LMT85/LMT85-Q1 SC70, Analog Temperature Sensors with Class-AB Output

Check for Samples: LMT85, LMT85-Q1

FEATURES

- **LMT85-Q1 is AEC-Q100 Grade 0 qualified and is Manufactured on an Automotive Grade Flow**
- **Push-Pull Output with 50 µA Source Current Capability**
- **Very Accurate Over Wide Temperature Range of −50°C to 150°C**
- **Low Quiescent Current**
- **Output is Short-Circuit Protected**
- **Extremely Small SC70 Package**
- **Cost-effective Alternative to Thermistors**

APPLICATIONS

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

DESCRIPTION

The LMT85/LMT85-Q1 are precision analog output CMOS integrated-circuit temperature sensors that operates at a supply voltage as low as 1.8 Volts. A class-AB output structure gives the LMT85/LMT85-Q1 strong output source and sink current capability for driving heavy loads. This means it is well suited to source the input of a sample-and-hold analog-to-digital converter with its transient load requirements. While operating over the wide temperature range of −50°C to 150°C, the device delivers an output voltage that is inversely proportional to measured temperature. The LMT85/LMT85-Q1 low supply current makes it ideal for battery-powered systems as well as general temperature sensing applications.

The LMT85/LMT85-Q1 can operate with a 1.8V supply while measuring temperature over the full −50°C to150°C operating range.

The LMT85/LMT85-Q1 are cost-competitive alternatives to thermistors.

CONNECTION DIAGRAM

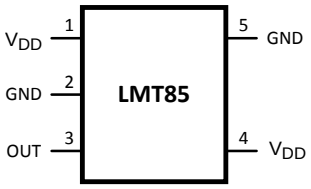
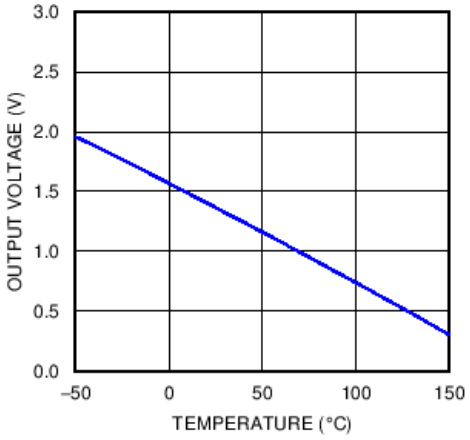


Figure 1. SOT Top View
See Package Number DCK0005A

TYPICAL TRANSFER CHARACTERISTIC

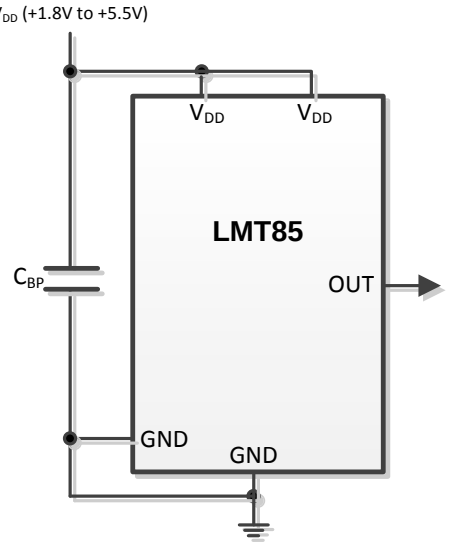
Output Voltage vs Temperature



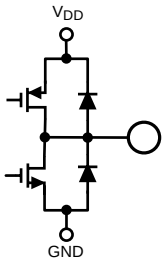
These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

TYPICAL APPLICATION

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



PIN DESCRIPTIONS

LABEL	PIN NUMBER	TYPE	EQUIVALENT CIRCUIT	FUNCTION
GND	5	Ground		Power Supply Ground
V_{DD}	1	Power		Positive Supply Voltage
OUT	3	Analog Output		Outputs a voltage which is inversely proportional to temperature
V_{DD}	4	Power		Positive Supply Voltage
GND	2	Ground		Power Supply Ground

