LMT86 SC70, Analog Temperature Sensor with Class-AB Output

Check for Samples: LMT86

FEATURES

- 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 LMT86 is a precision analog output CMOS integrated-circuit temperature sensor that operates at a supply voltage as low as 2.2 Volts. A class-AB output structure gives the LMT86 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 LMT86 low supply current makes it ideal for battery-powered systems as well as general temperature sensing applications.

The LMT86 can operate with a 2.2 V supply while measuring temperature over the full −50°C to 150°C operating range.

The LMT86 is a cost-competitive alternative to thermistors.

CONNECTION DIAGRAM

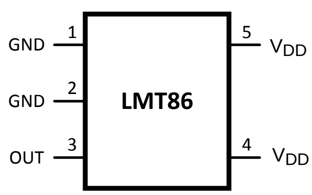
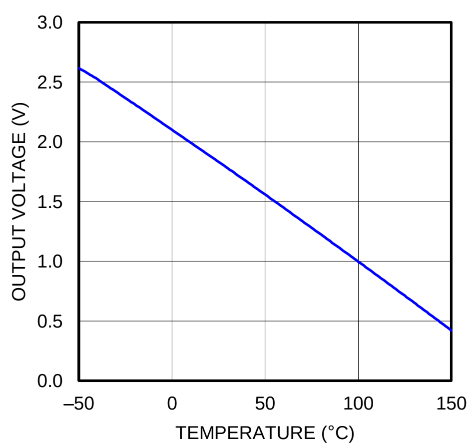


Figure 1. SOT Top View
See Package Number DCK0005A

TYPICAL TRANSFER CHARACTERISTIC

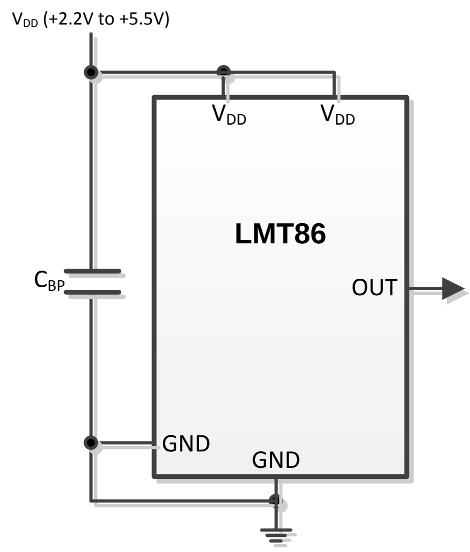
Output Voltage vs Temperature



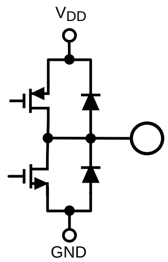
These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

TYPICAL APPLICATION

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



PIN DESCRIPTIONS

LABEL	PIN NUMBER	TYPE	EQUIVALENT CIRCUIT	FUNCTION
V_{DD}	5	Power		Positive Supply Voltage
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 TI's 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})	2.2 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)	40°C to 150°C; V_{DD} = 2.4 V to 5.5 V	0.4	2.7	°C
	0°C to 40°C; V_{DD} = 2.4 V to 5.5 V	0.7	2.7	°C
	0°C to 70°C; V_{DD} = 3.0 V to 5.5 V	0.3		2.7
	–50°C to 0°C; V_{DD} = 3.0 V to 5.5 V	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) 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 $+V_{DD}$ = 2.2 V to 5.5 V. **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		–10.9		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 LMT86. Sink currents are flowing into the LMT86.
(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

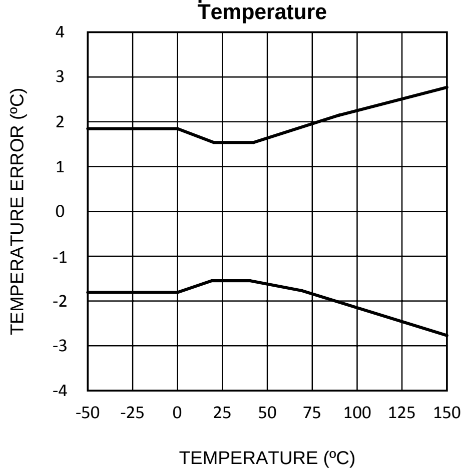


Figure 2.

