LMT84 1.5V, SC70, Analog Temperature Sensor with Class-AB Output

Check for Samples: LMT84

FEATURES

- **Low 1.5 V Operation**
- **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**
- **Footprint Compatible with the Industry-Standard LM20 Temperature Sensor**
- **Cost-effective Alternative to Thermistors**

APPLICATIONS

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

DESCRIPTION

The LMT84 is a precision analog output CMOS integrated-circuit temperature sensor that operates at a supply voltage as low as 1.5 Volts. A class-AB output structure gives the LMT84 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 LMT84 delivers an output voltage that is inversely proportional to measured temperature. The LMT84 low supply current makes it ideal for battery-powered systems as well as general temperature sensing applications.

The LMT84 can operate with a 1.5V supply while measuring temperature over the full −50°C to 150°C operating range.

The LMT84 is a cost-competitive alternative to thermistors.

CONNECTION DIAGRAM

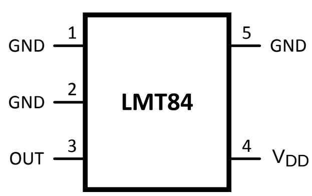
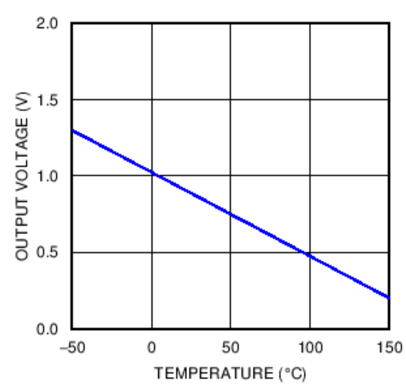


Figure 1. SOT Top View
See Package Number DCK0005A

TYPICAL TRANSFER CHARACTERISTIC

Output Voltage vs Temperature

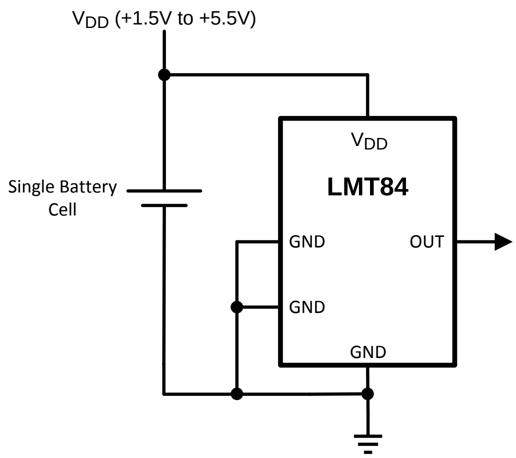


Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

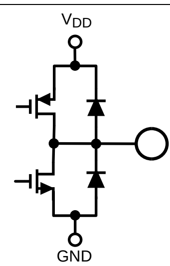
These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

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
GND	1	Ground		Power Supply Ground
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 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 specified 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})	1.5 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} = 1.5 V to 5.5 V	0.6	2.7	°C
	0°C to 70°C; V_{DD} = 1.5 V to 5.5 V	0.9	2.7	°C
	–50°C to 0°C; V_{DD} = 1.6 V to 5.5 V	0.9	2.7	°C
	–50°C to 150°C; V_{DD} = 2.3 V to 5.5 V	0.4		°C

(1) Typicals are at $T_J = T_A$ = 25°C and represent most likely parametric norm.
(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 $+V_{DD}$ = 1.5V 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	TYP[1]	MAX [2]	UNITS
	Sensor Gain		–5.5		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 LMT84. Sink currents are flowing into the LMT84.
(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

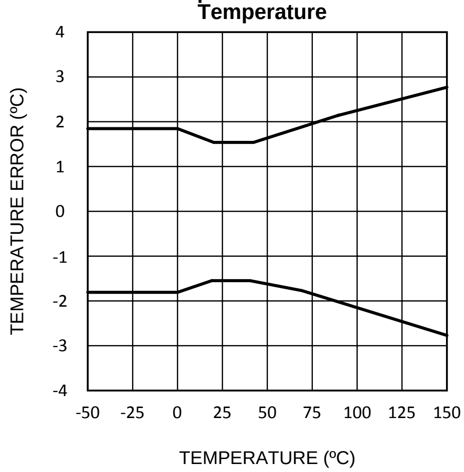


Figure 2.

