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# LM75

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

### General Description

The LM75A, LM75B and LM75C are a family of industry-standard digital temperature sensors with an integrated Sigma-Delta analog-to-digital converter and I<sup>2</sup>C® interface. The LM75 provides 9-bit digital temperature readings with an accuracy of  $\pm 2^{\circ}\text{C}$  from  $-25^{\circ}\text{C}$  to  $100^{\circ}\text{C}$  and  $\pm 3^{\circ}\text{C}$  over  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ .


The LM75A operates with a single supply from +2.7V to +5.5V. Communication is accomplished over a 2-wire interface which operates up to 400kHz. The LM75 has three address pins, allowing up to eight LM75 devices to operate on the same 2-wire bus. The LM75 has a dedicated over-temperature output (O.S.) with programmable limit and hysteresis. This output has programmable fault tolerance, which allows the user to define the number of consecutive error conditions that must occur before O.S. is activated.

The wide temperature and supply range and I<sup>2</sup>C interface make the LM75 ideal for a number of applications including base stations, electronic test equipment, office electronics, personal computers, and any other system where thermal management is critical to performance. The LM75A, LM75B and LM75C are available in an SOP-8 package. The LM75B and LM75C are available in an MSOP-8 package.

### Applications

- General System Thermal Management
- Communications Infrastructure
- Electronic Test Equipment
- Environmental Monitoring

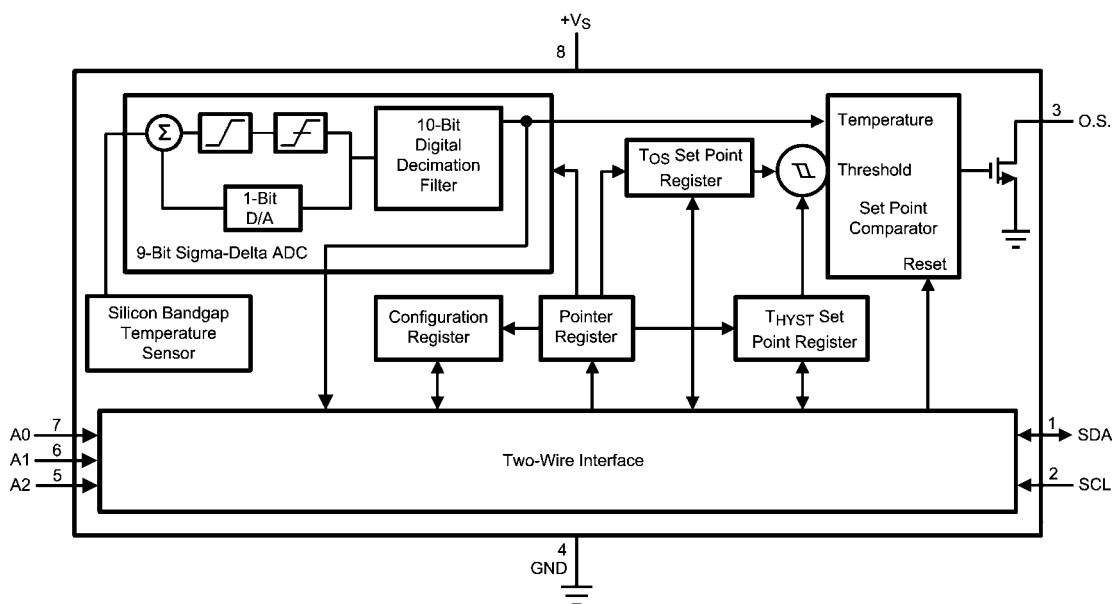
### Features

- No external components required
- Shutdown mode to minimize power consumption
- Up to eight LM75s can be connected to a single bus
- Power up defaults permit stand-alone operation as thermostat
- UL Recognized Component (LM75B and LM75C) 

### Key Specifications

|                        |  |                               |
|------------------------|--|-------------------------------|
| ■ Supply Voltage       | LM75A  | 2.7V to 5.5V                  |
|                        | LM75B, LM75C                                   | 3.0V to 5.5V                  |
| ■ Supply Current       | operating                                      | 280 $\mu\text{A}$ (typ)       |
|                        | shutdown                                       | 4 $\mu\text{A}$ (typ)         |
| ■ Temperature Accuracy | $-25^{\circ}\text{C}$ to $100^{\circ}\text{C}$ | $\pm 2^{\circ}\text{C}$ (max) |
|                        | $-55^{\circ}\text{C}$ to $125^{\circ}\text{C}$ | $\pm 3^{\circ}\text{C}$ (max) |

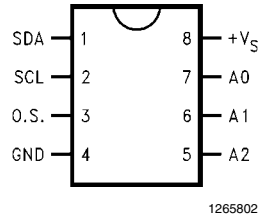
### Simplified Block Diagram



1265801

## Connection Diagram

LM75A SOP-8 Only  
LM75B, LM75C SOP-8 and Mini SOP-8



## Pin Descriptions

| Label           | Pin # | Function  | Typical Connection  |
|-----------------|-------|---|---|
| SDA             | 1     | I <sup>2</sup> C Serial Bi-Directional Data Line. Open Drain. | From Controller, tied to a pull-up resistor or current source   |
| SCL             | 2     | I <sup>2</sup> C Clock Input                                  | From Controller, tied to a pull-up resistor or current source   |
| O.S.            | 3     | Overtemperature Shutdown. Open Drain Output                   | Pull-up Resistor, Controller Interrupt Line   |
| GND             | 4     | Power Supply Ground   | Ground  |
| +V <sub>S</sub> | 8     | Positive Supply Voltage Input                                 | DC Voltage from 3V to 5.5V (2.7V to 5.5V for LM75A); 100 nF bypass capacitor with 10 μF bulk capacitance in the near vicinity |
| A0–A2           | 7,6,5 | User-Set I <sup>2</sup> C Address Inputs                      | Ground (Low, "0") or +V <sub>S</sub> (High, "1")  |

## Typical Application

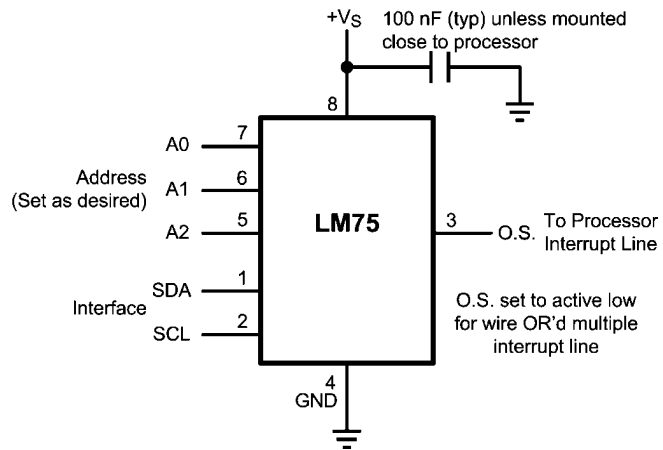


FIGURE 1. Typical Application

## Ordering Information

| Order Number | Package Marking | NS Package Number | Supply Voltage | Transport Media             | Noise Filter on SDA and SCL |
|--------------|-----------------|-------------------|----------------|-----------------------------|-----------------------------|
| LM75AIM      | LM75AIM         | M08A (SOP-8)      | 3.3V, 5V       | 95 Units in Rail            | Yes                         |
| LM75AIMX     | LM75AIM         | M08A (SOP-8)      | 3.3V, 5V       | 2500 Units on Tape and Reel | Yes                         |
| 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               |

