TEXAS INSTRUMENTS

LMT86, LMT86-Q1

SNIS169B –MARCH 2013– REVISED MAY 2014

LMT86/LMT86-Q1 SC70/TO-92/TO-126, Analog Temperature Sensors with Class-AB Output

1 Features

- LMT86-Q1 is AEC-Q100 Grade 0 qualified and is Manufactured on an Automotive Grade Flow
- Very Accurate ±0.25°C
- Wide Temperature Range of −50°C to 150°C
- Low 5.4 µA Quiescent Current
- Sensor Gain of -10.9 mV/°C
- Packages:
  - Small SC70 Package
  - Leaded TO-92
  - Leaded Heatsink or Chassis Screw-Mount TO-126
- Output is Short-Circuit Protected
- Push-Pull Output with ±50 µA Current Capability
- Footprint Compatible with the Industry-Standard LM20/19 and LM35 Temperature Sensor
- Cost-effective Alternative to Thermistors

2 Applications

- Automotive
- Industrial
- White Goods – Appliances
- Battery Management
- Disk Drives
- Games
- Wireless Transceivers
- Cell phones

3 Description

The LMT86/LMT86-Q1 are precision CMOS integrated-circuit temperature sensors with an analog output voltage that is linearly and inversely proportional to temperature. Its features make it suitable for many general temperature sensing applications. It can operate down to 2.2V supply with 5.4 µA power consumption making it ideal for battery powered devices. Multiple package options including through-hole TO-92 and TO-126 packages also allow the LMT86 to be mounted on-board, off-board, to a heat sink, or on multiple unique locations in the same application. A class-AB output structure gives the LMT86/LMT86-Q1 strong output source and sink current capability that can directly drive up to 1.1 nF capacitive loads. This means it is well suited to drive an analog-to-digital converter sample-and-hold input with its transient load requirements. It has accuracy specified in the operating range of −50°C to 150°C. The accuracy, 3-lead package options, and other features also make the LMT86/LMT86-Q1 an alternative to thermistors.
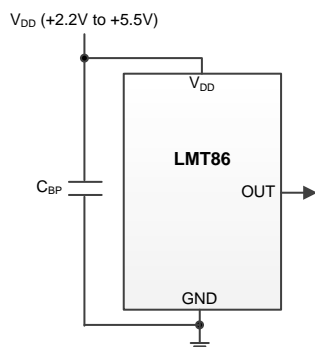
For devices with different average sensor gains and comparable accuracy the LMT84/LM84-Q1, LMT85/LMT85-Q1 and LMT87/LMT87-Q1 (For more details see Comparable Alternative Devices.)

Device Information[1]

PART NUMBER	PACKAGE	BODY SIZE (NOM)
LMT86	SOT (5)	2.00 mm x 1.25 mm
	TO-92 (3)	4.3 mm x 3.5 mm
	TO-126 (3)	8 mm x 11 mm
LMT86-Q1	SOT (5)	2.00 mm x 1.25 mm

(1) For all available packages, see the orderable addendum at the end of the data sheet.

4 Full-Range Celsius Temperature Sensor (−50°C to 150°C)
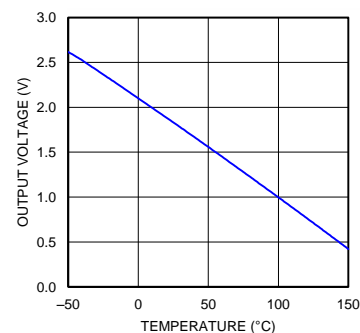

Output Voltage vs Temperature

An IMPORTANT NOTICE at the end of this data sheet addresses availability, warranty, changes, use in safety-critical applications, intellectual property matters and other important disclaimers. PRODUCTION DATA.

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5 Revision History

Changes from Revision A (June 2013) to Revision B   **Page**

- Changed data sheet flow and layout to conform with new TI standards. Added the following sections: Application and Implementation, Power Supply Recommendations, Layout, Device and Documentation Support, Mechanical, Packaging, and Orderable Information 1
- Added TO92 and TO126 package information.. 1
- Changed from 450 °C/W to 275 °C/W. New specification is derived using TI's latest methodology. 5
- Changed Temperature Accuracy V_{DD} condition from 2.4V to 2.2V for range of 40°C to 150°C. 6
- Deleted Note: The input current is leakage only and is highest at high temperature. It is typically only 0.001 µA. The 1 µA limit is solely based on a testing limitation and does not reflect the actual performance of the part............................ 6

Device Comparison Table[1]

ORDER NUMBER	PACKAGE	PIN	BODY SIZE (NOM)	MOUNTING TYPE
LMT86DCK	SOT (AKA[2]: SC70, DCK)	5	2.00 mm x 1.25 mm	Surface Mount
LMT86LP	TO-92 (AKA[2]: LP)	3	4.3 mm x 3.5 mm	Through-hole
LMT86LPC	TO-126 (AKA[2]: LPC)	3	8 mm x 11 mm	Screw-mount, Through-hole
LMT86DCK-Q1	SOT (AKA[2]: SC70, DCK)	5	2.00 mm x 1.25 mm	Surface Mount

(1)   For all available packages and complete order numbers, see the orderable addendum at the end of the data sheet.
(2)   AKA = Also Known As
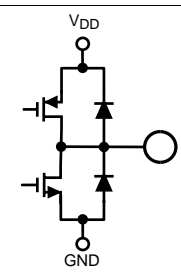
Comparable Alternative Devices

PART NUMBER	AVERAGE OUTPUT SENSOR GAIN	POWER SUPPLY RANGE
LMT84/LMT84-Q1	–5.5 mV/°C	1.5V to 5.5V
LMT85/LMT85-Q1	–8.2 mV/°C	1.8V to 5.5V
LMT86/LMT86-Q1	–10.9 mV/°C	2.2V to 5.5V
LMT87/LMT87-Q1	–13.6 mV/°C	2.7V to 5.5V

6 Pin Configuration and Functions

5-Pin SOT (SC70)
DCK Package
(TOP VIEW)

