MCP9808

±0.5°C Maximum Accuracy Digital Temperature Sensor

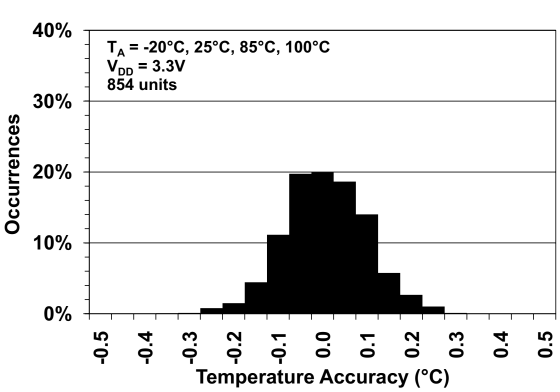
Features

- Accuracy:
  - ±0.25 (typical) from -40°C to +125°C
  - ±0.5°C (maximum) from -20°C to 100°C
  - ±1°C (maximum) from -40°C to +125°C
- User-Selectable Measurement Resolution:
  - +0.5°C, +0.25°C, +0.125°C, +0.0625°C
- User-Programmable Temperature Limits:
  - Temperature Window Limit
  - Critical Temperature Limit
- User-Programmable Temperature Alert Output
- Operating Voltage Range: 2.7V to 5.5V
- Operating Current: 200 µA (typical)
- Shutdown Current: 0.1 µA (typical)
- 2-wire Interface: I^2C™/SMBus Compatible
- Available Packages: 2x3 DFN-8, MSOP-8

Typical Applications

- General Purpose
- Industrial Applications
- Industrial Freezers and Refrigerators
- Food Processing
- Personal Computers and Servers
- PC Peripherals
- Consumer Electronics
- Handheld/Portable Devices

Temperature Accuracy



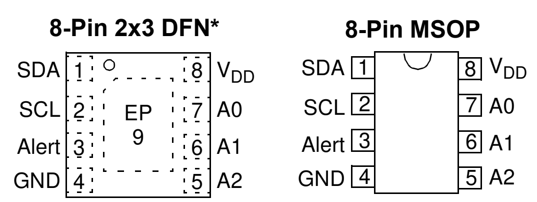
Description

Microchip Technology Inc.'s MCP9808 digital temperature sensor converts temperatures between -20°C and +100°C to a digital word with ±0.25°C/±0.5°C (typical/maximum) accuracy.

The MCP9808 comes with user-programmable registers that provide flexibility for temperature sensing applications. The registers allow user-selectable settings such as Shutdown or Low-Power modes and the specification of temperature Alert window limits and critical output limits. When the temperature changes beyond the specified boundary limits, the MCP9808 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 a temperature Alert interrupt output for microprocessor-based systems. The Alert output can also be configured as a critical temperature output only.

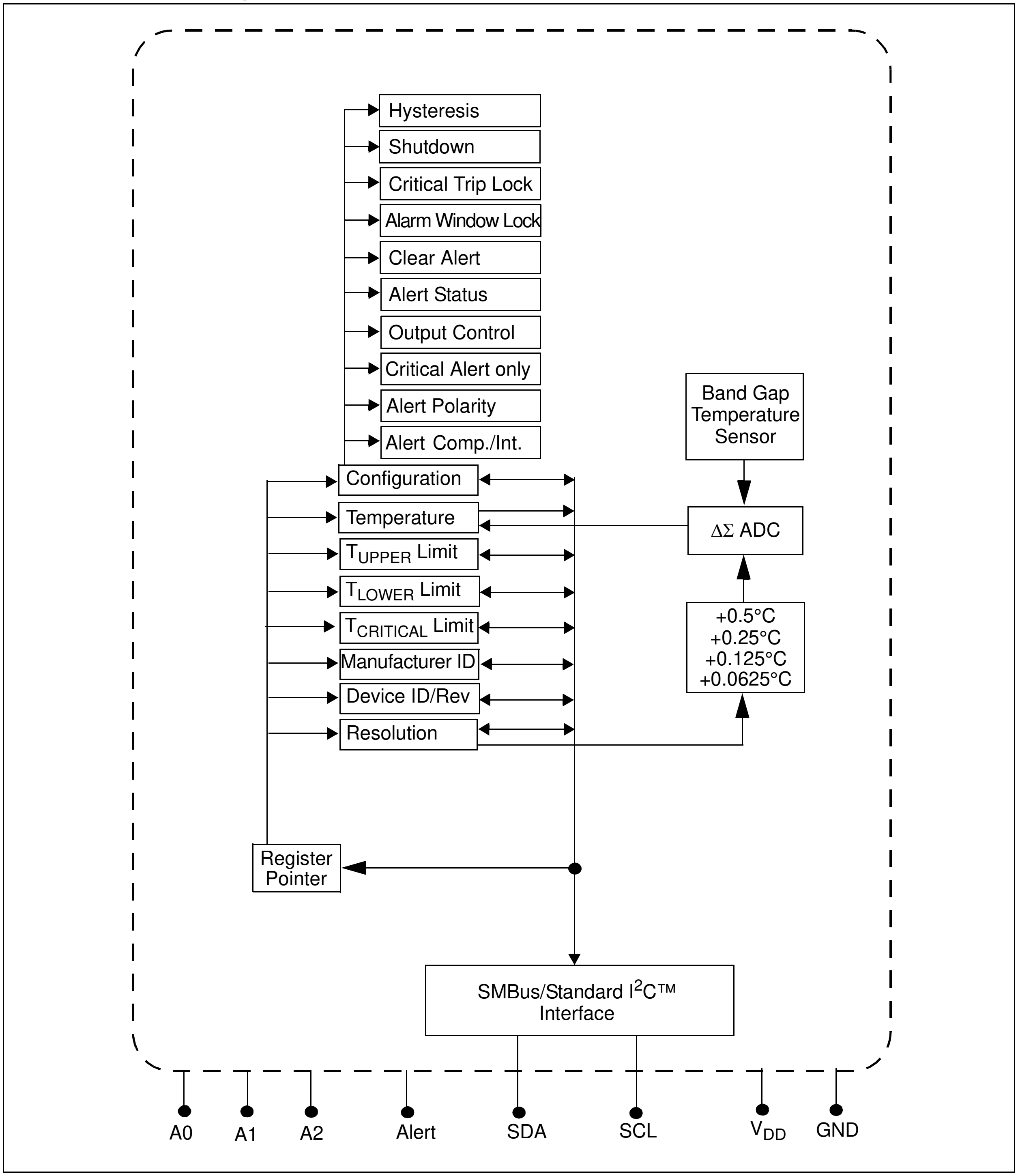
This sensor has an industry standard 400 kHz, 2-wire, SMBus/I^2C compatible serial interface, allowing up to eight or sixteen sensors to be controlled with a single serial bus (see Table 3-2 for available Address codes). These features make the MCP9808 ideal for sophisticated, multi-zone, temperature-monitoring applications.

