MCP9800/1/2/3

2-Wire High-Accuracy Temperature Sensor
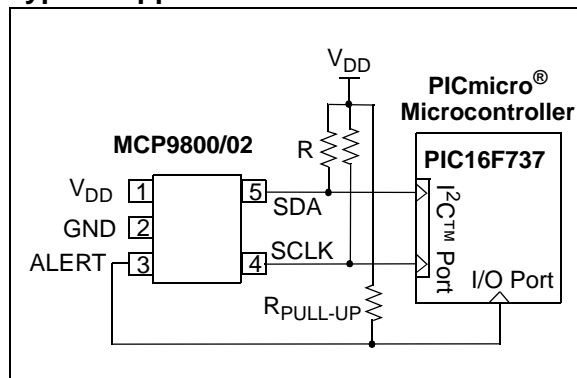
Features

- Temperature-to-Digital Converter
- Accuracy with 12-bit Resolution:
  - ±0.5°C (typ.) at +25°C
  - ±1°C (max.) from -10°C to +85°C
  - ±2°C (max.) from -10°C to +125°C
  - ±3°C (max.) from -55°C to +125°C
- User-selectable Resolution: 9 – 12 bit
- Operating Voltage Range: 2.7V to 5.5V
- 2-wire Interface: I^2C™/SMBus Compatible
- Operating Current: 200 µA (typ.)
- Shutdown Current: 1 µA (max.)
- Power-saving One-shot Temperature Measurement
- Available Packages: SOT-23-5, MSOP-8, SOIC-8

Typical Applications

- Personal Computers and Servers
- Hard Disk Drives and Other PC Peripherals
- Entertainment Systems
- Office Equipment
- Data Communication Equipment
- Mobile Phones
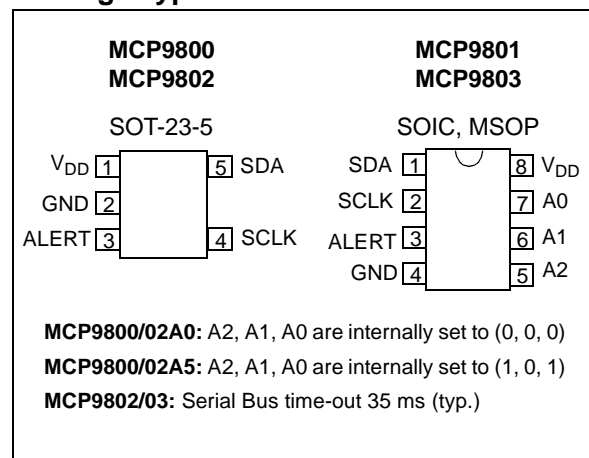- General-purpose Temperature Monitoring

Typical Application

Description

Microchip Technology Inc.'s MCP9800/1/2/3 family of digital temperature sensors converts temperatures between -55°C and +125°C to a digital word. They provide an accuracy of ±1°C (max.) from -10°C to +85°C.

The MCP9800/1/2/3 family comes with user-programmable registers that provide flexibility for temperature sensing applications. The register settings allow user-selectable 9-bit to 12-bit temperature measurement resolution, configuration of the power-saving Shutdown and One-shot (single conversion on command while in the Shutdown) modes and the specification of both temperature alert output and hysteresis limits. When the temperature changes beyond the specified limits, the MCP9800/1/2/3 outputs an alert signal. The user has the option of setting the alert output signal polarity as an active-low or active-high comparator output for thermostat operation, or as temperature event interrupt output for microprocessor-based systems.

This sensor has an industry standard 2-wire, I^2C™/SMBus compatible serial interface, allowing up to eight devices to be controlled in a single serial bus. These features make the MCP9800/1/2/3 ideal for sophisticated multi-zone temperature-monitoring applications.

Package Types

MCP9800/02A0: A2, A1, A0 are internally set to (0, 0, 0)
MCP9800/02A5: A2, A1, A0 are internally set to (1, 0, 1)
MCP9802/03: Serial Bus time-out 35 ms (typ.)

MCP9800/1/2/3

1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings †

V_{DD}.. 6.0V

Voltage at all Input/Output pins .... GND – 0.3V to 5.5V

Storage temperature ....-65°C to +150°C

Ambient temp. with power applied .....-55°C to +125°C

Junction Temperature (T_J)................................. 150°C

ESD protection on all pins (HBM:MM)....... (4 kV:400V)

Latch-Up Current at each pin .... ±200 mA

†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 operational listings of this specification is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability.

PIN FUNCTION TABLE

NAME	FUNCTION
SDA	Bidirectional Serial Data (open-drain output)
SCLK	Serial Clock Input
ALERT	Temperature Alert Output (open-drain)
A2	Address Select Pin (bit 2)
A1	Address Select Pin (bit 1)
A0	Address Select Pin (bit 0)
V_{DD}	Power Supply Input
GND	Ground

DC CHARACTERISTICS

Electrical Specifications: Unless otherwise indicated, V_{DD} = 2.7V to 5.5V, GND = Ground, and T_A = -55°C to +125°C.

Parameters	Sym	Min	Typ	Max	Unit	Conditions
Power Supply						
Operating Voltage Range	V_{DD}	2.7	—	5.5	V	
Operating Current	I_{DD}	—	200	400	µA	Continuous Operation
Shutdown Current	I_{SHDN}	—	0.1	1	µA	Shutdown Mode
Power On Reset Threshold (POR)	V_{POR}	—	1.7	—	V	V_{DD} falling edge
Temperature Sensor Accuracy						
Accuracy with 12-bit Resolution:						
T_A = +25°C	T_{ACY}	—	±0.5	—	°C	V_{DD} = 3.3V
-10°C < T_A ≤ +85°C	T_{ACY}	-1.0	—	+1.0	°C	V_{DD} = 3.3V
-10°C < T_A ≤ +125°C	T_{ACY}	-2.0	—	+2.0	°C	V_{DD} = 3.3V
-55°C < T_A ≤ +125°C	T_{ACY}	-3.0	—	+3.0	°C	V_{DD} = 3.3V
Internal ΣΔ ADC						
Conversion Time:						
9-bit Resolution	t_{CONV}	—	30	75	ms	33 samples/sec (typ.)
10-bit Resolution	t_{CONV}	—	60	150	ms	17 samples/sec (typ.)
11-bit Resolution	t_{CONV}	—	120	300	ms	8 samples/sec (typ.)
12-bit Resolution	t_{CONV}	—	240	600	ms	4 samples/sec (typ.)
Alert Output (Open-drain)						
High-level Current	I_{OH}	—	—	1	µA	V_{OH} = 5V
Low-level Voltage	V_{OL}	—	—	0.4	V	I_{OL}= 3 mA
Thermal Response						
Response Time	t_{RES}	—	1.4	—	s	Time to 63% (88°C) 27°C (Air) to 125°C (oil bath)

DIGITAL INPUT/OUTPUT PIN CHARACTERISTICS

Electrical Specifications: Unless otherwise indicated, V_{DD} = 2.7V to 5.5V, GND = Ground and T_A = -55°C to +125°C.

Parameters	Sym	Min	Typ	Max	Units	Conditions
Serial Input/Output (SCLK, SDA, A0, A1, A2)						
Input						
High-level Voltage	V_{IH}	0.7 V_{DD}	—	—	V	
Low-level Voltage	V_{IL}	—	—	0.3 V_{DD}	V	
Input Current	I_{IN}	-1	—	+1	µA	
Output (SDA)						
Low-level Voltage	V_{OL}	—	—	0.4	V	I_{OL}= 3 mA
High-level Current	I_{OH}	—	—	1	µA	V_{OH} = 5V
Low-level Current	I_{OL}	6	—	—	mA	V_{OL} = 0.6V
Capacitance	C_{IN}	—	10	—	pF	
SDA and SCLK Inputs						
Hysteresis	V_{HYST}	0.05 V_{DD}	—	—	V	

Graphical Symbol Description
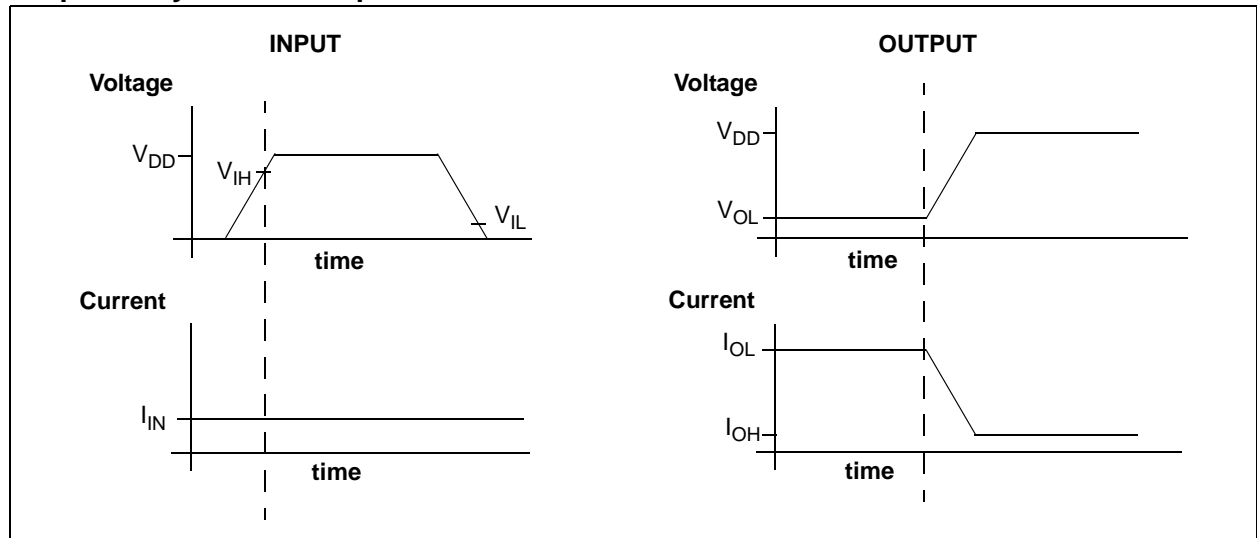
TEMPERATURE CHARACTERISTICS

Electrical Specifications: Unless otherwise indicated, V_{DD} = +2.7V to +5.5V, GND = Ground.

Parameters	Sym	Min	Typ	Max	Units	Conditions
Temperature Ranges						
Specified Temperature Range	T_A	-55	—	+125	°C	**(Note 1)**
Operating Temperature Range	T_A	-55	—	+125	°C	
Storage Temperature Range	T_A	-65	—	+150	°C	
Thermal Package Resistances						
Thermal Resistance, 5L-SOT23	θ_{JA}	—	256	—	°C/W	
Thermal Resistance, 8L-SOIC	θ_{JA}	—	163	—	°C/W	
Thermal Resistance, 8L-MSOP	θ_{JA}	—	206	—	°C/W	

Note 1: Operation in this range must not cause T_J to exceed Maximum Junction Temperature (+150°C).

