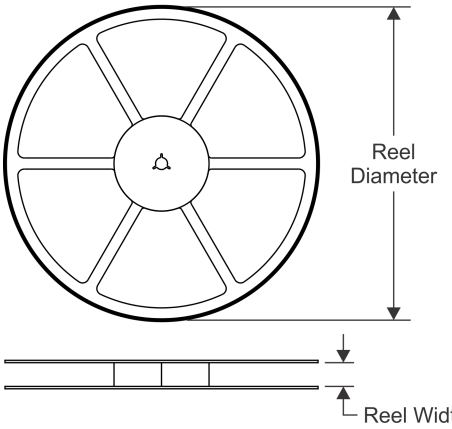
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- Automotive: LM50-Q1

NOTE: Qualified Version Definitions:

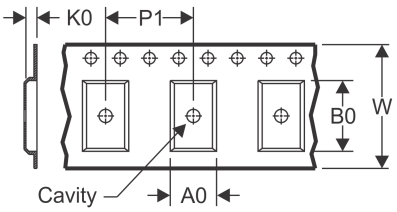
- Catalog - TI's standard catalog product
- Automotive - Q100 devices qualified for high-reliability automotive applications targeting zero defects

TAPE AND REEL INFORMATION

REEL DIMENSIONS

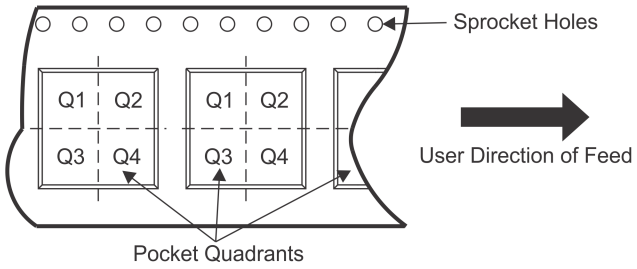


TAPE DIMENSIONS



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

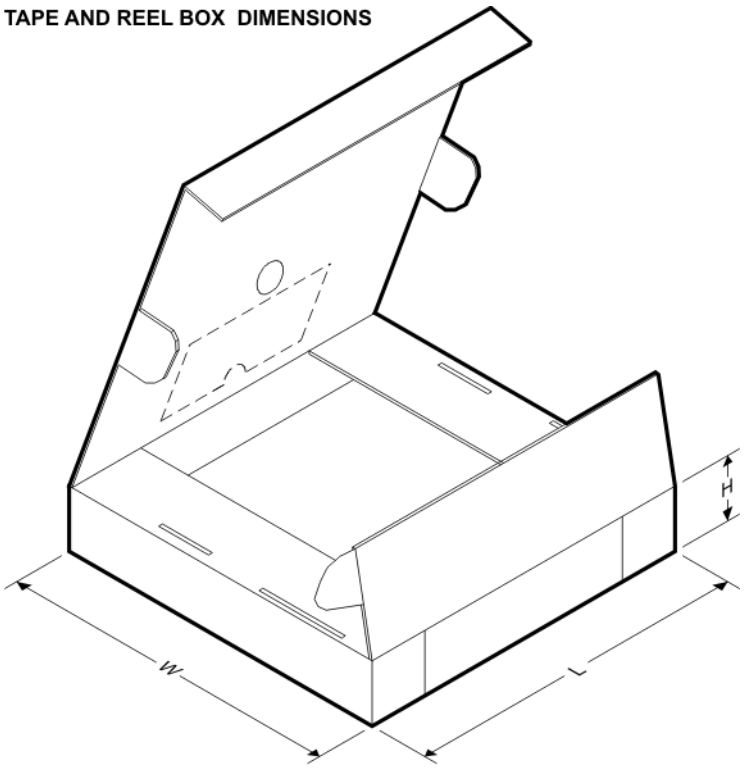
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
LM50BIM3	SOT-23	DBZ	3	1000	178.0	8.4	3.3	2.9	1.22	4.0	8.0	Q3
LM50BIM3X	SOT-23	DBZ	3	3000	178.0	8.4	3.3	2.9	1.22	4.0	8.0	Q3
LM50CIM3	SOT-23	DBZ	3	1000	178.0	8.4	3.3	2.9	1.22	4.0	8.0	Q3
LM50CIM3X	SOT-23	DBZ	3	3000	178.0	8.4	3.3	2.9	1.22	4.0	8.0	Q3
LM50QIM3/NOPB	SOT-23	DBZ	3	1000	178.0	8.4	3.3	2.9	1.22	4.0	8.0	Q3
LM50QIM3X/NOPB	SOT-23	DBZ	3	3000	178.0	8.4	3.3	2.9	1.22	4.0	8.0	Q3