Minimum Operating Temperature vs Supply Voltage

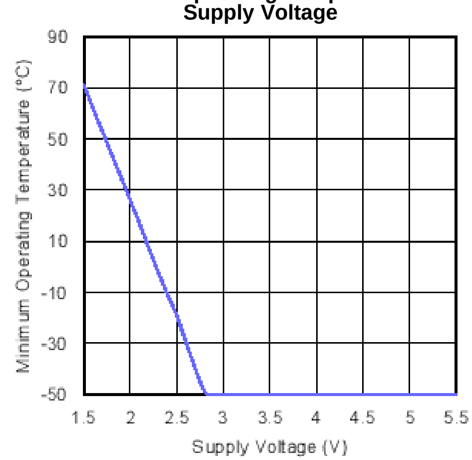


Figure 3.

Supply Current vs Temperature

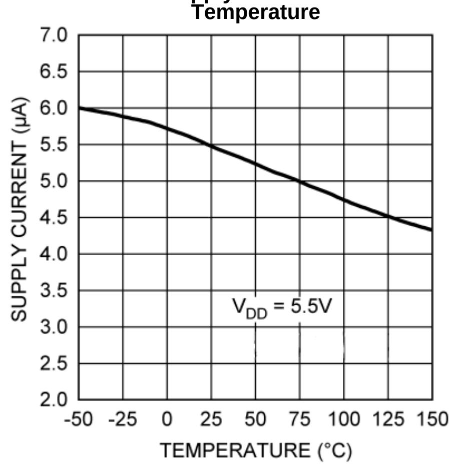


Figure 4.

Supply Current vs Supply Voltage

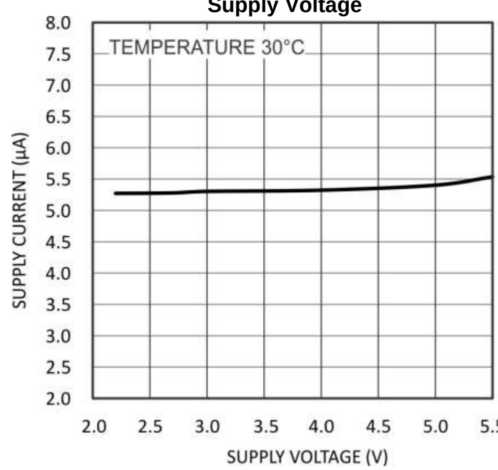


Figure 5.

Load Regulation, Sourcing Current

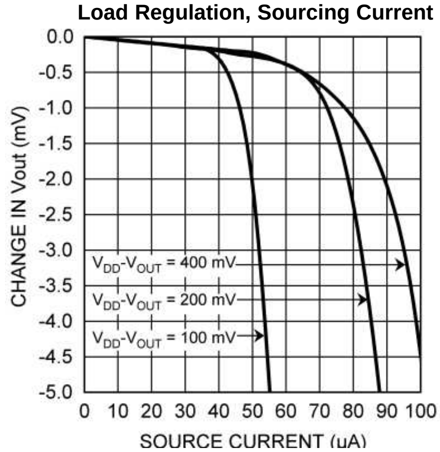


Figure 6.

