

TINY SERIAL DIGITAL THERMAL SENSOR

FEATURES

- Digital Temperature Sensing in SOT-23-5 Package
- Outputs Temperature as an 8-Bit Digital Word
- Simple Serial Port Interface
- Solid State Temperature Sensing $\pm 2^{\circ}\text{C}$ Accuracy from $+25^{\circ}\text{C}$ to $+85^{\circ}\text{C}$
..... $\pm 3^{\circ}\text{C}$ Accuracy from 0°C to $+125^{\circ}\text{C}$
- 3.0, and 5.5V Operating Range
- Low Power 200 μA Operating
5 μA Standby Mode

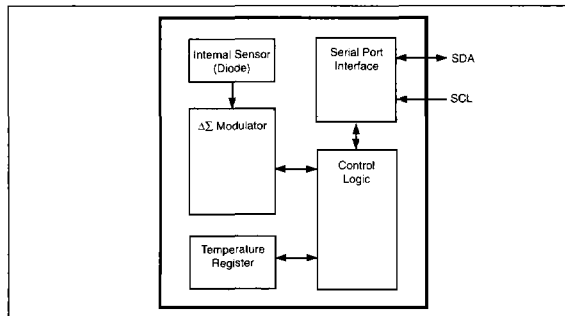
TYPICAL APPLICATIONS

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

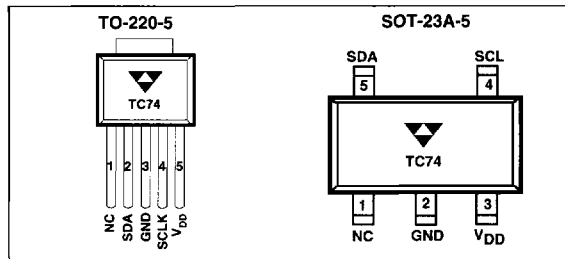
GENERAL DESCRIPTION

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 on-board thermal sensing element and made available as an 8-bit digital word.

FUNCTIONAL BLOCK DIAGRAM



PIN CONFIGURATION



Communication with the TC74 is accomplished via a simple 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. Power consumption is only 200 μA (5 μA Standby).

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

ORDERING INFORMATION

Part No.	Package	Address	Temp. Range
TC74A0-3.3VCT	SOT-23A-5	1001 000	-40°C to $+125^{\circ}\text{C}$
TC74A1-3.3VCT	SOT-23A-5	1001 001	-40°C to $+125^{\circ}\text{C}$
TC74A2-3.3VCT	SOT-23A-5	1001 010	-40°C to $+125^{\circ}\text{C}$
TC74A3-3.3VCT	SOT-23A-5	1001 011	-40°C to $+125^{\circ}\text{C}$
TC74A4-3.3VCT	SOT-23A-5	1001 100	-40°C to $+125^{\circ}\text{C}$
TC74A5-3.3VCT*	SOT-23A-5	1001 101	-40°C to $+125^{\circ}\text{C}$
TC74A6-3.3VCT	SOT-23A-5	1001 110	-40°C to $+125^{\circ}\text{C}$
TC74A7-3.3VCT	SOT-23A-5	1001 111	-40°C to $+125^{\circ}\text{C}$
TC74A0-5.0VCT	SOT-23A-5	1001 000	-40°C to $+125^{\circ}\text{C}$
TC74A1-5.0VCT	SOT-23A-5	1001 001	-40°C to $+125^{\circ}\text{C}$
TC74A2-5.0VCT	SOT-23A-5	1001 010	-40°C to $+125^{\circ}\text{C}$
TC74A3-5.0VCT	SOT-23A-5	1001 011	-40°C to $+125^{\circ}\text{C}$
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TC74A5-5.0VCT*	SOT-23A-5	1001 101	-40°C to $+125^{\circ}\text{C}$
TC74A6-5.0VCT	SOT-23A-5	1001 110	-40°C to $+125^{\circ}\text{C}$
TC74A7-5.0VCT	SOT-23A-5	1001 111	-40°C to $+125^{\circ}\text{C}$
TC74A0-3.3VAT	TO-220-5	1001 000	-40°C to $+125^{\circ}\text{C}$
TC74A1-3.3VAT	TO-220-5	1001 001	-40°C to $+125^{\circ}\text{C}$
TC74A2-3.3VAT	TO-220-5	1001 010	-40°C to $+125^{\circ}\text{C}$
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TC74A0-5.0VAT	TO-220-5	1001 000	-40°C to $+125^{\circ}\text{C}$
TC74A1-5.0VAT	TO-220-5	1001 001	-40°C to $+125^{\circ}\text{C}$
TC74A2-5.0VAT	TO-220-5	1001 010	-40°C to $+125^{\circ}\text{C}$
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TC74A7-5.0VAT	TO-220-5	1001 111	-40°C to $+125^{\circ}\text{C}$