## Absolute Maximum Ratings (Note 1)

|                                       |  |       |       |
|---------------------------------------|--|-------|-------|
| Supply Voltage Pin (+V <sub>S</sub> ) | -0.3V to 6.5V  |       |       |
| Voltage at A0, A1 and A2 Pins         | -0.3V to (+V <sub>S</sub> + 0.3V) and must be ≤ 6.5V |       |       |
| Voltage at OS, SCL and SDA Pins       | -0.3V to 6.5V  |       |       |
| Input Current at any Pin (Note 2)     | 5 mA   |       |       |
| Package Input Current (Note 2)        | 20 mA  |       |       |
| Storage Temperature                   | -65°C to +150°C                                      |       |       |
| ESD Susceptibility (Note 4)           | LM75A  | LM75B | LM75C |
| Human Body Model                      | 2500V  | 2500V | 1500V |
| Machine Model                         | 250V   | 250V  | 100V  |
| Charged Device Model                  | 1000V  |       |       |
| O.S. Output Sink Current              | 10 mA  |       |       |
| O.S. Output Voltage                   | 6.5V   |       |       |

## Operating Ratings

|   |   |
|---|---|
| Specified Temperature Range (Note 5)    | T <sub>MIN</sub> to T <sub>MAX</sub><br>-55°C to +125°C |
| Supply Voltage Range (+V <sub>S</sub> ) | LM75A +2.7V to +5.5V<br>LM75B, LM75C +3.0V to +5.5V     |

Soldering process must comply with National Semiconductor's Reflow Temperature Profile specifications. Refer to [www.national.com/packaging](http://www.national.com/packaging).(Note 3)

## Temperature-to-Digital Converter Characteristics

Unless otherwise noted, these specifications apply for: +V<sub>S</sub> = +2.7 to 5.5 Vdc for LM75AIM; +V<sub>S</sub> = +5 Vdc for LM75BIM-5, LM75BIMM-5, LM75CIM-5, and LM75CIMM-5; and +V<sub>S</sub> = +3.3 Vdc for LM75BIM-3, LM75BIMM-3, LM75CIM-3, and LM75CIMM-3 (Note 6). **Boldface limits apply for T<sub>A</sub> = T<sub>J</sub> = T<sub>MIN</sub> to T<sub>MAX</sub>**; all other limits T<sub>A</sub> = T<sub>J</sub> = +25°C, unless otherwise noted.

| Parameter                             | Conditions                       | Typical (Note 12)                   | Limits (Note 7) | Units (Limit)     |          |
|---------------------------------------|----------------------------------|-------------------------------------|-----------------|-------------------|----------|
| Accuracy                              | T <sub>A</sub> = -25°C to +100°C |                                     | <b>±2.0</b>     | °C (max)          |          |
|                                       | T <sub>A</sub> = -55°C to +125°C |                                     | <b>±3.0</b>     |                   |          |
| Resolution                            |                                  | 9                                   |                 | Bits              |          |
| Temperature Conversion Time           | (Note 8)                         | 100                                 | <b>300</b>      | ms (max)          |          |
| Quiescent Current                     | LM75A                            | I <sup>2</sup> C Inactive           | 0.28            | <b>0.5</b>        | mA (max) |
|                                       |                                  | Shutdown Mode, +V <sub>S</sub> = 3V | 4               |                   | μA       |
|                                       |                                  | Shutdown Mode, +V <sub>S</sub> = 5V | 6               |                   | μA       |
|                                       | LM75B                            | I <sup>2</sup> C Inactive           | 0.25            | <b>0.5</b>        | mA (max) |
|                                       |                                  | Shutdown Mode, +V <sub>S</sub> = 3V | 4               |                   | μA       |
|                                       |                                  | Shutdown Mode, +V <sub>S</sub> = 5V | 6               |                   | μA       |
|                                       | LM75C                            | I <sup>2</sup> C Inactive           | 0.25            | <b>1.0</b>        | mA (max) |
|                                       |                                  | Shutdown Mode, +V <sub>S</sub> = 3V | 4               |                   | μA       |
|                                       |                                  | Shutdown Mode, +V <sub>S</sub> = 5V | 6               |                   | μA       |
| O.S. Output Saturation Voltage        | I <sub>OUT</sub> = 4.0 mA        |                                     | <b>0.8</b>      | V (max)           |          |
| O.S. Delay                            | (Note 10)                        |                                     | <b>1</b>        | Conversion (min)  |          |
|                                       |                                  |                                     | <b>6</b>        | Conversions (max) |          |
| T <sub>OS</sub> Default Temperature   | (Note 11)                        | 80                                  |                 | °C                |          |
| T <sub>HYST</sub> Default Temperature | (Note 11)                        | 75                                  |                 | °C                |          |

## Logic Electrical Characteristics

### DIGITAL DC CHARACTERISTICS

Unless otherwise noted, these specifications apply for  $+V_S = +2.7$  to  $5.5$  Vdc for LM75AIM,  $+V_S = +5$  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  $T_A = T_J = +25^\circ\text{C}$ , unless otherwise noted.

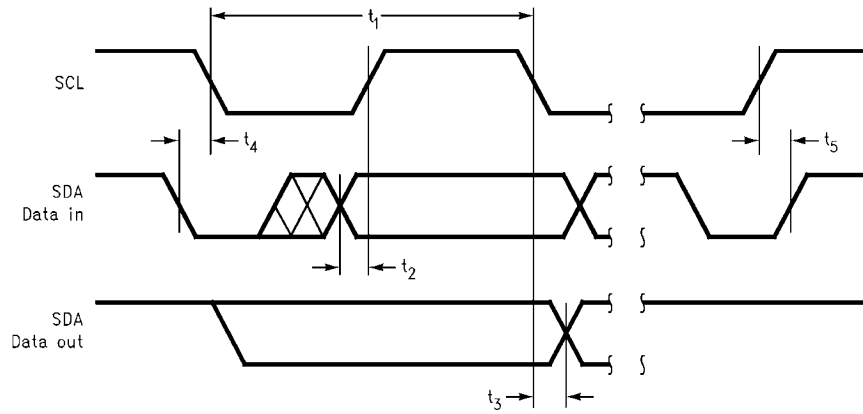
| Symbol      | Parameter                 | Conditions                                   | Typical<br>(Note 12) | Limits<br>(Note 7)                  | Units<br>(Limit)    |
|-------------|---------------------------|--|----------------------|-------------------------------------|---------------------|
| $V_{IN(1)}$ | Logical "1" Input Voltage |  |                      | <b><math>+V_S \times 0.7</math></b> | V (min)             |
|             |                           |  |                      | <b><math>+V_S + 0.3</math></b>      | V (max)             |
| $V_{IN(0)}$ | Logical "0" Input Voltage |  |                      | <b>-0.3</b>                         | V (min)             |
|             |                           |  |                      | <b><math>+V_S \times 0.3</math></b> | V (max)             |
| $I_{IN(1)}$ | Logical "1" Input Current | $V_{IN} = +V_S$                              | 0.005                | <b>1.0</b>                          | $\mu\text{A}$ (max) |
| $I_{IN(0)}$ | Logical "0" Input Current | $V_{IN} = 0\text{V}$                         | -0.005               | <b>-1.0</b>                         | $\mu\text{A}$ (max) |
| $C_{IN}$    | All Digital Inputs        |  | 5                    |                                     | pF                  |
| $I_{OH}$    | High Level Output Current | LM75A  | $V_{OH} = 5\text{V}$ | <b>1</b>                            | $\mu\text{A}$ (max) |
|             |                           | LM75B  | $V_{OH} = 5\text{V}$ | <b>10</b>                           | $\mu\text{A}$ (max) |
|             |                           | LM75C  | $V_{OH} = 5\text{V}$ | <b>100</b>                          | $\mu\text{A}$ (max) |
| $V_{OL}$    | Low Level Output Voltage  | $I_{OL} = 3\text{ mA}$                       |                      | <b>0.4</b>                          | V (max)             |
| $t_{OF}$    | Output Fall Time          | $C_L = 400\text{ pF}$<br>$I_O = 3\text{ mA}$ |                      | <b>250</b>                          | ns (max)            |