## SERIAL INTERFACE TIMING SPECIFICATIONS

Electrical Specifications: Unless otherwise indicated, V_{DD} = 2.7V to 5.5V, GND = Ground, -55°C < T_A < +125°C, C_L = 80 pF, and all limits measured to 50% point.

Parameters	Sym	Min	Typ	Max	Units	Conditions
2-Wire I²C/SMBus Compatible Interface						
Serial Port Frequency	f_{SC}	0	—	400	kHz	I^{2}C **MCP9800/01**
	f_{SC}	10	—	400	kHz	SMBus **MCP9802/03**
Clock Period	t_{SC}	2.5	—	—	µs	
Low Clock	t_{LOW}	1.3	—	—	µs	
High Clock	t_{HIGH}	0.6	—	—	µs	
Rise Time	t_R	20	—	300	ns	10% to 90% of V_{DD} (SCLK, SDA)
Fall Time	t_F	20	—	300	ns	90% to 10% of V_{DD} (SCLK, SDA)
Data Setup Before SCLK High	$t_{SU-DATA}$	0.1	—	—	µs	
Data Hold After SCLK Low	t_{H-DATA}	0	—	0.9	µs	
Start Condition Setup Time	$t_{SU-START}$	0.6	—	—	µs	
Start Condition Hold Time	$t_{H-START}$	0.6	—	—	µs	
Stop Condition Setup Time	$t_{SU-STOP}$	0.6	—	—	µs	
Bus Idle	t_{IDLE}	1.3	—	—	µs	
Time Out	t_{OUT}	25	35	50	ms	**MCP9802/03 only**

Timing Diagram

© 2004 Microchip Technology Inc.
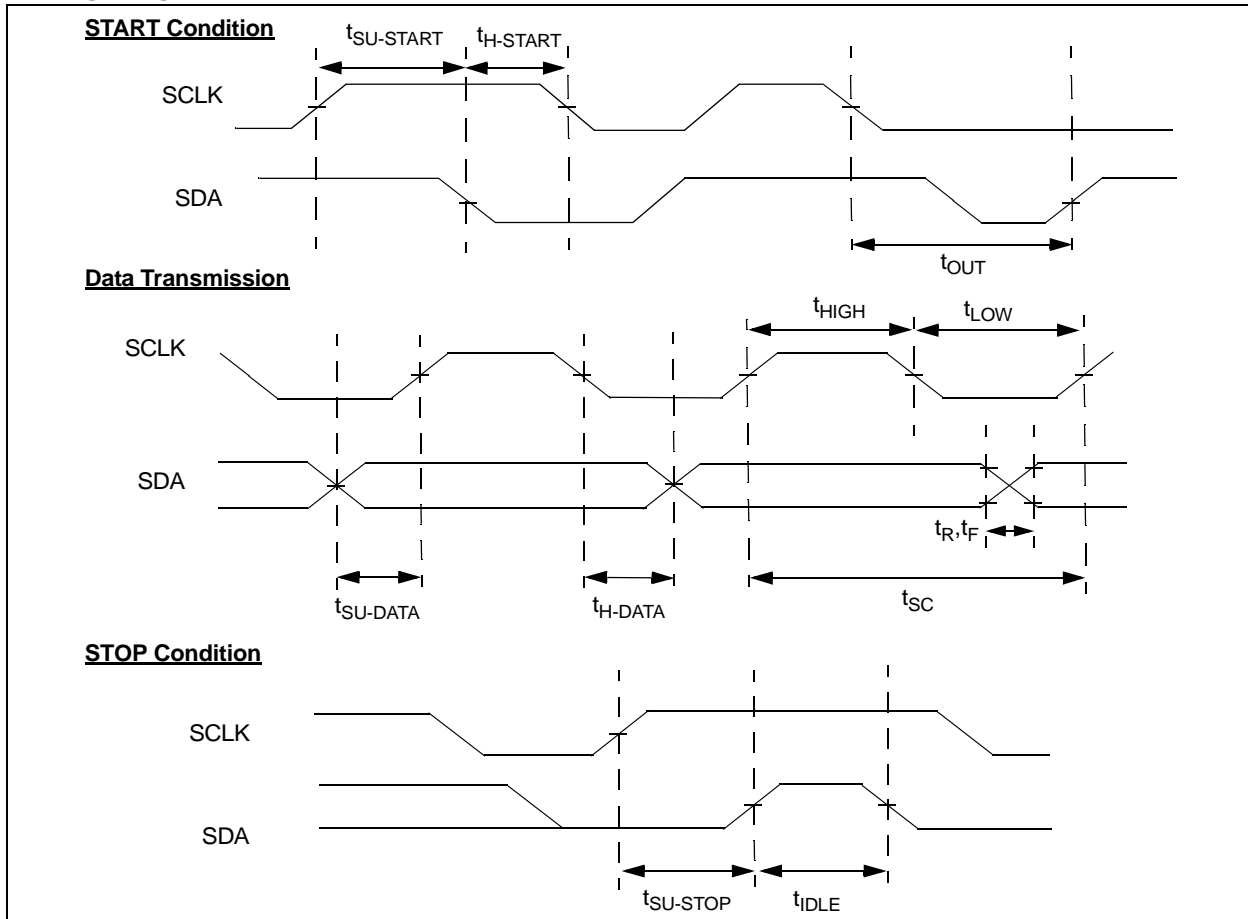
2.0 TYPICAL PERFORMANCE CURVES

Note: Unless otherwise noted: V_{DD} = 2.7V to 5.5V.

FIGURE 2-1: *Average Temperature Accuracy vs. Ambient Temperature, V_{DD} = 3.3V.*

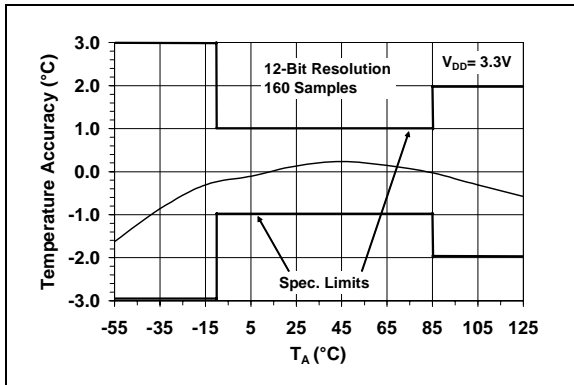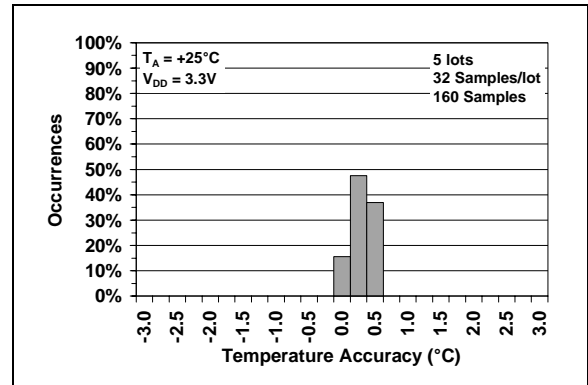**FIGURE 2-2:** *Average Temperature Accuracy vs. Ambient Temperature.*

FIGURE 2-3: *Average Temperature Accuracy vs. Ambient Temperature, V_{DD} = 3.3V.*

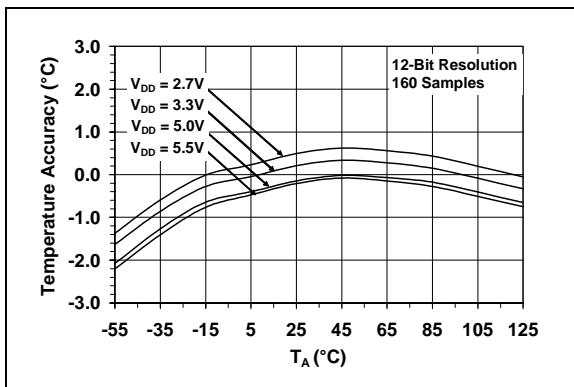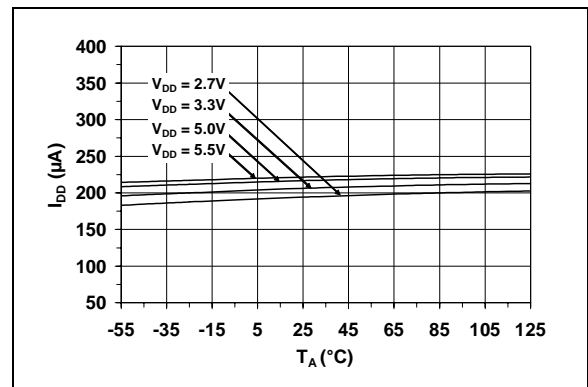**FIGURE 2-4:** *Temperature Accuracy Histogram, T_A = +25°C.*

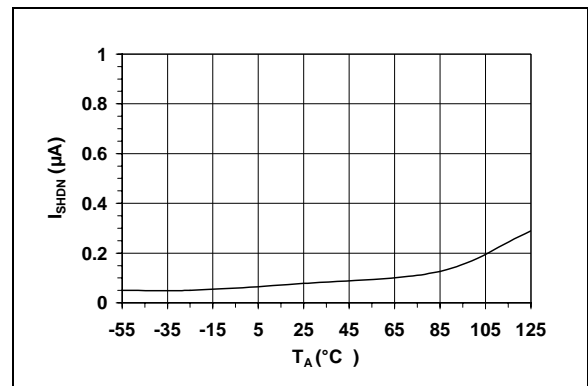**FIGURE 2-5:** *Supply Current vs. Ambient Temperature.*

FIGURE 2-6: *Shutdown Current vs. Ambient Temperature.*

Note: Unless otherwise noted: V_{DD} = 2.7V to 5.5V.
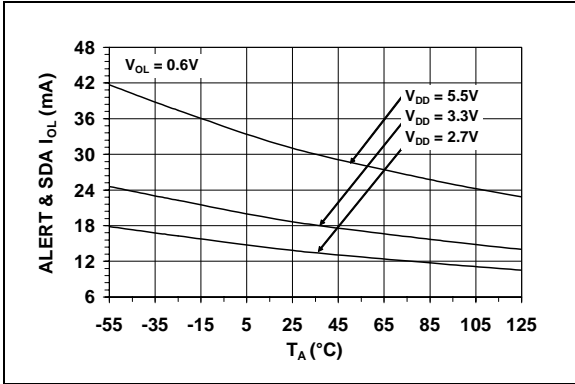

