

Tiny Serial Digital Thermal Sensor

Features

- Digital Temperature Sensing in SOT-23-5 or TO-220 Packages
- Outputs Temperature as an 8-Bit Digital Word
- Simple SMBus/I²C™ Serial Port Interface
- Solid-State Temperature Sensing:
 - ±2°C (max.) Accuracy from +25°C to +85°C
 - ±3°C (max.) Accuracy from 0°C to +125°C
- Supply Voltage of 2.7V to 5.5V
- Low Power:
 - 200 µA (typ.) Operating Current
 - 5 µA (typ.) Standby Mode Current

Applications

- Thermal Protection for Hard Disk Drives and other PC Peripherals
- PC Card Devices for Notebook Computers
- Low Cost Thermostat Controls
- Power Supplies
- Thermistor Replacement

Package Types



General Description

The TC74 is a serially accessible, digital temperature sensor particularly suited for low cost and small form-factor applications. Temperature data is converted from the onboard thermal sensing element and made available as an 8-bit digital word.

Communication with the TC74 is accomplished via a 2-wire SMBus/I²C compatible serial port. This bus also can be used to implement multi-drop/multi-zone monitoring. The SHDN bit in the CONFIG register can be used to activate the low power Standby mode.

Temperature resolution is 1°C. Conversion rate is a nominal 8 samples/sec. During normal operation, the quiescent current is 200 µA (typ). During standby operation, the quiescent current is 5 µA (typ).

Small size, low installed cost and ease of use make the TC74 an ideal choice for implementing thermal management in a variety of systems.

Functional Block Diagram



TC74

1.0 ELECTRICAL CHARACTERISTICS

1.1 Absolute Maximum Ratings†

| | |
|---|------------------------------------|
| Supply Voltage (V_{DD}) | +6V |
| Voltage On Any Pin | (GND – 0.3V) to (V_{DD} + 0.3V) |
| Current On Any Pin | ±50 mA |
| Operating Temperature (T_A) | -40°C ≤ T_A ≤ +125°C |
| Storage Temperature (T_{STG}) | -65°C to +150°C |
| Junction Temperature (T_J) | +150°C |

† **Notice:** Stresses above those listed under "Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at those or any other conditions above those indicated in the operation listings of this specification is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability.

DC CHARACTERISTICS

| Electrical Specifications: Unless otherwise noted, V_{DD} = 3.3V for TC74AX-3.3VXX and V_{DD} = 5.0V for TC74AX-5.0VXX, -40°C ≤ T_A ≤ 125°C. Note 5 | | | | | | |
|--|------------------|-------------------|----------------|-------------------|-------|--|
| Parameters | Sym | Min | Typ | Max | Units | Conditions |
| Power Supply | | | | | | |
| Power-on Reset Threshold | V_{POR} | 1.2 | — | 2.2 | V | V_{DD} Falling Edge or Rising Edge |
| Supply Voltage | V_{DD} | 2.7 | — | 5.5 | V | Note 5 |
| Operating Current | I_{DD} | — | 200 | 350 | μA | V_{DD} = 5.5V, Note 1 |
| Standby Supply Current | $I_{DD-STANDBY}$ | — | 5.0 | 10 | μA | V_{DD} = 3.3V Serial Port Inactive, Note 4 |
| Temperature-to-Bits Converter | | | | | | |
| Temperature Accuracy | T_{ERR} | -2.0 -3.0 — | — — ±2.0 | +2.0 +3.0 — | °C | +25°C < T_A < +85°C 0°C < T_A < +125°C -40°C < T_A < 0°C |
| Conversion Rate | CR | 4 | 8 | — | SPS | Note 2 |
| Serial Port Interface | | | | | | |
| Logic Input High | V_{IH} | 0.8 × V_{DD} | — | — | V | |
| Logic Input Low | V_{IL} | — | — | 0.2 × V_{DD} | V | |
| SDA Output Low | V_{OL} | — | — | 0.4 0.6 | V | I_{OL} = 3 mA I_{OL} = 6 mA, Note 3 |
| Input Capacitance SDA, SCLK | C_{IN} | — | 5.0 | — | pF | |
| I/O Leakage | I_{LEAK} | -1.0 | 0.1 | 1.0 | μA | |
| Serial Port AC Timing (C_{LOAD} = 80 pF) | | | | | | |
| SMBus/I ² C Clock Frequency | f_{SMB} | 10 | — | 100 | kHz | |
| Low Clock Period | t_{LOW} | 4.7 | — | — | μsec | 10% to 10% |
| High Clock Period | t_{HIGH} | 4.0 | — | — | μsec | 90% to 90% |
| SMBus/I ² C Rise Time | t_R | — | — | 1000 | nsec | 10% to 90% |
| SMBus/I ² C Fall Time | t_F | — | — | 300 | nsec | 90% to 10% |