### I<sup>2</sup>C DIGITAL SWITCHING CHARACTERISTICS

Unless otherwise noted, these specifications apply for  $+V_S = +2.7$  to  $5.5$  Vdc for LM75AIM and  $V_S = +5$  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 =  $80\text{ pF}$  unless otherwise specified. **Boldface limits apply for  $T_A = T_J = T_{MIN}$  to  $T_{MAX}$** ; all other limits  $T_A = T_J = +25^\circ\text{C}$ , unless otherwise noted.

The switching characteristics of the LM75 fully meet or exceed the published specifications of the I<sup>2</sup>C bus. The following parameters are the timing relationships between SCL and SDA signals related to the LM75. They are not the I<sup>2</sup>C bus specifications.

| Symbol        | Parameter  | Conditions      | Typical<br>(Note 12) | Limits<br>(Note 7) | Units<br>(Limit)    |
|---------------|--|-----------------|----------------------|--------------------|---------------------|
| $t_1$         | SCL (Clock) Period                                   |                 |                      | <b>2.5</b>         | $\mu\text{s}$ (min) |
| $t_2$         | Data in Set-Up Time to SCL High                      |                 |                      | <b>100</b>         | ns (min)            |
| $t_3$         | Data Out Stable after SCL Low                        |                 |                      | <b>0</b>           | ns (min)            |
| $t_4$         | SDA Low Set-Up Time to SCL Low (Start Condition)     |                 |                      | <b>100</b>         | ns (min)            |
| $t_5$         | SDA High Hold Time after SCL High (Stop Condition)   |                 |                      | <b>100</b>         | ns (min)            |
| $t_{TIMEOUT}$ | SDA Time Low for Reset of Serial Interface (Note 13) | LM75A,<br>LM75B |                      | <b>75</b>          | ms (min)            |
|               |  |                 |                      | <b>325</b>         | ms (max)            |
|               |  | LM75C           |                      |                    | Not Applicable      |



1265804

**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 ( $V_I < \text{GND}$  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 exceed the power supplies with an input current of 5 mA to four.

**Note 3:** Reflow temperature profiles are different for lead-free and non-lead-free packages.

**Note 4:** Human body model, 100 pF discharged through a 1.5 k $\Omega$  resistor. Machine model, 200 pF discharged directly into each pin. The Charged Device Model (CDM) is a specified circuit characterizing an ESD event that occurs when a device acquires charge through some triboelectric (frictional) or electrostatic induction processes and then abruptly touches a grounded object or surface.

**Note 5:** LM75  $\theta_{JA}$  (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 ( $\theta_{JA}$ ) |
|---|-------------------|--------------------------------------|
| LM75AIM, 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:** The conversion-time specification is provided to indicate how often the temperature data is updated. The LM75 can be accessed at any time and reading the Temperature Register will yield result from the last temperature conversion. When the LM75 is accessed, the conversion that is in process will be interrupted and it will be restarted after the end of the communication. Accessing the LM75 continuously without waiting at least one conversion time between communications will prevent the device from updating the Temperature Register with a new temperature conversion result. Consequently, the LM75 should not be accessed continuously with a wait time of less than 300 ms.

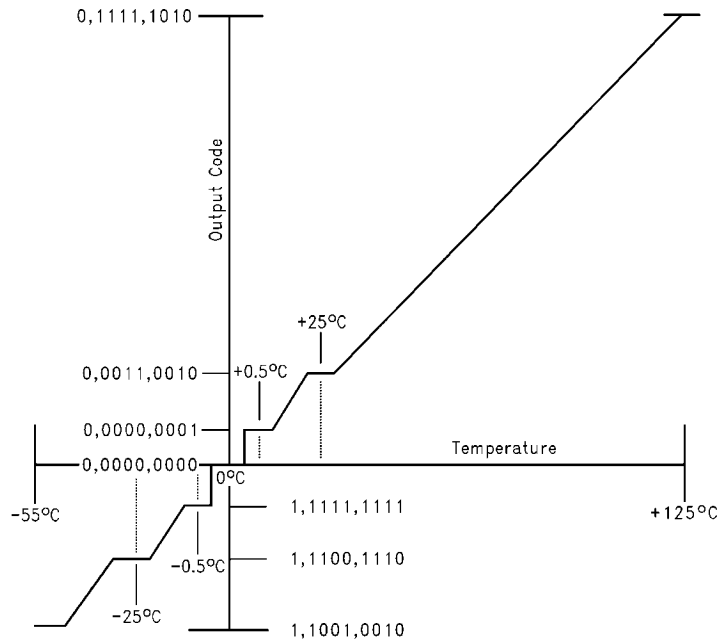
**Note 9:** For best accuracy, minimize output loading. Higher sink currents can affect sensor accuracy with internal heating. This can cause an error of 0.64°C at full rated sink current and saturation voltage based on junction-to-ambient thermal resistance.

**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.

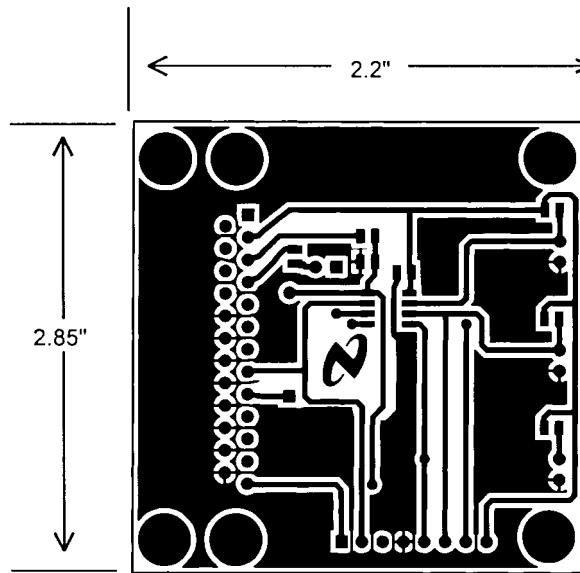
**Note 12:** Typical values are at  $T_A = 25^\circ\text{C}$  and represent most likely parametric norm.

**Note 13:** Holding the SDA line low for a time greater than  $t_{\text{TIMEOUT}}$  will cause the LM75A and LM75B to reset SDA to the IDLE state of the serial bus communication (SDA set High).



