National Semiconductor

February 2004

LM75
Digital Temperature Sensor and Thermal Watchdog with Two-Wire Interface

General Description

The LM75 is a temperature sensor, Delta-Sigma analog-to-digital converter, and digital over-temperature detector with I²C® interface. The host can query the LM75 at any time to read temperature. The open-drain Overtemperature Shutdown (O.S.) output becomes active when the temperature exceeds a programmable limit. This pin can operate in either "Comparator" or "Interrupt" mode.

The host can program both the temperature alarm threshold (T_{OS}) and the temperature at which the alarm condition goes away (T_{HYST}). In addition, the host can read back the contents of the LM75's T_{OS} and T_{HYST} registers. Three pins (A0, A1, A2) are available for address selection. The sensor powers up in Comparator mode with default thresholds of 80˚C T_{OS} and 75˚C T_{HYST}.

The LM75's 3.0V to 5.5V supply voltage range, low supply current and I²C interface make it ideal for a wide range of applications. These include thermal management and protection applications in personal computers, electronic test equipment, and office electronics.

Features

- SOP-8 and Mini SOP-8 (MSOP) packages save space
- I²C Bus interface
- Separate open-drain output pin operates as interrupt or comparator/thermostat output
- Register readback capability
- Power up defaults permit stand-alone operation as thermostat
- Shutdown mode to minimize power consumption
- Up to 8 LM75s can be connected to a single bus
- UL Recognized Component

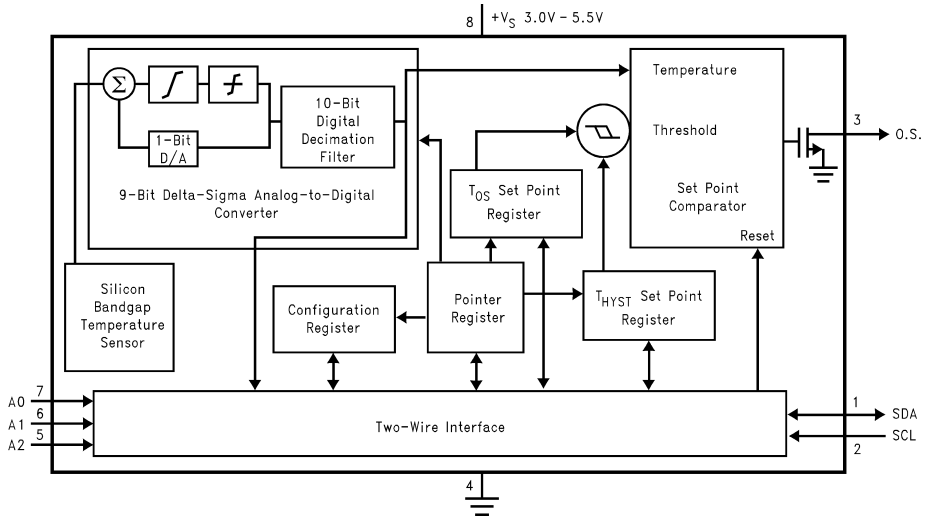
Key Specifications

■ Supply Voltage		3.0V to 5.5V
■ Supply Current	operating	250 µA (typ)
		1 mA (max)
	shutdown	4 µA (typ)
■ Temperature Accuracy	–25˚C to 100˚C	±2˚C(max)
	–55˚C to 125˚C	±3˚C(max)

Applications

- System Thermal Management
- Personal Computers
- Office Electronics
- Electronic Test Equipment

Simplified Block Diagram



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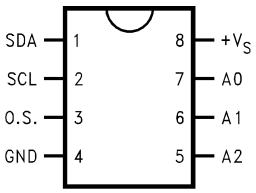
Connection Diagram