FIGURE 2-7: *ALERT and SDA I_{OL} vs. Ambient Temperature.*
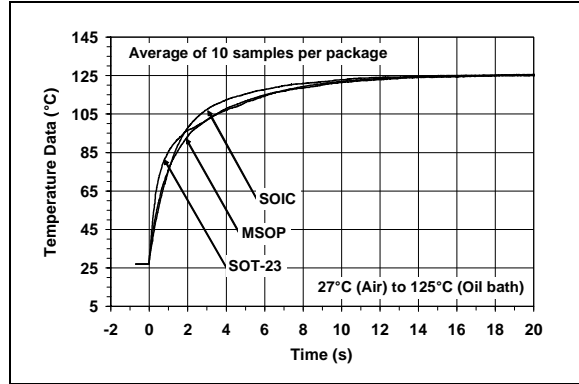

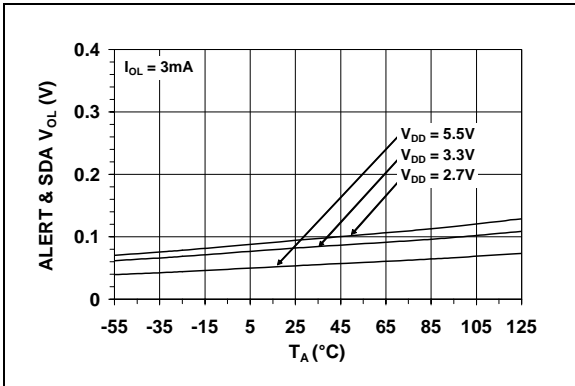**FIGURE 2-9:** *MCP980X Thermal Response vs Time.*

FIGURE 2-8: *ALERT and SDA Output V_{OL} vs. Ambient Temperature.*

3.0 PIN DESCRIPTION

The descriptions of the pins are listed in Table 3-1.

TABLE 3-1: PIN FUNCTION TABLE

MCP9800 MCP9802 SOT-23-5	MCP9801 MCP9803 MSOP, SOIC	Symbol	Function
5	1	SDA	Bidirectional Serial Data
4	2	SCLK	Serial Clock Input
3	3	ALERT	Temperature Alert Output
2	4	GND	Ground
—	5	A2	Address Select Pin (bit 2)
—	6	A1	Address Select Pin (bit 1)
—	7	A0	Address Select Pin (bit 0)
1	8	V_{DD}	Power Supply Input

3.1 Serial Data Pin (SDA)

The SDA is a bidirectional input/output pin, used to serially transmit data to and from the host controller. This pin requires a pull-up resistor to output data.

3.2 Serial Clock Pin (SCLK)

The SCLK is a clock input pin. All communication and timing is relative to the signal on this pin. The clock is generated by the host controller on the bus.

3.3 Power Supply Input (V_{DD})

The V_{DD} pin is the power pin. The operating voltage, as specified in the DC electrical specification table, is applied on this pin.

3.4 Ground (GND)

The GND pin is the system ground pin.

3.5 ALERT Output

The MCP9800/1/2/3's ALERT pin is an open-drain output pin. The device outputs an alert signal when the ambient temperature goes beyond the user-programmed temperature limit.

3.6 Address Pins (A2, A1, A0)

These pins are device or slave address input pins and are available only with the MCP9801/03. The device addresses for the MCP9800/02 are factory-set.

The address pins are the Least Significant bits (LSb) of the device address bits. The Most Significant bits (MSb) (A6, A5, A4, A3) are factory-set to <1001>. This is illustrated in Table 3-2.

TABLE 3-2: SLAVE ADDRESS

Device	A6	A5	A4	A3	A2	A1	A0
MCP9800/02A0	1	0	0	1	0	0	0
MCP9800/02A5	1	0	0	1	1	0	1
MCP9801/03	1	0	0	1	X	X	X

Note: User-selectable address is shown by X.

MCP9800/1/2/3

4.0   FUNCTIONAL DESCRIPTION

The MCP9800/1/2/3 family of temperature sensors consists of a band-gap type temperature sensor, a $\Sigma\Delta$ Analog-to-Digital Converter (ADC), user-programmable registers and a 2-wire I²C/SMBus protocol compatible serial interface.
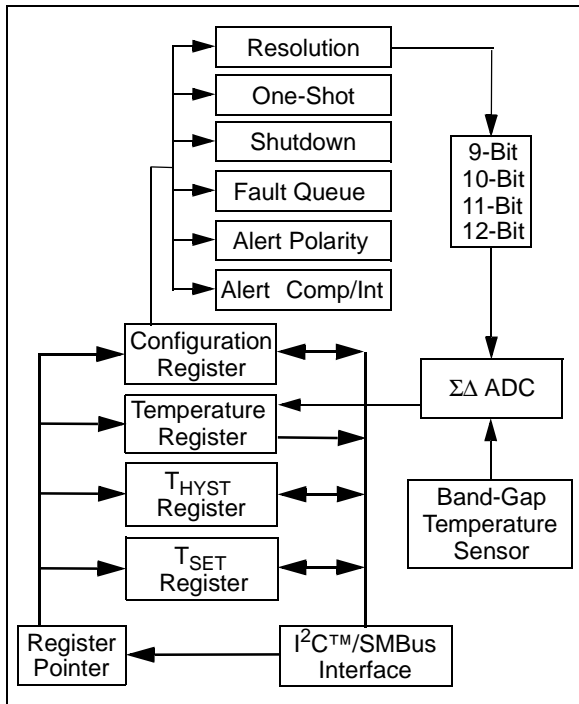

FIGURE 4-1:   *Functional Block Diagram.*

4.1   Temperature Sensor

The MCP9800/1/2/3 uses the difference in the base-emitter voltage of a transistor while its collector current is changed from IC_1 to IC_2. With this method, the ΔV_{BE} depends only on the ratio of the two currents and the ambient temperature, as shown in Equation 4-1.

EQUATION 4-1:

$$\Delta V_{BE} = \left(\frac{kT}{q}\right) \times ln(IC_1/IC_2)$$

Where:

$$T = \text{temperature in kelvin}$$
$$\Delta V_{BE} = \text{change in diode base-emitter voltage}$$
$$k = \text{Boltzmann's constant}$$
$$q = \text{electron charge}$$
$$IC_1 \text{ and } IC_2 = \text{currents with n:1 ratio}$$

4.2 $\Sigma\Delta$ Analog-to-Digital Converter

A sigma-delta analog-to-digital converter is used to convert ΔV_{BE} to a digital word that corresponds to the transistor temperature. The converter has an adjustable resolution from 9-bits (at 30 ms conversion time) to 12-bits (at 240 ms conversion time). Thus, it allows the user to make trade-offs between resolution and conversion time. Refer to **Section 4.3.4 "Sensor Configuration Register (CONFIG)"** and **Section 4.3.4.7 "$\Sigma\Delta$ ADC Resolution"** for details.

4.3   Registers

The MCP9800/1/2/3 family has four registers that are user-accessible. These registers are specified as the ambient temperature register, the temperature limit-set register, the temperature hysteresis register and device configuration registers.

The ambient temperature register is a read-only register and is used to access the ambient temperature data. The data from the ADC is loaded in parallel in the register. The temperature limit-set and temperature hysteresis registers are read/write registers that provide user-programmable temperature limits. If the ambient temperature drifts beyond the programmed limits, the MCP9800/1/2/3 outputs an alert signal using the ALERT pin (refer to **Section 4.3.4.3 "ALERT Output Configuration"**). The device configuration register provides access for the user to configure the MCP9800/1/2/3's various features. These registers are described in further detail in the following sections.
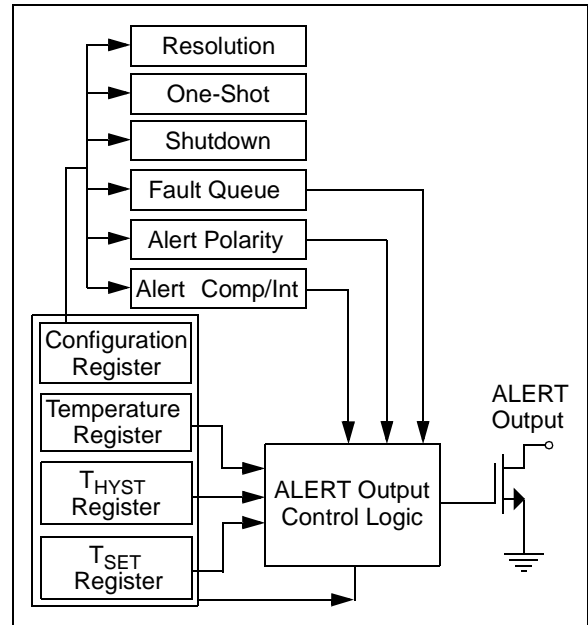

FIGURE 1:   *Register Block Diagram.*

The registers are accessed by sending register pointer to the MCP9800/1/2/3 using the serial interface. This is an 8-bit pointer. However, the two Least Significant bits (LSb) are used as pointers and all other bits need to be cleared <0>. This device has additional registers that are reserved for test and calibration. If these registers are accessed, the device may not perform according to the specification. The pointer description is shown below.

REGISTER 4-1:   REGISTER POINTER

U-0	U-0	U-0	U-0	U-0	U-0	R/W-0	R/W-0
0	0	0	0	0	0	P1	P0

bit 7   bit 0

bit 7-3   **Unimplemented:** Read as '0'

bit 2-0   **Pointer bits**

00 =   Temperature Register
01 =   Configuration Register
10 =   Temperature Hysteresis Register
11 =   Temperature Limit-set Register

Legend:		
R = Readable bit	W = Writable bit	U = Unimplemented bit, read as '0'
- n = Value at POR	'1' = Bit is set	'0' = Bit is cleared x = Bit is unknown

MCP9800/1/2/3

4.3.1 AMBIENT TEMPERATURE REGISTER (T_A)

The MCP9800/1/2/3 has a 16-bit read-only ambient temperature register (T_A) that contains 9-bit to 12-bit temperature data. This data is formatted in two's complement. The bit assignments, as well as the corresponding resolution, is shown in the register assignment below.

The refresh rate of this register depends on the selected ADC resolution. It takes 30 ms (typ.) for 9-bit data and 240 ms (typ.) for 12-bit data. Since this register is double-buffered, the user can read the register while the MCP9800/1/2/3 performs analog-to-digital conversion in the background. The decimal code to ambient temperature conversion is shown in Equation 4-2:

EQUATION 4-2:

$$T_A = Code \times 2^n$$

Where:

n	=	-1, -2, -3 and -4 for 9-bit, 10-bit, 11-bit and 12-bit resolution, respectively
T_A	=	Ambient Temperature (°C)
Code	=	MCP980X output in decimal (Table 4-1)

REGISTER 4-2: AMBIENT TEMPERATURE REGISTER (T_A)

Upper Half:

R-0	R-0	R-0	R-0	R-0	R-0	R-0	R-0
Sign	2^6 °C/bit	2^5 °C/bit	2^4 °C/bit	2^3 °C/bit	2^2 °C/bit	2^1 °C/bit	2^0 °C/bit
bit 15							bit 8

Lower Half:

R-0	R-0	R-0	R-0	R-0	R-0	R-0	R-0
2^{-1} °C/bit	2^{-2} °C/bit	2^{-3} °C/bit	2^{-4} °C/bit	0	0	0	0
bit 7							bit 0

Note: When the 9-bit, 10-bit or 11-bit resolutions are selected, bit 6, bit 7 or bit 8 will remain clear <0>, respectively.