GND	1	5 V_{DD}
GND	2	LMT86	4 V_{DD}
OUT	3	4 V_{DD}

3-Pin TO-126
LPC Package

V_{DD} GND OUT

3-Pin TO-92
LP Package

V_{DD}
OUT
GND
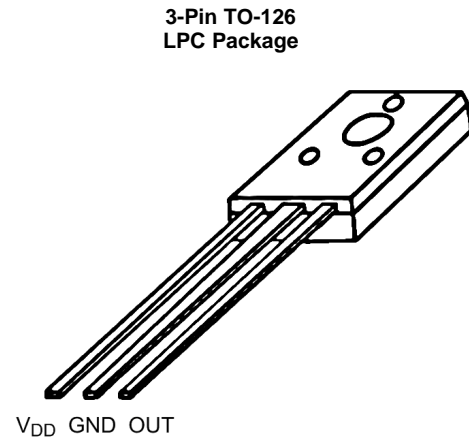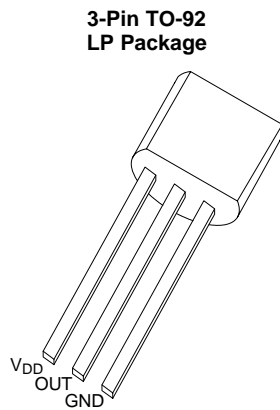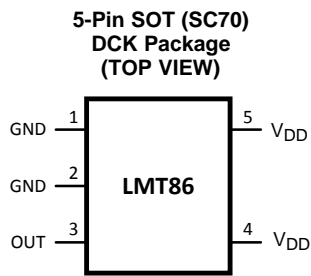
Pin Functions

PIN				DESCRIPTION		
LABEL	DCK NUMBER	LP NUMBER	LPC NUMBER	TYPE	EQUIVALENT CIRCUIT	FUNCTION
V_{DD}	5			Power		Power Supply Voltage
V_{DD}	1			Power		Power Supply Voltage
OUT	3	See Pin Diagrams	See Pin Diagrams	Analog Output	V_{DD} / GND	Outputs a voltage which is inversely proportional to temperature
V_{DD}	4			Power		Positive Supply Voltage
GND	2			Ground		Power Supply Ground, (direct connection to the back side of the die)

Product Folder Links: *LMT86 LMT86-Q1*

7 Specifications

7.1 Absolute Maximum Ratings [(1)](2)

	MIN	MAX	UNIT
Supply Voltage	–0.3	6	V
Voltage at Output Pin	–0.3	$(V_{DD} + 0.5)$	V
Output Current	-7	7	mA
Input Current at any pin [(3)]	-5	5	mA
Maximum Junction Temperature (T_{JMAX})		150	°C

(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 specific performance limits. For specifications and test conditions, see the Electrical Characteristics. The specifications apply only for the test conditions listed. Some performance characteristics may degrade when the device is not operated under the listed test conditions.
(2) *Soldering process must comply with TI's Reflow Temperature Profile specifications. Refer to* www.ti.com/packaging. Reflow temperature profiles are different for lead-free and non-lead-free packages.
(3) When the input voltage (V_I) at any pin exceeds power supplies (V_I < GND or V_I > V), the current at that pin should be limited to 5 mA.

7.2 Handling Ratings

			MIN	MAX	UNIT
T_{stg}	Storage temperature range		-65	150	°C
$V_{(ESD)}$	Electrostatic discharge	Human body model (HBM), per ANSI/ESDA/JEDEC JS-001, all pins.[(1)]Applies for TO-92 package LMT86LP.	-2.5	2.5	kV
		Human body model (HBM), per JESD22-A114, all pin. Applies for SC70 package LMT86DCK and LMT86DCK-Q1.	-2.5	2.5	
		Charged device model (CDM), per JEDEC specification JESD22-C101, all pins.[(2)] Applies for all parts.	-1	1	
		Machine model ESD stress voltage, per JEDEC specification JESD22-A115.[(3)] Applies for SC70 package LMT86DCK and LMT86DCK-Q1	-250	250	V

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.
(3) The machine model is a 200pF capacitor discharged directly into each pin.

7.3 Recommended Operating Ratings

		MIN MAX	UNIT
	Specified temperature range	$T_{MIN} \le T_A \le T_{MAX}$	°C
		$-50 \le T_A \le 150$	°C
V_{DD}	Supply voltage range	2.2 5.5	V

7.4 Thermal Information[(1)]

THERMAL METRIC[(2)]	LMT86 LMT86-Q1	LMT86	LMT86	UNIT
	DCK	LP	LPC	
	5 PINS	3 PINS	3 PINS	
$R_{\theta JA}$ Junction-to-ambient thermal resistance[(3)(4)]	275	167	TBD	°C/W
$R_{\theta JC(top)}$ Junction-to-case (top) thermal resistance	84	80	TBD	
$R_{\theta JB}$ Junction-to-board thermal resistance	56	146	TBD	
ψ_{JT} Junction-to-top characterization parameter	1.2	35	TBD	
ψ_{JB} Junction-to-board characterization parameter	55	146	TBD	

(1) For information on self-heating and thermal response time see section *Mounting and Thermal Conductivity*.
(2) For more information about traditional and new thermal metrics, see the *IC Package Thermal Metrics* application report, SPRA953.
(3) The junction to ambient thermal resistance ($R_{\theta JA}$) under natural convection is obtained in a simulation on a JEDEC-standard, High K board as specified in JESD51-7, in an environment described in JESD51-2. Exposed pad packages assume that thermal vias are included in the PCB, per JESD 51-5.
(4) Changes in output due to self heating can be computed by multiplying the internal dissipation by the thermal resistance.

7.5 Accuracy Characteristics

These limits do not include DC load regulation. These stated accuracy limits are with reference to the values in Table 1.

PARAMETER	CONDITIONS	MIN[1]	TYP[2]	MAX[1]	UNIT
Temperature accuracy[3]	40°C to 150°C; V_{DD} = 2.2 V to 5.5 V	-2.7	±0.4	2.7	°C
	0°C to 40°C; V_{DD} = 2.4 V to 5.5 V	-2.7	±0.7	2.7	°C
	0°C to 70°C; V_{DD} = 3.0 V to 5.5 V		±0.3		°C
	–50°C to 0°C; V_{DD} = 3.0 V to 5.5 V	-2.7	±0.7	2.7	°C
	–50°C to 0°C; V_{DD} = 3.6 V to 5.5 V		±0.25		°C

(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 measured and reference output voltages, tabulated in the Transfer Table at the specified conditions of supply gain setting, voltage, and temperature (expressed in °C). Accuracy limits include line regulation within the specified conditions. Accuracy limits do not include load regulation; they assume no dc load.

7.6 Electrical Characteristics

Unless otherwise noted, these specifications apply for $+V_{DD}$ = 2.2 V to 5.5 V. MIN and MAX limits apply for $T_A = T_J = T_{MIN}$ to T_{MAX} , unless otherwise noted; typical values apply for $T_A = T_J$ = 25°C.