SOP-8 and Mini SOP-8



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Ordering Information

Order Number	Package Marking	NS Package Number	Supply Voltage	Transport Media	Noise Filter on SDA and SCL
LM75BIM-3	LM75BIM-3	M08A (SOP-8)	3.3V	95 Units in Rail	Yes
LM75BIMX-3	LM75BIM-3	M08A (SOP-8)	3.3V	2500 Units on Tape and Reel	Yes
LM75BIMM-3	T01B	MUA08A (MSOP-8)	3.3V	1000 Units on Tape and Reel	Yes
LM75BIMMX-3	T01B	MUA08A (MSOP-8)	3.3V	3500 Units on Tape and Reel	Yes
LM75BIM-5	LM75BIM-5	M08A (SOP-8)	5V	95 Units in Rail	Yes
LM75BIMX-5	LM75BIM-5	M08A (SOP-8)	5V	2500 Units on Tape and Reel	Yes
LM75BIMM-5	T00B	MUA08A (MSOP-8)	5V	1000 Units on Tape and Reel	Yes
LM75BIMMX-5	T00B	MUA08A (MSOP-8)	5V	3500 Units on Tape and Reel	Yes
LM75CIM-3	LM75CIM-3	M08A (SOP-8)	3.3V	95 Units in Rail	Not Available
LM75CIMX-3	LM75CIM-3	M08A (SOP-8)	3.3V	2500 Units on Tape and Reel	Not Available
LM75CIMM-3	T01C	MUA08A (MSOP-8)	3.3V	1000 Units on Tape and Reel	Not Available
LM75CIMMX-3	T01C	MUA08A (MSOP-8)	3.3V	3500 Units on Tape and Reel	Not Available
LM75CIM-5	LM75CIM-5	M08A (SOP-8)	5V	95 Units in Rail	Not Available
LM75CIMX-5	LM75CIM-5	M08A (SOP-8)	5V	2500 Units on Tape and Reel	Not Available
LM75CIMM-5	T00C	MUA08A (MSOP-8)	5V	1000 Units on Tape and Reel	Not Available
LM75CIMMX-5	T00C	MUA08A (MSOP-8)	5V	3500 Units on Tape and Reel	Not Available

Pin Description

Label	Pin #	Function	Typical Connection
SDA	1	I^2C Serial Bi-Directional Data Line. Open Drain.	From Controller, tied to a pull-up
SCL	2	I^2C Clock Input	From Controller
O.S.	3	Overtemperature Shutdown Open Drain Output	Pull–up Resistor, Controller Interrupt Line
GND	4	Power Supply Ground	Ground
$+V_S$	8	Positive Supply Voltage Input	DC Voltage from 3V to 5.5V; 0.1µF bypass capacitor with 10µF bulk capacitance in the near vicinity
A0–A2	7,6,5	User-Set I^2C Address Inputs	Ground (Low, “0”) or $+V_S$ (High, “1”)

Absolute Maximum Ratings (Note 1)

Supply Voltage	−0.3V to 6.5V
Voltage at any Pin	−0.3V to $+V_S$ + 0.3V
Input Current at any Pin (Note 2)	5 mA
Package Input Current (Note 2)	20 mA
O.S. Output Sink Current	10 mA
O.S. Output Voltage	6.5V
Storage Temperature	−65˚C to +150˚C
Soldering Information, Lead Temperature	
SOP and MSOP Package (Note 3)	
Vapor Phase (60 seconds)	215˚C
Infrared (15 seconds)	220˚C

ESD Susceptibility (Note 4)	LM75B	LM75C
Human Body Model	2500V	1500V
Machine Model	250V	100V

Operating Ratings

Specified Temperature Range	T_{MIN} to T_{MAX}
(Note 5)	−55˚C to +125˚C
Supply Voltage Range ($+V_S$)	+3.0V to +5.5V

Temperature-to-Digital Converter Characteristics

Unless otherwise noted, these specifications apply for $+V_S$ = +5 Vdc for LM75BIM-5, LM75BIMM-5, LM75CIM-5, and LM75CIMM-5 and $+V_S$ = +3.3 Vdc for LM75BIM-3, LM75BIMM-3, LM75CIM-3, and LM75CIMM-3 (Note 6). **Boldface limits apply for $T_A = T_J = T_{MIN}$ to T_{MAX};** all other limits $T_A = T_J$ = +25˚C, unless otherwise noted.

