November 2004

National Semiconductor

LM74A
SPI/MICROWIRE™ 12-Bit Plus Sign Temperature Sensor (LM74 in Die Form)

General Description

The LM74A is a temperature sensor, Delta-Sigma analog-to-digital converter with an SPI and MICROWIRE compatible interface in die form. The host can query the LM74A at any time to read temperature. A shutdown mode decreases power consumption to less than 10 µA. This mode is useful in systems where low average power consumption is critical.

This particular data sheet applies to the LM74 in die form. The LM74 is available in the SO-8 package as well as an 5-Bump micro SMD package please refer to LM74 data sheet for detailed specifictions pertaining to the packaged parts.

The LM74A has 12-bit plus sign temperature resolution (0.0625˚C per LSB) while operating over a temperature range of –40˚C to +150˚C. The LM74A-5 MDA accuracy of ±3.5˚C is specified over a temperature range of 0˚C to +150˚C.

The LM74A's 4.5V to 5.5V or 3.0V to 3.6V supply voltage range, low supply current and simple SPI interface make it ideal for a wide range of applications. These include thermal management and protection applications in hard disk drives, printers, electronic test equipment, and office electronics.

Applications

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

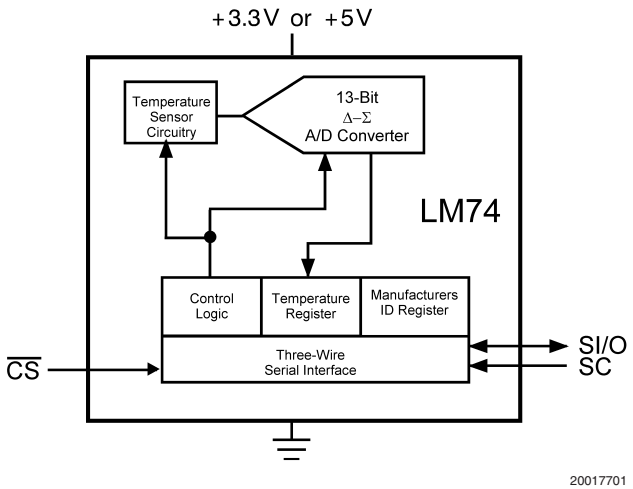
Features

- 0.0625˚C temperature resolution.
- Shutdown mode conserves power between temperature reading
- SPI and MICROWIRE Bus interface
- LM74 is also available in a 5-Bump micro SMD and 8-pin MSOP

Key Specifications

■ Supply Voltage	LM74A-5		4.5V to 5.5V
	LM74A-3		3.0V to 3.6V
■ Supply Current		operating	310µA (typ)
			520µA (max)
		shutdown	8µA (typ)
■ LM74A-5 MDA Temperature Accuracy		0˚C to 140˚C	±3.0˚C(max)
		140˚C to 150˚C	±3.5˚C(max)

Simplified Block Diagram



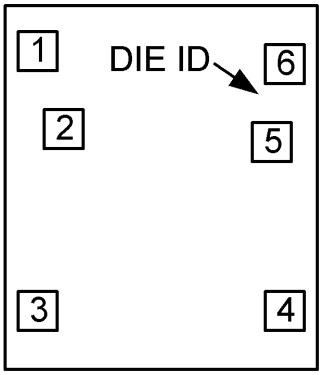
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TRI-STATE® is a registered trademark of National Semiconductor Corporation.

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Connection Diagram

LM74A
Bond Pad Layout



20017727

TOP VIEW
1.40mm x 1.57 mm (55 x 62 mils)

Bond Pad Mechanical Dimensions

Dimensions of bond pad coordinates are in millimeters.
Origin of coordinates: center of die.
X-Direction is in the longitudinal axis of the die.
Coordinates refer to center of Bond Pad.