Legend:

R = Readable bit	W = Writable bit	U = Unimplemented bit, read as '0'
- n = Value at POR	'1' = Bit is set	'0' = Bit is cleared x = Bit is unknown

TABLE 4-1: AMBIENT TEMPERATURE TO CODE CONVERSION

Ambient Temperature				Code			T_A (°C)
9-Bit	**10-Bit**	**11-Bit**	**12-Bit**	**Binary**	**Hexadecimal**	**Decimal**	
+125°C				0111 1101 0uuu uuuu**(1)**	0FA	250	+125
+25.4375°C				0001 1001 0uuu uuuu	032	50	+25
+0.5°C				0000 0000 1uuu uuuu	001	1	+0.5
	+125°C			0111 1101 00uu uuuu	1F4	500	+125
	+25.4375°C			0001 1001 01uu uuuu	065	101	+25.25
	+0.25°C			0000 0000 01uu uuuu	001	1	+0.25
		+125°C		0111 1101 000u uuuu	3E8	1000	+125
		+25.4375°C		0001 1001 011u uuuu	0CB	203	+25.375
		+0.125°C		0000 0000 001u uuuu	001	1	+0.125
			+125°C	0111 1101 0000 uuuu	7D0	2000	+125
			+25.4375°C	0001 1001 0111 uuuu	197	407	+25.4375
			+0.0625°C	0000 0000 0001 uuuu	001	1	+0.0625
	0°C			0000 0000 0000 uuuu	000	0	0
			−0.0625°C	1111 1111 1111 uuuu**(2)**	001**(3)**	-1	-0.0625
			−25.4375°C	1110 0110 1001 uuuu	197	-407	-25.4375
			−55°C	1100 1001 0000 uuuu	370	-880	-55

Note 1: 'u' represents unused bits. The MCP9800/1/2/3 clears <0> the unused bits.

2: This data is in two's complement format, which indicates ambient temperature below 0°C.

3: Negative temperature magnitude in Hexadecimal. This conversion is done by complimenting each binary bit and adding 1.

4.3.2 TEMPERATURE LIMIT-SET REGISTER (T_{SET})

The MCP9800/1/2/3 has a 16-bit read/write Temperature Limit-Set register (T_{SET}) which contains a 9-bit data in two's compliment format. This data represents a maximum temperature limit. If the ambient temperature exceeds this specified limit, the MCP9800/1/2/3 asserts an alert output. (Refer to **Section 4.3.4.3 "ALERT Output Configuration"**).

This register uses the nine Most Significant bits (MSb) and all other bits are don't cares.

The power-up default value of T_{SET} register is 80°C `<0 1010 0000>` in binary.

REGISTER 4-3: TEMPERATURE LIMIT-SET REGISTER (T_{SET})

Upper Half:

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
Sign	2^6 °C/bit	2^5 °C/bit	2^4 °C/bit	2^3 °C/bit	2^2 °C/bit	2^1 °C/bit	2^0 °C/bit
bit 15							bit 8

Lower Half:

R/W-0	R-0	R-0	R-0	R-0	R-0	R-0	R-0
2^{-1} °C/bit	0	0	0	0	0	0	0
bit 7							bit 0

Legend:			
R = Readable bit	W = Writable bit	U = Unimplemented bit, read as '0'	
- n = Value at POR	'1' = Bit is set	'0' = Bit is cleared	x = Bit is unknown

MCP9800/1/2/3

4.3.3 TEMPERATURE HYSTERESIS REGISTER (T_{HYST})

The MCP9800/1/2/3 has a 16-bit read/write temperature hysteresis register (T_{HYST}) that contains a 9-bit data in two's compliment format. This register is used to set a hysteresis for the T_{SET} limit. Therefore, the data represents a minimum temperature limit. If the ambient temperature drifts below the specified limit, the MCP9800/1/2/3 asserts an alert output (refer to **Section 4.3.4.3 "ALERT Output Configuration"**).

This register uses the nine Most Significant bits (MSb) and all other bits are don't cares.

The power-up default value of T_{HYST} register is 75°C `<0 1001 0110>` in binary.

REGISTER 4-4:   TEMPERATURE HYSTERESIS REGISTER (T_{HYST})

Upper Half:							
R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
Sign	2^6 °C/bit	2^5 °C/bit	2^4 °C/bit	2^3 °C/bit	2^2 °C/bit	2^1 °C/bit	2^0 °C/bit
bit 15							bit 8

Lower Half:							
R/W-0	R-0	R-0	R-0	R-0	R-0	R-0	R-0
2^{-1} °C/bit	0	0	0	0	0	0	0
bit 7							bit 0

Legend:		
R = Readable bit	W = Writable bit	U = Unimplemented bit, read as '0'
- n = Value at POR	'1' = Bit is set	'0' = Bit is cleared x = Bit is unknown

4.3.4 SENSOR CONFIGURATION REGISTER (CONFIG)

The MCP9800/1/2/3 has an 8-bit read/write configuration register (CONFIG) that allows the user to select the different features. These features include shutdown, ALERT output select as comparator or interrupt output, ALERT output polarity, fault queue cycle, temperature measurement resolution and One-shot mode (single conversion while in shutdown). These functions are described in detail in the following sections.

REGISTER 4-5:   CONFIGURATION REGISTER (CONFIG)

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
One-Shot	Resolution		Fault Queue		ALERT Polarity	COMP/ INT	Shut-down

bit 7   bit 0

bit 7   **ONE-SHOT bit**

1 = Enabled
0 = Disabled (Power-up default)

bit 5-6 $\Sigma\Delta$ **ADC RESOLUTION bit**

00 = 9 bit (Power-up default)
01 = 10 bit
10 = 11 bit
11 = 12 bit

bit 3-4   **FAULT QUEUE bit**

00 = 1 (Power-up default)
01 = 2
10 = 4
11 = 6

bit 2   **ALERT POLARITY bit**

1 = Active-High
0 = Active-Low (Power-up default)

bit 1   **COMP/INT bit**

1 = Interrupt Mode
0 = Comparator Mode (Power-up default)

bit 0   **SHUTDOWN bit**

1 = Enable
0 = Disable (Power-up default)

Legend:		
R = Readable bit	W = Writable bit	U = Unimplemented bit, read as '0'
- n = Value at POR	'1' = Bit is set	'0' = Bit is cleared x = Bit is unknown

4.3.4.1 Shutdown Mode

The Shutdown mode disables all power-consuming activities (including temperature sampling operations) while leaving the serial interface active. The device consumes 1 µA (max.) in this mode. It remains in this mode until the configuration register is updated to enable continuous conversion or until power is recycled.

In Shutdown mode, the CONFIG, T_A, T_{SET} and T_{HYST} registers can be read or written. However, the serial bus activity will increase the shutdown current.

4.3.4.2 One-Shot Mode

The MCP9800/1/2/3 can also be used in a One-shot mode that can be selected using bit 7 of the CONFIG register. The One-shot mode performs a single temperature measurement and returns to Shutdown mode. This mode is especially useful for low-power applications where temperature is measured upon command from a controller. For example, a 9-bit T_A in One-shot mode consumes 200 µA (typ.) for 30 ms and 0.1 µA (typ.) during shutdown.

To access this feature, the device needs to initially be in Shutdown mode. This is done by sending a byte to the CONFIG register with bit 0 set <1> and bit 7 cleared <0>. Once the device is in Shutdown mode, CONFIG needs to be written again with bit 0 and bit 7 set <1>. This begins the single conversion cycle of 30 ms for 9-bit data. Once the conversion is completed, T_A is updated and bit 7 of CONFIG becomes cleared <0> by the MCP9800/1/2/3.

TABLE 4-6: SHUTDOWN AND ONE-SHOT MODE DESCRIPTION

Operational Mode	One-Shot (Bit 7)	Shutdown (Bit 0)
Continuous Conversion	0	0
Shutdown	0	1
Continuous Conversion (One-shot is ignored)	1	0
One-Shot	1	1

Note: The shutdown command <01> needs to be programmed before sending a one-shot command <11>.

4.3.4.3 ALERT Output Configuration

The ALERT output can be configured as either a comparator output or as Interrupt Output mode using bit 1 of CONFIG. The polarity can also be specified as an active-high or active-low, using bit 2 of CONFIG. The following sections describe each Output mode and Figure 4-2 shows graphical description.

4.3.4.4 Comparator Mode

In the Comparator mode, the ALERT output is asserted when T_A is greater than T_{SET}. The pin remains active until T_A is lower than T_{HYST}. The Comparator mode is useful for thermostat-type applications such as turning on a cooling fan or triggering a system shutdown when the temperature exceeds a safe operating range.

In the Comparator mode, if the device enters the Shutdown mode with asserted ALERT output, the output remains active during shutdown. The device must be operating in continuous conversion, with T_A below T_{HYST}, for the ALERT output to be deasserted.

4.3.4.5 Interrupt Mode

In the Interrupt mode, the ALERT output is asserted when T_A is greater than T_{SET}. However, the output is deasserted when the user performs a read from any register. This mode is designed for interrupt driven microcontroller based systems. The microcontroller receiving the interrupt will have to acknowledge the interrupt by reading any register from the MCP9800/1/2/3. This will clear the interrupt and the ALERT pin will become deasserted. When T_A drifts below T_{HYST}, the MCP9800/1/2/3 outputs another interrupt and the controller needs to read a register to deassert the ALERT output. Shutting down the device will also reset or deassert the ALERT output.
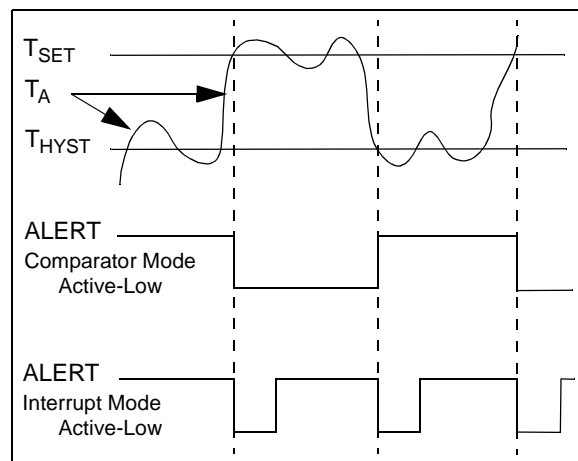

FIGURE 4-2: Alert Output.