1265805

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



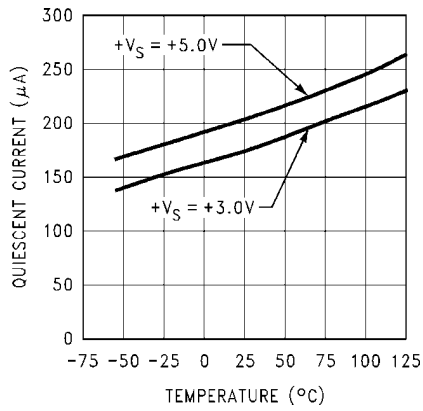
1265806

FIGURE 3. Printed Circuit Board Used for Thermal Resistance Specifications



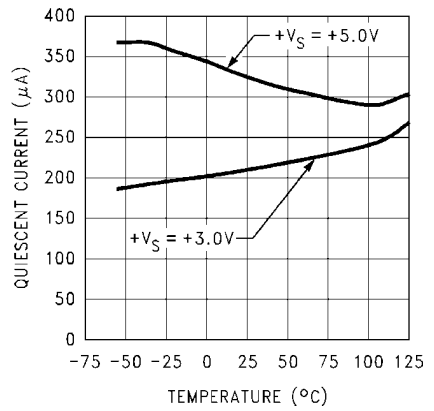
# Typical Performance Characteristics

**Static Quiescent Current vs Temperature (LM75C)**



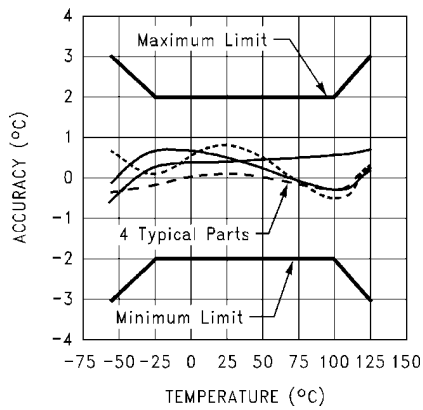
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**Dynamic Quiescent Current vs Temperature (LM75C)**



1265817

**Accuracy vs Temperature (LM75C)**



1265818

## 1.0 Functional Description

The LM75 temperature sensor incorporates a band-gap type temperature sensor and 9-bit ADC (Sigma-Delta Analog-to-Digital Converter). The temperature data output of the LM75 is available at all times via the I<sup>2</sup>C bus. If a conversion is in progress, it will be stopped and restarted after the read. A digital comparator is also incorporated that compares a series of readings, the number of which is user-selectable, to user-programmable setpoint and hysteresis values. The comparator trips the O.S. output line, which is programmable for mode and polarity.

The LM75A and LM75B contain all the functionality of the LM75C, plus two additional features:

1. The LM75A and LM75B have an integrated low-pass filter on both the SDA and the SCL line. These filters increase communications reliability in noisy environments.
2. The LM75A and LM75B also have a bus fault timeout feature. If the SDA line is held low for longer than  $t_{\text{TIMEOUT}}$  (see specification) the LM75A and LM75B will reset to the IDLE state (SDA set to high impedance) and wait for a new start condition. The TIMEOUT feature is not functional in Shutdown Mode.

### 1.1 O.S. OUTPUT, $T_{\text{OS}}$ AND $T_{\text{HYST}}$ LIMITS

In Comparator mode the O.S. Output behaves like a thermostat. The output becomes active when temperature exceeds the  $T_{\text{OS}}$  limit, and leaves the active state when the temperature drops below the  $T_{\text{HYST}}$  limit. In this mode the O.S. output can be used to turn a cooling fan on, initiate an emergency system shutdown, or reduce system clock speed. Shutdown mode does not reset O.S. state in a comparator mode.

In Interrupt mode exceeding  $T_{\text{OS}}$  also makes O.S. active but O.S. will remain active indefinitely until reset by reading any register via the I<sup>2</sup>C interface. Once O.S. has been activated by crossing  $T_{\text{OS}}$ , then reset, it can be activated again only by Temperature going below  $T_{\text{HYST}}$ . Again, it will remain active indefinitely until being reset by a read. Placing the LM75 in shutdown mode also resets the O.S. Output.

## 1.2 POWER UP AND POWER DOWN

The LM75 always powers up in a known state. The power up default conditions are:

1. Comparator mode
2.  $T_{\text{OS}} = 80^{\circ}\text{C}$
3.  $T_{\text{HYST}} = 75^{\circ}\text{C}$
4. O.S. active low
5. Pointer = "00"

When the supply voltage is less than about 1.7V, the LM75 is considered powered down. As the supply voltage rises above the nominal 1.7V power up threshold, the internal registers are reset to the power up default values listed above.

### 1.2.1 Stand-Alone Thermostat Mode

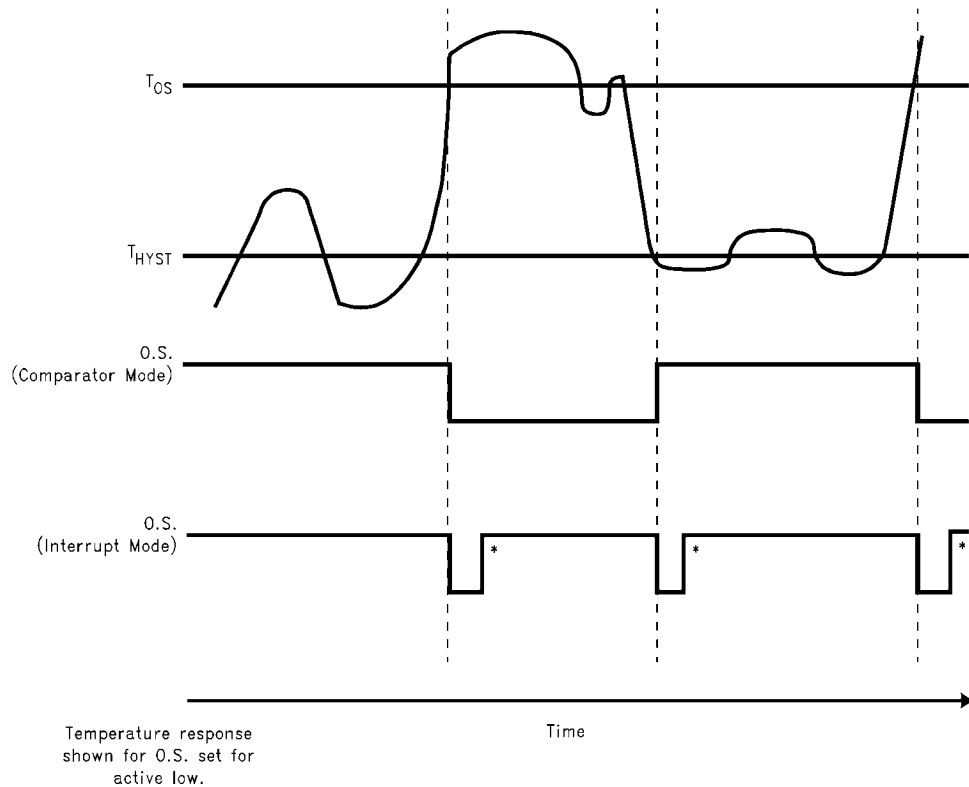
If the LM75 is *not connected* to the I<sup>2</sup>C bus on power up, it will act as a stand-alone thermostat with the power up default conditions listed above. It is optional, but recommended, to connect the address pins (A2, A1, A0) and the SCL and SDA pins together and to a 10k pull-up resistor to  $+V_{\text{S}}$  for better noise immunity. Any of these pins may also be tied high separately through a 10k pull-up resistor.