Package Types



* Includes Exposed Thermal Pad (EP); see Table 3-1.

Functional Block Diagram



1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings †

V_{DD} 6.0V
Voltage at All Input/Output Pins .... GND – 0.3V to 6.0V
Storage Temperature ....-65°C to +150°C
Ambient Temperature with Power Applied ....-40°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 (+25°C) .... ±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.

TEMPERATURE SENSOR DC CHARACTERISTICS

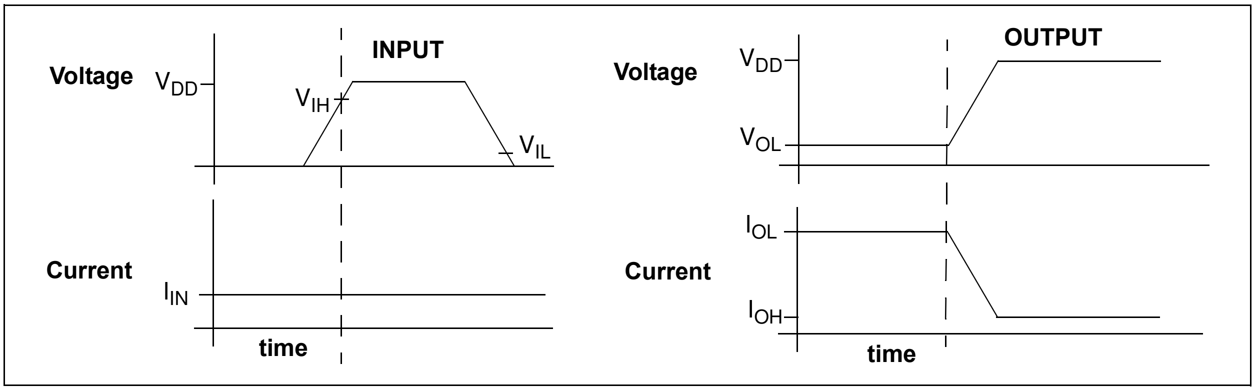
Electrical Specifications: Unless otherwise indicated, V_{DD} = 2.7V to 5.5V, GND = Ground and T_A = -40°C to +125°C.