Minimum Operating Temperature vs Supply Voltage

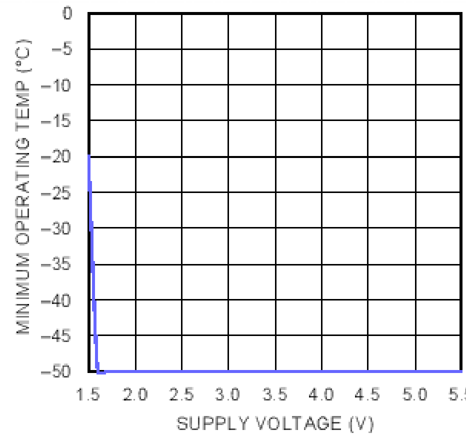


Figure 3.

Supply Current vs Temperature

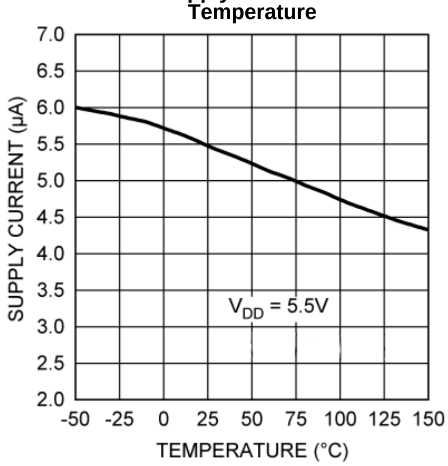


Figure 4.

Supply Current vs Supply Voltage

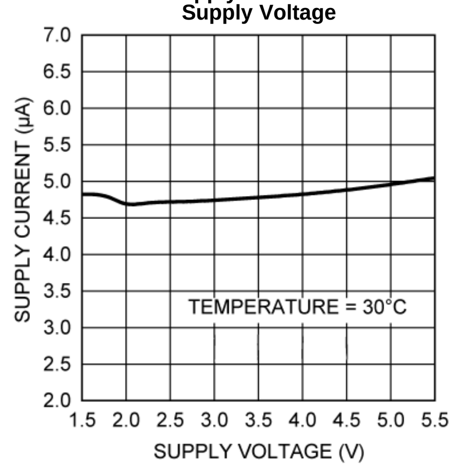


Figure 5.

Load Regulation, Sourcing Current

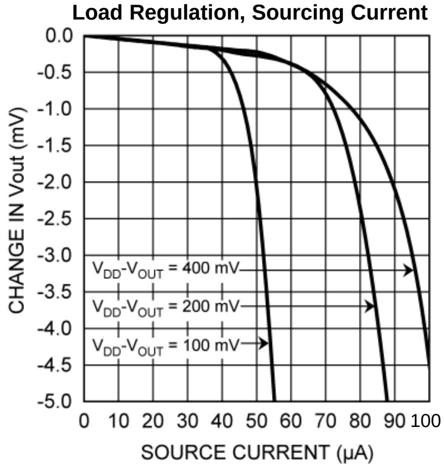


Figure 6.

Load Regulation, Sinking Current

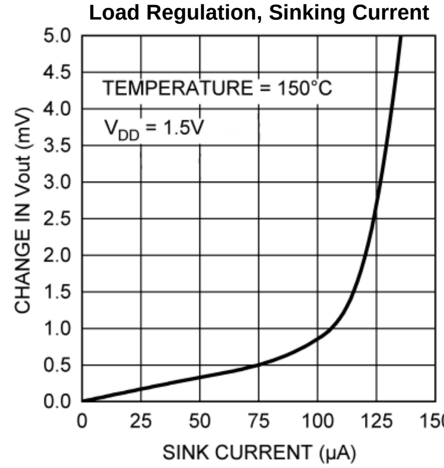


Figure 7.

TYPICAL PERFORMANCE CHARACTERISTICS (continued)

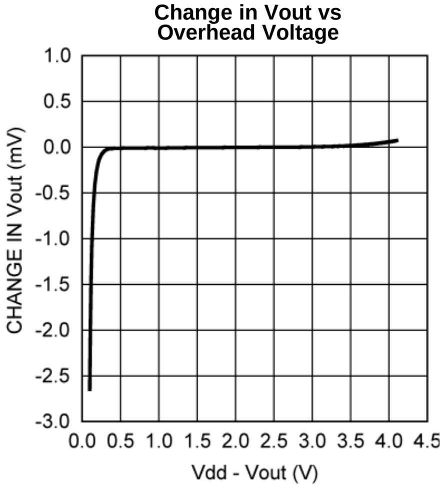


Figure 8.