Load Regulation, Sinking Current

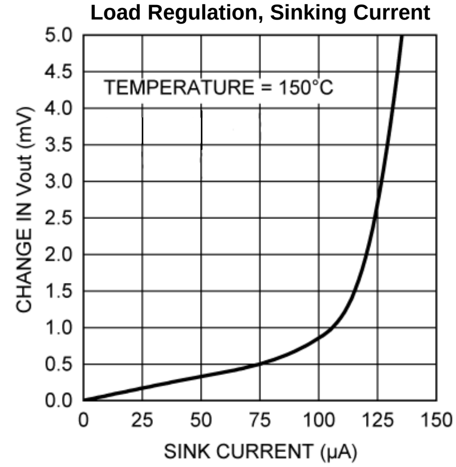


Figure 7.

TYPICAL PERFORMANCE CHARACTERISTICS (continued)

Change in Vout vs Overhead Voltage

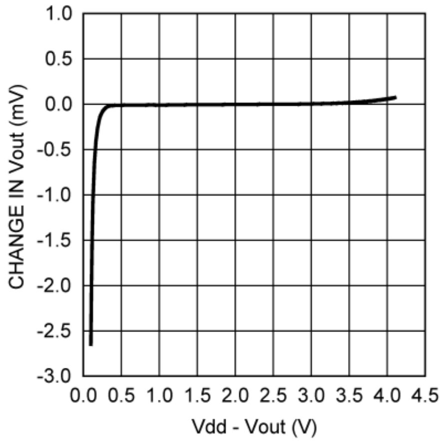


Figure 8.

Supply-Noise Gain vs Frequency

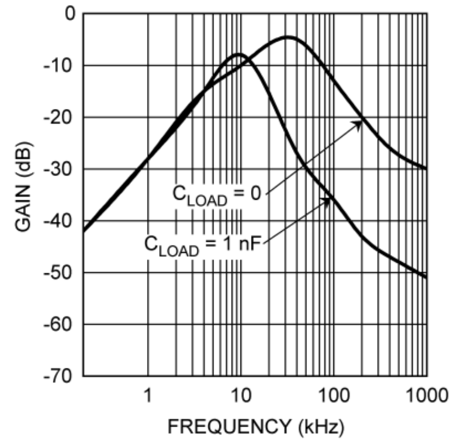


Figure 9.

Output Voltage vs Supply Voltage

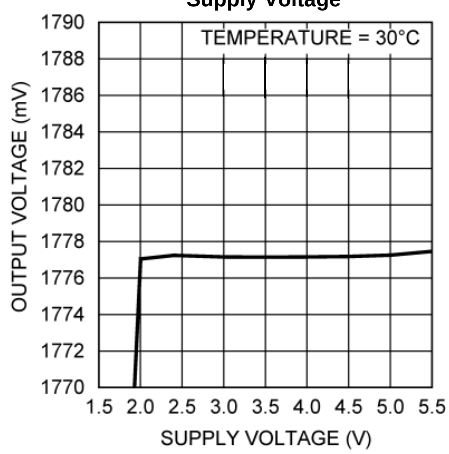


Figure 10.

LMT86 TRANSFER FUNCTION

The output voltage of the LMT86, across the complete operating temperature range is shown in Table 1. This table is the reference from which the LMT86 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/appinfo/tempsensors.

Table 1. LMT86 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	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
-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

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

Although the LMT86 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:

$$V - 1885\ mV = \left(\frac{1558\ mV - 1885\ mV}{50^oC - 20^oC}\right) \times (T - 20^oC) \quad (2)$$

$$V - 1885\ mV = (-10.9\ mV / {}^oC) \times (T - 20^oC) \quad (3)$$

$$V = (-10.9\ mV / {}^oC) \times T + 2103\ mV \quad (4)$$

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 LMT86 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 die is directly attached to the GND pin (Pin 2). The temperatures of the lands and traces to the other leads of the LMT86 will also affect the temperature reading.

Alternatively, the LMT86 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 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 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 LMT86 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} = 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's junction temperature is the actual temperature being measured, care should be taken to minimize the load current that the LMT86 is required to drive. Table 2 shows the thermal resistance of the LMT86.