*Default address.

TC74-4 3/25/99

TC74

ABSOLUTE MAXIMUM RATINGS*

Supply Voltage (V_{DD})	+6V
Voltage On Any Pin	(GND – 0.3V) to (V_{DD} + 0.3V)
Operating Temperature (T_A)	See Below
Storage Temperature (T_{STG})	– 65°C to +150°C
Current On Any Pin	±50 mA
Package Thermal Resistance (θ_{JA})	330°C/W

*Static-sensitive device. Unused devices must be stored in conductive material. Protect devices from static discharge and static fields. Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any other conditions above those indicated in the operational sections of the specifications is not implied. Exposure to Absolute Maximum Rating Conditions for extended periods may affect device reliability.

ELECTRICAL CHARACTERISTICS: $V_{DD} = 3.3V$ or $5.0V$ (Note 5), $-40^\circ C \leq T_A \leq 125^\circ C$, unless otherwise noted.

Symbol	Parameter	Test Conditions	Min	Typ	Max	Unit
Power Supply						
V_{POR}	Power-On Reset Threshold	V_{DD} Falling Edge or Rising Edge	1.2	—	2.2	V
I_{DD}	Operating Current	$V_{DD} = 5.5V$ Serial Port Inactive (Note 1)	—	200	350	μA
$I_{DD-STANDBY}$	Standby Supply Current	$V_{DD} = 3.3V$ Serial Port Inactive (Note 4)	—	5	10	μA
Temperature-to-Bits Converter						
T_{ERR}	Temperature Accuracy TC74A	+25°C < T_A < +85°C 0°C < T_A < +125°C –40°C < T_A < 0°C	–2 –3 —	— — ±2	+2 +3 —	°C °C °C
CR	Conversion Rate	(Note 2)	4	8	—	Sa/Sec
Serial Port Interface						
V_{IH}	Logic Input High		$0.8 \times V_{DD}$	—	—	V
V_{IL}	Logic Input Low		—	—	$0.2 \times V_{DD}$	V
V_{OL}	SDA Output Low	$I_{OL} = 3\text{ mA}$ $I_{OL} = 6\text{ mA}$ (Note 3)	— —	— —	0.4 0.6	V V
C_{IN}	Input Capacitance SDA, SCL		—	5	—	pF
I_{LEAK}	I/O Leakage		–1	0.1	1	μA

- NOTES:**
- Operating current is an average value integrated over multiple conversion cycles. Transient current may exceed this specification.
 - Maximum guaranteed conversion time after Power-On RESET (POR to DATA_RDY) is 250 msec.
 - Output current should be minimized for best temperature accuracy. Power dissipation within the TC74 will cause self-heating and temperature drift error.
 - SDA and SCL must be connected to V_{DD} or GND.
 - $V_{DD} = 3.3V$ for TC74x -3.3VCT, $V_{DD} = 5.0V$ for TC74x -5.0VCT. 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.