- Note 1:** Operating current is an average value integrated over multiple conversion cycles. Transient current may exceed this specification.
- 2:** Maximum ensured conversion time after Power-on Reset (POR to DATA_RDY) is 250 msec.
- 3:** Output current should be minimized for best temperature accuracy. Power dissipation within the TC74 will cause self-heating and temperature drift error.
- 4:** SDA and SCLK must be connected to V_{DD} or GND.
- 5:** V_{DD} = 3.3V for TC74AX -3.3 VXX. V_{DD} = 5.0V for TC74AX -5.0 VXX. All part types of the TC74 will operate properly over the wider power supply range of 2.7V to 5.5V. Each part type is tested and specified for rated accuracy at its nominal supply voltage. As V_{DD} varies from the nominal value, accuracy will degrade 1°C/V of V_{DD} change.

DC CHARACTERISTICS (CONTINUED)

| Electrical Specifications: Unless otherwise noted, $V_{DD} = 3.3V$ for TC74AX-3.3VXX and $V_{DD} = 5.0V$ for TC74AX-5.0VXX, $-40^{\circ}C \leq T_A \leq 125^{\circ}C$. Note 5 | | | | | | |
|---|-----------------|------|-----|-----|-----------------|-------------------------------------|
| Parameters | Sym | Min | Typ | Max | Units | Conditions |
| START Condition Setup Time (for repeated START Condition) | $t_{SU(START)}$ | 4.0 | — | — | μsec | 90% SCLK to 10% SDA |
| START Condition Hold Time | $t_{H(START)}$ | 4.0 | — | — | μsec | |
| Data In Setup Time | $t_{SU-DATA}$ | 1000 | — | — | nsec | |
| Data In Hold Time | t_{H-DAT} | 1250 | — | — | nsec | |
| STOP Condition Setup Time | $t_{SU(STOP)}$ | 4.0 | — | — | μsec | |
| Bus Free Time Prior to New Transition | t_{IDLE} | 4.7 | — | — | μsec | |
| Power-on Reset Delay | t_{POR} | — | 500 | — | μsec | $V_{DD} \geq V_{POR}$ (Rising Edge) |

- Note 1:** Operating current is an average value integrated over multiple conversion cycles. Transient current may exceed this specification.
- 2:** Maximum ensured conversion time after Power-on Reset (POR to DATA_RDY) is 250 msec.
- 3:** Output current should be minimized for best temperature accuracy. Power dissipation within the TC74 will cause self-heating and temperature drift error.
- 4:** SDA and SCLK must be connected to V_{DD} or GND.
- 5:** $V_{DD} = 3.3V$ for TC74AX -3.3 VXX. $V_{DD} = 5.0V$ for TC74AX -5.0 VXX. All part types of the TC74 will operate properly over the wider power supply range of 2.7V to 5.5V. Each part type is tested and specified for rated accuracy at its nominal supply voltage. As V_{DD} varies from the nominal value, accuracy will degrade $1^{\circ}C/V$ of V_{DD} change.