	PARAMETER	CONDITIONS	MIN[1]	TYP[2]	MAX[1]	UNIT
	Average sensor gain (output transfer function slope)	-30°C and 90°C used to calculate average sensor gain		−10.9		mV/°C
	Load regulation[3]	Source ≤ 50 µA, ($V_{DD} − V_{OUT}$) ≥ 200 mV	-1	−0.22		mV
		Sink ≤ 50 µA, V_{OUT} ≥ 200 mV		0.26	1	mV
	Line regulation[4]			200		µV/V
I_S	Supply current	T_A = 30°C to 150°C, ($V_{DD} − V_{OUT}$) ≥ 100 mV		5.4	8.1	µA
		T_A = -50°C to 150°C, ($V_{DD} − V_{OUT}$) ≥ 100 mV		5.4	9	µA
C_L	Output load capacitance			1100		pF
	Power-on time[5]	C_L= 0 pF to 1100 pF		0.7	1.9	ms
	Output drive	$T_A = T_J$ = 25°C	-50		50	µA

(1) Limits are specific 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) Source currents are flowing out of the LMT86 and LMT86-Q1. Sink currents are flowing into the LMT86 and LMT86-Q1.
(4) Line regulation (DC) is calculated by subtracting the output voltage at the highest supply voltage from the output voltage at the lowest supply voltage. The typical DC line regulation specification does not include the output voltage shift discussed in Output Voltage Shift.
(5) Specified by design and characterization.

Product Folder Links: *LMT86 LMT86-Q1*

7.7 Typical Characteristics
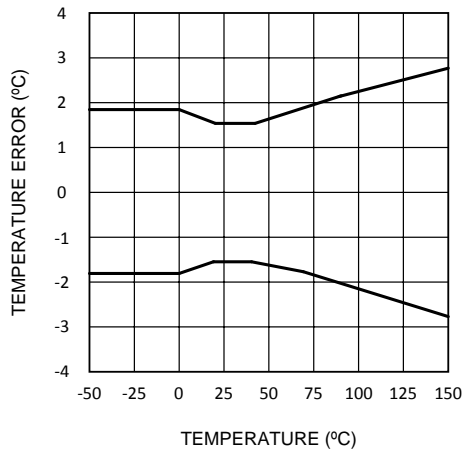
Figure 1. Temperature Error vs Temperature
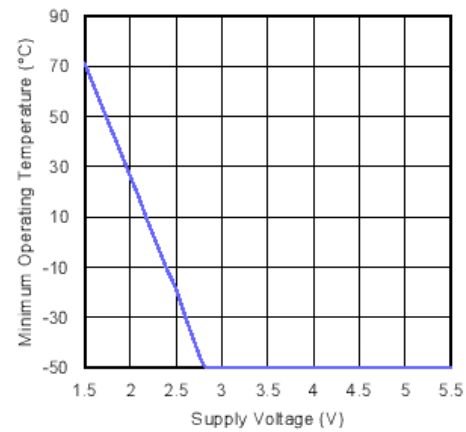
Figure 2. Minimum Operating Temperature vs
Supply Voltage
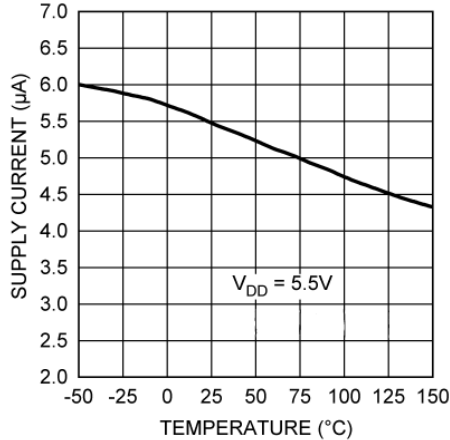
Figure 3. Supply Current vs Temperature

Figure 4. Supply Current vs Supply Voltage
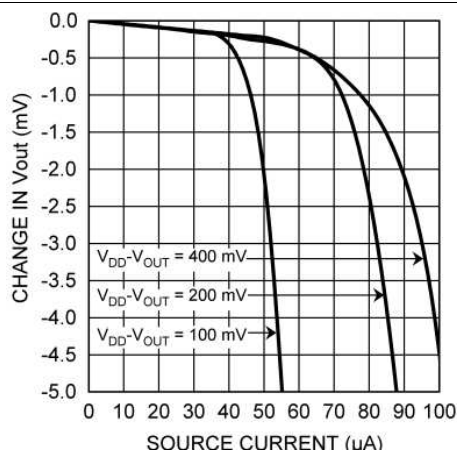
Figure 5. Load Regulation, Sourcing Current
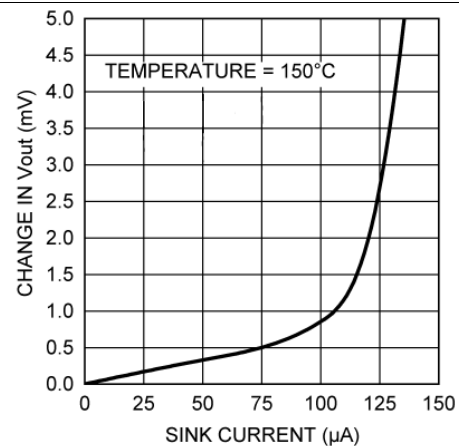
Figure 6. Load Regulation, Sinking Current

Product Folder Links: *LMT86 LMT86-Q1*

Typical Characteristics (continued)

Figure 7. Change in V_{OUT} vs Overhead Voltage
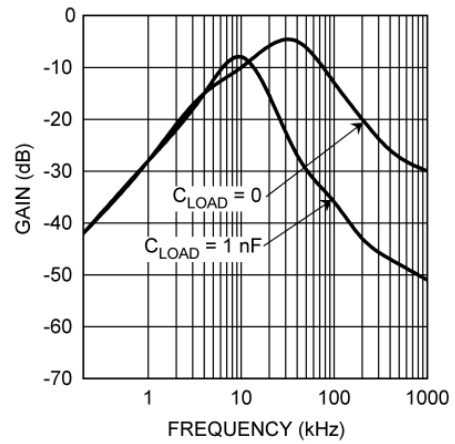
Figure 8. Supply-Noise Gain vs Frequency