SERIAL PORT AC TIMING: $V_{DD} = 3.3V$ or $5.0V$ (Note 5), $-40^\circ C \leq (T_A = T_J) \leq 125^\circ C$; $C_L = 80\text{ pF}$, unless otherwise noted.)

Symbol	Parameter	Test Conditions	Min	Typ	Max	Unit
f_{SMB}	SMBus Clock Frequency		10	—	100	KHz
t_{LOW}	Low Clock Period	10% to 10%	4.7	—	—	μsec
t_{HIGH}	High Clock Period	90% to 90%	4	—	—	μsec
t_R	SMBus Rise Time	10% to 90%	—	—	1000	nsec
t_F	SMBus Fall Time	90% to 10%	—	—	300	nsec
$t_{SU(START)}$	Start Condition Setup Time (for repeated Start Condition)	90% SCL to 10% SDA	4	—	—	μsec
$t_{H(START)}$	Start Condition Hold Time		4	—	—	μsec
$t_{SU-DATA}$	Data In Setup Time		1000	—	—	nsec

SERIAL PORT AC TIMING: ($V_{DD} = 3.3V$ or $5.0V$ (Note 5), $-40^{\circ}C \leq (T_A = T_J) \leq 125^{\circ}C$; $C_L = 80$ pF, unless otherwise noted.)

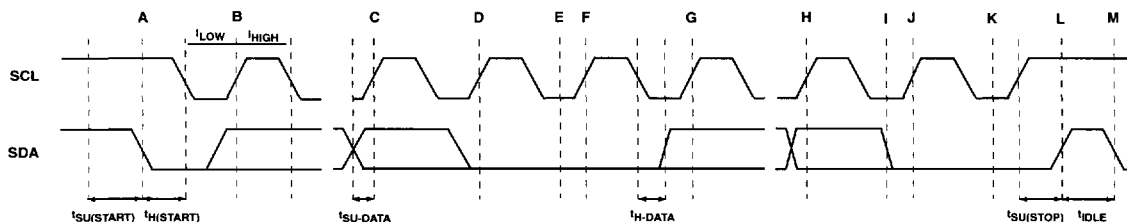
Symbol	Parameter	Test Conditions	Min	Typ	Max	Unit
t_{H-DATA}	Data In Hold Time		1250	—	—	nsec
$t_{SU(STOP)}$	Stop Condition Setup Time		4	—	—	μ sec
t_{IDLE}	Bus Free Time Prior to New Transition		4.7	—	—	μ sec
t_{POR}	Power-On Reset Delay	$V_{DD} \geq V_{POR}$ (Rising Edge)	—	500	—	μ sec

PIN DESCRIPTION

Pin No.	Symbol	Type	Description
1	NC	None	Not Connected
2	GND	Power	System Ground
3	V_{DD}	Power	Power Supply Input
4	SCL	Input	SMBus Serial Clock
5	SDA	Bi-Directional	SMBus Serial Data

TIMING DIAGRAMS

SMBUS Write 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 Slave

H = LSB of Data Clocked into Slave

I = Slave Pulls SDA Line Low

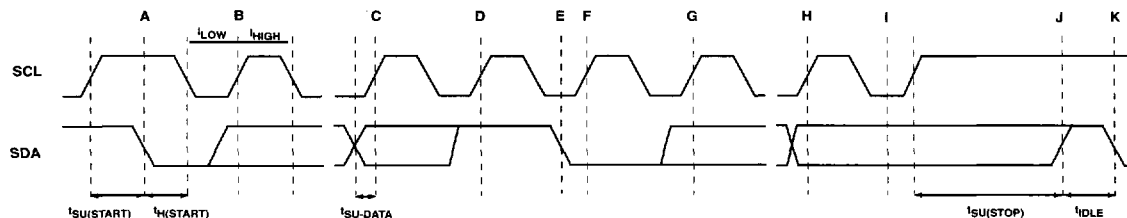
J = Acknowledge Clocked into Master

K = Acknowledge Clock Pulse

L = Stop Condition, Data Executed by Slave

M = New Start Condition

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

TC74

DETAILED DESCRIPTION

SCL

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

SDA

Bi-directional. Serial data is transferred on the SMBus in both directions using this pin. See System Management Bus Specification rev. 1.0 for timing diagrams.