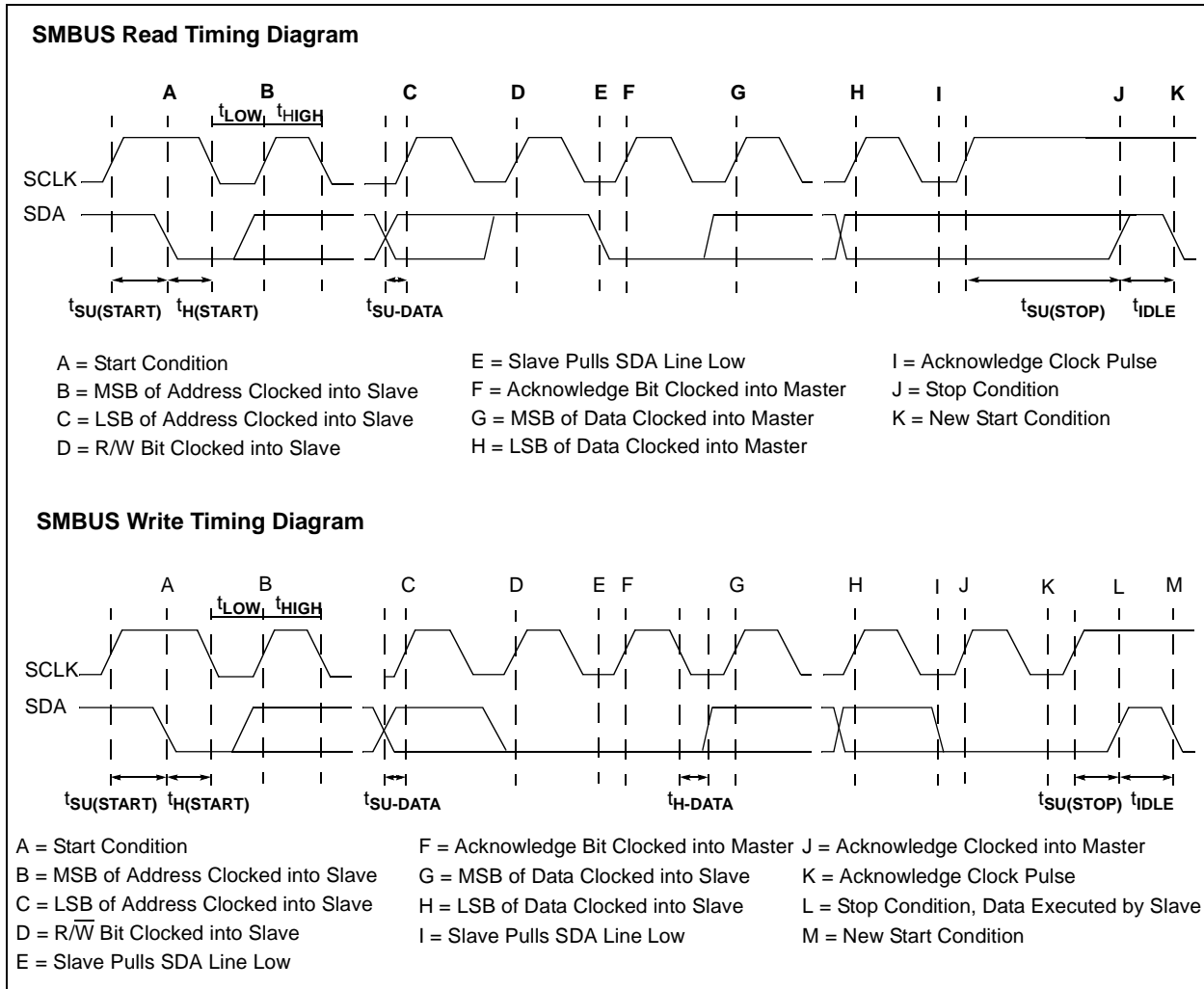


FIGURE 1-1: Timing Diagrams.