Figure 9. Output Voltage vs Supply Voltage

Product Folder Links: *LMT86 LMT86-Q1*

8 Detailed Description

8.1 Overview

The LMT86/LMT86-Q1 is an analog output temperature sensor. The temperature sensing element is comprised of a simple base emitter junction that is forward biased by a current source. The temper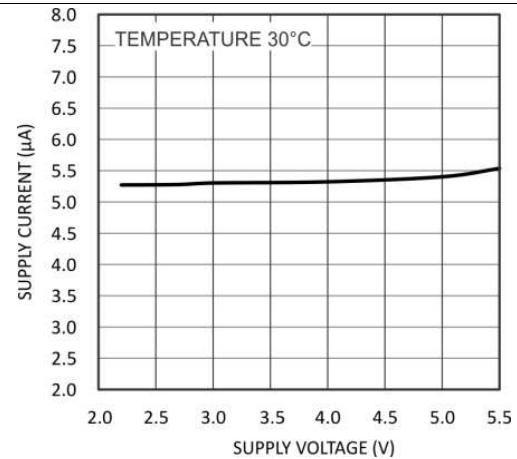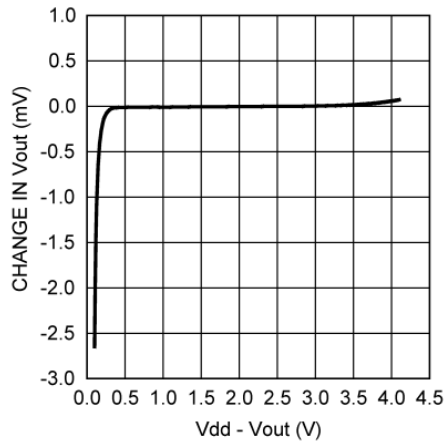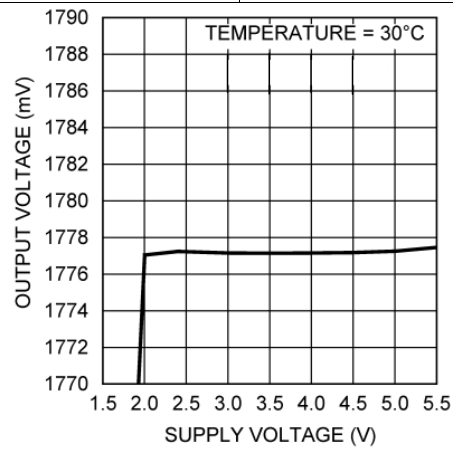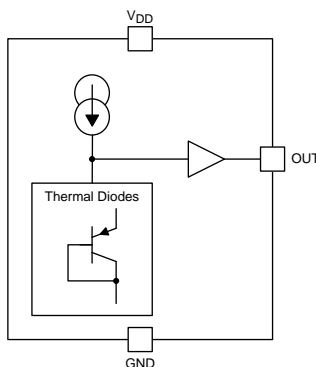ature sensing element is then buffered by an amplifier and provided to the OUT pin. The amplifier has a simple push-pull output stage thus providing a low impedance output source.

8.2 Functional Block Diagram

Full-Range Celsius Temperature Sensor (−50°C to 150°C).

8.3 Feature Description

8.3.1 LMT86 and LMT86-Q1 Transfer Function

The output voltage of the LMT86 and LMT86-Q1, across the complete operating temperature range is shown in Table 1. This table is the reference from which the LMT86 and LMT86-Q1 accuracy specifications (listed in the *Accuracy Characteristics* section) are determined. This table can be used, for example, in a host processor look-up table. A file containing this data is available for download at LMT86 product folder under Tools and Software Models.

Table 1. LMT86 and LMT86-Q1 Transfer Table

TEMP (°C)	V_{OUT} (mV)	TEMP (°C)	V_{OUT} (mV)	TEMP (°C)	V_{OUT} (mV)	TEMP (°C)	V_{OUT} (mV)	TEMP (°C)	V_{OUT} (mV)
-50	2616	-10	2207	30	1777	70	1335	110	883
-49	2607	-9	2197	31	1766	71	1324	111	872
-48	2598	-8	2186	32	1756	72	1313	112	860
-47	2589	-7	2175	33	1745	73	1301	113	849
-46	2580	-6	2164	34	1734	74	1290	114	837
-45	2571	-5	2154	35	1723	75	1279	115	826
-44	2562	-4	2143	36	1712	76	1268	116	814
-43	2553	-3	2132	37	1701	77	1257	117	803
-42	2543	-2	2122	38	1690	78	1245	118	791
-41	2533	-1	2111	39	1679	79	1234	119	780
-40	2522	0	2100	40	1668	80	1223	120	769
-39	2512	1	2089	41	1657	81	1212	121	757
-38	2501	2	2079	42	1646	82	1201	122	745
-37	2491	3	2068	43	1635	83	1189	123	734
-36	2481	4	2057	44	1624	84	1178	124	722
-35	2470	5	2047	45	1613	85	1167	125	711
-34	2460	6	2036	46	1602	86	1155	126	699
-33	2449	7	2025	47	1591	87	1144	127	688

Feature Description (continued)

Table 1. LMT86 and LMT86-Q1 Transfer Table (continued)

TEMP (°C)	V_OUT (mV)		TEMP (°C)	V_OUT (mV)		TEMP (°C)	V_OUT (mV)		TEMP (°C)	V_OUT (mV)		TEMP (°C)	V_OUT (mV)
-32	2439		8	2014		48	1580		88	1133		128	676
-31	2429		9	2004		49	1569		89	1122		129	665
-30	2418		10	1993		50	1558		90	1110		130	653
-29	2408		11	1982		51	1547		91	1099		131	642
-28	2397		12	1971		52	1536		92	1088		132	630
-27	2387		13	1961		53	1525		93	1076		133	618
-26	2376		14	1950		54	1514		94	1065		134	607
-25	2366		15	1939		55	1503		95	1054		135	595
-24	2355		16	1928		56	1492		96	1042		136	584
-23	2345		17	1918		57	1481		97	1031		137	572
-22	2334		18	1907		58	1470		98	1020		138	560
-21	2324		19	1896		59	1459		99	1008		139	549
-20	2313		20	1885		60	1448		100	997		140	537
-19	2302		21	1874		61	1436		101	986		141	525
-18	2292		22	1864		62	1425		102	974		142	514
-17	2281		23	1853		63	1414		103	963		143	502
-16	2271		24	1842		64	1403		104	951		144	490
-15	2260		25	1831		65	1391		105	940		145	479
-14	2250		26	1820		66	1380		106	929		146	467
-13	2239		27	1810		67	1369		107	917		147	455
-12	2228		28	1799		68	1358		108	906		148	443
-11	2218		29	1788		69	1346		109	895		149	432
												150	420

Although the LMT86 and LMT86-Q1 is very linear, its response does have a slight umbrella parabolic shape. This shape is very accurately reflected in Table 1. The Transfer Table can be calculated by using the parabolic equation.

$$V_{TEMP}(mV) = 1777.3mV - \left[10.888 \frac{mV}{°C}(T - 30°C) \right] - \left[0.00347 \frac{mV}{°C^2}(T - 30°C)^2 \right]$$

(1)

The parabolic equation is an approximation of the transfer table and the accuracy of the equation degrades slightly at the temperature range extremes. Equation 1 can be solved for T resulting in:

$$T = \frac{10.888 - \sqrt{(-10.888)^2 + 4 \times 0.00347 \times (1777.3 - V_{TEMP}(mV))}}{2 \times (-0.00347)} + 30$$

(2)

For an even less accurate linear transfer function approximation, a line can easily be calculated over the desired temperature range from the Table using the two-point equation:

$$V - V_1 = \left(\frac{V_2 - V_1}{T_2 - T_1} \right) \times (T - T_1)$$

(3)

Where V is in mV, T is in °C, T_1 and V_1 are the coordinates of the lowest temperature, T_2 and V_2 are the coordinates of the highest temperature.