## 1.3 I<sup>2</sup>C BUS INTERFACE

The LM75 operates as a slave on the I<sup>2</sup>C bus, so the SCL line is an input (no clock is generated by the LM75) and the SDA line is a bi-directional serial data path. According to I<sup>2</sup>C bus specifications, the LM75 has a 7-bit slave address. The four most significant bits of the slave address are hard wired inside the LM75 and are "1001". The three least significant bits of the address are assigned to pins A2–A0, and are set by connecting these pins to ground for a low, (0); or to  $+V_{\text{S}}$  for a high, (1).

Therefore, the complete slave address is:

|     |   |   |   |     |    |    |
|-----|---|---|---|-----|----|----|
| 1   | 0 | 0 | 1 | A2  | A1 | A0 |
| MSB |   |   |   | LSB |    |    |



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**Note 14:** These interrupt mode resets of O.S. occur only when LM75 is read or placed in shutdown. Otherwise, O.S. would remain active indefinitely for any event.

**FIGURE 4. O.S. Output Temperature Response Diagram**

#### 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  $0.5^{\circ}\text{C}$ :

| 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<sup>2</sup>C bus. Shutdown mode reduces power supply current significantly. See specified quiescent current specification in the electrical tables. In Interrupt mode O.S. is reset if previously set and is undefined in Comparator mode during shutdown. The I<sup>2</sup>C interface remains active. Activity on the clock and data lines of the I<sup>2</sup>C 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.

For the LM75A and LM75B the TIMEOUT feature is turned off 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

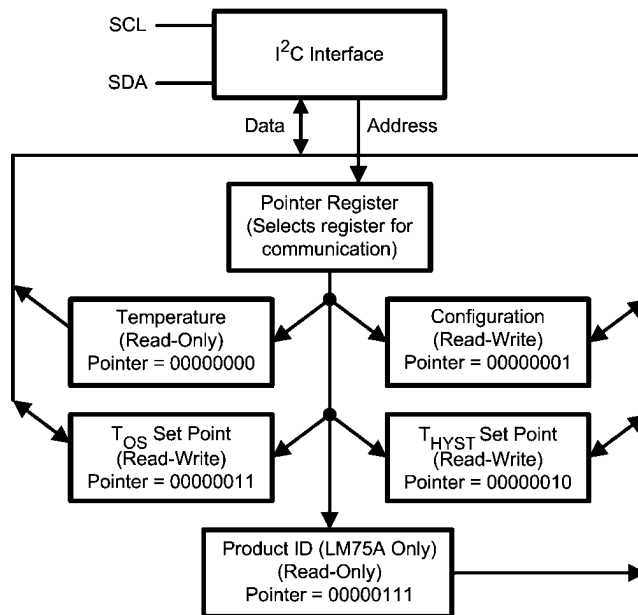
The O.S. output is an open-drain output and does not have an internal pull-up. A "high" level will not be observed on this pin until pull-up current is provided from some external source, typically a pull-up resistor. Choice of resistor value depends on many system factors but, in general, the pull-up 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.

**1.10 INTERNAL REGISTER STRUCTURE**



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There are four data registers in the LM75B and LM75C, and an additional Product ID register in the LM75A, selected by the Pointer register. At power-up the Pointer is set to "000"; the location for the Temperature Register. The Pointer register latches whatever the last location it was set to. In Interrupt Mode, a read from the LM75, or placing the device in shut-down mode, resets the O.S. output. All registers are read and write, except the Temperature register and the LM75A's Product ID register, which are read only.

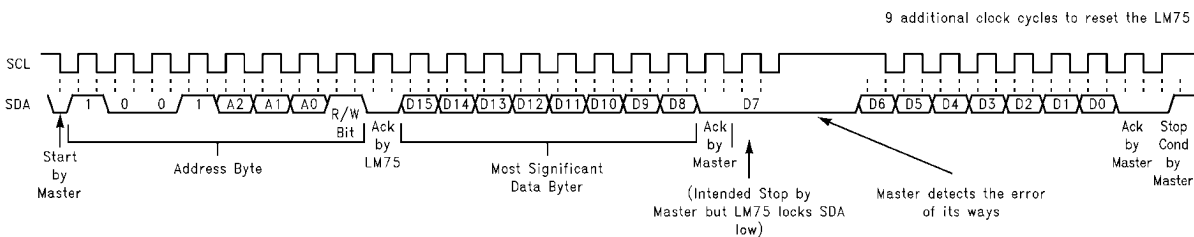
A write to the LM75 will always include the address byte and the Pointer byte. A write to the Configuration register requires one data byte, and the T<sub>OS</sub> and T<sub>HYST</sub> registers require two data bytes.

Reading the LM75 can take place either of two ways: If the location latched in the Pointer is correct (most of the time it is expected that the Pointer will point to the Temperature register because it will be the data most frequently read from the LM75), then the read can simply consist of an address byte, followed by retrieving the corresponding number of data bytes. If the Pointer needs to be set, then an address byte,

pointer byte, repeat start, and another address byte will accomplish a read.

The first data byte is the most significant byte with most significant bit first, permitting only as much data as necessary to be read to determine temperature condition. For instance, if the first four bits of the temperature data indicates an overtemperature condition, the host processor could immediately take action to remedy the excessive temperatures. At the end of a read, the LM75 can accept either Acknowledge or No Acknowledge from the Master (No Acknowledge is typically used as a signal for the slave that the Master has read its last byte).

An inadvertent 8-bit read from a 16-bit register, with the D7 bit low, can cause the LM75 to stop in a state where the SDA line is held low as shown in *Figure 5*. This can prevent any further bus communication until at least 9 additional clock cycles have occurred. Alternatively, the master can issue clock cycles until SDA goes high, at which time issuing a "Stop" condition will reset the LM75.



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**FIGURE 5. Inadvertent 8-Bit Read from 16-Bit Register where D7 is Zero ("0")**

### 1.11 POINTER REGISTER (Selects which registers will be read from or written to):

| P7 | P6 | P5 | P4 | P3 | P2              | P1 | P0 |
|----|----|----|----|----|-----------------|----|----|
| 0  | 0  | 0  | 0  | 0  | Register Select |    |    |

P0-P1: Register Select:

| P2 | P1 | P0 | Register                                   |
|----|----|----|--|
| 0  | 0  | 0  | Temperature (Read only) (Power-up default) |
| 0  | 0  | 1  | Configuration (Read/Write)                 |
| 0  | 1  | 0  | T <sub>HYST</sub> (Read/Write)             |
| 0  | 1  | 1  | T <sub>OS</sub> (Read/Write)               |
| 1  | 1  | 1  | Product ID Register (LM75A Only)           |

P3-P7: Must be kept zero.

### 1.12 TEMPERATURE REGISTER (Read Only):

| D15 | D14   | D13   | D12   | D11   | D10   | D9    | D8    | D7  | D6 | D5 | D4 | D3 | D2 | D1 | D0 |
|-----|-------|-------|-------|-------|-------|-------|-------|-----|----|----|----|----|----|----|----|
| MSB | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | LSB | X  | X  | X  | X  | X  | X  | X  |

D0-D6: Undefined. D7-D15: Temperature Data. One LSB = 0.5°C. Two's complement format.