Table 2. LMT86 Thermal Resistance

DEVICE NUMBER	TI PACKAGE NUMBER	THERMAL RESISTANCE (θ_{JA})
LMT86DCK	DCK0005A	415°C/W

OUTPUT AND NOISE CONSIDERATIONS

A push-pull output gives the LMT86 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 LMT86 is ideal for this and other applications which require strong source or sink current.

The LMT86'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 LMT86.

CAPACITIVE LOADS

The LMT86 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 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.

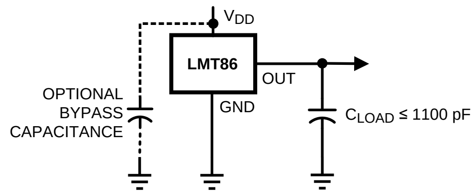


Figure 11. LMT86 No Decoupling Required for Capacitive Loads Less than 1100 pF

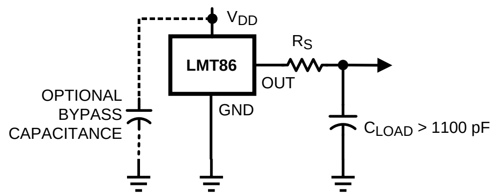


Figure 12. LMT86 with Series Resistor for Capacitive Loading Greater than 1100 pF

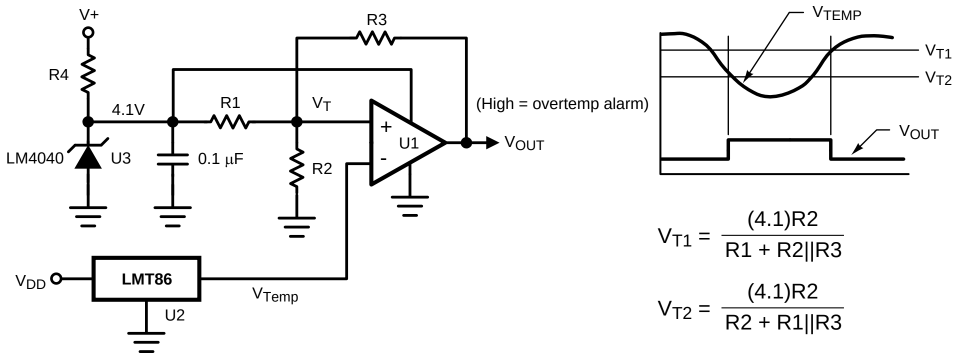
C_{LOAD}	MINIMUM R_S
1.1 nF to 99 nF	3 kΩ
100 nF to 999 nF	1.5 kΩ
1 µF	800 Ω

OUTPUT VOLTAGE SHIFT

The LMT86 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 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



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

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

Figure 13. Celsius Thermostat

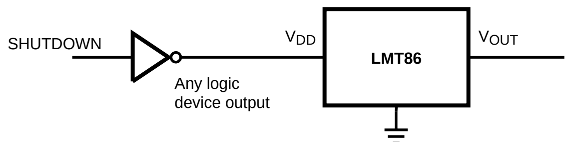
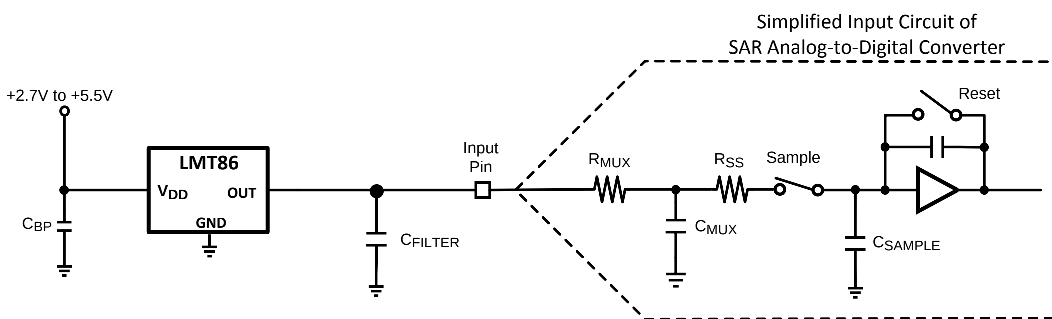


