TC74

Tiny Serial Digital Thermal Sensor

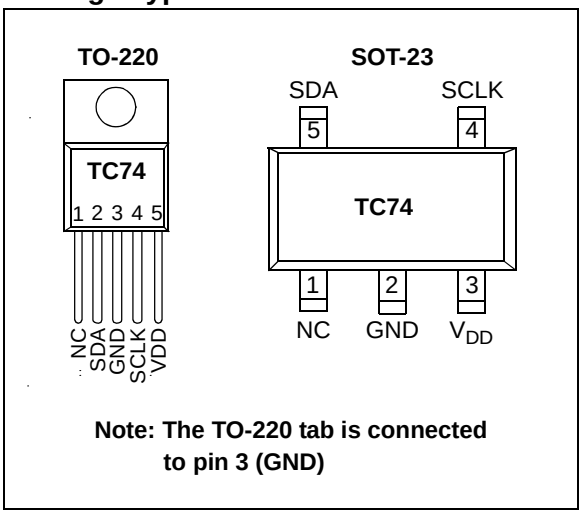
Features

- Digital Temperature Sensing in SOT-23-5 or TO-220 Packages
- Outputs Temperature as an 8-Bit Digital Word
- Simple SMBus/I^{2}C™ 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



Note: The TO-220 tab is connected to pin 3 (GND)

General Description

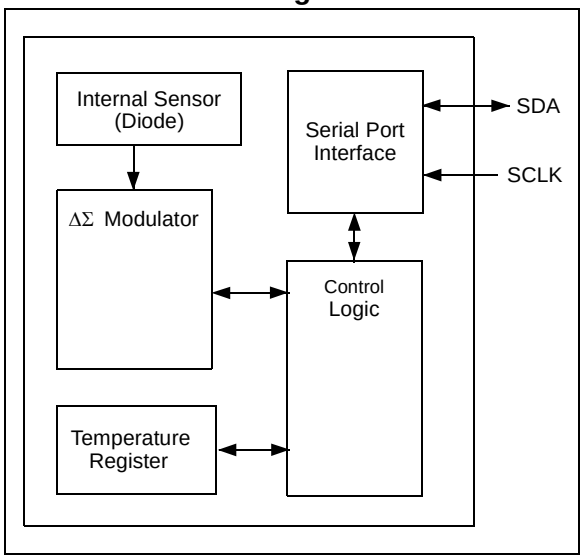
The TC74 is a serially accessible, digital temperature sensor particularly suited for low cost and small form-factor applications. Temperature data is converted from the onboard thermal sensing element and made available as an 8-bit digital word.

Communication with the TC74 is accomplished via a 2-wire SMBus/I^{2}C 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



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 x V_{DD}	—	—	V	
Logic Input Low	V_{IL}	—	—	0.2 x V_{DD}	V	
SDA Output Low	V_{OL}	— —	— —	0.4 0.6	V 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^2C 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^2C Rise Time SMBus/I^2C Fall Time	t_R t_F	— —	— —	1000 300	nsec nsec	10% to 90% 90% to10%

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°C ≤ T_A ≤ 125°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.

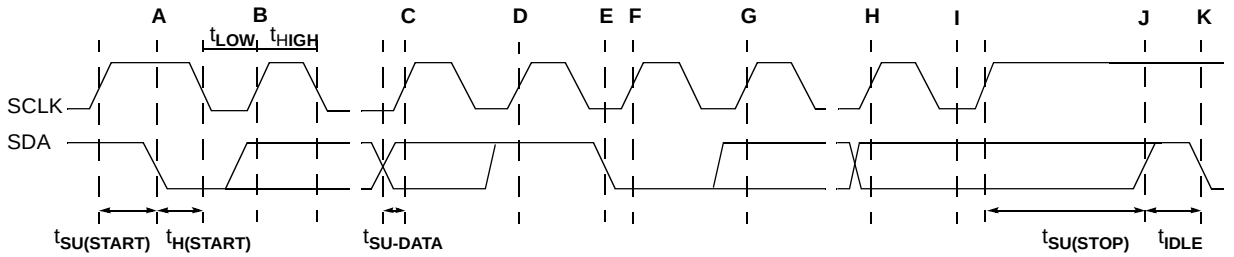
2: Maximum ensured conversion time after Power-on Reset (POR to DATA_RDY) is 250 msec.

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.