Pin#	X	Y
1	-0.569 mm	+0.585 mm
2	-0.537 mm	+0.314 mm
3	-0.569 mm	-0.554 mm
4	n/a	n/a
5	+0.537 mm	+0.277 mm
6	+0.569 mm	+0.569 mm
Back		

Ordering Information

Order Number	NS Package Number	Supply Voltage	Transport Media
LM74A-5 MDA	No Package, Die	4.5V to 5.5V	7k unit surftape tape-and-reel
LM74A-3 MDA	No Package, Die	3.0V to 3.6V	7k unit surftape tape-and-reel

Pin Descriptions

Label	Pin #	Function	Typical Connection
SI/O	1	Slave Input/Output - Serial bus bi-directional data line. Shmitt trigger input.	From and to Controller
SC	2	Slave Clock - Serial bus clock Shmitt trigger input line.	From Controller
GND	3	Power Supply Ground	Ground
NC	4	No Connection	No Connection
$\overline{CS}$	5	Chip Select input.	From Controller
V^+	6	Positive Supply Voltage Input	DC Voltage from 4.5V to 5.5V for the LM74A-5 and 3.0V to 3.6V for the LM74A-3. Bypass with a 0.1 µF ceramic capacitor.
Back	(Backside)		Can go to GND connection

Typical Application

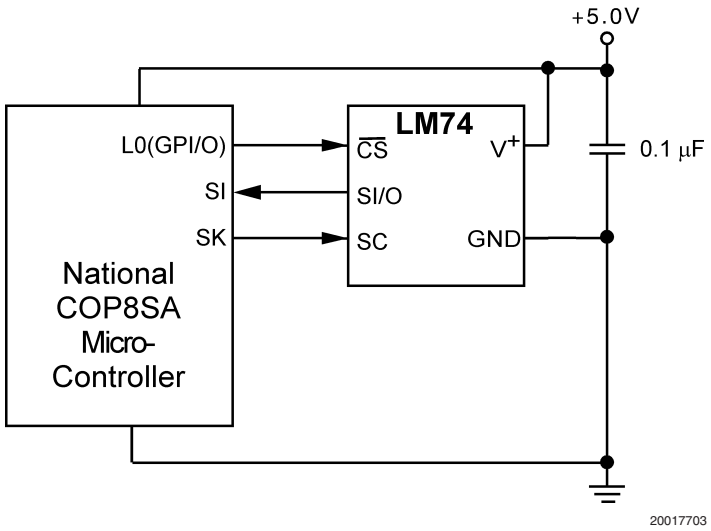


FIGURE 1. COP Microcontroller Interface

Absolute Maximum Ratings (Note 1)

Supply Voltage	−0.3V to 6.0V
Voltage at any Pin	−0.3V to V^+ + 0.3V
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 3)	
Human Body Mode	2000V
Machine Model	200V

Operating Ratings

Operating Temperature Range	−40˚C to +150˚C
Specified Temperature Range	T_{MIN} to T_{MAX}
(Note 4)	
LM74A	-40˚C to +150˚C
Supply Voltage Range ($+V_S$)	
LM74-5 MDA	+4.5V to +5.5V
LM74-3 MDA	+3.0V to +3.6V

Temperature-to-Digital Converter Characteristics

Unless otherwise noted, these specifications apply for V^+ = 4.5V to 5.5V for the LM74-5 MDA and V^+ = 3.0V to 3.6V for the LM74-3 MDA.(Note 5). **Boldface limits apply for $T_A = T_J = T_{MIN}$ to T_{MAX};** all other limits $T_A = T_J$=+25˚C, unless otherwise noted.

Parameter	Conditions	Typical (Note 6)	LM74-5 MDA Limits (Note 7)	LM74-3 MDA Limits (Note 7)	Units (Limit)
Temperature Error (Note 5)	T_A = 0˚C to +140˚C		**±3.0**		˚C (max)
	T_A = +140˚C to +150˚C		**±3.5**		˚C (max)
	T_A = -40˚C to +150˚C			**±5**	˚C (max)
Resolution		13			Bits
Temperature Conversion Time	(Note 8)	280	**425**		ms (max)
Quiescent Current	Serial Bus Inactive	310	**520**		µA (max)
	Serial Bus Active	310			µA
	Shutdown Mode, V^+ = 5V	8			µA

Logic Electrical Characteristics

DIGITAL DC CHARACTERISTICS Unless otherwise noted, these specifications apply for V^+ = 4.5V to 5.5V for the LM74-5 MDA and V^+ = 3.0V to 3.6V for the LM74-3 MDA.(Note 5). **Boldface limits apply for $T_A = T_J = T_{MIN}$ to T_{MAX};** all other limits $T_A = T_J$=+25˚C, unless otherwise noted.