### 1.13 CONFIGURATION REGISTER (Read/Write):

| D7 | D6 | D5 | D4          | D3 | D2            | D1      | D0       |
|----|----|----|-------------|----|---------------|---------|----------|
| 0  | 0  | 0  | Fault Queue |    | O.S. Polarity | Cmp/Int | Shutdown |

Power up default is with all bits "0" (zero).

D0: Shutdown: When set to 1 the LM75 goes to low power shutdown mode.

D1: Comparator/Interrupt mode: 0 is Comparator mode, 1 is Interrupt mode.

D2: O.S. Polarity: 0 is active low, 1 is active high. O.S. is an open-drain output under all conditions.

D3-D4: Fault Queue: Number of faults necessary to detect before setting O.S. output to avoid false tripping due to noise. Faults are determined at the end of a conversion. See specified temperature conversion time in the electrical tables.

| D4 | D3 | Number of Faults     |
|----|----|----------------------|
| 0  | 0  | 1 (Power-up default) |
| 0  | 1  | 2                    |
| 1  | 0  | 4                    |
| 1  | 1  | 6                    |

D5-D7: These bits are used for production testing and must be kept zero for normal operation.

### 1.14 T<sub>HYST</sub> AND T<sub>OS</sub> REGISTER (Read/Write):

| D15 | D14   | D13   | D12   | D11   | D10   | D9    | D8    | D7  | D6 | D5 | D4 | D3 | D2 | D1 | D0 |
|-----|-------|-------|-------|-------|-------|-------|-------|-----|----|----|----|----|----|----|----|
| MSB | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | LSB | X  | X  | X  | X  | X  | X  | X  |

D0-D6: Undefined D7-D15: T<sub>HYST</sub> Or T<sub>OS</sub> Trip Temperature Data. Power up default is T<sub>OS</sub> = 80°C, T<sub>HYST</sub> = 75°C

### 1.15 PRODIG: PRODUCT ID REGISTER (LM75A Only)

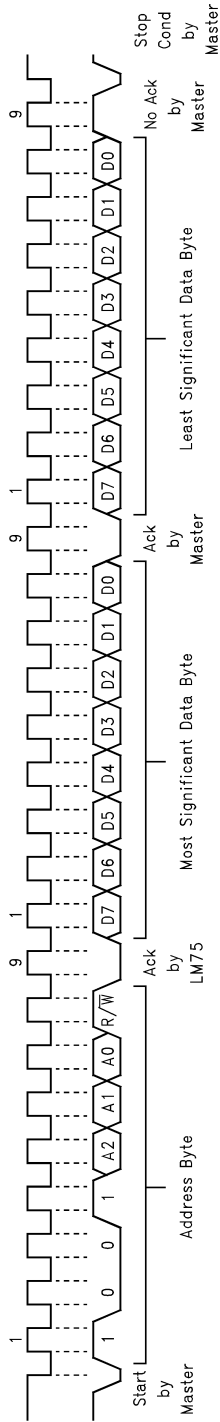
(Read Only) Pointer Address: 07h

| D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 |
|----|----|----|----|----|----|----|----|
| 1  | 0  | 1  | 0  | 0  | 0  | 0  | 1  |

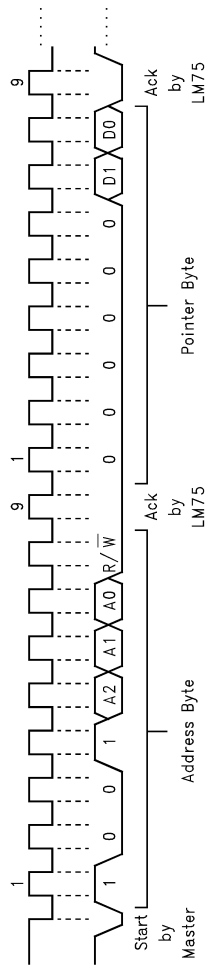
D4--D7 Product Identification Nibble. Always returns Ah to uniquely identify this part as the LM75A.

D0--D3 Die Revision Nibble. Returns 1h to uniquely identify the revision level as one.

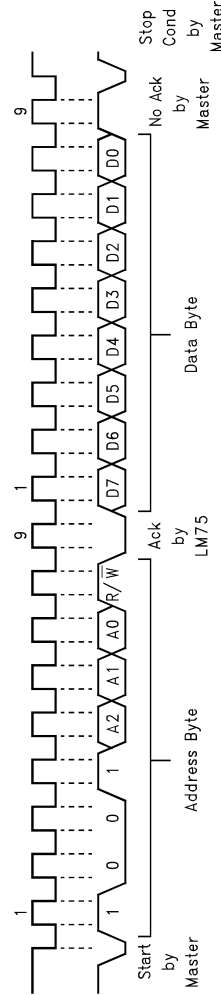
## 2.0 I<sup>2</sup>C Timing Diagrams



(a) Typical 2-Byte Read From Preset Pointer Location Such as Temp, T<sub>OS</sub>, T<sub>HYST</sub>



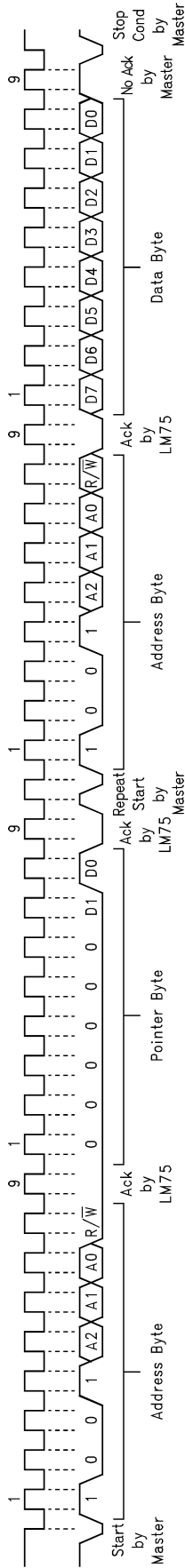
(b) Typical Pointer Set Followed by Immediate Read for 2-Byte Register such as Temp, T<sub>OS</sub>, T<sub>HYST</sub>



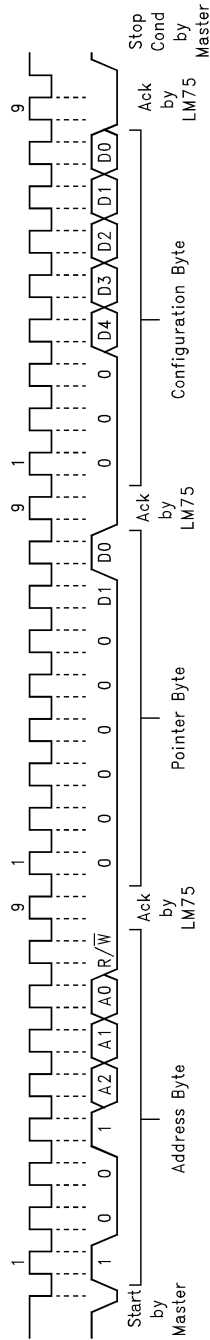
(c) Typical 1-Byte Read From Configuration Register With Preset Pointer