2.0 PIN DESCRIPTIONS

The descriptions of the pins are listed in Table 2-1.

TABLE 2-1: PIN FUNCTION TABLE

| Pin No. (5-Pin SOT-23) | Pin No. (5-Pin TO-220) | Symbol | Type | Description |
|------------------------------|---------------------------|-----------------|---------------|-------------------------------------|
| 1 | 1 | NC | None | No Internal Connection |
| 2 | 3 | GND | Power | System Ground |
| 3 | 5 | V _{DD} | Power | Power Supply Input |
| 4 | 4 | SCLK | Input | SMBus/I ² C Serial Clock |
| 5 | 2 | SDA | Bidirectional | SMBus/I ² C Serial Data |

2.1 Ground (GND)

Input. Ground return for all TC74 functions.

2.2 Power Supply Input (V_{DD})

Power supply input. See Electrical Specifications.

2.3 SMBus/I²C Serial Clock (SCLK)

Input. SMBus/I²C serial clock. Clocks data into and out of the TC74. See System Management Bus Specification, Rev. 1.0, for timing diagrams.

2.4 Serial Data (SDA)

Bidirectional. Serial data is transferred on the SMBus/I²C in both directions using this pin. See System Management Bus Specification, Rev. 1.0 for timing diagrams.

3.0 DETAILED DESCRIPTION

3.1 Functional Description

The TC74 acquires and converts temperature information from its onboard solid-state sensor with a resolution of $\pm 1^{\circ}\text{C}$. It stores the data in an internal register which is then read through the serial port. The system interface is a slave SMBus/I²C port, through which temperature data can be read at any time. Eight SMBus/I²C addresses are programmable for the TC74, which allows for a multi-sensor configuration. Also, there is low power Standby mode when temperature acquisition is suspended.

3.1.1 STANDBY MODE

The host is allowed, by the TC74, to put it into a low power ($I_{DD} = 5 \mu\text{A}$, typical) Standby mode. In this mode, the A/D converter is halted and the temperature data registers are frozen. The SMBus/I²C port, though, operates normally. Standby mode is enabled by setting the SHDN bit in the CONFIG register. Table 3-1 summarizes this operation.

TABLE 3-1: STANDBY MODE OPERATION

| SHDN Bit | Operating Mode |
|----------|----------------|
| 0 | Normal |
| 1 | Standby |

3.1.2 SMBUS/I²C SLAVE ADDRESS

The TC74 is internally programmed to have a default SMBus/I²C address value of 1001 101b. Seven other addresses are available by custom order (contact Microchip Technology Inc).

3.2 Serial Port Operation

The Serial Clock input (SCLK) and bidirectional data port (SDA) form a 2-wire bidirectional serial port for programming and interrogating the TC74. The conventions used in this bus architecture are listed in Table 3-2.

TABLE 3-2: SERIAL BUS CONVENTIONS

| Term | Explanation |
|-------------|---|
| Transmitter | The device sending data to the bus. |
| Receiver | The device receiving data from the bus. |
| Master | The device which controls the bus initiating transfers (START), generating the clock and terminating transfers (STOP). |
| Slave | The device addressed by the master. |
| START | A unique condition signaling the beginning of a transfer indicated by SDA falling (high-low) while SCLK is high. |
| STOP | A unique condition signaling the end of a transfer indicated by SDA rising (low-high) while SCLK is high. |
| ACK | A Receiver acknowledges the receipt of each byte with this unique condition. The Receiver drives SDA low during SCLK high of the ACK clock-pulse. The Master provides the clock pulse for the ACK cycle. |
| Busy | Communication is not possible because the bus is in use. |
| NOT Busy | When the bus is idle, both SDA and SCLK will remain high. |
| Data Valid | The state of SDA must remain stable during the high period of SCLK in order for a data bit to be considered valid. SDA only changes state while SCLK is low during normal data transfers (see START and STOP conditions). |

All transfers take place under the control of a host, usually a CPU or microcontroller, acting as the Master. This host provides the clock signal for all transfers. The TC74 always operates as a Slave. The serial protocol is illustrated in Figure 3-1. All data transfers have two phases and all bytes are transferred MSB first. Accesses are initiated by a START condition, followed by a device address byte and one or more data bytes. The device address byte includes a Read/Write selection bit. Each access must be terminated by a STOP condition. A convention called "Acknowledge" (ACK) confirms receipt of each byte. Note that SDA can change only during periods when SCLK is low (SDA changes while SCLK is high are reserved for START and STOP conditions).