4.3.4.6 Fault Queue

The fault queue feature can be used as a filter to lessen the probability of spurious activation of the ALERT pin. T_A must remain above T_{SET} for the consecutive number of conversion cycles selected using the Fault Queue bits. Bit 3 and bit 4 of CONFIG can be used to select up to six fault queue cycles. For example, if six fault queues are selected, T_A must be greater than T_{SET} for six consecutive conversions before ALERT is asserted as a comparator or an interrupt output.

This queue setting also applies for T_{HYST}. T_A must remain below T_{HYST} for six consecutive conversions before ALERT is deasserted (comparator mode) or before another interrupt is asserted (interrupt mode).

4.3.4.7 ΣΔ ADC Resolution

The MCP9800/1/2/3 provides access to select the ADC resolution from 9-bit to 12-bit using bit 6 and bit 5 of the CONFIG register. The user can gain better insight into the trends and characteristics of the ambient temperature by using a finer resolution. Increasing the resolution also reduces the quantization error. Figure 2-4 shows accuracy versus resolution.

Table 4-1 shows the T_A register conversion time for the corresponding resolution.

TABLE 4-1: RESOLUTION AND CONVERSION TIME

Bits	Resolution °C/Bit (typ.)	Conversion time t_{CONV} ms (typ.)
9	0.5	30
10	0.25	60
11	0.125	120
12	0.0625	240

4.4 Summary of Power-up Default

The MCP9800/1/2/3 has an internal Power-on Reset (POR) circuit. If the power supply voltage V_{DD} glitches down to the 1.7V (typ.) threshold, the device resets the registers to the power-up default settings.

Table 4-2 shows the power-up default summary.

TABLE 4-2: POWER-UP DEFAULTS

Register	Data (Hex)	Power-up Defaults
T_A	0000	0°C
T_{SET}	A000	80°C
T_{HYST}	9600	75°C
Pointer	00	Temperature register
CONFIG	00	Continuous Conversion Comparator mode Active-Low Output Fault Queue 1 9-bit Resolution

MCP9800/1/2/3

5.0   SERIAL COMMUNICATION

5.1   2-Wire I²C/SMBus Compatible Interface

The MCP9800/1/2/3 serial clock input (SCLK) and the bidirectional serial data line (SDA) form a 2-Wire bidirectional serial port for communication.

The following bus protocol has been defined:

TABLE 5-1:   MCP980X SERIAL BUS CONVENTIONS

Term	Description
Transmitter	Device sending data to the bus
Receiver	Device receiving data from the bus
Master	The device that controls the serial bus, typically a microcontroller
Slave	The device addressed by the master, such as the MCP9800/1/2/3
START	A unique signal from master to initiate serial interface with a slave
STOP	A unique signal from the master to terminate serial interface from a slave
Read/Write	A read or write to the MCP9800/1/2/3 registers
ACK	A receiver Acknowledges (ACK) the reception of each byte by polling the bus
NAK	A receiver Not-Acknowledges (NAK) or releases the bus to show End-of-Data (EOD)
Busy	Communication is not possible because the bus is in use
Not Busy	The bus is in the idle state, both SDA and SCLK remain high
Data Valid	SDA must remain stable before SCLK becomes high in order for a data bit to be considered valid. During normal data transfers, SDA only changes state while SCLK is low

5.1.1   DATA TRANSFER

Data transfers are initiated by a start condition (START), followed by a 7-bit device address and a 1-bit read/write. Acknowledge (ACK) from slave confirms the reception of each byte. Each access must be terminated by a stop condition (STOP).

Data transfer may be initiated when the bus is in IDLE.

5.1.2   MASTER/SLAVE

The bus is controlled by a master device (typically a microcontroller) that controls the bus access and generates the start and stop conditions. The MCP9800/1/2/3 is a slave device and does not control other devices in the bus. Both master and slave devices can operate as either transmitter or receiver. However, the master device determines which mode is activated.

5.1.3   START/STOP CONDITION

A high-to-low transition of the SDA line (while SCLK is high) is the start condition. All data transfers must be preceded by a start condition from the master. If a start condition is generated during data transfer, the MCP9800/1/2/3 resets and accepts the new start condition.

A low-to-high transition of the SDA line (while SCLK is high) is the stop condition. All data transfers must be ended by a stop condition from the master. If a stop condition is introduced during data transmission, the MCP9800/1/2/3 releases the bus.

5.1.4   ADDRESS BYTE

Following the start condition, the host must transmit the address byte to the MCP9800/1/2/3. The 7-bit address for the MCP9800/02A0 and MCP9800/02A5 is `<1001000>` and `<1001101>` in binary, respectively. The address for the MCP9802/03 is `<1001,A2,A1,A0>` in binary, where the A0, A1 and A2 bits are set externally by connecting the corresponding pins to V_{DD} `<1>` or GND `<0>`. The 7-bit address transmitted in the serial bit stream must match the selected address for the MCP9800/1/2/3 to respond with an ACK.

Bit 8 in the address byte is a read/write bit. Setting this bit to '`1`' commands a read operation, while '`0`' commands a write operation.
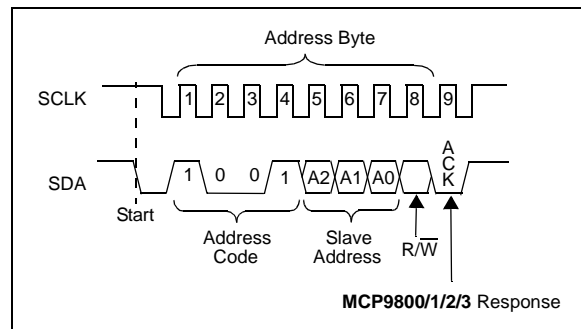
FIGURE 5-1:   Device Addressing.

5.1.5 DATA VALID

After the start condition, each bit of data in transmission needs to be settled for time specified by $t_{SU\text{-}DATA}$ before SCLK toggles from low-to-high (refer to the Serial Interface Timing Specification).

5.1.6 ACKNOWLEDGE (ACK)

Each receiving device, when addressed, is obliged to generate an acknowledge bit after the reception of each byte. The master device must generate an extra clock pulse for ACK to be recognized.

The acknowledging device has to pull down the SDA line for $t_{SU\text{-}DATA}$ before the low-to-high transition of SCLK from the Master and remains pulled down for $t_{H\text{-}DATA}$ after high-to-low transition of SCLK.

During read, the master must signal an End-of-Data (EOD) to the slave by not generating an ACK bit once the last bit has been clocked out of the slave. In this case, the slave will leave the data line released to enable the master to generate the stop condition.

5.1.7 TIME OUT (MCP9802/03)

If the SCLK stays low for time specified by t_{OUT}, the MCP9802/03 resets the serial interface. This dictates the minimum clock speed as specified in the SMBus specification. The I^2C bus specification does not limit clock speed and, therefore, the master can hold the clock indefinitely to process data (MCP9800/01 only).

MCP9800/1/2/3

5.2 Graphical Representation of the MCP9800/1/2/3 Serial Protocols

Read 1-byte Data

Read 2-byte Data

S = START Condition
P = STOP Condition
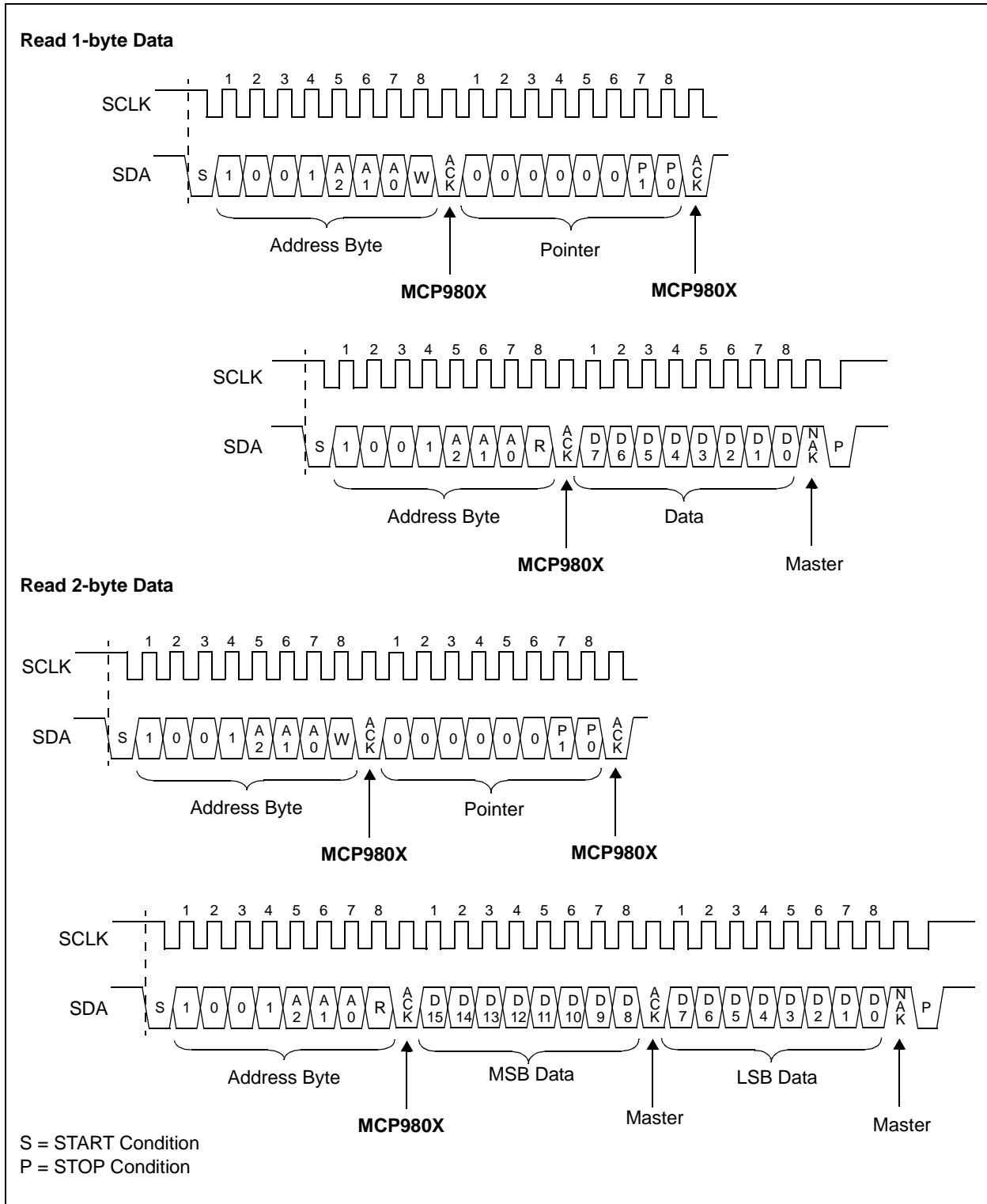
FIGURE 5-2:   *Read 1-byte and 2-byte data from a Register.*