For example, if we want to resolve this equation, over a temperature range of 20°C to 50°C, we would proceed as follows:

$$V - 1885\ mV = \left(\frac{1558\ mV - 1885\ mV}{50°C - 20°C} \right) \times (T - 20°C)$$

(4)

$$V - 1885\ mV = (-10.9\ mV/°C) \times (T - 20°C)$$

(5)

$$V = (-10.9\ mV/°C) \times T + 2103\ mV$$

(6)

Product Folder Links: *LMT86 LMT86-Q1*

Using this method of linear approximation, the transfer function can be approximated for one or more temperature ranges of interest.

8.4 Device Functional Modes

8.4.1 Mounting and Thermal Conductivity

The LMT86 and LMT86-Q1 can be applied easily in the same way as other integrated-circuit temperature sensors. It can be glued or cemented to a surface.

To ensure good thermal conductivity, the backside of the LMT86 and LMT86-Q1 die is directly attached to the GND pin (Pin 2). The temperatures of the lands and traces to the other leads of the LMT86 and LMT86-Q1 will also affect the temperature reading.

Alternatively, the LMT86 and LMT86-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 LMT86 and LMT86-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. If moisture creates a short circuit from the output to ground or V_{DD}, the output from the LMT86 and LMT86-Q1 will not be correct. Printed-circuit coatings are often used to ensure that moisture cannot corrode the leads or circuit traces.

The thermal resistance junction to ambient ($R_{\theta JA}$ or θ_{JA}) is the parameter used to calculate the rise of a device junction temperature due to its power dissipation. The equation used to calculate the rise in the LMT86 and LMT86-Q1 die temperature is:

$$T_J = T_A + \theta_{JA}\left[(V_{DD}I_S) + (V_{DD} - V_O)\, I_L\,\right] \tag{7}$$

where T_A is the ambient temperature, I_S is the supply current, I_L is the load current on the output, and V_O is the output voltage. For example, in an application where T_A = 30°C, V_{DD} = 5V, I_S = 5.4 μA, V_O = 1777 mV junction temp 30.014°C self-heating error of 0.014°C. Since the LMT86 and LMT86-Q1's junction temperature is the actual temperature being measured, care should be taken to minimize the load current that the LMT86 and LMT86-Q1 is required to drive. *Thermal Information*[1] shows the thermal resistance of the LMT86 and LMT86-Q1.

8.4.2 Output Noise Considerations

A push-pull output gives the LMT86 and LMT86-Q1 the ability to sink and source significant current. This is beneficial when, for example, driving dynamic loads like an input stage on an analog-to-digital converter (ADC). In these applications the source current is required to quickly charge the input capacitor of the ADC. See the section for more discussion of this topic. The LMT86 and LMT86-Q1 is ideal for this and other applications which require strong source or sink current.

The LMT86 and LMT86-Q1's supply-noise gain (the ratio of the AC signal on V_{OUT} to the AC signal on V_{DD}) was measured during bench tests. Its typical attenuation is shown in *Figure 8* found in the Typical Characteristics section. A load capacitor on the output can help to filter noise.

For operation in very noisy environments, some bypass capacitance should be present on the supply within approximately 5 centimeters of the LMT86 and LMT86-Q1.

8.4.3 Capacitive Loads

The LMT86 and LMT86-Q1 handles capacitive loading well. In an extremely noisy environment, or when driving a switched sampling input on an ADC, it may be necessary to add some filtering to minimize noise coupling. Without any precautions, the LMT86 and LMT86-Q1 can drive a capacitive load less than or equal to 1100 pF as shown in *Figure 10*. For capacitive loads greater than 1100 pF, a series resistor may be required on the output, as shown in *Figure 11*.

---

(1) For information on self-heating and thermal response time see section *Mounting and Thermal Conductivity*.

Device Functional Modes (continued)
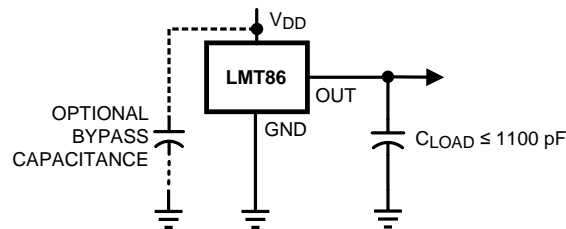
Figure 10. LMT86 No Decoupling Required for Capacitive Loads Less than 1100 pF
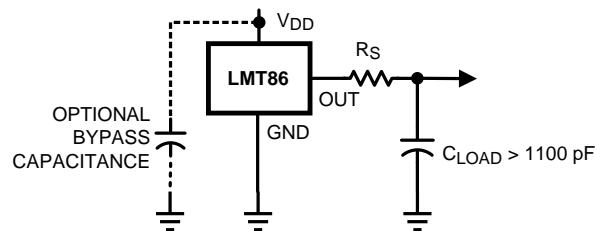
Figure 11. LMT86 with Series Resistor for Capacitive Loading Greater than 1100 pF

C_{LOAD}	MINIMUM R_S
1.1 nF to 99 nF	3 kΩ
100 nF to 999 nF	1.5 kΩ
1 µF	800 Ω

8.4.4 Output Voltage Shift

The LMT86 and LMT86-Q1 are very linear over temperature and supply voltage range. Due to the intrinsic behavior of an NMOS/PMOS rail-to-rail buffer, a slight shift in the output can occur when the supply voltage is ramped over the operating range of the device. The location of the shift is determined by the relative levels of V_{DD} and V_{OUT}. The shift typically occurs when V_{DD}- V_{OUT} = 1 V.

This slight shift (a few millivolts) takes place over a wide change (approximately 200 mV) in V_{DD} or V_{OUT}. Since the shift takes place over a wide temperature change of 5°C to 20°C, V_{OUT} is always monotonic. The accuracy specifications in the *Accuracy Characteristics* table already include this possible shift.

9 Application and Implementation

9.1 Application Information

The LMT86/LMT86-Q1 features make it suitable for many general temperature sensing applications. It can operate down to 2.2V supply with 5.4 uA power consumption making it ideal for battery powered devices. Multiple package options including through-hole TO-92 and TO-126 packages also allow the LMT86 to be mounted on-board, off-board, to a heat sink, or on multiple unique locations in the same application.