ABSOLUTE MAXIMUM RATINGS (1)

		VALUE		UNIT
		MIN	MAX	
Supply Voltage		−0.3	6.	V
Voltage at Output Pin		−0.3	(V_{DD} + 0.5)	V
Output Current			±7	mA
Input Current at any pin (2)			5	mA
Storage Temperature		−65	150	°C
Maximum Junction Temperature (T_{JMAX})			150	°C
ESD Susceptibility (3) :	Human Body Model		2500	V
	Machine Model		250	V
Soldering process must comply with Texas Instruments Reflow Temperature Profile specifications. Refer to www.ti.com/packaging. (4)				

(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) 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.
(3) The human body model is a 100 pF capacitor discharged through a 1.5 kΩ resistor into each pin. The machine model is a 200 pF capacitor discharged directly into each pin.
(4) Reflow temperature profiles are different for lead-free and non-lead-free packages.

OPERATING RATINGS

	VALUE	UNIT
Specified Temperature Range:	$T_{MIN} \le T_A \le T_{MAX}$	°C
	$-50 \le T_A \le +150$	°C
Supply Voltage Range (V_{DD})	1.8 to 5.5	V
Thermal Resistance (θ_{JA}) (1)(2) (SOT)	415	°C/W

(1) The junction to ambient thermal resistance (θ_{JA}) is specified without a heat sink in still air.
(2) Changes in output due to self heating can be computed by multiplying the internal dissipation by the thermal resistance.

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	TYPICAL	LIMITS (1)	UNIT
Temperature Error (2)	70°C to 150°C; V_{DD} = 1.9 V to 5.5 V	0.4	2.7	°C
	0°C to 150°C; V_{DD} = 1.9 V to 5.5 V	0.7	2.7	°C
	0°C to 150°C; V_{DD} = 2.6 V to 5.5 V	0.3		°C
	–50°C to 0°C; V_{DD} = 2.3 V to 5.5 V	0.7	2.7	°C
	–50°C to 0°C; V_{DD} = 2.9 V to 5.5 V	0.25		°C

(1) Limits are specific to TI's AOQL (Average Outgoing Quality Level).
(2) 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.

ELECTRICAL CHARACTERISTICS

Unless otherwise noted, these specifications apply for $+V_{DD}$ = 1.8V to 5.5V. **Boldface limits apply for $T_A = T_J = T_{MIN}$ to T_{MAX}** ; all other limits $T_A = T_J$ = 25°C.

PARAMETER		CONDITIONS	TYPICAL (1)	MAX (2)	UNITS
	Sensor Gain		–8.2		mV/°C
	Load Regulation (3)	Source ≤ 50 µA, (V_{DD} - V_{OUT}) ≥ 200 mV	–0.22	**–1**	mV
		Sink ≤ 50 µA, V_{OUT} ≥ 200 mV	0.26	**1**	mV
	Line Regulation (4)		200		µV/V
I_S	Supply Current(5)	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 (6)	C_L= 0 pF to 1100 pF	0.7	**1.9**	ms
	Output drive			±50	µA

(1) Typicals are at $T_J = T_A$ = 25°C and represent most likely parametric norm.
(2) Limits are specific to TI's AOQL (Average Outgoing Quality Level).
(3) Source currents are flowing out of the LMT85/LMT85-Q1. Sink currents are flowing into the LMT85/LMT85-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) 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) Specified by design and characterization.

TYPICAL PERFORMANCE CHARACTERISTICS

Temperature Error vs Temperature

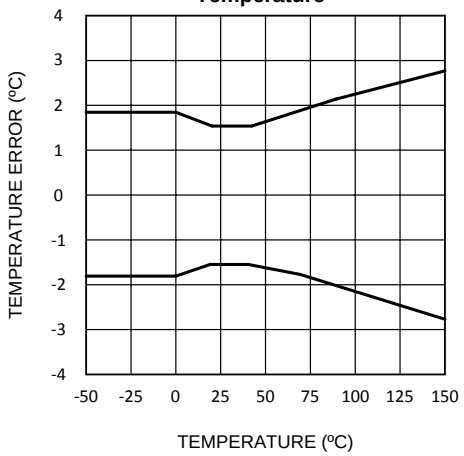


Figure 2.