Write 1-byte Data

Write 2-byte Data

S = START Condition
P = STOP Condition
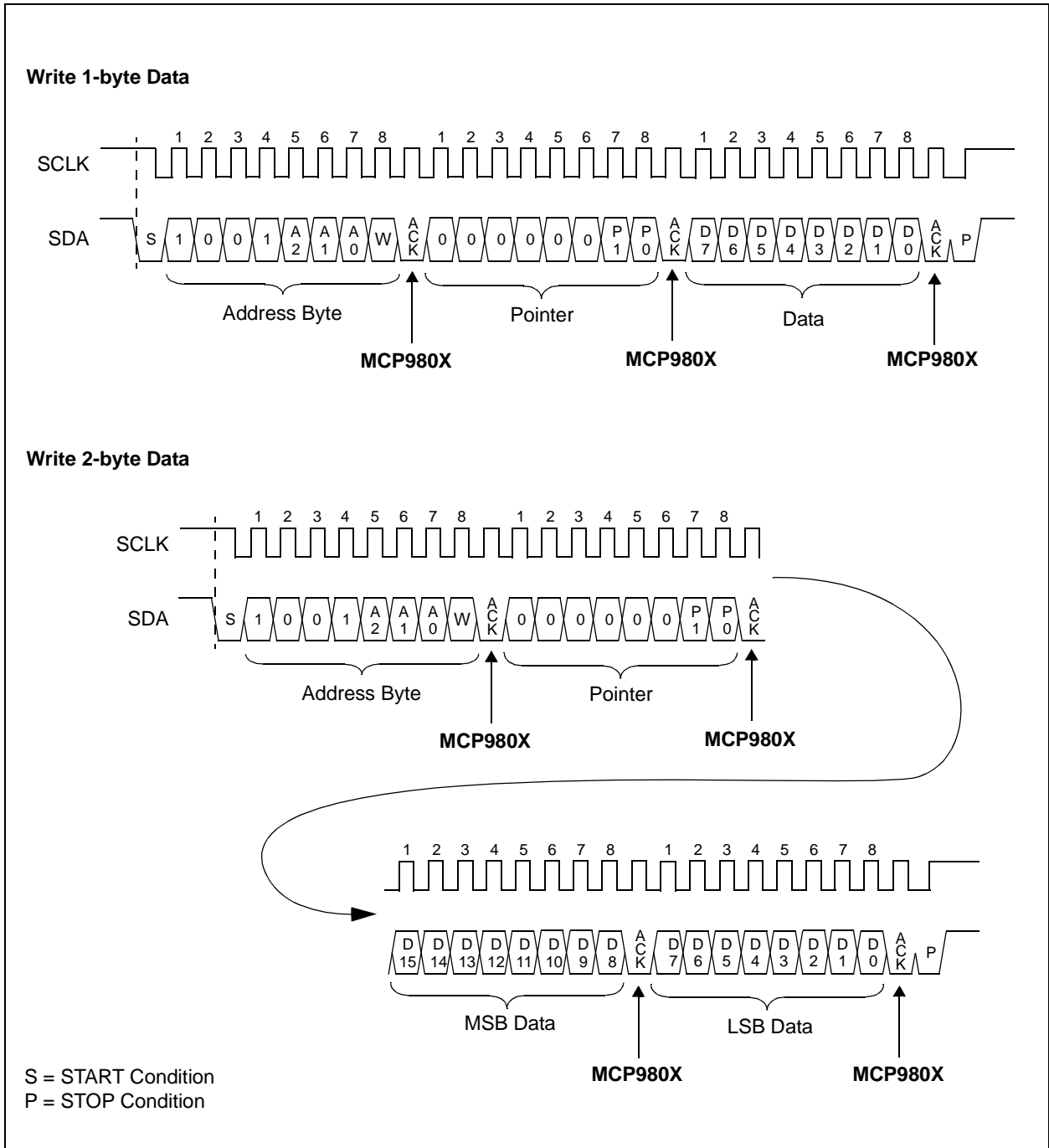
FIGURE 5-3: *Write 1-byte and 2-byte data from a Register.*

Register Pointer Setting for Continuous Reception
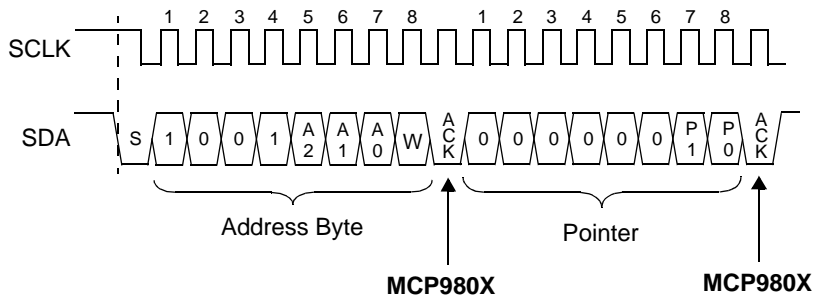
Receive 1-byte Data
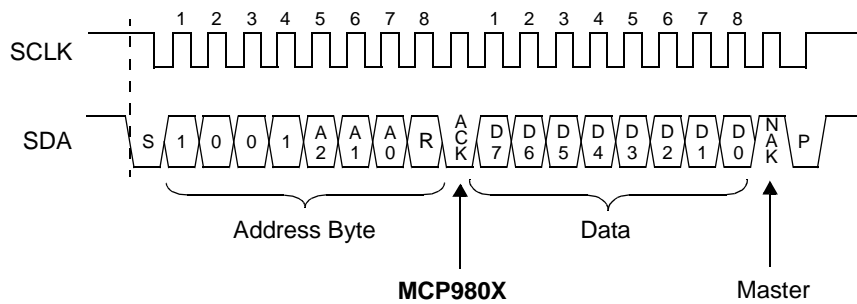
Receive Another 1-byte Data
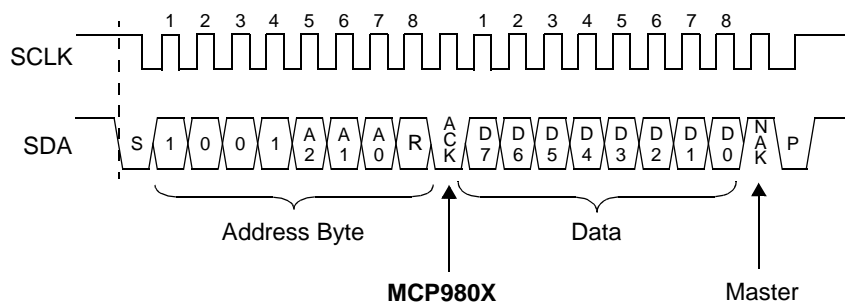
Note: User can continue to receive 1-byte data indefinitely from a previously set register pointer.

S = START Condition
P = STOP Condition

FIGURE 5-4: *Receive 1-byte data from previously set pointer.*

Register Pointer Setting for Continuous Reception

SCLK

SDA

S | 1 | 0 | 0 | 1 | A2 | A1 | A0 | W | ACK | 0 | 0 | 0 | 0 | 0 | 0 | P1 | P0 | ACK

Address Byte | Pointer

MCP980X | **MCP980X**

Receive 2-byte Data

S | 1 | 0 | 0 | 1 | A2 | A1 | A0 | R | ACK | D15 | D14 | D13 | D12 | D11 | D10 | D9 | D8 | ACK | D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 | NAK | P

Address Byte | MSB Data | LSB Data

MCP980X | Master | Master

Receive Another 2-byte Data

S | 1 | 0 | 0 | 1 | A2 | A1 | A0 | R | ACK | D15 | D14 | D13 | D12 | D11 | D10 | D9 | D8 | ACK | D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 | NAK | P

Address Byte | MSB Data | LSB Data

MCP980X | Master | Master
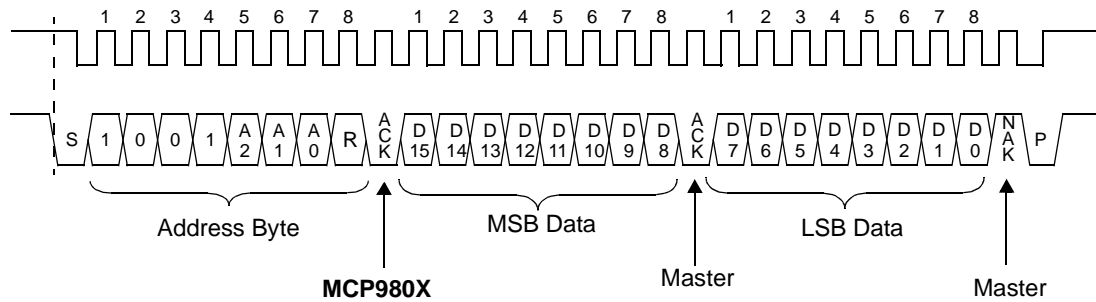
Note: User can continue to receive 2-byte data indefinitely from a previously set register pointer.

S = START Condition
P = STOP Condition

FIGURE 5-5: *Receive 2-byte data from previously set pointer.*

MCP9800/1/2/3

6.0   APPLICATIONS INFORMATION

6.1   Connecting to the Serial Bus

The SDA and SCLK serial interface are open-drain pins that require pull-up resistors. This configuration is shown in Figure 6-1.
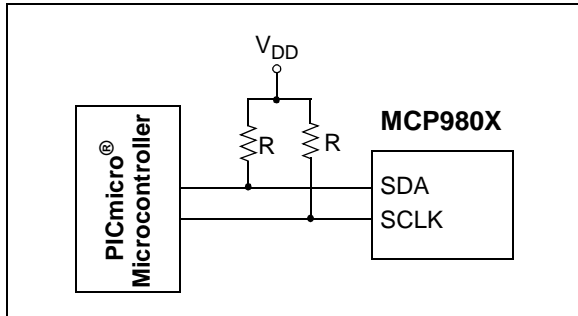
FIGURE 6-1:   *Pull-up Resistors On Serial Interface.*

For the SMBus protocol, the number of devices connected to the bus are limited only by the maximum rise and fall times of the SDA and SCLK lines. Unlike the I²C specifications, SMBus does not specify a maximum bus capacitance value. Rather, it specifies 350 µA (max.) current through the pull-up resistor. Therefore, the value of the pull-up resistors will vary depending on the system's supply voltage (V_{DD}). The pull-up resistor values for a 5V system ranges 14.3 kΩ to 50 kΩ. Minimizing bus capacitance is still very important, as it directly affects the rise and fall times of the SDA and SCLK lines.