V_{DD}

Input. Power supply input. See electrical specifications.

GND

Input. Ground return for all TC74 functions.

FUNCTIONAL DESCRIPTION

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

Standby Mode

The TC74 allows the host 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 port operates normally. Standby mode is enabled by setting the SHDN bit in the CONFIG register. The table below summarizes this operation.

Standby Mode Operation

SHDN Bit	Operating Mode
0	Normal
1	Standby

SMBus Slave Address

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

SERIAL PORT OPERATION

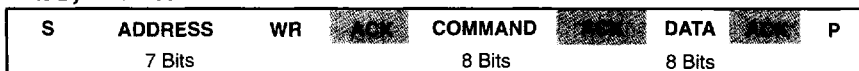
The Serial Clock input (SCL) and bi-directional data port (SDA) form a 2-wire bi-directional serial port for programming and interrogating the TC74. The following conventions are used in this bus architecture:

TC74 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 SCL is high.
Stop	A unique condition signaling the end of a transfer indicated by SDA rising (Low –High) while SCL is high.
ACK	A Receiver acknowledges the receipt of each byte with this unique condition. The Receiver drives SDA low during SCL 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 SCL will remain high.
Data Valid	The state of SDA must remain stable during the High period of SCL in order for a data bit to be considered valid. SDA only changes state while SCL is low during normal data transfers. (See Start and Stop conditions.)

All transfers take place under control of a host, usually a CPU or microcontroller, acting as the Master, which provides the clock signal for all transfers. The TC74 *always* operates as a Slave. The serial protocol is illustrated in Figure 1. All data transfers have two phases; all bytes are transferred MSB first. Accesses are initiated by a start condition (START), 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 (STOP). A convention called *Acknowledge* (ACK) confirms receipt of each byte. Note that SDA can change only during periods when SCL is LOW (SDA changes while SCL is HIGH are reserved for Start and Stop Conditions).

Write Byte Format

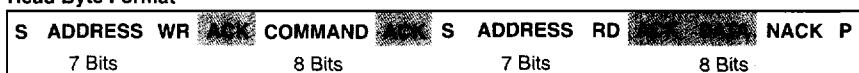


Slave Address

Command Byte: selects which register you are writing to.

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

Read Byte Format



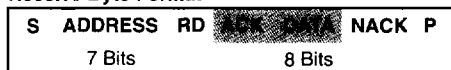
Slave Address

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



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

S = Start Condition

P = Stop Condition

Shaded = Slave Transmission

Figure 1. SMBus Protocols

TC74

Start Condition (START)

The TC74 continuously monitors the SDA and SCL lines for a start condition (a HIGH to LOW transition of SDA while SCL is HIGH), and will not respond until this condition is met.

Address Byte

Immediately following the Start Condition, the host must transmit the address byte to the TC74. The states of A1 and A0 determine the 7-bit SMBus 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 eighth 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 to indicate that the command byte is being written.

Acknowledge (ACK)

Acknowledge (ACK) provides a positive handshake between the host and the TC74. The host releases SDA after transmitting eight bits, then generates a ninth clock cycle to allow the TC74 to pull the SDA line LOW to acknowledge that it successfully received the previous eight bits of data or address.

Data Byte

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

Stop Condition (STOP)

Communications must be terminated by a stop condition (a LOW to HIGH transition of SDA while SCL is HIGH). The Stop Condition must be communicated by the transmitter to the TC74. NOTE: Refer to Timing Diagrams for serial bus timing.