FIGURE 3-1: SMBus/I²C Protocols.

3.3 START Condition (S)

The TC74 continuously monitors the SDA and SCLK lines for a START condition (a high-to-low transition of SDA while SCLK is high) and will not respond until this condition is met.

3.4 Address Byte

Immediately following the START condition, the host must transmit the address byte to the TC74. The states of A2, A1 and A0 determine the SMBus/I²C address for the TC74. The 7-bit address transmitted in the serial bit stream must match for the TC74 to respond with an Acknowledge (indicating the TC74 is on the bus and ready to accept data). The 8-bit in the address byte is a Read/Write bit. This bit is a '1' for a read operation or '0' for a write operation. During the first phase of any transfer, this bit will be set = 0, indicating that the command byte is being written.

3.5 Acknowledge (ACK)

Acknowledge (ACK) provides a positive handshake between the host and the TC74. The host releases SDA after transmitting 8 bits. The host then generates a ninth clock cycle to allow the TC74 to pull the SDA line low. This action acknowledges that the TC74 successfully received the previous 8 bits of data or address.

3.6 Data Byte

After a successful ACK of the address byte, the host must transmit the data byte to be written, or clock-in the data to be read (see the appropriate timing diagrams). ACK will be generated upon a successful write of a data byte into the TC74.

3.7 STOP Condition (P)

Communications must be terminated by a STOP condition (a low-to-high transition of SDA while SCLK is high). The STOP condition must be communicated by the transmitter to the TC74. Refer to Figure 1-1, "Timing Diagrams", for serial bus timing.

4.0 REGISTER SET AND PROGRAMMER'S MODEL

TABLE 4-1: COMMAND BYTE DESCRIPTION (SMBUS/I²C READ_BYTE AND WRITE_BYTE)

| Command | Code | Function |
|---------|------|-----------------------------------|
| RTR | 00h | Read Temperature (TEMP) |
| RWCR | 01h | Read/Write Configuration (CONFIG) |

TABLE 4-2: CONFIGURATION REGISTER (CONFIG); 8 BITS, READ/WRITE)

| Bit | POR | Function | Type | Operation |
|-----------|-----|--|------------|-------------------------|
| D[7] | 0 | STANDBY Switch | Read/Write | 1 = standby, 0 = normal |
| D[6] | 0 | Data Ready * | Read Only | 1 = ready 0 = not ready |
| D[5]-D[0] | 0 | Reserved - Always returns zero when read | N/A | N/A |

Note 1: *DATA_RDY bit RESET at power-up and SHDN enable.

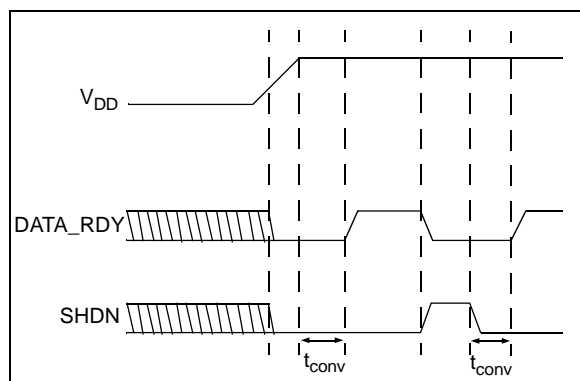


FIGURE 4-1: DATA_RDY, SHDN Operation Logic Diagram.