Symbol	Parameter	Conditions	Typical (Note 6)	Limits (Note 7)	Units (Limit)
$V_{IN(1)}$	Logical “1” Input Voltage			**V^+ x 0.7** **V^+ + 0.3**	V (min) V (max)
$V_{IN(0)}$	Logical “0” Input Voltage			**−0.3** **V^+ x 0.3**	V (min) V (max)
	Input Hysteresis Voltage	V^+ = 4.5V to 5.5V	0.8	**0.33**	V (min)
$I_{IN(1)}$	Logical “1” Input Current	$V_{IN} = V^+$	0.005	**3.0**	µA (max)
$I_{IN(0)}$	Logical “0” Input Current	V_{IN} = 0V	−0.005	**−3.0**	µA (min)
C_{IN}	All Digital Inputs		20		pF
V_{OH}	High Level Output Voltage	I_{OH} = −400 µA		**V^+ x 0.7**	V (min)
V_{OL}	Low Level Output Voltage	I_{OL} = +2 mA		**0.4**	V (max)
$I_{O_TRI\text{-}STATE}$	TRI-STATE Output Leakage Current	V_O = GND $V_O = V^+$		**−1** **+1**	µA (min) µA (max)

Serial Bus Digital Switching Characteristics

Unless otherwise noted, these specifications apply for V^+ = 4.5V to 5.5V for the LM74-5 MDA and V^+ = 3.0V to 3.6V for the LM74-3 MDA.(Note 5). **Boldface limits apply for $T_A = T_J = T_{MIN}$ to T_{MAX};** all other limits $T_A = T_J$=+25˚C, unless otherwise noted.

Symbol	Parameter	Conditions	Typical (Note 6)	Limits (Note 7)	Units (Limit)
t_1	SC (Clock) Period			**0.16** DC	µs (min) (max)
t_2	$\overline{CS}$ Low to SC (Clock) High Set-Up Time			**100**	ns (min)
t_3	$\overline{CS}$ Low to Data Out (SO) Delay			**70**	ns (max)
t_4	SC (Clock) Low to Data Out (SO) Delay			**100**	ns (max)
t_5	$\overline{CS}$ High to Data Out (SO) TRI-STATE			**200**	ns (max)
t_6	SC (Clock) High to Data In (SI) Hold Time			**50**	ns (min)
t_7	Data In (SI) Set-Up Time to SC (Clock) High			**30**	ns (min)

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

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

Note 3: Human body model, 100 pF discharged through a 1.5 kΩ resistor. Machine model, 200 pF discharged directly into each pin.

Note 4: The life expectancy of the LM74A will be reduced when operating at elevated temperatures.

Note 5: All LM74A parts will function over the V^+ supply voltage range of 3V to 5.5V. The LM74A temperature error specifications for temperature ranges of 0˚C to +140˚C, 0˚C to +150˚C and –40˚C to +150˚C include error induced by power supply variation of ±10% from the nominal value of 5V or 3.3V.

Note 6: Typicals are at T_A = 25˚C and represent most likely parametric norm.

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

Note 8: This specification is provided only to indicate how often temperature data is updated. The LM74A can be read at any time without regard to conversion state (and will yield last conversion result). A conversion in progress will not be interrupted. The output shift register will be updated at the completion of the read and a new conversion restarted.

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.

Timing Diagrams

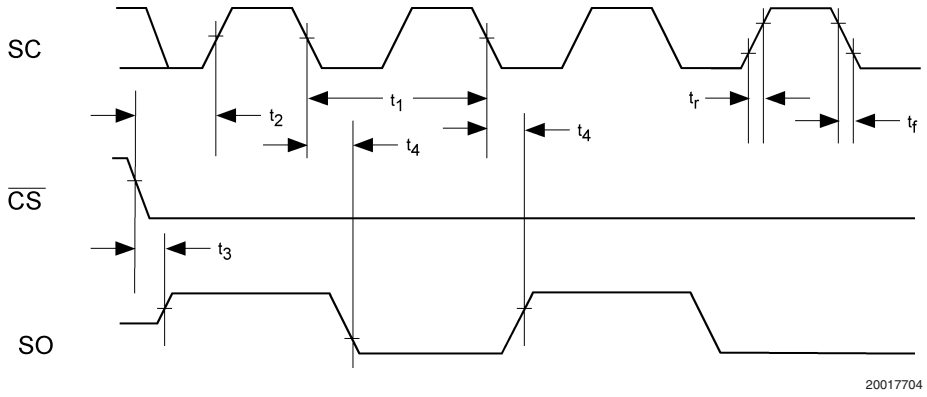


FIGURE 2. Data Output Timing Diagram

Timing Diagrams (Continued)