9.2 Typical Applications

9.2.1 Connection to an ADC
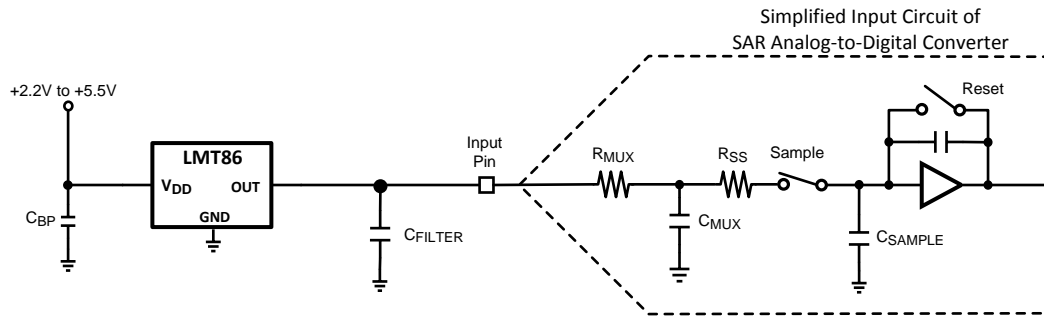
Figure 12. Suggested Connection to a Sampling Analog-to-Digital Converter Input Stage

9.2.1.1 Design Requirements

Most CMOS ADCs found in microcontrollers and ASICs have a sampled data comparator input structure. When the ADC charges the sampling cap, it requires instantaneous charge from the output of the analog source such as the LMT86 and LMT86-Q1 temperature sensor and many op amps. This requirement is easily accommodated by the addition of a capacitor, C_{FILTER}.

9.2.1.2 Detailed Design Procedure

The size of C_{FILTER} depends on the size of the sampling capacitor and the sampling frequency. Since not all ADCs have identical input stages, the charge requirements will vary. This general ADC application is shown as an example only.

9.2.1.3 Application Curves
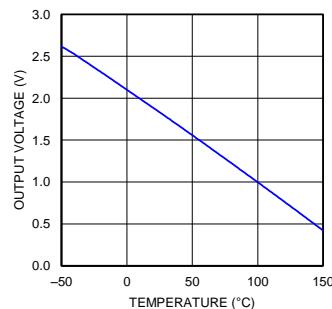
Figure 13. Analog Output Transfer Function

9.2.2 Conserving Power Dissipation with Shutdown
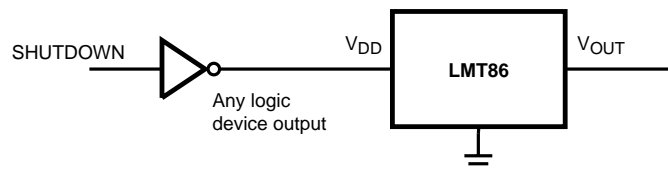
Figure 14. Conserving Power Dissipation with Shutdown

9.2.2.1 Design Requirements

Since the power consumption of the LMT86 is less than 9 µA it can simply be powered directly from any logic gate output, thus not requiring a specific shutdown pin. The device can even be powered directly from a micro controller GPIO. In this way it can easily be turned off for cases such as battery powered systems where power savings is critical.

Typical Applications (continued)

9.2.2.2 Detailed Design Procedure

Simply connect the V_{DD} pin of the LMT86 directly to the logic shutdown signal from a microcontroller.

9.2.2.3 Application Curves

Time: 500 µsec/div; Top Trace: V_{DD} 1 V/div;
Bottom Trace: OUT 1 V/div

Figure 15. Output Turn-on Response Time without a Capacitive Load and V_{DD}=3.3V

Time: 500 µsec/div; Top Trace: V_{DD} 1 V/div;
Bottom Trace: OUT 1 V/div

Figure 16. Output Turn-on Response Time with a 1.1 nF Capacitive Load and V_{DD}=3.3V

Time: 500 µsec/div; Top Trace: V_{DD} 2 V/div;
Bottom Trace: OUT 1 V/div

Figure 17. Output Turn-on Response Time without a Capacitive Load and V_{DD}=5V

Time: 500 µsec/div; Top Trace: V_{DD} 2 V/div;
Bottom Trace: OUT 1 V/div

Figure 18. Output Turn-on Response Time with 1.1 nF Capacitive Load and V_{DD}=5V

10 Power Supply Recommendations

The LMT86's low supply current and supply range of 2.2V to 5.5V allow the device to easily be powered from many sources.

Power supply bypassing is optional and is mainly dependent on the noise on the power supply used. In noisy systems it may be necessary to add bypass capacitors to lower the noise that is coupled to the LMT86's output.

11 Layout

11.1 Layout Guidelines

The LMT86 is extremely simple to layout. If a power supply bypass capacitor is used it should be connected as shown in the Layout Example.

Product Folder Links: *LMT86 LMT86-Q1*

11.2 Layout Example
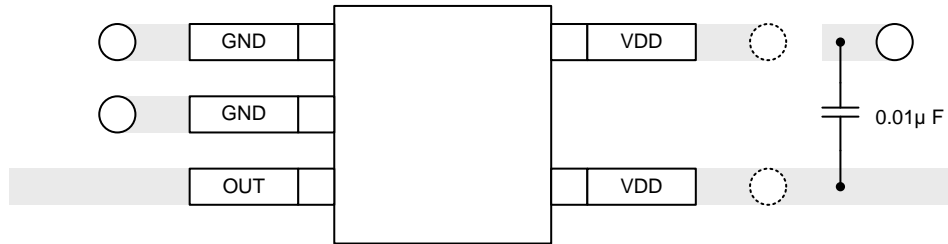
Figure 19. SC70 Package Recommended Layout

Product Folder Links: *LMT86 LMT86-Q1*

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 2. Related Links

PARTS	PRODUCT FOLDER	SAMPLE & BUY	TECHNICAL DOCUMENTS	TOOLS & SOFTWARE	SUPPORT & COMMUNITY
LMT86	Click here	Click here	Click here	Click here	Click here
LMT86-Q1	Click here	Click here	Click here	Click here	Click here

12.2 Trademarks

All trademarks are the property of their respective owners.

12.3 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.