4.1 Temperature Register (TEMP), 8 Bits, READ ONLY

The binary value (2's complement format) in this register represents temperature of the onboard sensor following a conversion cycle. The registers are automatically updated in an alternating manner.

TABLE 4-3: TEMPERATURE REGISTER (TEMP)

| D[7] | D[6] | D[5] | D[4] | D[3] | D[2] | D[1] | D[0] |
|------|------|------|------|------|------|------|------|
| MSB | X | X | X | X | X | X | LSB |

In temperature data registers, each unit value represents one degree (Celsius). The value is in 2's complement binary format such that a reading of 0000 0000b corresponds to 0°C. Examples of this temperature to binary value relationship are shown in Table 4-4.

TABLE 4-4: TEMPERATURE-TO-DIGITAL VALUE CONVERSION (TEMP)

| Actual Temperature | Registered Temperature | Binary Hex |
|--------------------|------------------------|------------|
| +130.00°C | +127°C | 0111 1111 |
| +127.00°C | +127°C | 0111 1111 |
| +126.50°C | +126°C | 0111 1110 |
| +25.25°C | +25°C | 0001 1001 |
| +0.50°C | 0°C | 0000 0000 |
| +0.25°C | 0°C | 0000 0000 |
| 0.00°C | 0°C | 0000 0000 |
| -0.25°C | -1°C | 1111 1111 |
| -0.50°C | -1°C | 1111 1111 |
| -0.75°C | -1°C | 1111 1111 |
| -1.00°C | -1°C | 1111 1111 |
| -25.00°C | -25°C | 1110 0111 |
| -25.25°C | -26°C | 1110 0110 |
| -54.75°C | -55°C | 1100 1001 |
| -55.00°C | -55°C | 1100 1001 |
| -65.00°C | -65°C | 1011 1111 |

4.2 Register Set Summary

The TC74 register set is summarized in Table 4-5. All registers are 8 bits wide.

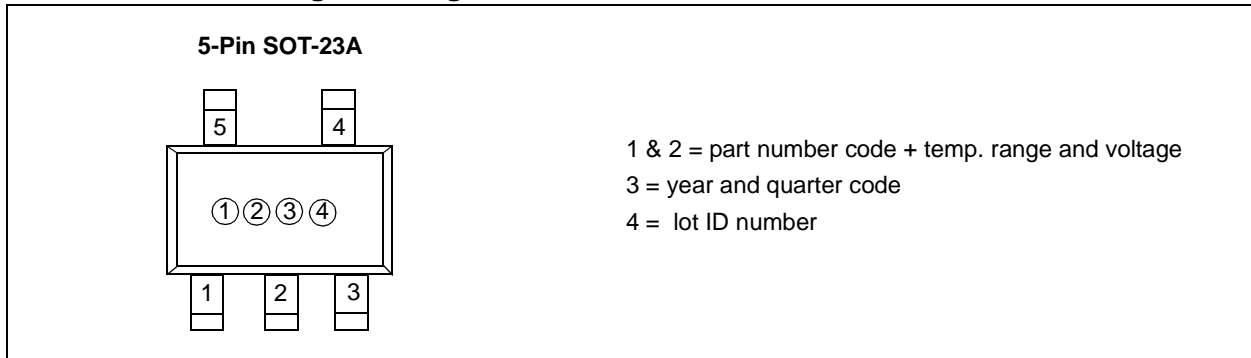
TABLE 4-5: TC74 REGISTER SET SUMMARY

| Name | Description | POR State | Read | Write |
|--------|--|---------------------------|------|-------|
| TEMP | Internal Sensor Temperature (2's Complement) | 0000 0000b ⁽¹⁾ | √ | N/A |
| CONFIG | CONFIG Register | 0000 0000b | √ | √ |

Note 1: The TEMP register will be immediately updated by the A/D converter after the DATA_RDY Bit goes high.