Minimum Operating Temperature vs Supply Voltage

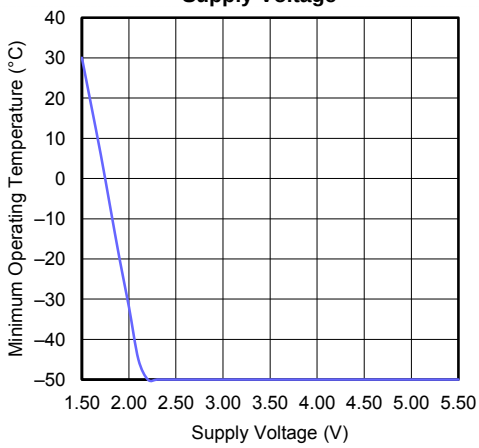


Figure 3.

Supply Current vs Temperature

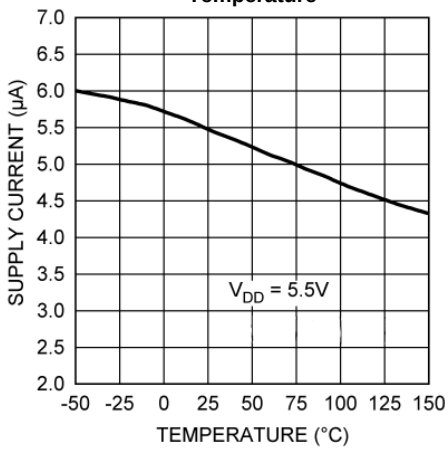


Figure 4.

Supply Current vs Supply Voltage

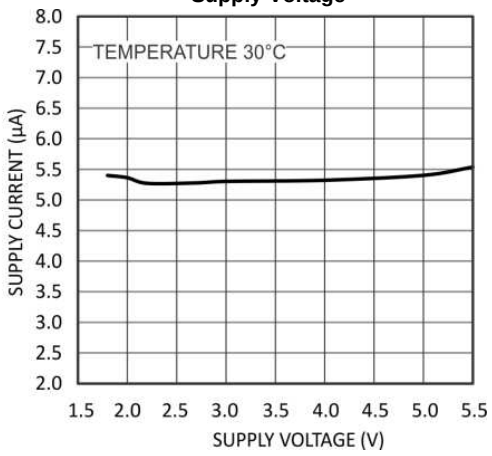


Figure 5.

Load Regulation, Sourcing Current

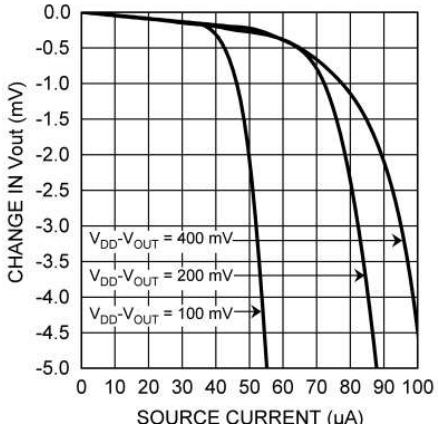


Figure 6.

Load Regulation, Sinking Current

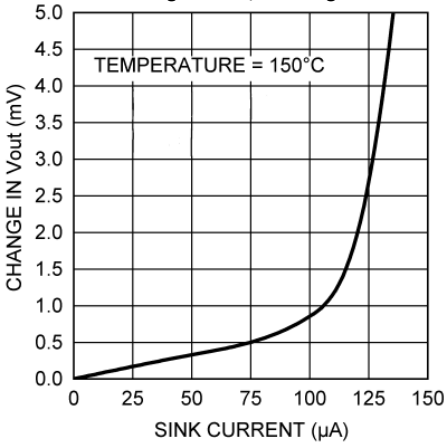


Figure 7.