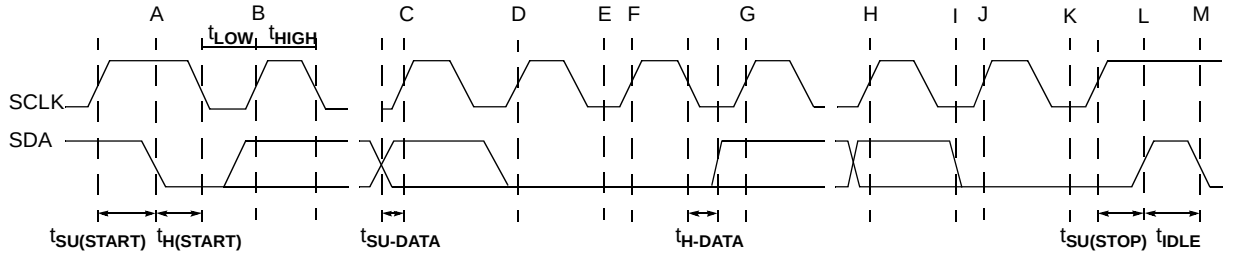
5: V_{DD} = 3.3V for TC74AX -3.3 VXX. V_{DD} = 5.0V for TC74AX -5.0 VXX. All part types of the TC74 will operate properly over the wider power supply range of 2.7V to 5.5V. Each part type is tested and specified for rated accuracy at its nominal supply voltage. As V_{DD} varies from the nominal value, accuracy will degrade 1°C/V of V_{DD} change.

SMBUS Read Timing Diagram



A = Start Condition
B = MSB of Address Clocked into Slave
C = LSB of Address Clocked into Slave
D = R/W Bit Clocked into Slave
E = Slave Pulls SDA Line Low
F = Acknowledge Bit Clocked into Master
G = MSB of Data Clocked into Master
H = LSB of Data Clocked into Master
I = Acknowledge Clock Pulse
J = Stop Condition
K = New Start Condition

SMBUS Write Timing Diagram



A = Start Condition
B = MSB of Address Clocked into Slave
C = LSB of Address Clocked into Slave
D = R/$\overline{W}$ Bit Clocked into Slave
E = Slave Pulls SDA Line Low
F = Acknowledge Bit Clocked into Master
G = MSB of Data Clocked into Slave
H = LSB of Data Clocked into Slave
I = Slave Pulls SDA Line Low
J = Acknowledge Clocked into Master
K = Acknowledge Clock Pulse
L = Stop Condition, Data Executed by Slave
M = New Start Condition

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^2C Serial Clock
5	2	SDA	Bidirectional	SMBus/I^2C 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/I^2C Serial Clock (SCLK)

Input. SMBus/I^2C 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/I^2C 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 ±1°C. It stores the data in an internal register which is then read through the serial port. The system interface is a slave SMBus/I^{2}C port, through which temperature data can be read at any time. Eight SMBus/I^{2}C 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 µA, typical) Standby mode. In this mode, the A/D converter is halted and the temperature data registers are frozen. The SMBus/I^{2}C 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/I^{2}C SLAVE ADDRESS

The TC74 is internally programmed to have a default SMBus/I^{2}C 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).

Write Byte Format

S	Address	WR	ACK	Command	ACK	Data	ACK	P
	7 Bits			8 Bits		8 Bits		

Slave Address

Command Byte: selects which register you are writing to.

Data Byte: data goes into the register set by the command byte.

Read Byte Format

S	Address	WR	ACK	Command	ACK	S	Address	RD	ACK	Data	NACK	P
	7 Bits			8 Bits			7 Bits			8 Bits		

Slave Address

Command Byte: selects which register you are reading from.

Slave Address: repeated due to change in data-flow direction.

Data Byte: reads from the register set by the command byte.

Receive Byte Format

S	Address	RD	ACK	Data	NACK	P
	7 Bits			8 Bits		

S = START Condition
P = STOP Condition
Shaded = Slave Transmission

Data Byte: reads data from the register commanded by the last Read Byte or Write Byte transmission.

FIGURE 3-1: SMBus/I^{2}C *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/I^{2}C 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.

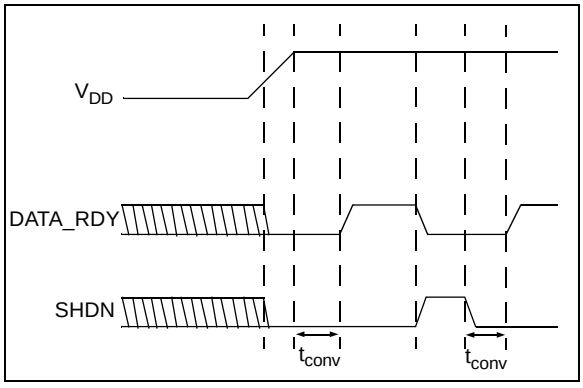


FIGURE 4-1: *DATA_RDY, SHDN Operation Logic Diagram.*

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

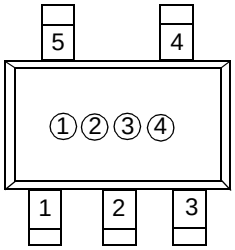
Name	Description	POR State	Read	Write
TEMP	Internal Sensor Temperature (2's Complement)	0000 0000b (1)	√	N/A
CONFIG	CONFIG Register	0000 0000b	√	√