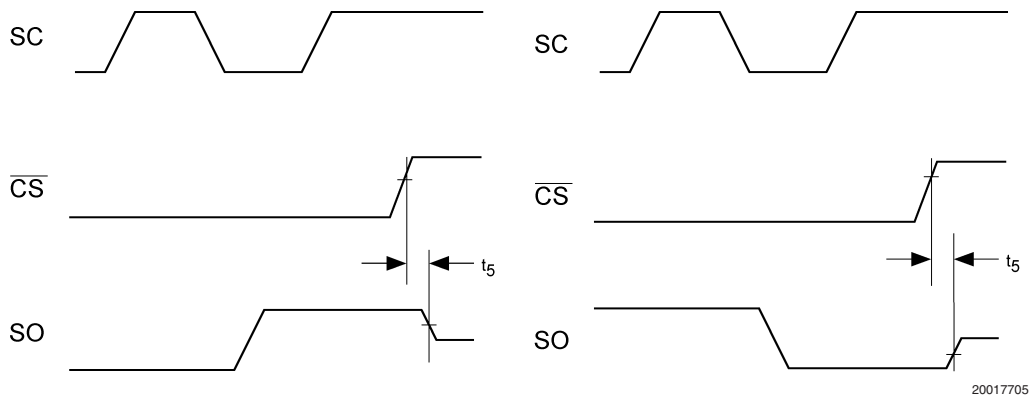


FIGURE 3. TRI-STATE Data Output Timing Diagram

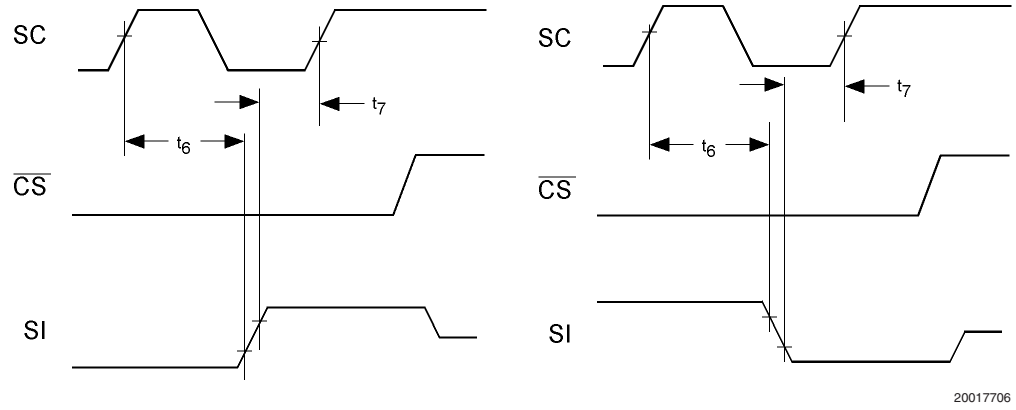
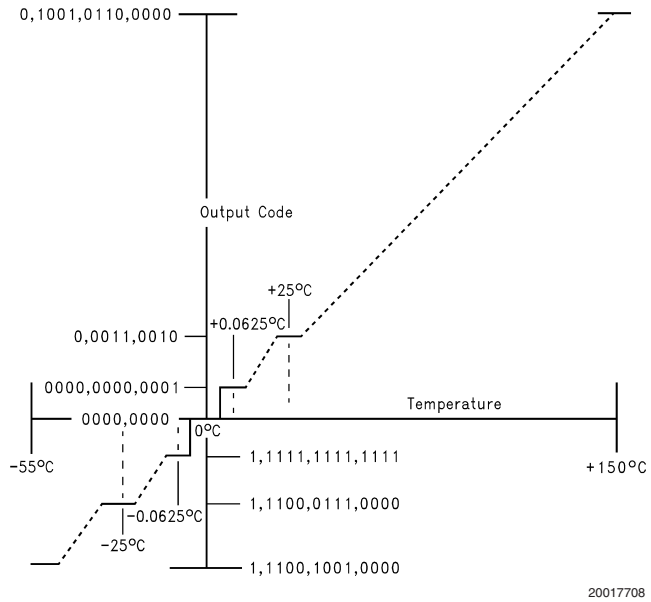


FIGURE 4. Data Input Timing Diagram



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

FIGURE 5.