TYPICAL PERFORMANCE CHARACTERISTICS (continued)

Change in Vout vs Overhead Voltage

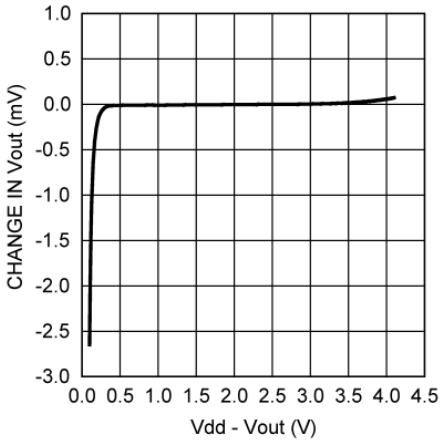


Figure 8.

Supply-Noise Gain vs Frequency

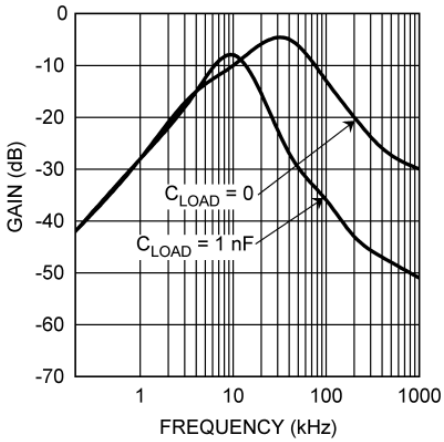


Figure 9.

Output Voltage vs Supply Voltage

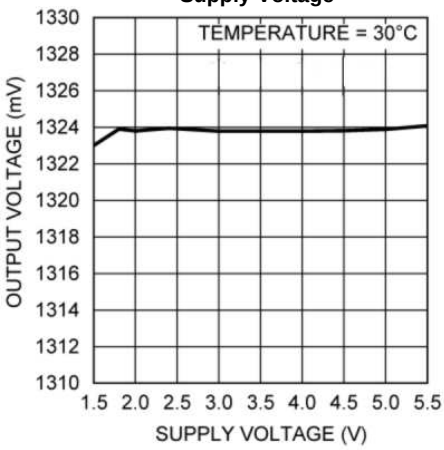


Figure 10.

LMT85/LMT85-Q1 TRANSFER FUNCTION

The output voltage of the LMT85/LMT85-Q1, across the complete operating temperature range, is shown in Table 1. This table is the reference from which the LMT85/LMT85-Q1 accuracy specifications (listed in the ELECTRICAL 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 www.ti.com

Table 1. LMT85/LMT85-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	1955		-10	1648		30	1324		70	991		110	651
-49	1949		-9	1639		31	1316		71	983		111	642
-48	1942		-8	1631		32	1308		72	974		112	634
-47	1935		-7	1623		33	1299		73	966		113	625
-46	1928		-6	1615		34	1291		74	957		114	617
-45	1921		-5	1607		35	1283		75	949		115	608
-44	1915		-4	1599		36	1275		76	941		116	599
-43	1908		-3	1591		37	1267		77	932		117	591
-42	1900		-2	1583		38	1258		78	924		118	582
-41	1892		-1	1575		39	1250		79	915		119	573
-40	1885		0	1567		40	1242		80	907		120	565
-39	1877		1	1559		41	1234		81	898		121	556
-38	1869		2	1551		42	1225		82	890		122	547
-37	1861		3	1543		43	1217		83	881		123	539
-36	1853		4	1535		44	1209		84	873		124	530
-35	1845		5	1527		45	1201		85	865		125	521
-34	1838		6	1519		46	1192		86	856		126	513
-33	1830		7	1511		47	1184		87	848		127	504
-32	1822		8	1502		48	1176		88	839		128	495
-31	1814		9	1494		49	1167		89	831		129	487
-30	1806		10	1486		50	1159		90	822		130	478
-29	1798		11	1478		51	1151		91	814		131	469
-28	1790		12	1470		52	1143		92	805		132	460
-27	1783		13	1462		53	1134		93	797		133	452
-26	1775		14	1454		54	1126		94	788		134	443
-25	1767		15	1446		55	1118		95	779		135	434
-24	1759		16	1438		56	1109		96	771		136	425
-23	1751		17	1430		57	1101		97	762		137	416
-22	1743		18	1421		58	1093		98	754		138	408
-21	1735		19	1413		59	1084		99	745		139	399
-20	1727		20	1405		60	1076		100	737		140	390
-19	1719		21	1397		61	1067		101	728		141	381
-18	1711		22	1389		62	1059		102	720		142	372
-17	1703		23	1381		63	1051		103	711		143	363
-16	1695		24	1373		64	1042		104	702		144	354
-15	1687		25	1365		65	1034		105	694		145	346
-14	1679		26	1356		66	1025		106	685		146	337
-13	1671		27	1348		67	1017		107	677		147	328
-12	1663		28	1340		68	1008		108	668		148	319
-11	1656		29	1332		69	1000		109	660		149	310
												150	301