REGISTER SET AND PROGRAMMER'S MODEL

TC74 Command Set

(SMBus READ_BYTE and WRITE_BYTE)

COMMAND BYTE DESCRIPTION

COMMAND	CODE	FUNCTION
RTR	00h	Read Temperature (TEMP)
RWCR	01h	Read/Write Configuration (CONFIG)

Configuration Register (CONFIG), 8-BITS, READ/WRITE

CONFIGURATION REGISTER (CONFIG)							
D[7]	D[6]	D[5]	D[4]	D[3]	D[2]	D[1]	D[0]
SHDN	DATA_RDY	RESERVED					

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

*DATA_RDY bit reset at power-up and SHDN enable (see below).

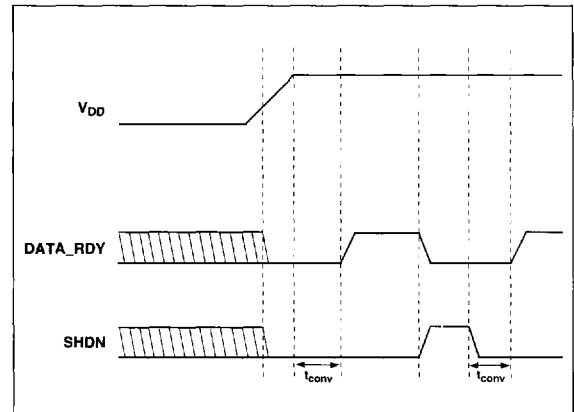


Figure 2. DATA_RDY, SHDN Operation Logic Diagram

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

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

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

TINY SERIAL DIGITAL
THERMAL SENSOR

TC74

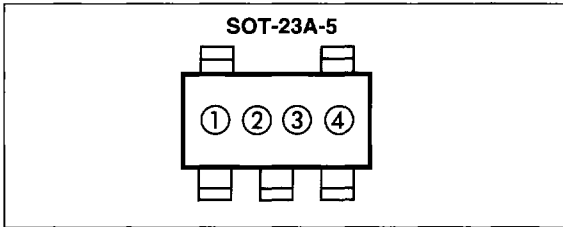
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In the temperature data registers, each unit value represents one degree (Celsius). The value is in 2's-complement binary format such that a reading of 0000 0000b corresponds to 0°C. Examples of this temperature to binary value relationship are shown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

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	+127°C	0111 1111
+25.25°C	+25°C	0001 1001
+0.50°C	+1°C	0000 0001
+0.25°C	0°C	0000 0000
0.00°C	0°C	0000 0000
-0.25°C	0°C	0000 0000
-0.50°C	0°C	0000 0000
-0.75°C	-1°C	1111 1111
-1.00°C	-1°C	1111 1111
-25.00°C	-25°C	1110 0111
-25.25°C	-25°C	1110 0110
-54.75°C	-55°C	1100 1001
-55.00°C	-55°C	1100 1001
-65.00°C	-65°C	1011 1111

MARKINGS



- ① & ② = part number code + temperature range and voltage
- ③ represents year and quarter code
- ④ represents lot ID number

Register Set Summary

The TC74's register set is summarized below. All registers are 8-bits wide.

NAME	DESCRIPTION	POR State	READ	WRITE
TEMP	Internal Sensor Temperature (2's Complement)	0000 0000b*	✓	
CONFIG	CONFIG Register	0000 0000b	✓	✓

*NOTE: The TEMP register will be immediately updated by the A/D converter after the DATA_RDY bit goes high.

TC74 (V)	Code
TC74A0-3.3VCT	V0
TC74A1-3.3VCT	V1
TC74A2-3.3VCT	V2
TC74A3-3.3VCT	V3
TC74A4-3.3VCT	V4
TC74A5-3.3VCT	V5
TC74A6-3.3VCT	V6
TC74A7-3.3VCT	V7
TC74A0-5.0VCT	U0
TC74A1-5.0VCT	U1
TC74A2-5.0VCT	U2
TC74A3-5.0VCT	U3
TC74A4-5.0VCT	U4
TC74A5-5.0VCT	U5
TC74A6-5.0VCT	U6
TC74A7-5.0VCT	U7