Although SMBus specifications only require the SDA and SCLK lines to pull down 350 µA (max.) with 0.4V (max.) voltage drop, the MCP9800/1/2/3 is designed to meet 0.4V (max.) voltage drop at 3 mA of current. This allows the MCP9800/1/2/3 to drive lower values of pull-up resistors and higher bus capacitance. In this application, all devices on the bus must meet the same pull-down current requirements.

6.2   Typical Application

Microchip provides several microcontroller product lines with Master Synchronous Serial Port Modules (MSSP) that include I²C interface mode. This module implements all master and slave functions and simplifies the firmware development overhead. Figure 6-2 shows a typical application using the PIC16F737 as a master to control other Microchip slave products, such as EEPROM, fan speed controllers and the MCP980X temperature sensor connected to the bus.
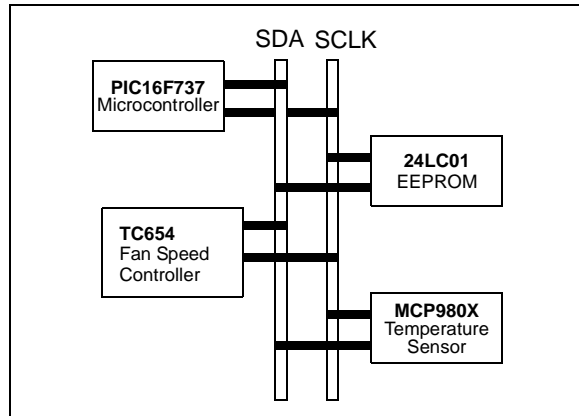
FIGURE 6-2:   *Multiple Devices on SMBus.*

The ALERT output can be wire-ORed with a number of other open-drain devices. In such applications, the output needs to be programmed as an active-low output. Most systems will require pull-up resistors for this configuration.

6.3   Layout Considerations

The MCP9800/1/2/3 does not require any additional components besides the Master controller in order to measure temperature. However, it is recommended that a decoupling capacitor of 0.1 µF to 1 µF be used between the V_{DD} and GND pins. A high-frequency ceramic capacitor is recommended. It is necessary for the capacitor to be located as close as possible to the power pins in order to provide effective noise protection.

6.4   Thermal Considerations

The MCP9800/1/2/3 measures temperature by monitoring the voltage of a diode located in the die. A low impedance thermal path between the die and the Printed Circuit Board (PCB) is provided by the pins. Therefore, the MCP9800/1/2/3 effectively monitors the temperature of the PCB. However, the thermal path for the ambient air is not as efficient because the plastic device package functions as a thermal insulator.

A potential for self-heating errors can exist if the MCP9800/1/2/3 SDA and SCLK communication lines are heavily loaded with pull-ups. Typically, the self-heating error is negligible because of the relatively small current consumption of the MCP9800/1/2/3. However, in order to maximize the temperature accuracy, the SDA and SCLK pins need to be lightly loaded.

7.0   PACKAGING INFORMATION
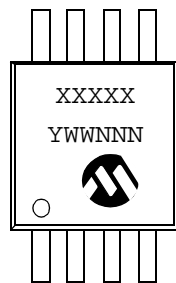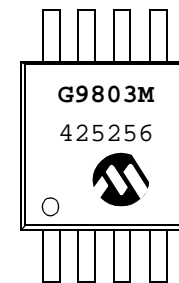
7.1   Package Marking Information

5-Lead SOT-23

XXNN
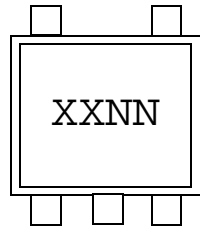
Example:

Part Number	MCP9800	Part Number	MCP9802
MCP9800A0T-M/OTG	LDNN	MCP9802A0T-M/OTG	JKNN
MCP9800A5T-M/OTG	LJNN	MCP9802A5T-M/OTG	JRNN

8-Lead MSOP

XXXXX
YWWNNN

Example:

G9803M
425256

8-Lead SOIC (150 mil)

XXXXXXXX
XXXXYYWW
       NNN

Example:

GMCP9803
M/SN0425
      256
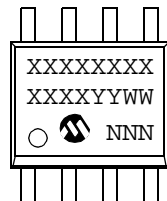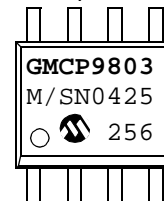
Legend:	XX...X	Customer specific information*
	YY	Year code (last 2 digits of calendar year)
	WW	Week code (week of January 1 is week '01')
	NNN	Alphanumeric traceability code
Note:		In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line thus limiting the number of available characters for customer specific information.

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

MCP9800/1/2/3

5-Lead Plastic Small Outline Transistor (OT) (SOT-23)
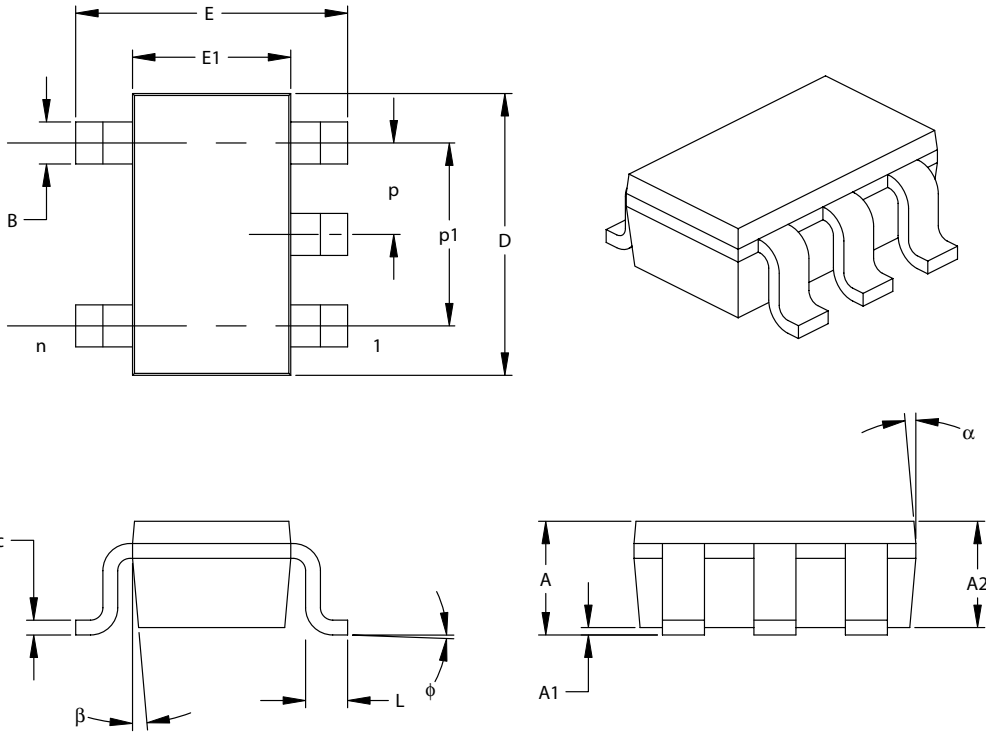
Units		INCHES*			MILLIMETERS		
Dimension Limits		MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n		5			5	
Pitch	p		.038			0.95	
Outside lead pitch (basic)	p1		.075			1.90	
Overall Height	A	.035	.046	.057	0.90	1.18	1.45
Molded Package Thickness	A2	.035	.043	.051	0.90	1.10	1.30
Standoff	A1	.000	.003	.006	0.00	0.08	0.15
Overall Width	E	.102	.110	.118	2.60	2.80	3.00
Molded Package Width	E1	.059	.064	.069	1.50	1.63	1.75
Overall Length	D	.110	.116	.122	2.80	2.95	3.10
Foot Length	L	.014	.018	.022	0.35	0.45	0.55
Foot Angle	φ	0	5	10	0	5	10
Lead Thickness	c	.004	.006	.008	0.09	0.15	0.20
Lead Width	B	.014	.017	.020	0.35	0.43	0.50
Mold Draft Angle Top	α	0	5	10	0	5	10
Mold Draft Angle Bottom	β	0	5	10	0	5	10

*Controlling Parameter

Notes:

Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .005" (0.127mm) per side.

EIAJ Equivalent: SC-74A

Drawing No. C04-091

8-Lead Plastic Micro Small Outline Package (MS) (MSOP)
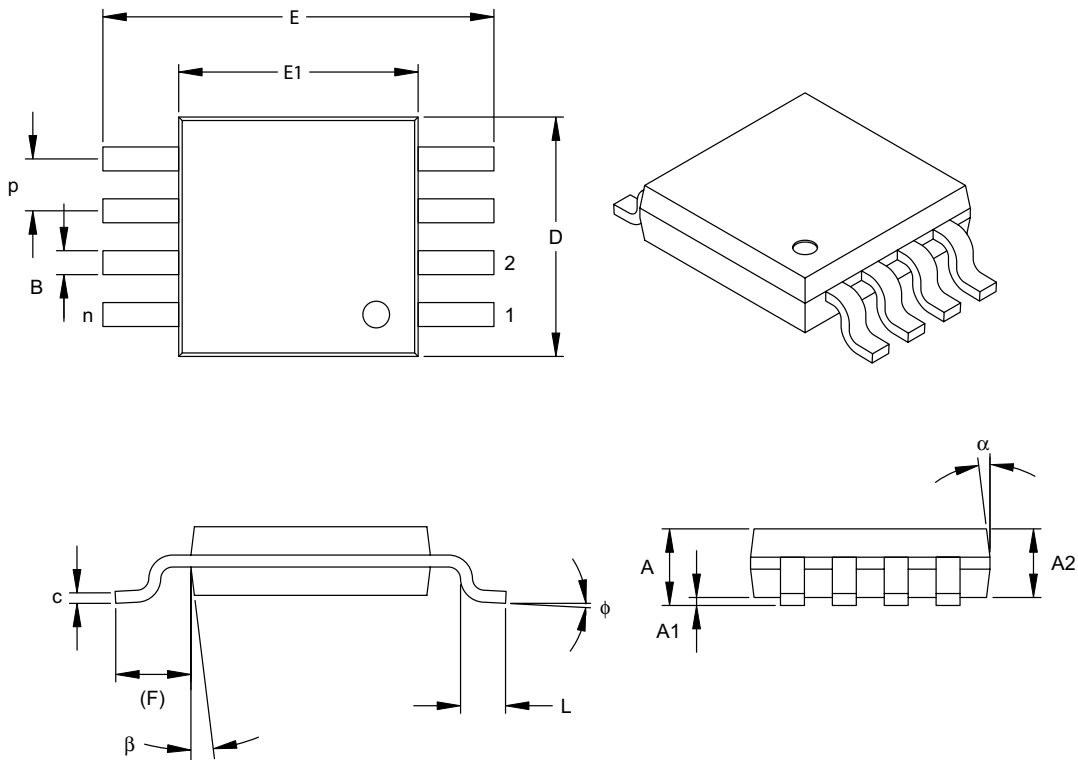
	Units	INCHES			MILLIMETERS*		
Dimension Limits		MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n		8			8	
Pitch	p		.026 BSC			0.65 BSC	
Overall Height	A	-	-	.043	-	-	1.10
Molded Package Thickness	A2	.030	.033	.037	0.75	0.85	0.95
Standoff	A1	.000	-	.006	0.00	-	0.15
Overall Width	E		.193 TYP.			4.90 BSC	
Molded Package Width	E1		.118 BSC			3.00 BSC	
Overall Length	D		.118 BSC			3.00 BSC	
Foot Length	L	.016	.024	.031	0.40	0.60	0.80
Footprint (Reference)	F		.037 REF			0.95 REF	
Foot Angle	φ	0°	-	8°	0°	-	8°
Lead Thickness	c	.003	.006	.009	0.08	-	0.23
Lead Width	B	.009	.012	.016	0.22	-	0.40
Mold Draft Angle Top	α	5°	-	15°	5°	-	15°
Mold Draft Angle Bottom	β	5°	-	15°	5°	-	15°

*Controlling Parameter

Notes:

Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .010" (0.254mm) per side.