Although the LMT85/LMT85-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.

$$V_{TEMP}(mV) = 1324.0mV - \left[8.194\frac{mV}{°C}(T - 30°C)\right] - \left[0.00262\frac{mV}{°C^2}(T - 30°C)^2\right] \quad (1)$$

For a linear approximation, a line can easily be calculated over the desired temperature range from the Table using the two-point equation:

$$V - V_1 = \left(\frac{V_2 - V_1}{T_2 - T_1}\right) \times (T - T_1) \quad (2)$$

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:

$$V - 1405\ mV = \left(\frac{1159\ mV - 1405\ mV}{50^oC - 20^oC}\right) \times (T - 20^oC) \quad (3)$$

$$V - 1405\ mV = (-8.20\ mV / {}^oC) \times (T - 20^oC) \quad (4)$$

$$V = (-8.20\ mV / {}^oC) \times T + 1569\ mV \quad (5)$$

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

MOUNTING AND THERMAL CONDUCTIVITY

The LMT85/LMT85-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 LMT85/LMT85-Q1 die is directly attached to the GND pin (Pin 2). The temperatures of the lands and traces to the other leads of the LMT85/LMT85-Q1 will also affect the temperature reading.

Alternatively, the LMT85/LMT85-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 LMT85/LMT85-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 LMT85/LMT85-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 (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 LMT85/LMT85-Q1 die temperature is:

$$T_J = T_A + \theta_{JA}\left[(V_{DD}I_S) + (V_{DD} - V_{OUT})\,I_L\right] \quad (6)$$

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} = 5 V, I_S = 5.4 µA, V_{OUT} = 1324 mV, and I_L = 2 µA, the junction temperature would be 30.0143°C, showing a self-heating error of only 0.0143°C. Since the LMT85/LMT85-Q1's junction temperature is the actual temperature being measured, care should be taken to minimize the load current that the LMT85/LMT85-Q1 is required to drive. Table 2 shows the thermal resistance of the LMT85/LMT85-Q1.

Table 2. LMT85/LMT85-Q1 Thermal Resistance

DEVICE NUMBER	TI PACKAGE NUMBER	THERMAL RESISTANCE (θ_{JA})
LMT85DCK	DCK0005A	415°C/W

OUTPUT AND NOISE CONSIDERATIONS

A push-pull output gives the LMT85/LMT85-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 APPLICATION CIRCUITS section for more discussion of this topic. The LMT85/LMT85-Q1 are ideal for this and other applications which require strong source or sink current.

The LMT85/LMT85-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 the TYPICAL PERFORMANCE 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 LMT85/LMT85-Q1.

CAPACITIVE LOADS

The LMT85/LMT85-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 LMT85/LMT85-Q1 can drive a capacitive load less than or equal to 1100 pF as shown in Figure 11. For capacitive loads greater than 1100 pF, a series resistor may be required on the output, as shown in Figure 12.