TRI-STATE Test Circuit

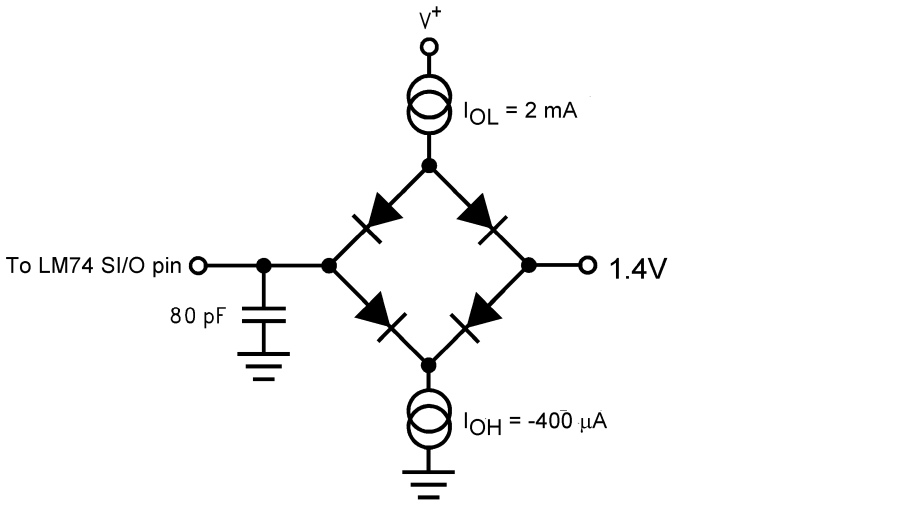
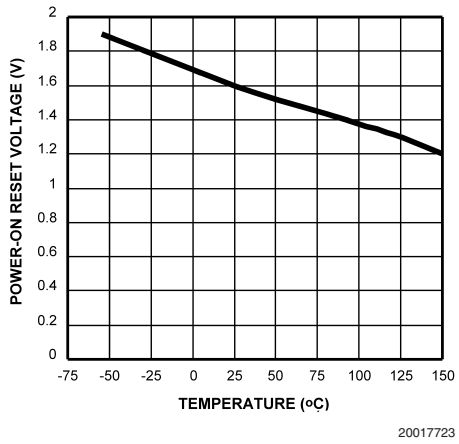


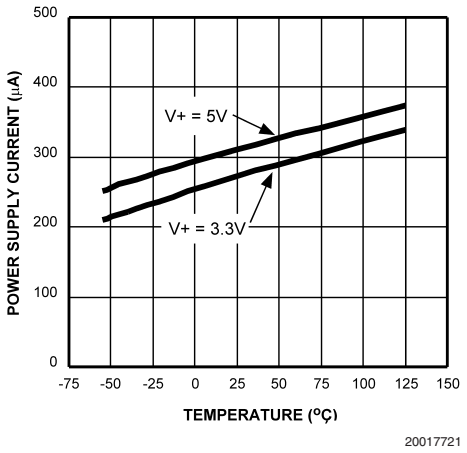
FIGURE 6.

Typical Performance Characteristics

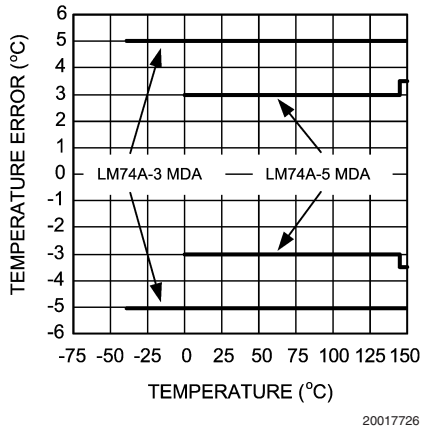
Average Power-On Reset Voltage vs Temperature



Static Supply Current vs Temperature



Temperature Error



1.0 Functional Description

The LM74A temperature sensor incorporates a band-gap type temperature sensor and 12-bit plus sign ΔΣ ADC (Delta-Sigma Analog-to-Digital Converter). Compatibility of the LM74's three wire serial interface with SPI and MICROWIRE allows simple communications with common microcontrollers and processors. Shutdown mode can be used to optimize current drain for different applications. A Manufacture's/Device ID register identifies the LM74A as National Semiconductor product.

1.1 POWER UP AND POWER DOWN

The LM74A always powers up in a known state. The power up default condition is continuous conversion mode. Immediatly after power up the LM74A will output an erroneous code until the first temperature conversion has completed.