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

5-Pin SOT-23A



1 & 2 = part number code + temp. range and voltage
3 = year and quarter code
4 = lot ID number

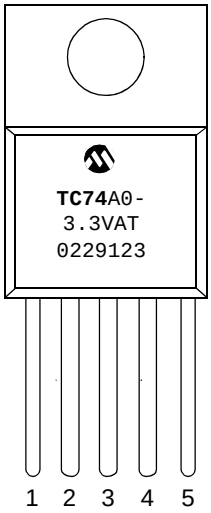
SOT-23 Package Marking Codes

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

TO-220



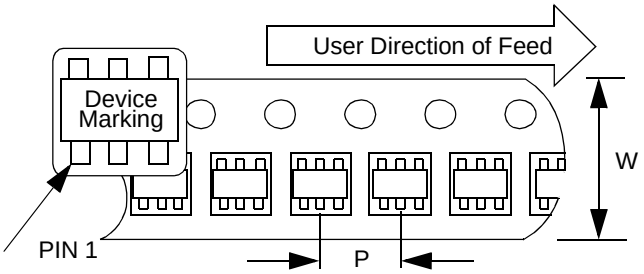
Legend:	XX...X	Customer specific information*
	YY	Year code (last 2 digits of calendar year)
	WW	Week code (week of January 1 is week '01')
	NNN	Alphanumeric traceability code

Note: In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line thus limiting the number of available characters for customer specific information.

***** Standard marking consists of Microchip part number, year code, week code, and traceability code.

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)

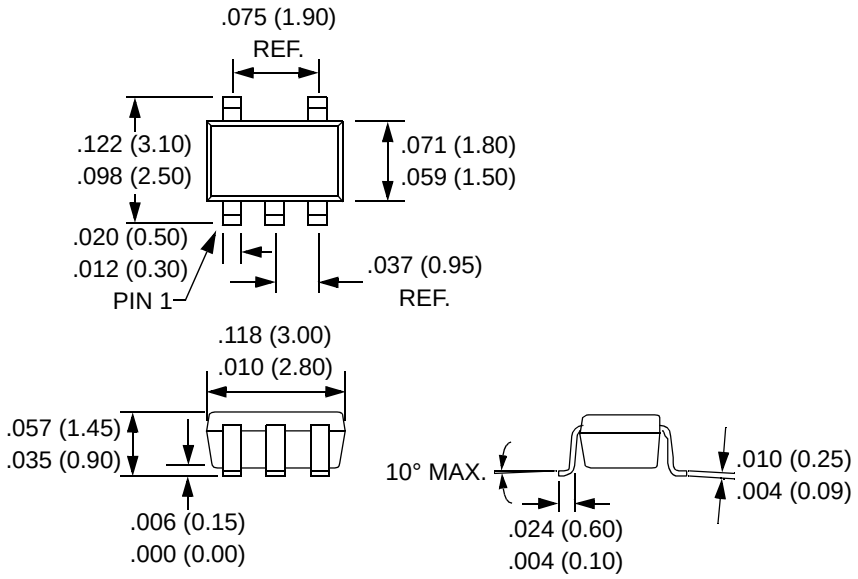
Carrier Tape, Number of Components Per Reel and Reel Size:

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

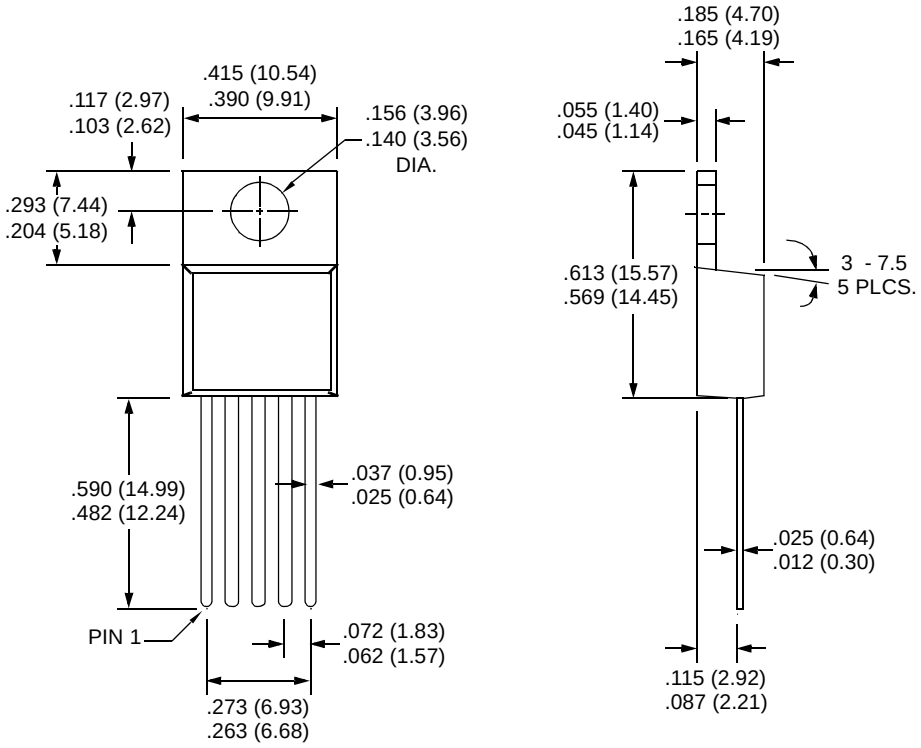
SOT-23A-5



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.

NOTES:

PRODUCT IDENTIFICATION SYSTEM

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

PART NO.	XX	-XX	X	XX
Device	Address Options	Supply Voltage	Operating Temperature	Package

Device:	TC74: Serial Digital Thermal Sensor
Address Options:	A0 = 1001 000 A1 = 1001 001 A2 = 1001 010 A3 = 1001 011 A4 = 1001 100 A5 = 1001 101 * A6 = 1001 110 A7 = 1001 111 * Default Address
Supply Voltage:	3.3 = Accuracy optimized for 3.3V 5.0 = Accuracy optimized for 5.0V
Operating Temperature:	V = -40°C ≤ T_A ≤ +125°C
Package:	CTTR = SOT-23-5 (Tape and Reel only)

Examples:

a) TC74A0-3.3VCTTR: SOT-23 Serial Digital Thermal Sensor
b) TC74A1-3.3VCTTR: SOT-23 Serial Digital Thermal Sensor
c) TC74A2-3.3VCTTR: SOT-23 Serial Digital Thermal Sensor
d) TC74A3-3.3VCTTR: SOT-23 Serial Digital Thermal Sensor
e) TC74A4-3.3VCTTR: SOT-23 Serial Digital Thermal Sensor
f) TC74A5-3.3VCTTR: SOT-23 Serial Digital Thermal Sensor *
g) TC74A6-3.3VCTTR: SOT-23 Serial Digital Thermal Sensor
h) TC74A7-3.3VCTTR: SOT-23 Serial Digital Thermal Sensor

a) TC74A0-5.0VCTTR: SOT-23 Serial Digital Thermal Sensor
b) TC74A1-5.0VCTTR: SOT-23 Serial Digital Thermal Sensor
c) TC74A2-5.0VCTTR: SOT-23 Serial Digital Thermal Sensor
d) TC74A3-5.0VCTTR: SOT-23 Serial Digital Thermal Sensor
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

PART NO.	XX	-XX	X	XX
Device	Address Options	Supply Voltage	Operating Temperature	Package

Device:	TC74: Serial Digital Thermal Sensor
Address Options:	A0 = 1001 000 A1 = 1001 001 A2 = 1001 010 A3 = 1001 011 A4 = 1001 100 A5 = 1001 101 * A6 = 1001 110 A7 = 1001 111 * Default Address
Output Voltage:	3.3 = Accuracy optimized for 3.3V 5.0 = Accuracy optimized for 5.0V
Operating Temperature:	V = -40°C ≤ T_A ≤ +125°C
Package:	AT = TO-220-5

Examples:

a) TC74A0-3.3VAT: TO-220 Serial Digital Thermal Sensor
b) TC74A1-3.3VAT: TO-220 Serial Digital Thermal Sensor
c) TC74A2-3.3VAT: TO-220 Serial Digital Thermal Sensor
d) TC74A3-3.3VAT: TO-220 Serial Digital Thermal Sensor
e) TC74A4-3.3VAT: TO-220 Serial Digital Thermal Sensor
f) TC74A5-3.3VAT: TO-220 Serial Digital Thermal Sensor *
g) TC74A6-3.3VAT: TO-220 Serial Digital Thermal Sensor
h) TC74A7-3.3VAT: TO-220 Serial Digital Thermal Sensor

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