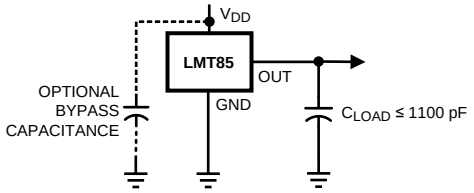


Figure 11. LMT85 No Decoupling Required for Capacitive Loads Less than 1100 pF

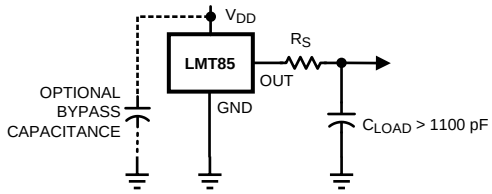


Figure 12. LMT85 with Series Resistor for Capacitive Loading Greater than 1100 pF

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

OUTPUT VOLTAGE SHIFT

The LMT85/LMT85-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 ELECTRICAL CHARACTERISTICS table already include this possible shift.

APPLICATION CIRCUITS

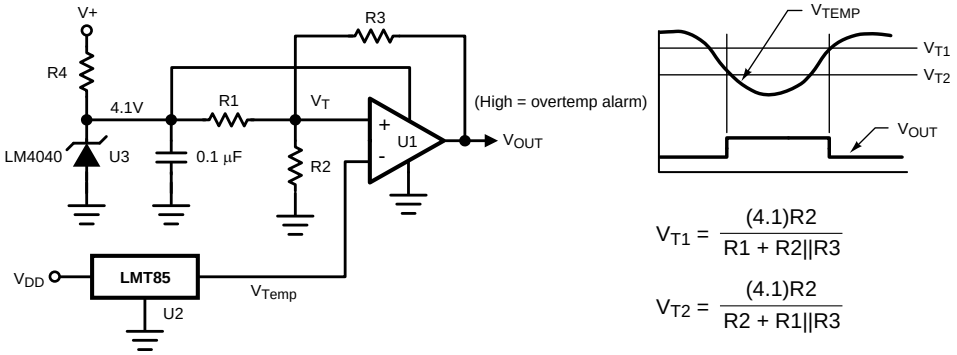


Figure 13. Celsius Thermostat

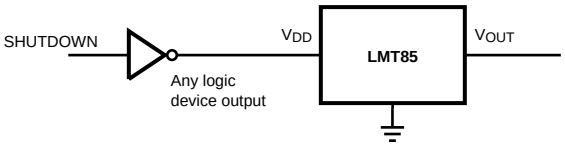
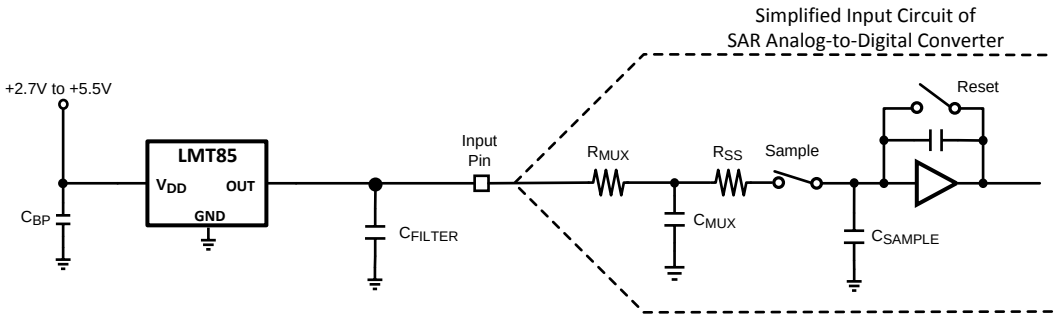


Figure 14. Conserving Power Dissipation with Shutdown



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 LMT85/LMT85-Q1 temperature sensor and many op amps. This requirement is easily accommodated by the addition of a capacitor (C_{FILTER}). 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.