Parameter		Conditions	Typical (Note 12)	Limits (Note 7)	Units (Limit)
Accuracy		T_A = −25˚C to +100˚C		**±2.0**	˚C (max)
		T_A = −55˚C to +125˚C		**±3.0**	˚C (max)
Resolution			9		Bits
Temperature Conversion Time		(Note 8)	100		ms
Quiescent Current	LM75B	I^2C Inactive	0.25	**0.5**	mA (max)
		Shutdown Mode, $+V_S$ = 3V	4		µA
		Shutdown Mode, $+V_S$ = 5V	6		µA
	LM75C	I^2C Inactive	0.25	**1.0**	mA (max)
		Shutdown Mode, $+V_S$ = 3V	4		µA
		Shutdown Mode, $+V_S$ = 5V	6		µA
O.S. Output Saturation Voltage		I_{OUT} = 4.0 mA (Note 9)		**0.8**	V (max)
O.S. Delay		(Note 10)		**1**	Conversions (min)
				6	Conversions (max)
T_{OS} Default Temperature		(Note 11)	80		˚C
T_{HYST} Default Temperature		(Note 11)	75		˚C

Logic Electrical Characteristics

DIGITAL DC CHARACTERISTICS Unless otherwise noted, these specifications apply for $+V_S$ = +5 Vdc for LM75BIM-5, LM75BIMM-5, LM75CIM-5, and LM75CIMM-5 and $+V_S$ = +3.3 Vdc for LM75BIM-3, LM75BIMM-3, LM75CIM-3, and LM75CIMM-3 (Note 6). **Boldface limits apply for $T_A = T_J = T_{MIN}$ to T_{MAX};** all other limits $T_A = T_J$ = +25˚C, unless otherwise noted.

Symbol	Parameter	Conditions	Typical (Note 12)	Limits (Note 7)	Units (Limit)
$V_{IN(1)}$	Logical “1” Input Voltage			**$+V_S$ x 0.7**	V (min)
				$+V_S$ + 0.5	V (max)
$V_{IN(0)}$	Logical “0” Input Voltage			**−0.3**	V (min)
				$+V_S$ x 0.3	V (max)
$I_{IN(1)}$	Logical “1” Input Current	V_{IN} = 5V	0.005	**1.0**	µA (max)
$I_{IN(0)}$	Logical “0” Input Current	V_{IN} = 0V	−0.005	**−1.0**	µA (max)
C_{IN}	All Digital Inputs		20		pF
I_{OH}	High Level Output Current	V_{OH} = 5V		**100**	µA (max)
V_{OL}	Low Level Output Voltage	I_{OL} = 3 mA		**0.4**	V (max)
t_{OF}	Output Fall Time	C_L = 400 pF		**250**	ns (max)

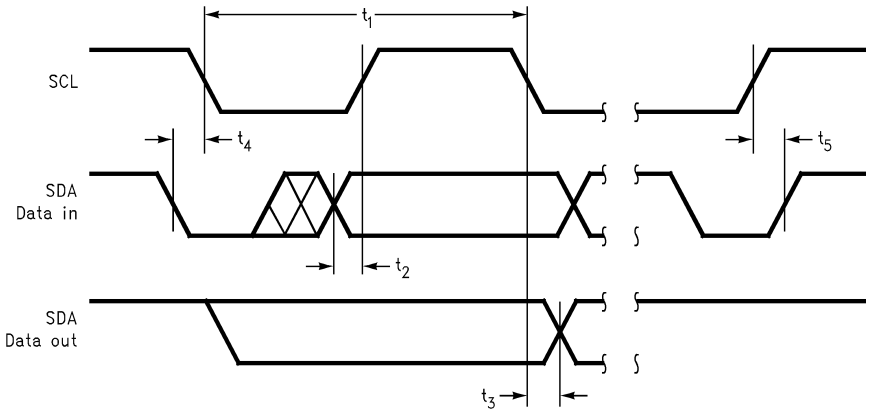
Logic Electrical Characteristics (Continued)

DIGITAL DC CHARACTERISTICS Unless otherwise noted, these specifications apply for $+V_S$ = +5 Vdc for LM75BIM-5, LM75BIMM-5, LM75CIM-5, and LM75CIMM-5 and $+V_S$ = +3.3 Vdc for LM75BIM-3, LM75BIMM-3, LM75CIM-3, and LM75CIMM-3 (Note 6). **Boldface limits apply for $T_A = T_J = T_{MIN}$ to T_{MAX};** all other limits $T_A = T_J$ = +25˚C, unless otherwise noted.