5.0 PACKAGING INFORMATION

5.1 SOT23A Package Marking Information



SOT-23 Package Marking Codes

| SOT-23 (V) | Address | Code | SOT-23 (V) | Address | Code |
|---------------|-----------|------|---------------|-----------|------|
| TC74A0-3.3VCT | 1001 000 | V0 | TC74A0-5.0VCT | 1001 000 | U0 |
| TC74A1-3.3VCT | 1001 001 | V1 | TC74A1-5.0VCT | 1001 001 | U1 |
| TC74A2-3.3VCT | 1001 010 | V2 | TC74A2-5.0VCT | 1001 010 | U2 |
| TC74A3-3.3VCT | 1001 011 | V3 | TC74A3-5.0VCT | 1001 011 | U3 |
| TC74A4-3.3VCT | 1001 100 | V4 | TC74A4-5.0VCT | 1001 100 | U4 |
| TC74A5-3.3VCT | 1001 101* | V5 | TC74A5-5.0VCT | 1001 101* | U5 |
| TC74A6-3.3VCT | 1001 110 | V6 | TC74A6-5.0VCT | 1001 110 | U6 |
| TC74A7-3.3VCT | 1001 111 | V7 | TC74A7-5.0VCT | 1001 111 | U7 |

Note: * Default Address

TO-220 Package Marking Information



5.2 Taping Forms

Component Taping Orientation for 5-Pin SOT-23A (EIAJ SC-74A) Devices



Standard Reel Component Orientation
for TR Suffix Device
(Mark Right Side Up)

Carrier Tape, Number of Components Per Reel and Reel Size:

| Package | Carrier Width (W) | Pitch (P) | Part Per Full Reel | Reel Size |
|---------------|-------------------|-----------|--------------------|-----------|
| 5-Pin SOT-23A | 8 mm | 4 mm | 3000 | 7 in. |

5.3 Package Dimensions

Note: For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>

SOT-23A-5



Dimensions: inches (mm)

Note: For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>

5-Pin TO-220



Dimensions: inches (mm)

6.0 REVISION HISTORY

Revision D (December 2012)

Added a note to each package outline drawing.

TC74

NOTES:

PRODUCT IDENTIFICATION SYSTEM

To order or obtain information, e.g., on pricing or delivery, refer to the factory or the listed sales office.

| <u>PART NO.</u> | <u>XX</u> | <u>-XX</u> | <u>X</u> | <u>XX</u> | Examples: |
|------------------------|--------------------------------------|----------------|-----------------------|-----------|--|
| Device | Address Options | Supply Voltage | Operating Temperature | Package | |
| Device: | TC74: Serial Digital Thermal Sensor | | | | a) TC74A0-3.3VCTTR: SOT-23 Serial Digital Thermal Sensor |
| Address Options: | A0 = 1001 000 | | | | b) TC74A1-3.3VCTTR: SOT-23 Serial Digital Thermal Sensor |
| | A1 = 1001 001 | | | | c) TC74A2-3.3VCTTR: SOT-23 Serial Digital Thermal Sensor |
| | A2 = 1001 010 | | | | d) TC74A3-3.3VCTTR: SOT-23 Serial Digital Thermal Sensor |
| | A3 = 1001 011 | | | | e) TC74A4-3.3VCTTR: SOT-23 Serial Digital Thermal Sensor |
| | A4 = 1001 100 | | | | f) TC74A5-3.3VCTTR: SOT-23 Serial Digital Thermal Sensor * |
| | A5 = 1001 101 * | | | | g) TC74A6-3.3VCTTR: SOT-23 Serial Digital Thermal Sensor |
| | A6 = 1001 110 | | | | h) TC74A7-3.3VCTTR: SOT-23 Serial Digital Thermal Sensor |
| | A7 = 1001 111 | | | | |
| | * Default Address | | | | a) TC74A0-5.0VCTTR: SOT-23 Serial Digital Thermal Sensor |
| Supply Voltage: | 3.3 = Accuracy optimized for 3.3V | | | | b) TC74A1-5.0VCTTR: SOT-23 Serial Digital Thermal Sensor |
| | 5.0 = Accuracy optimized for 5.0V | | | | c) TC74A2-5.0VCTTR: SOT-23 Serial Digital Thermal Sensor |
| Operating Temperature: | V = -40°C ≤ T _A ≤ +125°C | | | | d) TC74A3-5.0VCTTR: SOT-23 Serial Digital Thermal Sensor |
| Package: | CTTR = SOT-23-5 (Tape and Reel only) | | | | e) TC74A4-5.0VCTTR: SOT-23 Serial Digital Thermal Sensor |
| | | | | | f) TC74A5-5.0VCTTR: SOT-23 Serial Digital Thermal Sensor * |
| | | | | | g) TC74A6-5.0VCTTR: SOT-23 Serial Digital Thermal Sensor |
| | | | | | h) TC74A7-5.0VCTTR: SOT-23 Serial Digital Thermal Sensor |
| | | | | | * Default Address |