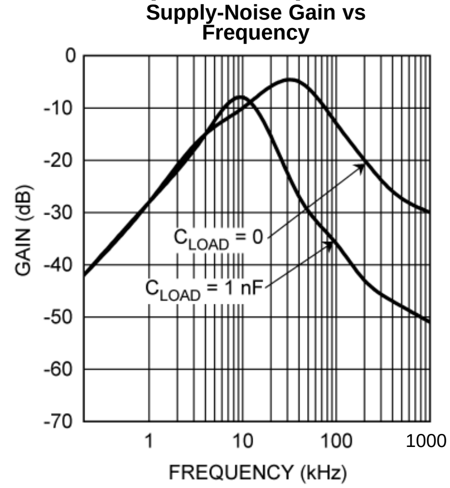


Figure 9.

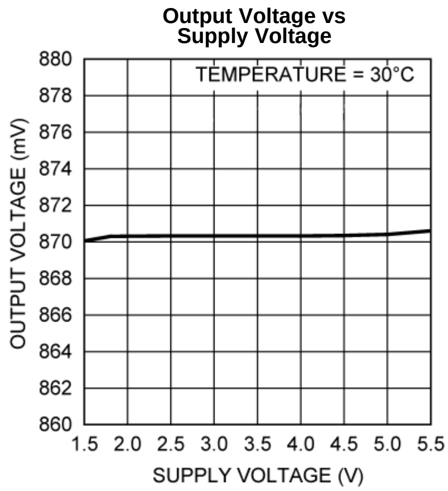


Figure 10.

LMT84 TRANSFER FUNCTION

The output voltage of the LMT84, across the complete operating temperature range, is shown in Table 1. This table is the reference from which the LMT84 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. LMT84 Transfer Table(1)

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	1299	-10	1088	30	871	70	647	110	419
-49	1294	-9	1082	31	865	71	642	111	413
-48	1289	-8	1077	32	860	72	636	112	407
-47	1284	-7	1072	33	854	73	630	113	401
-46	1278	-6	1066	34	849	74	625	114	396
-45	1273	-5	1061	35	843	75	619	115	390
-44	1268	-4	1055	36	838	76	613	116	384
-43	1263	-3	1050	37	832	77	608	117	378
-42	1257	-2	1044	38	827	78	602	118	372
-41	1252	-1	1039	39	821	79	596	119	367
-40	1247	0	1034	40	816	80	591	120	361
-39	1242	1	1028	41	810	81	585	121	355
-38	1236	2	1023	42	804	82	579	122	349
-37	1231	3	1017	43	799	83	574	123	343
-36	1226	4	1012	44	793	84	568	124	337
-35	1221	5	1007	45	788	85	562	125	332
-34	1215	6	1001	46	782	86	557	126	326
-33	1210	7	996	47	777	87	551	127	320
-32	1205	8	990	48	771	88	545	128	314
-31	1200	9	985	49	766	89	539	129	308
-30	1194	10	980	50	760	90	534	130	302
-29	1189	11	974	51	754	91	528	131	296
-28	1184	12	969	52	749	92	522	132	291
-27	1178	13	963	53	743	93	517	133	285
-26	1173	14	958	54	738	94	511	134	279
-25	1168	15	952	55	732	95	505	135	273
-24	1162	16	947	56	726	96	499	136	267
-23	1157	17	941	57	721	97	494	137	261
-22	1152	18	936	58	715	98	488	138	255
-21	1146	19	931	59	710	99	482	139	249
-20	1141	20	925	60	704	100	476	140	243
-19	1136	21	920	61	698	101	471	141	237
-18	1130	22	914	62	693	102	465	142	231
-17	1125	23	909	63	687	103	459	143	225
-16	1120	24	903	64	681	104	453	144	219
-15	1114	25	898	65	676	105	448	145	213
-14	1109	26	892	66	670	106	442	146	207
-13	1104	27	887	67	664	107	436	147	201
-12	1098	28	882	68	659	108	430	148	195
-11	1093	29	876	69	653	109	425	149	189
								150	183

(1) The output voltages in this table apply for V_{DD} = 5V.

Although the LMT84 is very linear, its response does have a slight downward parabolic shape. This shape is very accurately reflected in Table 1. For a linear approximation, a line can easily be calculated over the desired temperature range from the Table using the two-point equation:

$$V - V_1 = \left(\frac{V_2 - V_1}{T_2 - T_1}\right) \times (T - T_1) \quad (1)$$

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:

$$V - 925\text{ mV} = \left(\frac{760\text{ mV} - 925\text{ mV}}{50^{o}C - 20^{o}C}\right) \times (T - 20^{o}C) \quad (2)$$

$$V - 925\text{ mV} = (-5.50\text{ mV} / {}^{o}C) \times (T - 20^{o}C) \quad (3)$$

$$V = (-5.50\text{ mV} / {}^{o}C) \times T + 1035\text{ mV} \quad (4)$$

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 LMT84 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 LMT84 die is directly attached to the GND pin (Pin 2). The temperatures of the lands and traces to the other leads of the LMT84 will also affect the temperature reading.