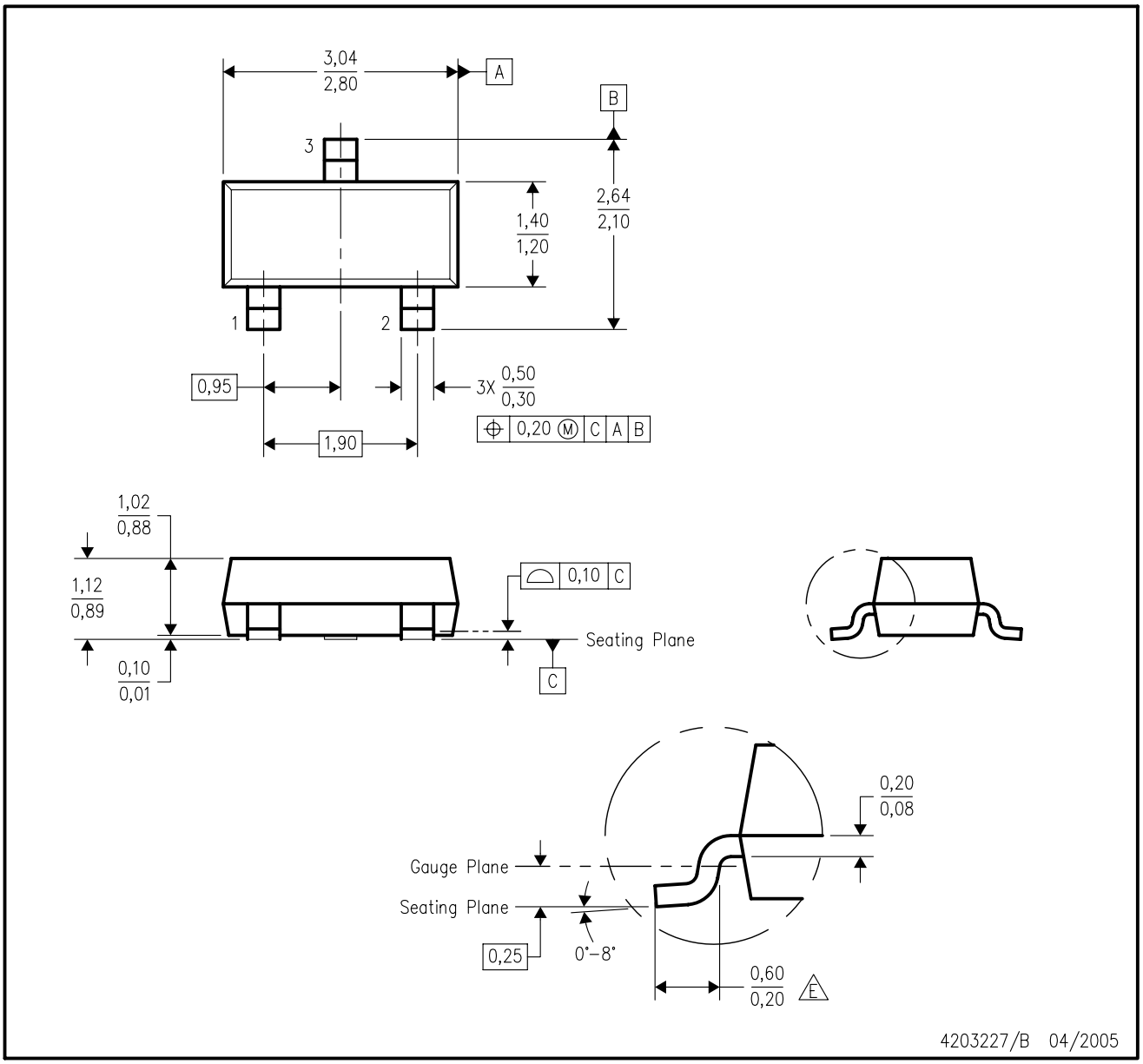
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
LM50BIM3	SOT-23	DBZ	3	1000	210.0	185.0	35.0
LM50BIM3X	SOT-23	DBZ	3	3000	210.0	185.0	35.0
LM50CIM3	SOT-23	DBZ	3	1000	210.0	185.0	35.0
LM50CIM3X	SOT-23	DBZ	3	3000	210.0	185.0	35.0
LM50QIM3/NOPB	SOT-23	DBZ	3	1000	210.0	185.0	35.0
LM50QIM3X/NOPB	SOT-23	DBZ	3	3000	210.0	185.0	35.0

DBZ (R–PDSO–G3) PLASTIC SMALL–OUTLINE



NOTES:
A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M–1994.
B. This drawing is subject to change without notice.
C. Lead dimensions are inclusive of plating.
D. Body dimensions are exclusive of mold flash and protrusion. Mold flash and protrusion not to exceed 0.25 per side.
E. Falls within JEDEC TO–236 variation AB, except minimum foot length.

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