When the supply voltage is less than about 1.6V (typical), the LM74A is considered powered down. As the supply voltage rises above the nominal 1.6V power up threshold, the internal registers are reset to the power up default state described above.

1.2 SERIAL BUS INTERFACE

The LM74A operates as a slave and is compatible with SPI or MICROWIRE bus specifications. Data is clocked out on the falling edge of the serial clock (SC), while data is clocked in on the rising edge of SC. A complete transmit/receive communication will consist of 32 serial clocks. The first 16 clocks comprise the transmit phase of communication, while the second 16 clocks are the receive phase.

When $\overline{CS}$ is high SI/O will be in TRI-STATE®. Communication should be initiated by taking chip select ($\overline{CS}$) low. This should not be done when SC is changing from a low to high state. Once $\overline{CS}$ is low the serial I/O pin (SI/O) will transmit the first bit of data. The master can then read this bit with the rising edge of SC. The remainder of the data will be clocked out by the falling edge of SC. Once the 14 bits of data (one sign bit, twelve temperature bits and 1 high bit) are transmitted the SI/O line will go into TRI-STATE. $\overline{CS}$ can be taken high at any time during the transmit phase. If $\overline{CS}$ is brought low in the middle of a conversion the LM74A will complete the conversion and the output shift register will be updated after $\overline{CS}$ is brought back high.

The receive phase of a communication starts after 16 SC periods. $\overline{CS}$ can remain low for 32 SC cycles. The LM74A will read the data available on the SI/O line on the rising edge of the serial clock. Input data is to an 8-bit shift register. The part will detect the last eight bits shifted into the register. The receive phase can last up to 16 SC periods. All ones must be shifted in order to place the part into shutdown. A zero in any location will take the LM74A out of shutdown. The following codes should only be transmitted to the LM74A:

- 00 hex
- 01 hex
- 03 hex
- 07 hex
- 0F hex
- 1F hex
- 3F hex
- 7F hex
- FF hex

any others may place the part into a Test Mode. Test Modes are used by National Semiconductor to thoroughly test the function of the LM74A during production testing. Only eight bits have been defined above since only the last eight transmitted are detected by the LM74A, before $\overline{CS}$ is taken HIGH.

The following communication can be used to determine the Manufacturer's/Device ID and then immediately place the part into continuous conversion mode. With $\overline{CS}$ continuously low:

- Read 16 bits of temperature data
- Write 16 bits of data commanding shutdown
- Read 16 bits of Manufacture's/Device ID data
- Write 8 to 16 bits of data commanding Conversion Mode
- Take $\overline{CS}$ HIGH.

Note that 250 ms will have to pass for a conversion to complete before the LM74A actually transmits temperature data.

1.3 TEMPERATURE DATA FORMAT

Temperature data is represented by a 13-bit, two's complement word with an LSB (Least Significant Bit) equal to 0.0625˚C:

Temperature	Digital Output	
	Binary	Hex
+150˚C	0100 1011 0000 0111	4B 07h
+125˚C	0011 1110 1000 0111	3E 87h
+25˚C	0000 1100 1000 0111	0B 87h
+0.0625˚C	0000 0000 0000 1111	00 0Fh
0˚C	0000 0000 0000 0111	00 07h
−0.0625˚C	1111 1111 1111 1111	FF FFh
−25˚C	1111 0011 1000 0111	F3 87h
−55˚C	1110 0100 1000 0111	E4 87h

Note: The last two bits are TRI-STATE and depicted as one in the table.

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 indicate an overtemperature condition, the host processor could immediately take action to remedy the excessive temperatures.

1.4 SHUTDOWN MODE/MANUFACTURER'S ID

Shutdown mode is enabled by writing XX FF to the LM74A as shown in *Figure 7*c. The serial bus is still active when the LM74A is in shutdown. Current draw drops to less than 10 µA between serial communications. When in shutdown mode the LM74A always will output 1000 0000 0000 0XX. This is the manufacturer's/Device ID information. The first 5-bits of the field (1000 0XXX) are reserved for manufacturer's ID.

1.0 Functional Description (Continued)

1.5 INTERNAL REGISTER STRUCTURE

The LM74A has three registers, the temperature register, the configuration register and the manufacturer's/device identification register. The temperature and manufacturer's/device identification registers are read only. The configuration register is write only.

1.5.1 Configuration Register

(Selects shutdown or continuous conversion modes):

(Write Only):

D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
X	X	X	X	X	X	X	X	Shutdown							

D0–D15 set to XX FF hex enables shutdown mode.