Alternatively, the LMT84 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 LMT84 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 LMT84 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 LMT84's die temperature is:

$$T_J = T_A + \theta_{JA}\left[(V_{DD}I_S) + (V_{DD} - V_O)\, I_L\right] \quad (5)$$

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} = 871 mV, and I_L = 2 µA, the junction temperature would be 30.0146°C, showing a self-heating error of only 0.014°C. Since the LMT84's junction temperature is the actual temperature being measured, care should be taken to minimize the load current that the LMT84 is required to drive. Table 2 shows the thermal resistance of the LMT84.

Table 2. LMT84 Thermal Resistance

DEVICE NUMBER	PACKAGE NUMBER	THERMAL RESISTANCE (θ_{JA})
LMT84DCK	DCK0005A	415°C/W

OUTPUT AND NOISE CONSIDERATIONS

A push-pull output gives the LMT84 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 LMT84 is ideal for this and other applications which require strong source or sink current.

The LMT84 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 LMT84.

CAPACITIVE LOADS

The LMT84 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 LMT84 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.

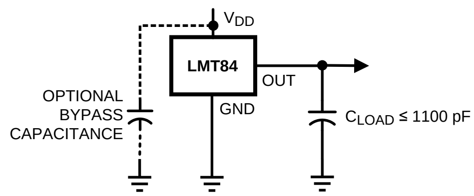


Figure 11. LMT84 No Decoupling Required for Capacitive Loads Less than 1100 pF

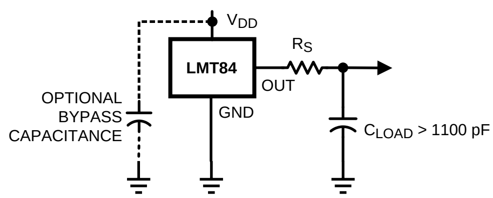


Figure 12. LMT84 with Series Resistor for Capacitive Loading Greater than 1100 pF

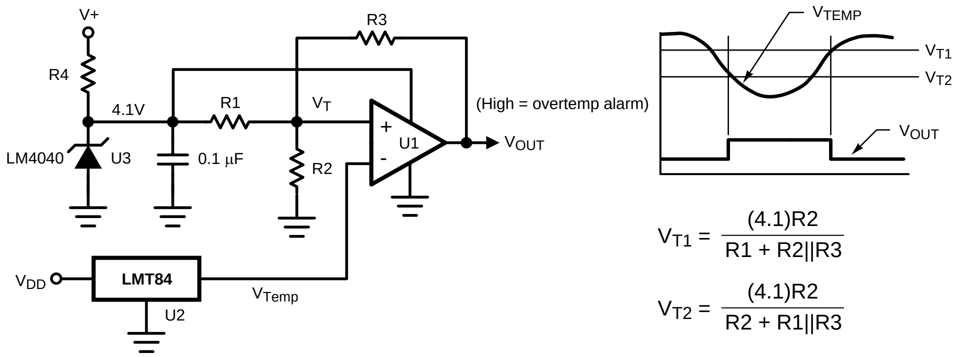
C_{LOAD}	MINIMUM R_S
1.1 nF to 99 nF	3 kΩ
100 nF to 999 nF	1.5 kΩ
1 µF	800 Ω

OUTPUT VOLTAGE SHIFT

The LMT84 is 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} = 1.0V.