| <u>PART NO.</u> | <u>XX</u> | <u>-XX</u> | <u>X</u> | <u>XX</u> | Examples: |
|------------------------|-------------------------------------|----------------|-----------------------|-----------|--|
| Device | Address Options | Supply Voltage | Operating Temperature | Package | |
| Device: | TC74: Serial Digital Thermal Sensor | | | | a) TC74A0-3.3VAT: TO-220 Serial Digital Thermal Sensor |
| Address Options: | A0 = 1001 000 | | | | b) TC74A1-3.3VAT: TO-220 Serial Digital Thermal Sensor |
| | A1 = 1001 001 | | | | c) TC74A2-3.3VAT: TO-220 Serial Digital Thermal Sensor |
| | A2 = 1001 010 | | | | d) TC74A3-3.3VAT: TO-220 Serial Digital Thermal Sensor |
| | A3 = 1001 011 | | | | e) TC74A4-3.3VAT: TO-220 Serial Digital Thermal Sensor |
| | A4 = 1001 100 | | | | f) TC74A5-3.3VAT: TO-220 Serial Digital Thermal Sensor * |
| | A5 = 1001 101 * | | | | g) TC74A6-3.3VAT: TO-220 Serial Digital Thermal Sensor |
| | A6 = 1001 110 | | | | h) TC74A7-3.3VAT: TO-220 Serial Digital Thermal Sensor |
| | A7 = 1001 111 | | | | |
| | * Default Address | | | | a) TC74A0-5.0VAT: TO-220 Serial Digital Thermal Sensor |
| Output Voltage: | 3.3 = Accuracy optimized for 3.3V | | | | b) TC74A1-5.0VAT: TO-220 Serial Digital Thermal Sensor |
| | 5.0 = Accuracy optimized for 5.0V | | | | c) TC74A2-5.0VAT: TO-220 Serial Digital Thermal Sensor |
| Operating Temperature: | V = -40°C ≤ T _A ≤ +125°C | | | | d) TC74A3-5.0VAT: TO-220 Serial Digital Thermal Sensor |
| Package: | AT = TO-220-5 | | | | e) TC74A4-5.0VAT: TO-220 Serial Digital Thermal Sensor |
| | | | | | f) TC74A5-5.0VAT: TO-220 Serial Digital Thermal Sensor * |
| | | | | | g) TC74A6-5.0VAT: TO-220 Serial Digital Thermal Sensor |
| | | | | | h) TC74A7-5.0VAT: TO-220 Serial Digital Thermal Sensor |
| | | | | | * Default Address |

Sales and Support

Data Sheets

Products supported by a preliminary Data Sheet may have an errata sheet describing minor operational differences and recommended workarounds. To determine if an errata sheet exists for a particular device, please contact one of the following:

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2. The Microchip Worldwide Site (www.microchip.com)

Please specify which device, revision of silicon and Data Sheet (include Literature #) you are using.

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TC74

NOTES:

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