Figure 15. Suggested Connection to a Sampling Analog-to-Digital Converter Input Stage

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
LMT85DCKR	ACTIVE	SC70	DCK	5	3000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-50 to 150	BPA	Samples
LMT85DCKT	ACTIVE	SC70	DCK	5	250	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-50 to 150	BPA	Samples
LMT85QDCKRQ1	PREVIEW	SC70	DCK	5	3000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-50 to 150	BRA	
LMT85QDCKTQ1	PREVIEW	SC70	DCK	5	250	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-50 to 150	BRA	

(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.

continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

OTHER QUALIFIED VERSIONS OF LMT85, LMT85-Q1 :

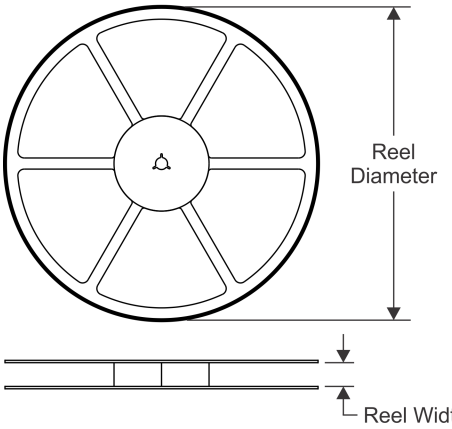
- Catalog: LMT85
- Automotive: LMT85-Q1

NOTE: Qualified Version Definitions:

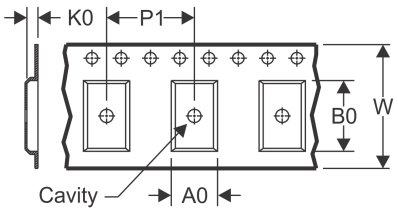
- Catalog - TI's standard catalog product
- Automotive - Q100 devices qualified for high-reliability automotive applications targeting zero defects

TAPE AND REEL INFORMATION

REEL DIMENSIONS

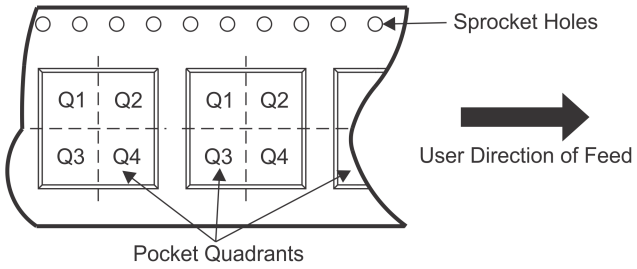


TAPE DIMENSIONS



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

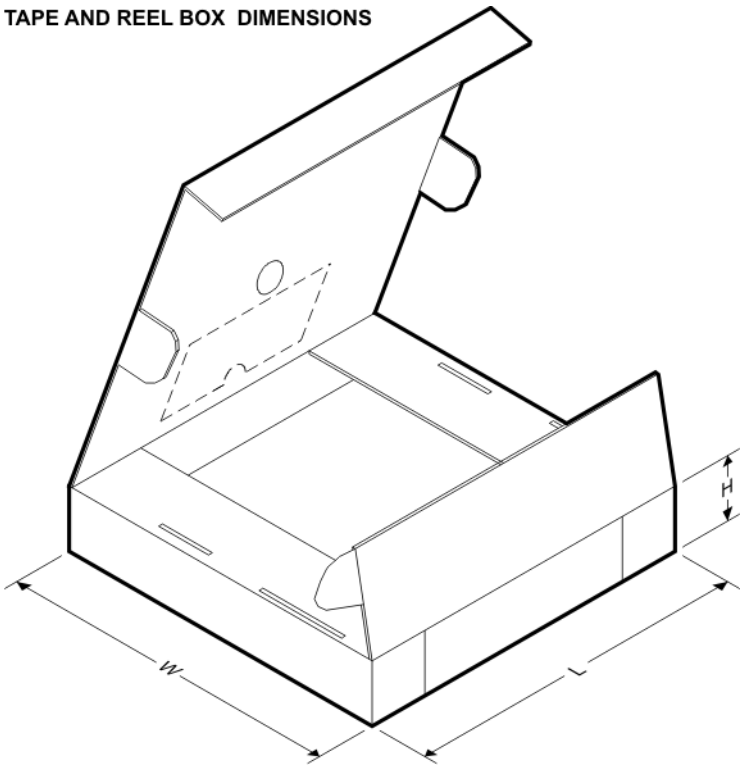
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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
LMT85DCKR	SC70	DCK	5	3000	178.0	8.4	2.25	2.45	1.2	4.0	8.0	Q3
LMT85DCKT	SC70	DCK	5	250	178.0	8.4	2.25	2.45	1.2	4.0	8.0	Q3