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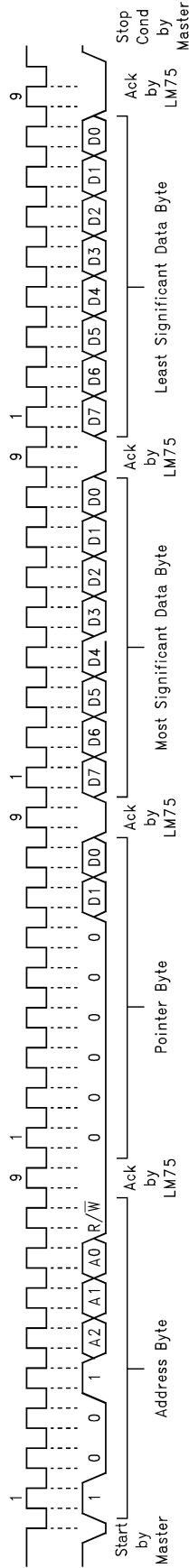
FIGURE 6. Timing Diagram



(a) Typical Pointer Set Followed by Immediate Read from Configuration Register



(b) Configuration Register Write



(c)  $T_{OS}$  and  $T_{HYST}$  Write

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FIGURE 7. Timing Diagrams (Continued)

## 2.0 Application Hints

To get the expected results when measuring temperature with an integrated circuit temperature sensor like the LM75, it is important to understand that the sensor measures its own die temperature. For the LM75, the best thermal path between the die and the outside world is through the LM75's pins. In the MSOP-8 package for the LM75B and LM75C, the GND pin is directly connected to the die, so the GND pin provides the best thermal path. If the other pins are at different temperatures (unlikely, but possible), they will affect the die temperature, but not as strongly as the GND pin. In the SO-8 package, none of the pins is directly connected to the die, so they will all contribute similarly to the die temperature. Because the pins represent a good thermal path to the LM75 die, the LM75 will provide an accurate measurement of the temperature of the printed circuit board on which it is mounted. There is a less efficient thermal path between the plastic package and the LM75 die. If the ambient air temperature is significantly different from the printed circuit board temperature, it will have a small effect on the measured temperature.

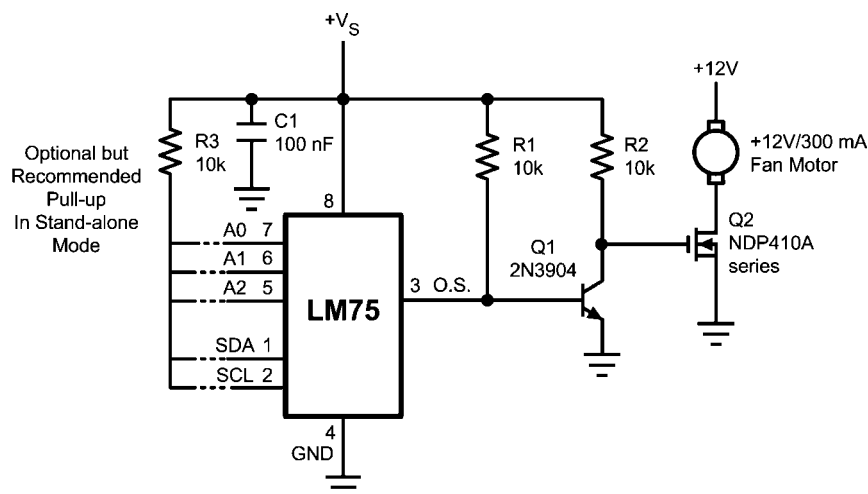
In probe-type applications, the LM75 can be mounted inside a sealed-end metal tube, and can then be dipped into a bath or screwed into a threaded hole in a tank. As with any IC, the LM75 and accompanying wiring and circuits must be kept insulated and dry, to avoid leakage and corrosion. This is especially true if the circuit may operate at cold temperatures where condensation can occur. Printed-circuit coatings and varnishes such as Humiseal and epoxy paints or dips are often used to insure that moisture cannot corrode the LM75 or its connections.

## 3.0 Typical Applications

### 2.1 DIGITAL NOISE ISSUES

The LM75A and LM75B feature an integrated low-pass filter on both the SCL and the SDA digital lines to mitigate the effects of bus noise. Although this filtering makes the LM75A and LM75B communication robust in noisy environments, good layout practices are always recommended. Minimize noise coupling by keeping digital traces away from switching power supplies. Also, ensure that digital lines containing high-speed data communications cross at right angles to the SDA and SCL lines.

Excessive noise coupling into the SDA and SCL lines on the LM75C—specifically noise with amplitude greater than  $400\text{ mV}_{pp}$  (the LM75's typical hysteresis), overshoot greater than  $300\text{ mV}$  above  $+V_S$ , and undershoot more than  $300\text{ mV}$  below GND—may prevent successful serial communication with the LM75C. Serial bus no-acknowledge is the most common symptom, causing unnecessary traffic on the bus. The layout procedures mentioned above apply also to the LM75C. Although the serial bus maximum frequency of communication is only  $400\text{ kHz}$ , care must be taken to ensure proper termination within a system with long printed circuit board traces or multiple parts on the bus. Resistance can be added in series with the SDA and SCL lines to further help filter noise and ringing. A  $5\text{ k}\Omega$  resistor should be placed in series with the SCL line, placed as close as possible to the SCL pin on the LM75C. This  $5\text{ k}\Omega$  resistor, with the  $5\text{ pF}$  to  $10\text{ pF}$  stray capacitance of the LM75 provides a  $6\text{ MHz}$  to  $12\text{ MHz}$  low pass filter, which is sufficient filtering in most cases.

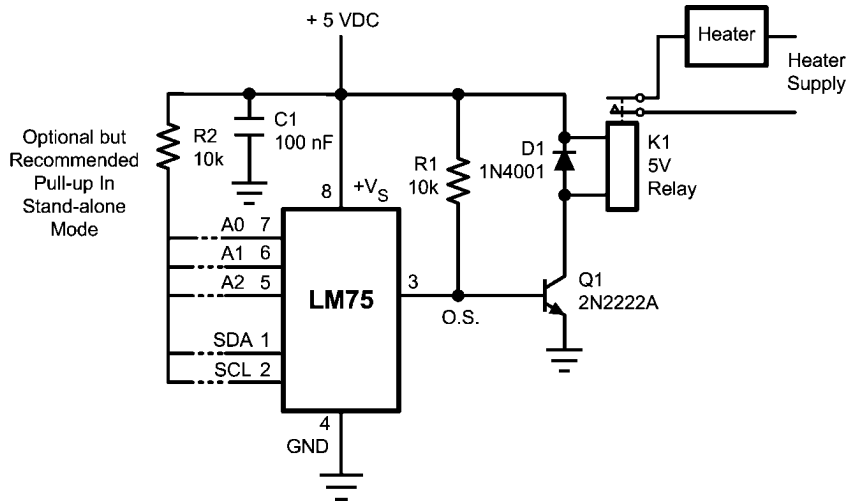


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When using the two-wire interface: program O.S. for active high and connect O.S. directly to Q2's gate.