Figure 14. Conserving Power Dissipation with Shutdown



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 LMT86 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
LMT86DCKR	PREVIEW	SC70	DCK	5	3000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-50 to 150		
LMT86DCKT	PREVIEW	SC70	DCK	5	250	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-50 to 150		

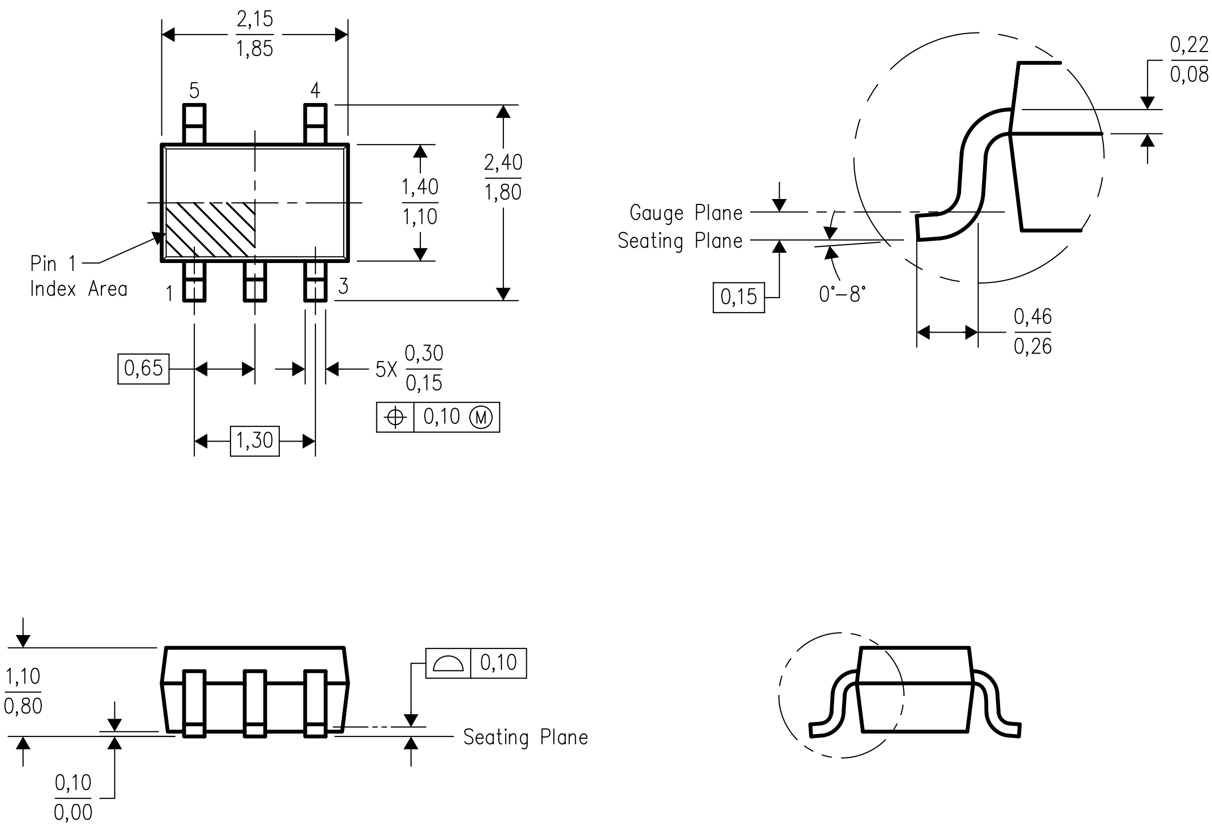
(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, 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.

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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