12.4 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
LMT86DCKR	ACTIVE	SC70	DCK	5	3000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-50 to 150	BSA	Samples
LMT86DCKT	ACTIVE	SC70	DCK	5	250	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-50 to 150	BSA	Samples
LMT86LP	ACTIVE	TO-92	LP	3	1800	Green (RoHS & no Sb/Br)	CU SN	N / A for Pkg Type	-50 to 150	LMT86	Samples
LMT86LPM	ACTIVE	TO-92	LP	3	2000	Green (RoHS & no Sb/Br)	CU SN	N / A for Pkg Type	-50 to 150	LMT86	Samples
LMT86QDCKRQ1	ACTIVE	SC70	DCK	5	3000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-50 to 150	BTA	Samples
LMT86QDCKTQ1	ACTIVE	SC70	DCK	5	250	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-50 to 150	BTA	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 LMT86, LMT86-Q1 :

● Catalog: LMT86

● Automotive: LMT86-Q1

NOTE: Qualified Version Definitions:

   ● Catalog - TI's standard catalog product

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

![Texas Instruments logo]

PACKAGE MATERIALS INFORMATION

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
LMT86DCKR	SC70	DCK	5	3000	178.0	8.4	2.25	2.45	1.2	4.0	8.0	Q3
LMT86DCKT	SC70	DCK	5	250	178.0	8.4	2.25	2.45	1.2	4.0	8.0	Q3
LMT86QDCKRQ1	SC70	DCK	5	3000	178.0	8.4	2.25	2.45	1.2	4.0	8.0	Q3
LMT86QDCKTQ1	SC70	DCK	5	250	178.0	8.4	2.25	2.45	1.2	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)
LMT86DCKR	SC70	DCK	5	3000	210.0	185.0	35.0
LMT86DCKT	SC70	DCK	5	250	210.0	185.0	35.0
LMT86QDCKRQ1	SC70	DCK	5	3000	210.0	185.0	35.0
LMT86QDCKTQ1	SC70	DCK	5	250	210.0	185.0	35.0

DCK (R−PDSO−G5)   PLASTIC SMALL−OUTLINE PACKAGE

2,15 / 1,85

2,40 / 1,80

1,40 / 1,10

Pin 1 Index Area

0,65

1,30

5X 0,30 / 0,15

⌖ 0,10 Ⓜ

0,22 / 0,08

Gauge Plane
Seating Plane

0,15

0°−8°

0,46 / 0,26

1,10 / 0,80

0,10 / 0,00

⌒ 0,10

Seating Plane

4093553−3/G 01/2007

NOTES: A. All linear dimensions are in millimeters.
        B. This drawing is subject to change without notice.
        C. Body dimensions do not include mold flash or protrusion. Mold flash and protrusion shall not exceed 0.15 per side.
        D. Falls within JEDEC MO−203 variation AA.

DCK (R−PDSO−G5)   PLASTIC SMALL OUTLINE

Example Board Layout

Stencil Openings
Based on a stencil thickness
of .127mm (.005inch).

2,2

6x0,35

0,85

2,2

2x0,65

2x1,30

2x0,65

2x1,30

0,4

Solder Mask Opening
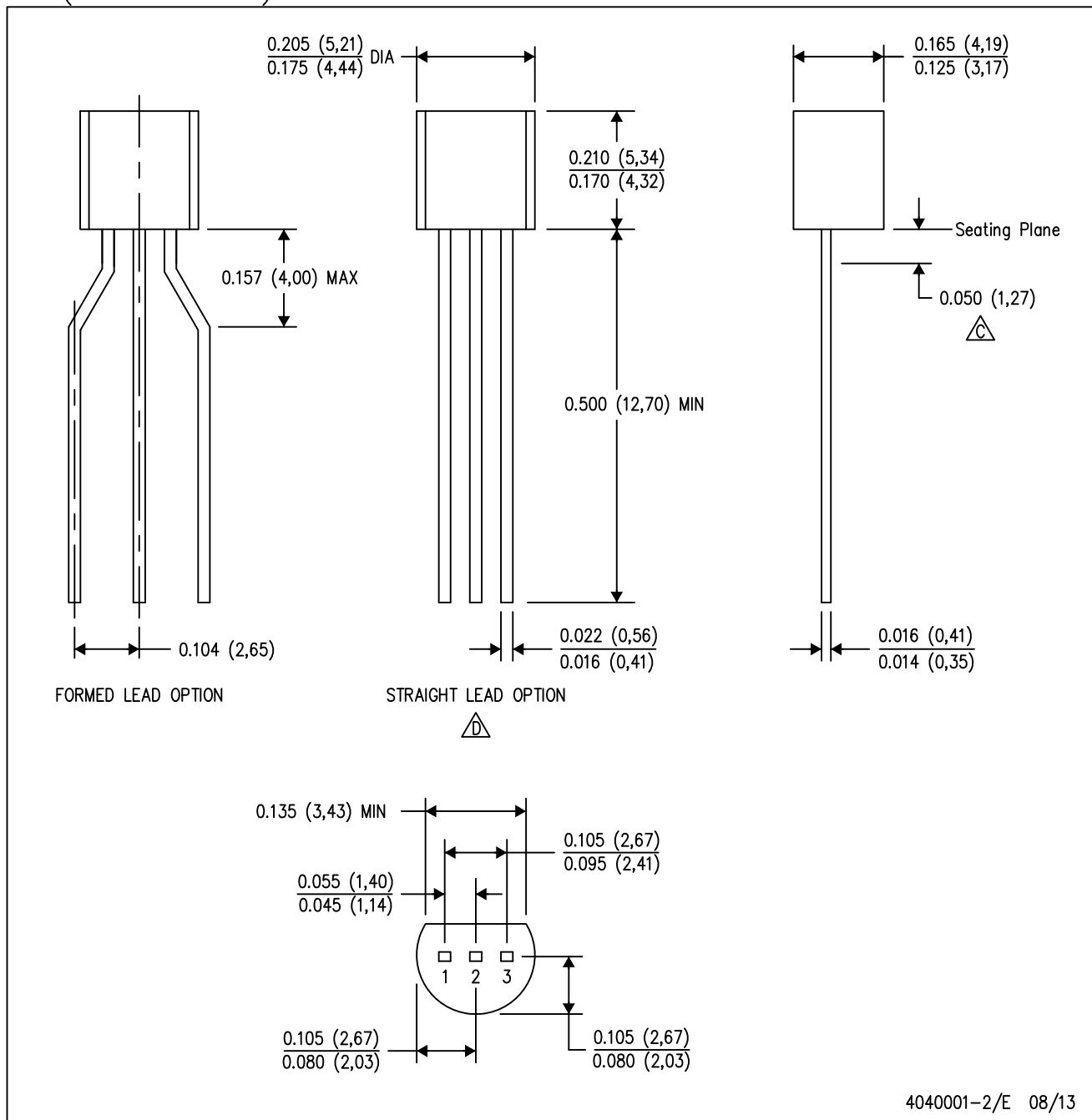
1,0   0,9

Pad Geometry

0,05

0,50

4210356−2/C 07/11

NOTES: A. All linear dimensions are in millimeters.
        B. This drawing is subject to change without notice.
        C. Customers should place a note on the circuit board fabrication drawing not to alter the center solder mask defined pad.
        D. Publication IPC−7351 is recommended for alternate designs.
        E. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should
            contact their board assembly site for stencil design recommendations. Example stencil design based on a 50% volumetric
            metal load solder paste. Refer to IPC−7525 for other stencil recommendations.