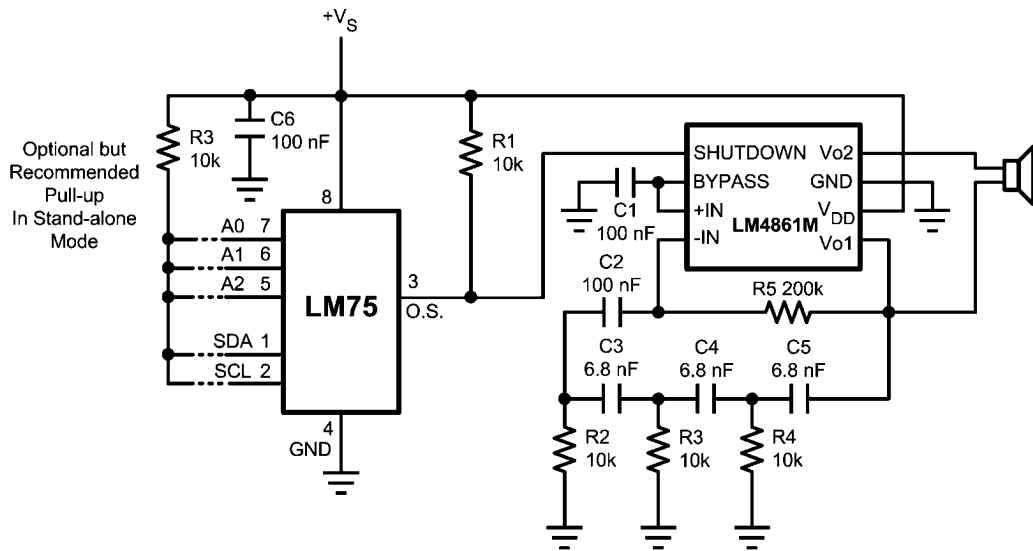
FIGURE 8. Simple Fan Controller, Interface Optional





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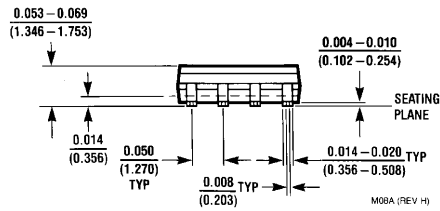
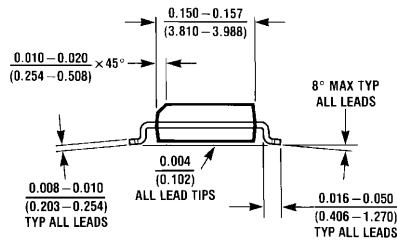
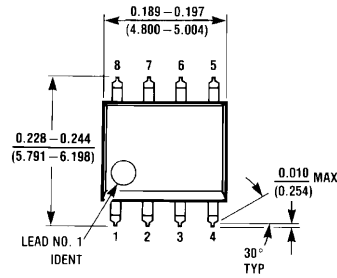
FIGURE 9. Simple Thermostat, Interface Optional



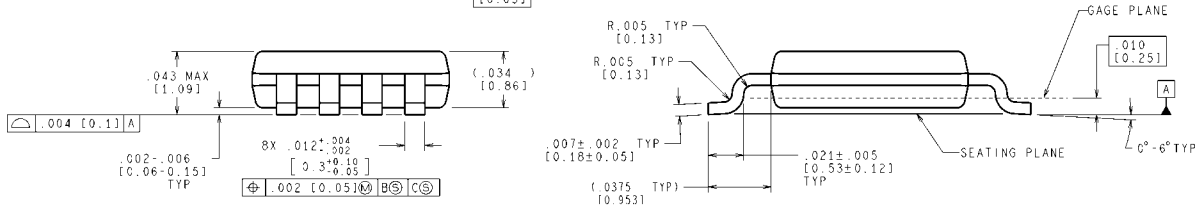
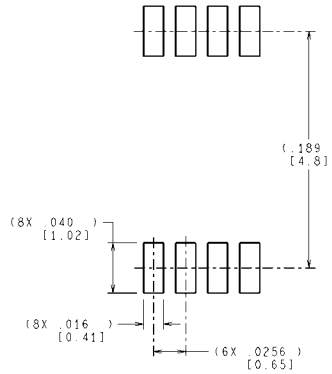
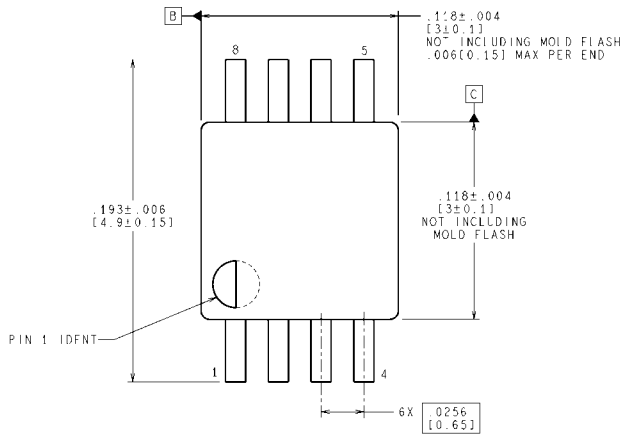
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FIGURE 10. Temperature Sensor with Loudmouth Alarm (Barking Watchdog)

**Physical Dimensions** inches (millimeters) unless otherwise noted



**8-Lead (0.150 Wide) Molded Small Outline Package (SOP), JEDEC**  
**Order Number LM75AIM, LM75AIMX, LM75CIM-3, LM75CIMX-3, LM75CIM-5, LM75CIMX-5,**  
**LM75BIM-3, LM75BIMX-3, LM75BIM-5, or LM75BIMX-5**  
**NS Package Number M08A**



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MUA08A (Rev F)

**8-Lead Molded Mini Small Outline Package (MSOP)**  
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**Order Number LM75CIMM-3, LM75CIMMX-3, LM75CIMM-5, LM75CIMMX-5, LM75BIMM-3, LM75BIMMX-3, LM75BIMM-5, or**  
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| Interface                      | <a href="http://www.national.com/interface">www.national.com/interface</a>     | Eval Boards             | <a href="http://www.national.com/evalboards">www.national.com/evalboards</a>       |
| LVDS                           | <a href="http://www.national.com/lvds">www.national.com/lvds</a>               | Packaging               | <a href="http://www.national.com/packaging">www.national.com/packaging</a>         |
| Power Management               | <a href="http://www.national.com/power">www.national.com/power</a>             | Green Compliance        | <a href="http://www.national.com/quality/green">www.national.com/quality/green</a> |
| Switching Regulators           | <a href="http://www.national.com/switchers">www.national.com/switchers</a>     | Distributors            | <a href="http://www.national.com/contacts">www.national.com/contacts</a>           |
| LDOs                           | <a href="http://www.national.com/ldo">www.national.com/ldo</a>                 | Quality and Reliability | <a href="http://www.national.com/quality">www.national.com/quality</a>             |
| LED Lighting                   | <a href="http://www.national.com/led">www.national.com/led</a>                 | Feedback/Support        | <a href="http://www.national.com/feedback">www.national.com/feedback</a>           |
| Voltage Reference              | <a href="http://www.national.com/vref">www.national.com/vref</a>               | Design Made Easy        | <a href="http://www.national.com/easy">www.national.com/easy</a>                   |
| PowerWise® Solutions           | <a href="http://www.national.com/powerwise">www.national.com/powerwise</a>     | Solutions               | <a href="http://www.national.com/solutions">www.national.com/solutions</a>         |
| Serial Digital Interface (SDI) | <a href="http://www.national.com/sdi">www.national.com/sdi</a>                 | Mil/Aero                | <a href="http://www.national.com/milaero">www.national.com/milaero</a>             |
| Temperature Sensors            | <a href="http://www.national.com/tempsensors">www.national.com/tempsensors</a> | SolarMagic™             | <a href="http://www.national.com/solarmagic">www.national.com/solarmagic</a>       |
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