JEDEC Equivalent: MO-187

Drawing No. C04-111

MCP9800/1/2/3

8-Lead Plastic Small Outline (SN) – Narrow, 150 mil Body (SOIC)
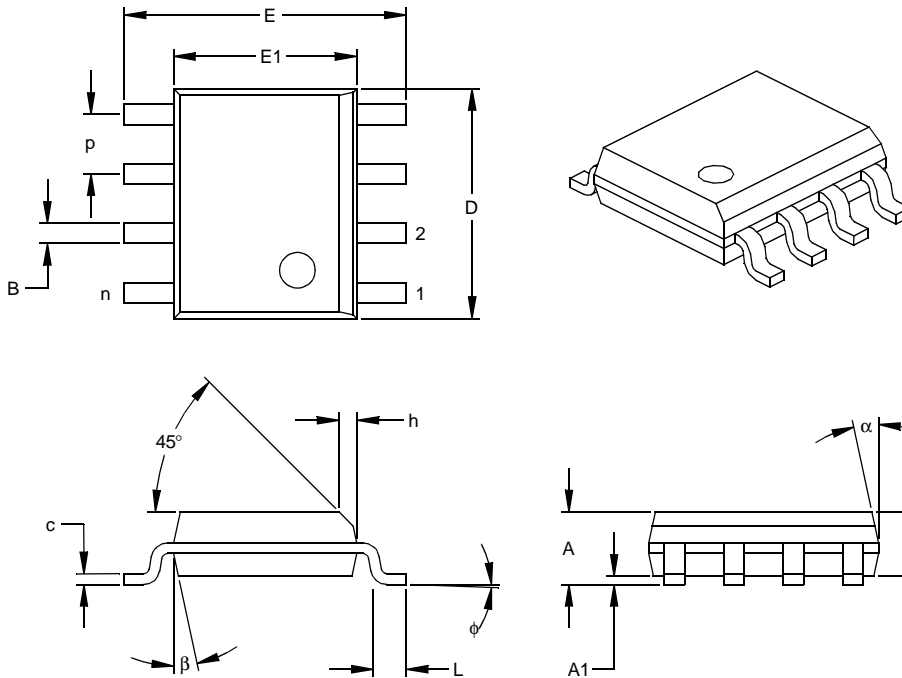
	Units	INCHES*			MILLIMETERS		
Dimension Limits		MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n		8			8	
Pitch	p		.050			1.27	
Overall Height	A	.053	.061	.069	1.35	1.55	1.75
Molded Package Thickness	A2	.052	.056	.061	1.32	1.42	1.55
Standoff §	A1	.004	.007	.010	0.10	0.18	0.25
Overall Width	E	.228	.237	.244	5.79	6.02	6.20
Molded Package Width	E1	.146	.154	.157	3.71	3.91	3.99
Overall Length	D	.189	.193	.197	4.80	4.90	5.00
Chamfer Distance	h	.010	.015	.020	0.25	0.38	0.51
Foot Length	L	.019	.025	.030	0.48	0.62	0.76
Foot Angle	φ	0	4	8	0	4	8
Lead Thickness	c	.008	.009	.010	0.20	0.23	0.25
Lead Width	B	.013	.017	.020	0.33	0.42	0.51
Mold Draft Angle Top	α	0	12	15	0	12	15
Mold Draft Angle Bottom	β	0	12	15	0	12	15

* Controlling Parameter
§ Significant Characteristic

Notes:
Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .010" (0.254mm) per side.
JEDEC Equivalent: MS-012
Drawing No. C04-057

© 2004 Microchip Technology Inc.

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	X	–X	/XX	X
Device	Slave Address	Tape & Reel	Temperature Range	Package	PB Free

Device:	MCP9800: Temperature Sensor
	MCP9801: Temperature Sensor
	MCP9802: Temperature Sensor
	MCP9803: Temperature Sensor
	A0 = Slave address set to '000'
	A5 = Slave address set to '101'
Tape and Reel:	= Blank
	T = Tape and Reel
Temperature Range:	M = -55°C to +125°C
Package:	OT = Plastic Small Outline Transistor (SOT-23), 5-lead
	MS = Plastic Micro Small Outline (MSOP), 8-lead
	SN = Plastic SOIC, (150 mil Body), 8-lead
PB Free:	G = Lead Free device

Examples:

a) MCP9800A0T-M/OTG Slave address '000', Tape and Reel, -55°C to +125°C, PB Free SOT-23 package.

b) MCP9800A5T-M/OTG Slave address '101', Tape and Reel, -55°C to +125°C, PB Free SOT-23 package.

a) MCP9801-M/MSG -55°C to +125°C, PB Free 8LD MSOP package.

b) MCP9801T-M/MSG Tape and Reel, -55°C to +125°C, PB Free 8LD MSOP package.

c) MCP9801-M/SNG -55°C to +125°C, PB Free 8LD SOIC package.

d) MCP9801T-M/SNG Tape and Reel, -55°C to +125°C, PB Free 8LD SOIC package.

a) MCP9802A0T-M/OT Slave address '000', Tape and Reel, -55°C to +125°C, SOT-23 package.

b) MCP9802A5T-M/OT Slave address '101', Tape and Reel, -55°C to +125°C, SOT-23 package.

a) MCP9803-M/MSG -55°C to +125°C, PB Free 8LD MSOP package.

b) MCP9803T-M/MSG Tape and Reel, -55°C to +125°C, PB Free 8LD MSOP package.

c) MCP9803-M/SNG -55°C to +125°C, PB Free 8LD SOIC package.

d) MCP9803T-M/SNG Tape and Reel, -55°C to +125°C, PB Free 8LD SOIC package.

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:

1. Your local Microchip sales office
2. The Microchip Corporate Literature Center U.S. FAX: (480) 792-7277
3. The Microchip Worldwide Site (www.microchip.com)

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

New Customer Notification System
Register on our web site (www.microchip.com) to receive the most current information on our products.

NOTES:

WORLDWIDE SALES AND SERVICE

AMERICAS

Corporate Office
2355 West Chandler Blvd.
Chandler, AZ 85224-6199
Tel: 480-792-7200
Fax: 480-792-7277
Technical Support:
http:\\support.microchip.com
Web Address:
www.microchip.com

Atlanta
Alpharetta, GA
Tel: 770-640-0034
Fax: 770-640-0307

Boston
Westford, MA
Tel: 978-692-3848
Fax: 978-692-3821

Chicago
Itasca, IL
Tel: 630-285-0071
Fax: 630-285-0075

Dallas
Addison, TX
Tel: 972-818-7423
Fax: 972-818-2924

Detroit
Farmington Hills, MI
Tel: 248-538-2250
Fax: 248-538-2260

Kokomo
Kokomo, IN
Tel: 765-864-8360
Fax: 765-864-8387

Los Angeles
Mission Viejo, CA
Tel: 949-462-9523
Fax: 949-462-9608

San Jose
Mountain View, CA
Tel: 650-215-1444
Fax: 650-961-0286

Toronto
Mississauga, Ontario,
Canada
Tel: 905-673-0699
Fax: 905-673-6509

ASIA/PACIFIC

Australia - Sydney
Tel: 61-2-9868-6733
Fax: 61-2-9868-6755

China - Beijing
Tel: 86-10-8528-2100
Fax: 86-10-8528-2104

China - Chengdu
Tel: 86-28-8676-6200
Fax: 86-28-8676-6599

China - Fuzhou
Tel: 86-591-750-3506
Fax: 86-591-750-3521

China - Hong Kong SAR
Tel: 852-2401-1200
Fax: 852-2401-3431

China - Shanghai
Tel: 86-21-5407-5533
Fax: 86-21-5407-5066

China - Shenyang
Tel: 86-24-2334-2829
Fax: 86-24-2334-2393

China - Shenzhen
Tel: 86-755-8203-2660
Fax: 86-755-8203-1760

China - Shunde
Tel: 86-757-2839-5507
Fax: 86-757-2839-5571

China - Qingdao
Tel: 86-532-502-7355
Fax: 86-532-502-7205

ASIA/PACIFIC

India - Bangalore
Tel: 91-80-2229-0061
Fax: 91-80-2229-0062

India - New Delhi
Tel: 91-11-5160-8632
Fax: 91-11-5160-8632

Japan - Kanagawa
Tel: 81-45-471- 6166
Fax: 81-45-471-6122

Korea - Seoul
Tel: 82-2-554-7200
Fax: 82-2-558-5932 or
82-2-558-5934

Singapore
Tel: 65-6334-8870
Fax: 65-6334-8850

Taiwan - Kaohsiung
Tel: 886-7-536-4818
Fax: 886-7-536-4803

Taiwan - Taipei
Tel: 886-2-2500-6610
Fax: 886-2-2508-0102

Taiwan - Hsinchu
Tel: 886-3-572-9526
Fax: 886-3-572-6459

EUROPE

Austria - Weis
Tel: 43-7242-2244-399
Fax: 43-7242-2244-393

Denmark - Ballerup
Tel: 45-4420-9895
Fax: 45-4420-9910

France - Massy
Tel: 33-1-69-53-63-20
Fax: 33-1-69-30-90-79

Germany - Ismaning
Tel: 49-89-627-144-0
Fax: 49-89-627-144-44

Italy - Milan
Tel: 39-0331-742611
Fax: 39-0331-466781

Netherlands - Drunen
Tel: 31-416-690399
Fax: 31-416-690340

England - Berkshire
Tel: 44-118-921-5869
Fax: 44-118-921-5820

09/27/04