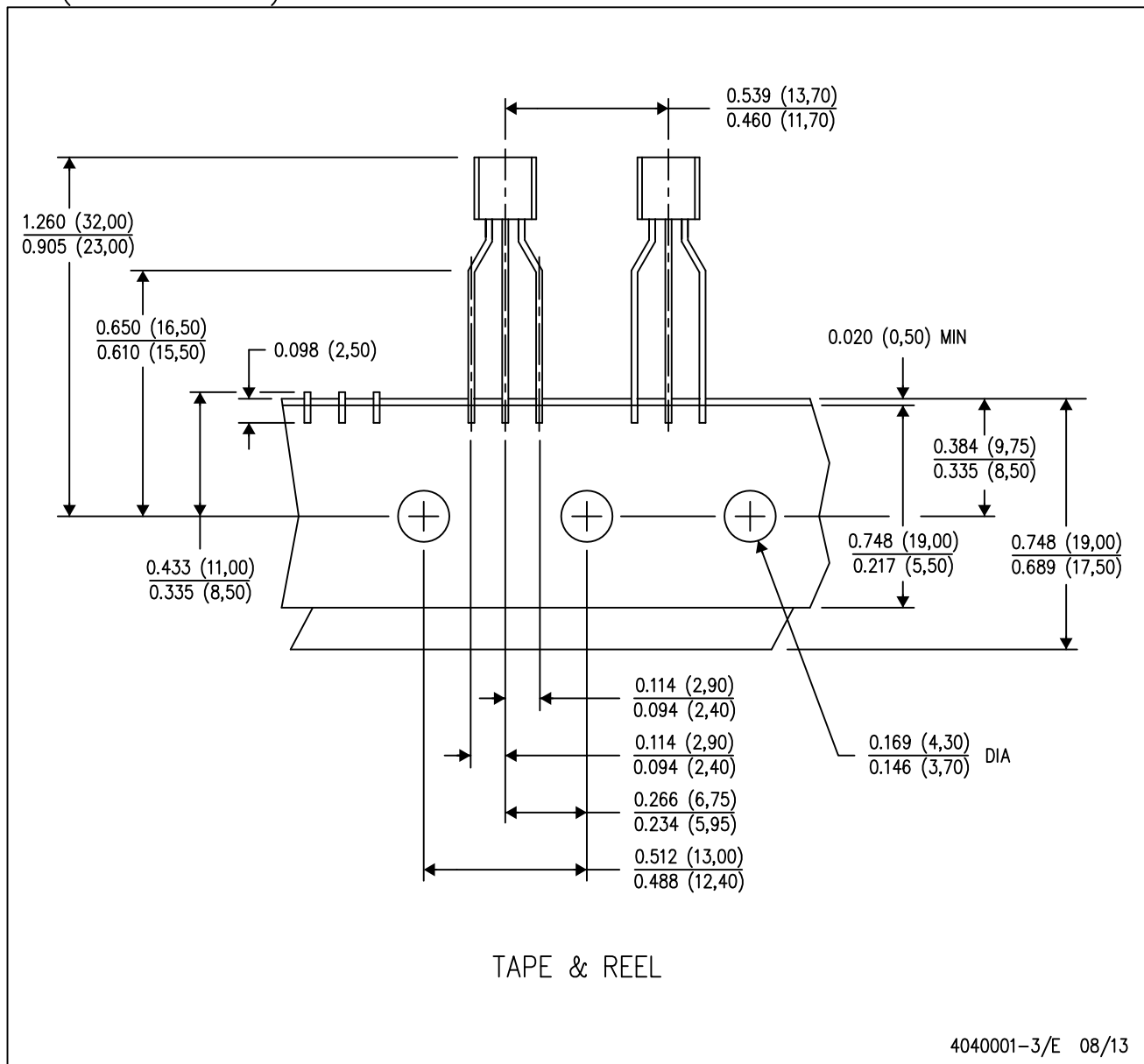LP (O−PBCY−W3)   PLASTIC CYLINDRICAL PACKAGE

0.205 (5,21)
─────────── DIA
0.175 (4,44)

0.165 (4,19)
───────────
0.125 (3,17)

0.210 (5,34)
───────────
0.170 (4,32)

0.157 (4,00) MAX

Seating Plane

0.050 (1,27)

/C\

0.500 (12,70) MIN

0.104 (2,65)

0.022 (0,56)
───────────
0.016 (0,41)

0.016 (0,41)
───────────
0.014 (0,35)

FORMED LEAD OPTION

STRAIGHT LEAD OPTION

/D\

0.135 (3,43) MIN

0.105 (2,67)
───────────
0.095 (2,41)

0.055 (1,40)
───────────
0.045 (1,14)

1   2   3

0.105 (2,67)
───────────
0.080 (2,03)

0.105 (2,67)
───────────
0.080 (2,03)

4040001−2/E   08/13

NOTES: A.   All linear dimensions are in inches (millimeters).
         B.   This drawing is subject to change without notice.
      /C\   Lead dimensions are not controlled within this area.
      /D\   Falls within JEDEC TO−226 Variation AA (TO−226 replaces TO−92).
         E.   Shipping Method:
                 Straight lead option available in bulk pack only.
                 Formed lead option available in tape & reel or ammo pack.
                 Specific products can be offered in limited combinations of shipping mediums and lead options.
                 Consult product folder for more information on available options.

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LP (O−PBCY−W3) PLASTIC CYLINDRICAL PACKAGE

0.539 (13,70)
0.460 (11,70)

1.260 (32,00)
0.905 (23,00)

0.650 (16,50)
0.610 (15,50)

0.098 (2,50)

0.020 (0,50) MIN

0.384 (9,75)
0.335 (8,50)

0.433 (11,00)
0.335 (8,50)

0.748 (19,00)
0.217 (5,50)

0.748 (19,00)
0.689 (17,50)

0.114 (2,90)
0.094 (2,40)

0.114 (2,90)
0.094 (2,40)

0.169 (4,30)
0.146 (3,70) DIA

0.266 (6,75)
0.234 (5,95)

0.512 (13,00)
0.488 (12,40)

TAPE & REEL

4040001−3/E 08/13

NOTES: A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Tape and Reel information for the Formed Lead Option package.

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DLP® Products	www.dlp.com	Consumer Electronics	www.ti.com/consumer-apps
DSP	dsp.ti.com	Energy and Lighting	www.ti.com/energy
Clocks and Timers	www.ti.com/clocks	Industrial	www.ti.com/industrial
Interface	interface.ti.com	Medical	www.ti.com/medical
Logic	logic.ti.com	Security	www.ti.com/security
Power Mgmt	power.ti.com	Space, Avionics and Defense	www.ti.com/space-avionics-defense
Microcontrollers	microcontroller.ti.com	Video and Imaging	www.ti.com/video
RFID	www.ti-rfid.com		
OMAP Applications Processors	www.ti.com/omap	**TI E2E Community**	e2e.ti.com
Wireless Connectivity	www.ti.com/wirelessconnectivity		