D0–D15 set to 00 00 hex sets Continuous conversion mode.

Note: setting D0-D15 to any other values may place the LM70 into a manufacturer's test mode, upon which the LM74A will stop responding as described. These test modes are to be used for National Semiconductor production testing only. See Section 1.2 Serial Bus Interface for a complete discussion.

1.5.2 Temperature Register

(Read Only):

D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
MSB	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	LSB	1	X	X

D0–D1: Undefined. TRI-STATE will be output on SI/0.

D2: Always set high.

D3–D15: Temperature Data. One LSB = 0.0625˚C. Two's complement format.

1.5.3 Manufacturer's/Device Id Register

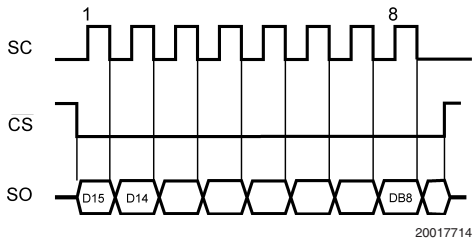
(Read Only):

D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	X	X

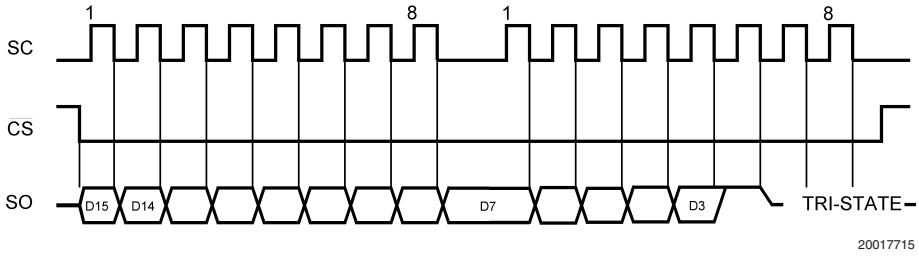
D0–D1: Undefined. TRI-STATE will be output on SI/0.

D2–D15: Manufacturer's/Device ID Data. This register is accessed whenever the LM74A is in shutdown mode.

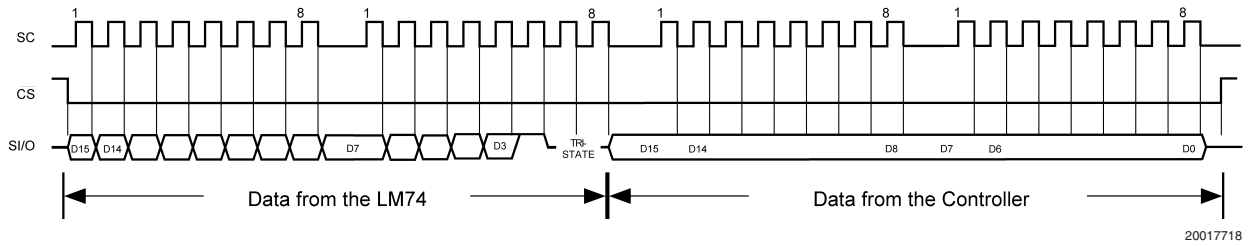
2.0 Serial Bus Timing Diagrams



a) Reading Continuous Conversion - Single Eight-Bit Frame



b) Reading Continuous Conversion - Two Eight-Bit Frames



c) Writing Shutdown Control

FIGURE 7. Timing Diagrams

3.0 Application Hints

3.1 LIGHT SENSITIVITY

The LM74A in die form should not be exposed to ultraviolet light. Exposing the LM74A to bright sunlight will not immediatly cause a change in the output reading. Our experiments show that directly exposing the circuit side (pad side) of the die to high intensity ($\geq 1mW/cm^2$) ultraviolet light, centered at a wavelength of 254nm, for greater than 20 minutes will deprogram the EEPROM cells in the LM74A. Since the EEPROM is used for storing calibration coefficients, the LM74A will function but the temperature accuracy will no longer be as specified. Light can penetrate through the side of the die as well.