Symbol	Parameter	Conditions	Typical (Note 12)	Limits (Note 7)	Units (Limit)
		I_O = 3 mA			

I^2C DIGITAL SWITCHING CHARACTERISTICS Unless otherwise noted, these specifications apply for $+V_S$ = +5 Vdc for LM75BIM-5, LM75BIMM-5, LM75CIM-5, and LM75CIMM-5 and $+V_S$ = +3.3 Vdc for LM75BIM-3, LM75BIMM-3, LM75CIM-3, and LM75CIMM-3. C_L (load capacitance) on output lines = 80 pF unless otherwise specified. **Boldface limits apply for $T_A = T_J = T_{MIN}$ to T_{MAX};** all other limits $T_A = T_J$ = +25˚C, unless otherwise noted. The switching characteristics of the LM75 fully meet or exceed the published specifications of the I^2C bus. The following parameters are the timing relationships between SCL and SDA signals related to the LM75. They are not the I^2C bus specifications.

Symbol	Parameter		Conditions	Typical (Note 12)	Limits (Note 7)	Units (Limit)
t_1	SCL (Clock) Period				**2.5**	µs (min)
t_2	Data in Set-Up Time to SCL High				**100**	ns (min)
t_3	Data Out Stable after SCL Low				**0**	ns (min)
t_4	SDA Low Set-Up Time to SCL Low (Start Condition)				**100**	ns (min)
t_5	SDA High Hold Time after SCL High (Stop Condition)				**100**	ns (min)
$t_{TIMEOUT}$	SDA Time Low for Reset of Serial Interface (Note 13)	LM75B			**75** **325**	ms (min) ms (max)
		LM75C			**Not Applicable**	



Note 1: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. DC and AC electrical specifications do not apply when operating the device beyond its rated operating conditions.

Note 2: When the input voltage (V_I) at any pin exceeds the power supplies (V_I < GND or V_I > $+V_S$) the current at that pin should be limited to 5 mA. The 20 mA maximum package input current rating limits the number of pins that can safely exceedthe power supplies with an input current of 5 mA to four.

Note 3: See AN-450 “Surface Mounting Methods and Their Effect on Product Reliability” or the section titled “Surface Mount” found in a current National Semiconductor Linear Data Book for other methods of soldering surface mount devices.

Note 4: Human body model, 100 pF discharged through a 1.5 kΩ resistor. Machine model, 200 pF discharged directly into each pin.

Note 5: LM75 θ_{JA} (thermal resistance, junction-to-ambient) when attached to a printed circuit board with 2 oz. foil similar to the one shown in *Figure 3* is summarized in the table below:

Device Number	NS Package Number	Thermal Resistance (θ_{JA})
LM75BIM-3, LM75BIM-5, LM75CIM-3, LM75CIM-5	M08A	200˚C/W
LM75BIMM-3, LM75BIMM-5, LM75CIMM-3, LM75CIMM-5	MUA08A	250˚C/W

Note 6: All part numbers of the LM75 will operate properly over the $+V_S$ supply voltage range of 3V to 5.5V. The devices are tested and specified for rated accuracy at their nominal supply voltage. Accuracy will typically degrade 1˚C/V of variation in $+V_S$ as it varies from the nominal value.

Note 7: Limits are guaranteed to National's AOQL (Average Outgoing Quality Level).

Note 8: This specification is provided only to indicate how often temperature data is updated. The LM75 can be read at any time without regard to conversion state (and will yield last conversion result). If a conversion is in process it will be interrupted and restarted after the end of the read.

Note 9: For best accuracy, minimize output loading. Higher sink currents can affect sensor accuracy with internal heating. This can cause an error of 0.64˚C at full rated sink current and saturation voltage based on junction-to-ambient thermal resistance.

Note 10: O.S. Delay is user programmable up to 6 "over limit" conversions before O.S. is set to minimize false tripping in noisy environments.

Note 11: Default values set at power up.

Note 12: Typicals are at T_A = 25˚C and represent most likely parametric norm.

Note 13: Holding the SDA line low for a time greater than $t_{TIMEOUT}$ will cause the LM75B to reset SDA to the IDLE state of the serial bus communication (SDA set High).