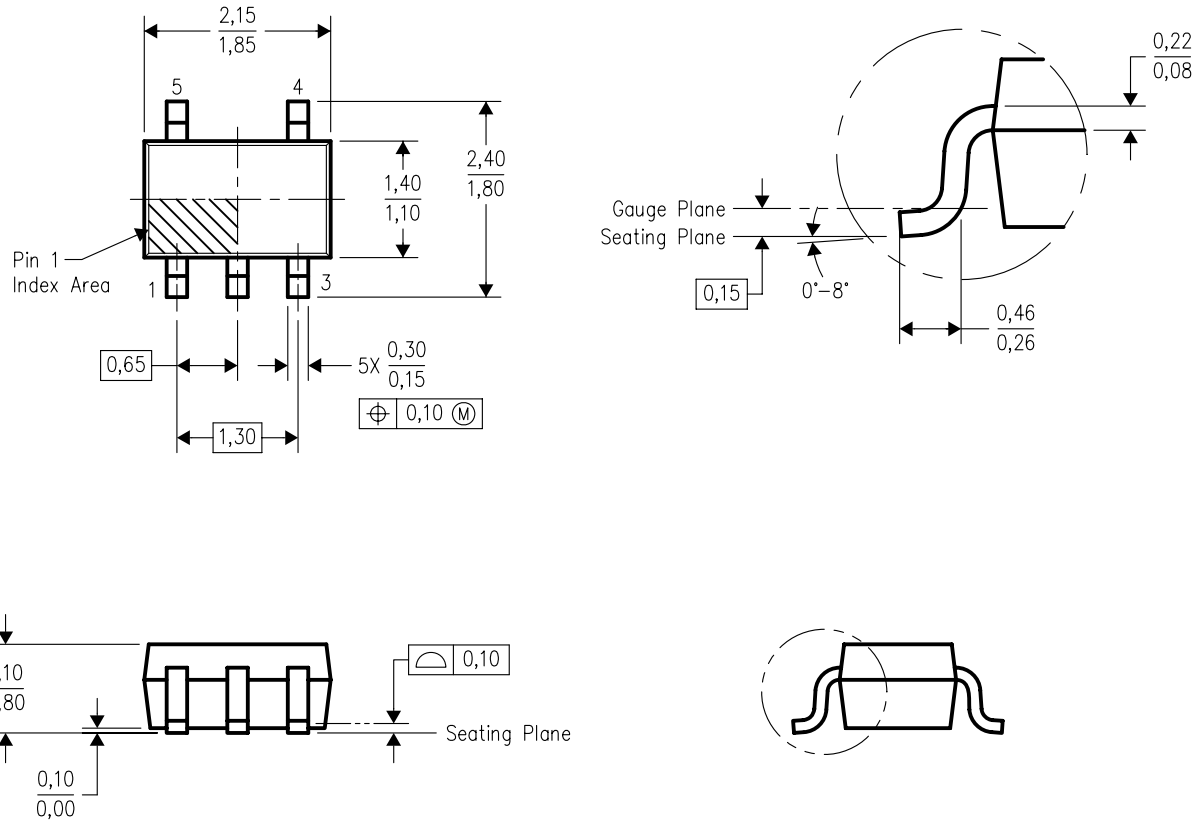
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
LMT85DCKR	SC70	DCK	5	3000	210.0	185.0	35.0
LMT85DCKT	SC70	DCK	5	250	210.0	185.0	35.0

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



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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.

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