4.0 Typical Applications

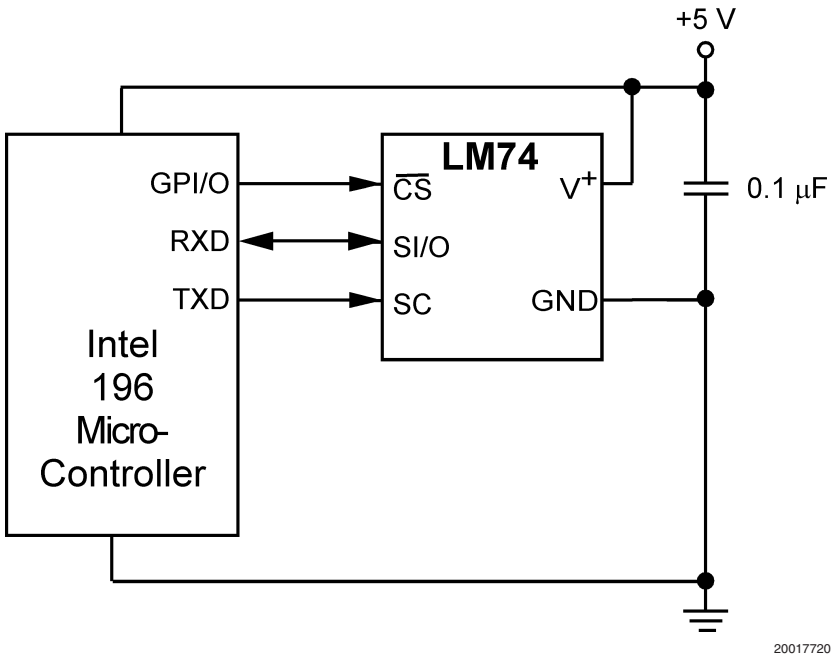


FIGURE 8. Temperature monitor using Intel 196 processor

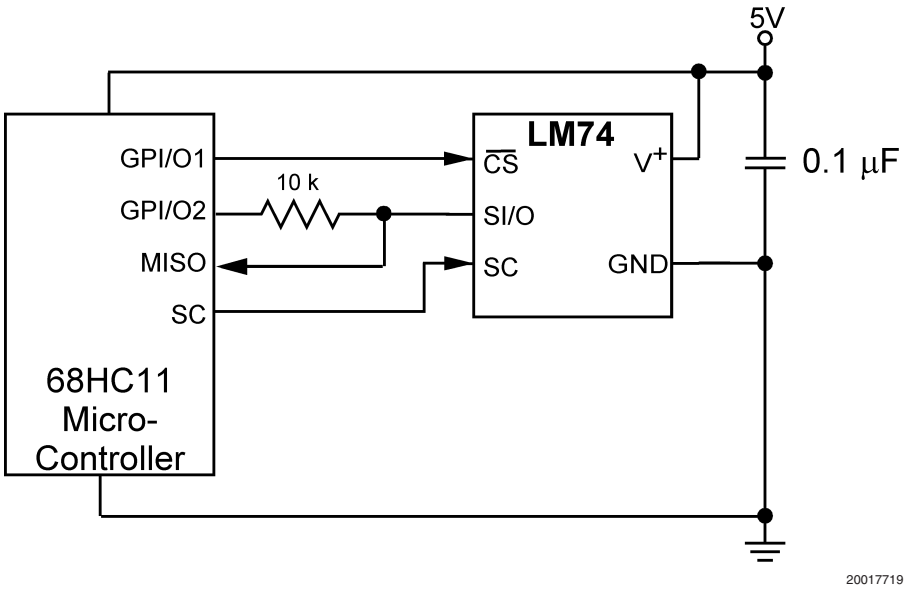
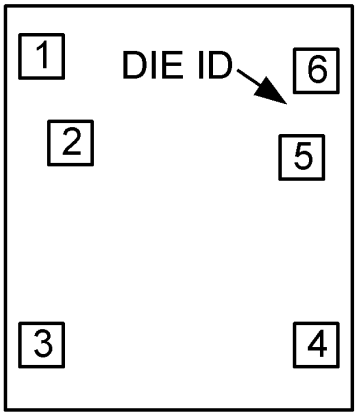


FIGURE 9. LM74A digital input control using micro-controller's general purpose I/O.

5.0 Revision History

Date	Revision
10/12/2004	1. Added LM74A-3 MDA specifications. 2. Updated order number of LM74A MDA to LM74A-5 MDA.
07/17/2001	Released to web originaly.

Bond Pad Layout



20017727

Bond Pad Layout
Order Number LM74A-5 MDA or LM74A-3 MDA
Bare Die
TOP VIEW
1.40mm x 1.57 mm (55 x 62 mils)
For Bond Pad Mechanical Dimensions see Connection Diagram Section

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