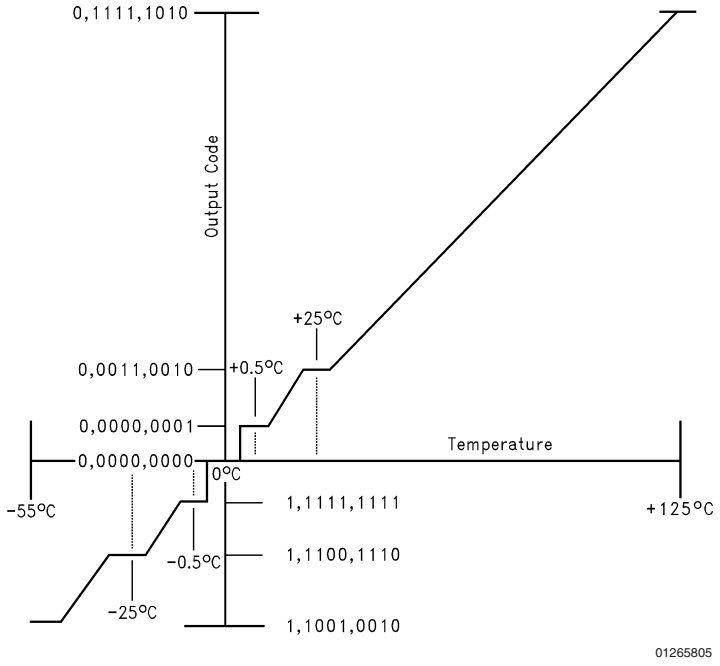


FIGURE 2. Temperature-to-Digital Transfer Function (Non-linear scale for clarity)

1.0 Functional Description (Continued)

1.4 TEMPERATURE DATA FORMAT

Temperature data can be read from the Temperature, T_{OS} Set Point, and T_{HYST} Set Point registers; and written to the T_{OS} Set Point, and T_{HYST} Set Point registers. Temperature data is represented by a 9-bit, two's complement word with an LSB (Least Significant Bit) equal to 0.5˚C:

Temperature	Digital Output	
	Binary	Hex
+125˚C	0 1111 1010	0FAh
+25˚C	0 0011 0010	032h
+0.5˚C	0 0000 0001	001h
0˚C	0 0000 0000	000h
–0.5˚C	1 1111 1111	1FFh
–25˚C	1 1100 1110	1CEh
–55˚C	1 1001 0010	192h

1.5 SHUTDOWN MODE

Shutdown mode is enabled by setting the shutdown bit in the Configuration register via the I^2C bus. Shutdown mode reduces power supply current to 4 µA typical. In Interrupt mode O.S. is reset if previously set and is undefined in Comparator mode during shutdown. The I^2C interface remains active. Activity on the clock and data lines of the I^2C bus may slightly increase shutdown mode quiescent current. T_{OS}, T_{HYST}, and Configuration registers can be read from and written to in shutdown mode.

1.6 FAULT QUEUE

A fault queue of up to 6 faults is provided to prevent false tripping of O.S. when the LM75 is used in noisy environments. The number of faults set in the queue must occur consecutively to set the O.S. output.

1.7 COMPARATOR/INTERRUPT MODE

As indicated in the O.S. Output Temperature Response Diagram, *Figure 4*, the events that trigger O.S. are identical for either Comparator or Interrupt mode. The most important difference is that in Interrupt mode the O.S. will remain set indefinitely once it has been set. To reset O.S. while in Interrupt mode, perform a read from any register in the LM75.

1.8 O.S. OUTPUT

The O.S. output is an open-drain output and does not have an internal pull-up. A "high" level will not be observed on this pin until pull-up current is provided from some external source, typically a pull-up resistor. Choice of resistor value depends on many system factors but, in general, the pull-up resistor should be as large as possible. This will minimize any errors due to internal heating of the LM75. The maximum resistance of the pull up, based on LM75 specification for High Level Output Current, to provide a 2V high level, is 30 kΩ.

1.9 O.S. POLARITY

The O.S. output can be programmed via the configuration register to be either active low (default mode), or active high. In active low mode the O.S. output goes low when triggered exactly as shown on the O.S. Output Temperature Response Diagram, *Figure 4*. Active high simply inverts the polarity of the O.S. output.