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



$$V_{T1} = \frac{(4.1)R2}{R1 + R2||R3}$$

$$V_{T2} = \frac{(4.1)R2}{R2 + R1||R3}$$

Figure 13. Celsius Thermostat

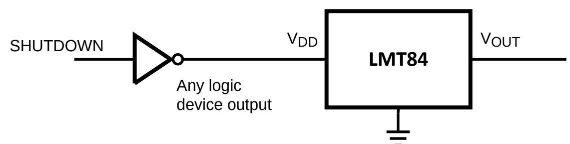
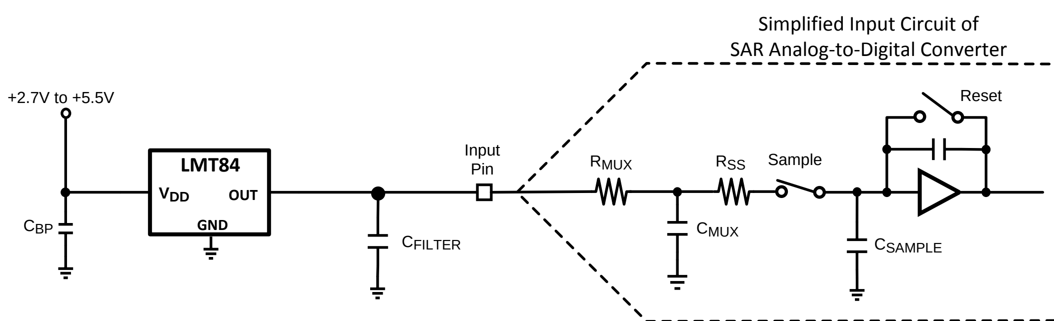


Figure 14. Conserving Power Dissipation with Shutdown



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 LMT84 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)	Top-Side Markings (4)	Samples
LMT84DCKR	PREVIEW	SC70	DCK	5	3000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-50 to 150		
LMT84DCKT	PREVIEW	SC70	DCK	5	250	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-50 to 150		

(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) Only one of markings shown within the brackets will appear on the physical device.

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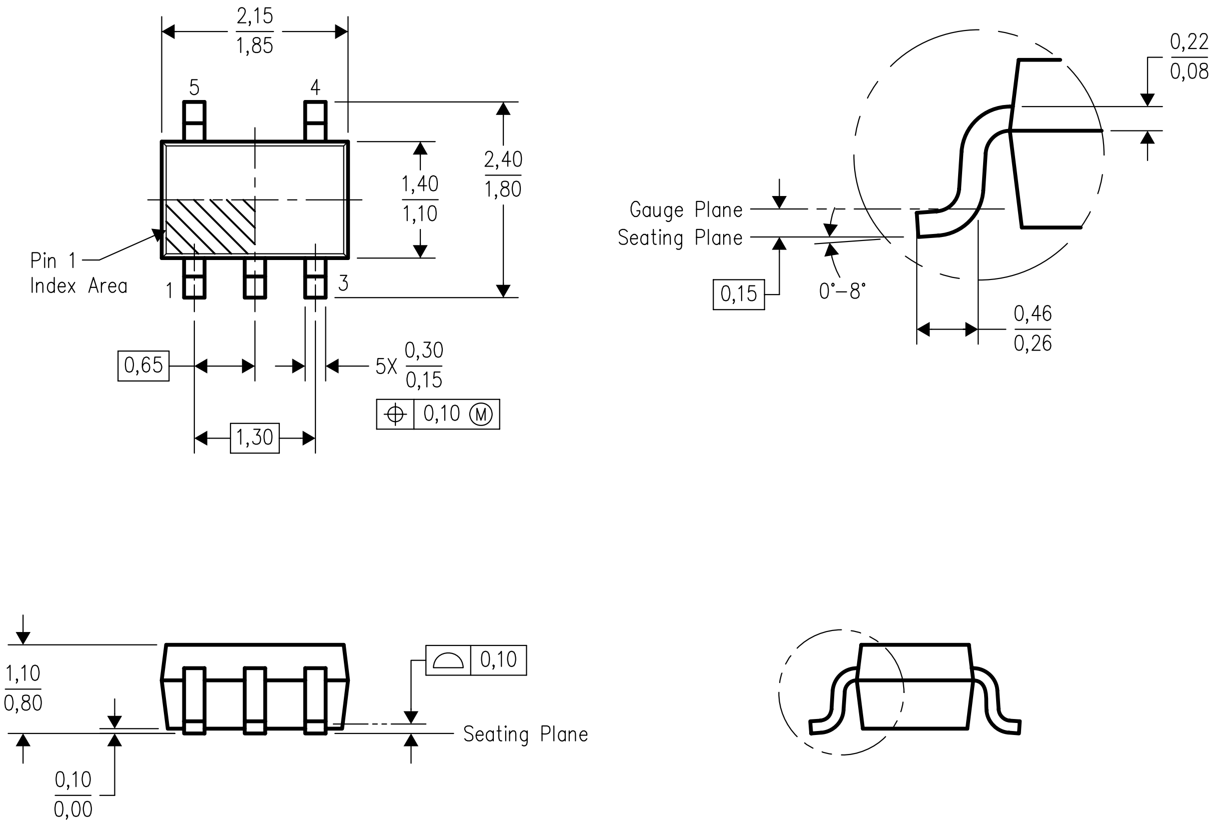
DCK (R-PDSO-G5) PLASTIC SMALL-OUTLINE PACKAGE



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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.