Parameters	Sym	Min	Typ	Max	Unit	Conditions
Temperature Sensor Accuracy						
-20°C < $T_A \le$ +100°C	T_{ACY}	-0.5	±0.25	+0.5	°C	V_{DD} = 3.3V
-40°C < $T_A \le$ +125°C	T_{ACY}	-1.0	±0.25	+1.0	°C	V_{DD} = 3.3V
Temperature Conversion Time						
0.5°C/bit	t_{CONV}	—	30	—	ms	33s/sec (typical)
0.25°C/bit		—	65	—	ms	15s/sec (typical)
0.125°C/bit		—	130	—	ms	7s/sec (typical)
0.0625°C/bit		—	250	—	ms	4s/sec (typical)
Power Supply						
Operating Voltage Range	V_{DD}	2.7	—	5.5	V	
Operating Current	I_{DD}	—	200	400	µA	
Shutdown Current	I_{SHDN}	—	0.1	2	µA	
Power-on Reset (POR)	V_{POR}	—	2.2	—	V	Threshold for falling V_{DD}
Power Supply Rejection	$\Delta°C/\Delta V_{DD}$	—	-0.1	—	°C/V	V_{DD} = 2.7V to 5.5V, T_A = +25°C
Alert Output (open-drain output, external pull-up resistor required), see Section 5.2.3 “Alert Output Configuration”						
High-Level Current (leakage)	I_{OH}	—	—	1	µA	$V_{OH} = V_{DD}$ (Active-Low, Pull-up Resistor)
Low-Level Voltage	V_{OL}	—	—	0.4	V	I_{OL} = 3 mA (Active-Low, Pull-up Resistor)
Thermal Response, from +25°C (air) to +125°C (oil bath)						
8L-DFN	t_{RES}	—	0.7	—	s	Time to 63% (+89°C)
8L-MSOP		—	1.4	—	s	

DIGITAL INPUT/OUTPUT PIN CHARACTERISTICS

Electrical Specifications: Unless otherwise indicated, V_{DD} = 2.7V to 5.5V, GND = Ground and T_A = -40°C to +125°C.						
Parameters	**Sym**	**Min**	**Typ**	**Max**	**Units**	**Conditions**
Serial Input/Output (SCL, SDA, A0, A1, A2)						
Input						
High-Level Voltage	V_{IH}	0.7 V_{DD}	—	V_{DD}	V	
Low-Level Voltage	V_{IL}	GND	—	0.3 V_{DD}	V	
Input Current	I_{IN}	—	—	±5	µA	
Output (SDA)						
Low-Level Voltage	V_{OL}	—	—	0.4	V	I_{OL}= 3 mA
High-Level Current (leakage)	I_{OH}	—	—	1	µA	V_{OH} = 5.5V
Low-Level Current	I_{OL}	6	—	—	mA	V_{OL} = 0.6V
SDA and SCL Inputs						
Hysteresis	V_{HYST}	—	0.05 V_{DD}	—	V	
Spike Suppression	t_{SP}	—	—	50	ns	
Capacitance	C_{IN}	—	5	—	pF	

GRAPHICAL SYMBOL DESCRIPTION



TEMPERATURE CHARACTERISTICS

Electrical Specifications: Unless otherwise indicated, V_{DD} = 2.7V to 5.5V and GND = Ground.						
Parameters	**Sym**	**Min**	**Typ**	**Max**	**Units**	**Conditions**
Temperature Ranges						
Specified Temperature Range	T_A	-40	—	+125	°C	(**Note 1**)
Operating Temperature Range	T_A	-40	—	+125	°C	
Storage Temperature Range	T_A	-65	—	+150	°C	
Thermal Package Resistances						
Thermal Resistance, 8L-DFN	θ_{JA}	—	68	—	°C/W	
Thermal Resistance, 8L-MSOP	θ_{JA}	—	211	—	°C/W	

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

SENSOR SERIAL INTERFACE TIMING SPECIFICATIONS

Electrical Specifications: Unless otherwise indicated, V_{DD} = 2.7V to 5.5V, T_A = -40°C to +125°C, GND = Ground and C_L = 80 pF. (**Note 1**)					
Parameters	**Sym**	**Min**	**Max**	**Units**	**Conditions**
2-Wire SMBus/Standard Mode I²C™ Compatible Interface (Note 1)					
Serial Port Clock Frequency	f_{SC}	0	400	kHz	**(Note 2, 4)**
Low Clock	t_{LOW}	1300	—	ns	**(Note 2)**
High Clock	t_{HIGH}	600	—	ns	**(Note 2)**
Rise Time	t_R	20	300	ns	
Fall Time	t_F	20	300	ns	
Data in Setup Time	$t_{SU\text{-}DI}$	100	—	ns	**(Note 3)**
Data In Hold Time	$t_{HD\text{-}DI}$	0	—	ns	**(Note 5)**
Data Out Hold Time	$t_{HD\text{-}DO}$	200	900	ns	**(Note 4)**
Start Condition Setup Time	$t_{SU\text{-}START}$	600	—	ns	
Start Condition Hold Time	$t_{HD\text{-}START}$	600	—	ns	
Stop Condition Setup Time	$t_{SU\text{-}STOP}$	600	—	ns	
Bus Free	$t_{B\text{-}FREE}$	1300	—	ns	
Time-out	t_{OUT}	25	35	ms	
Bus Capacitive Load	C_b	—	400	pf	

Note 1: All values referred to $V_{IL\ MAX}$ and $V_{IH\ MIN}$ levels.

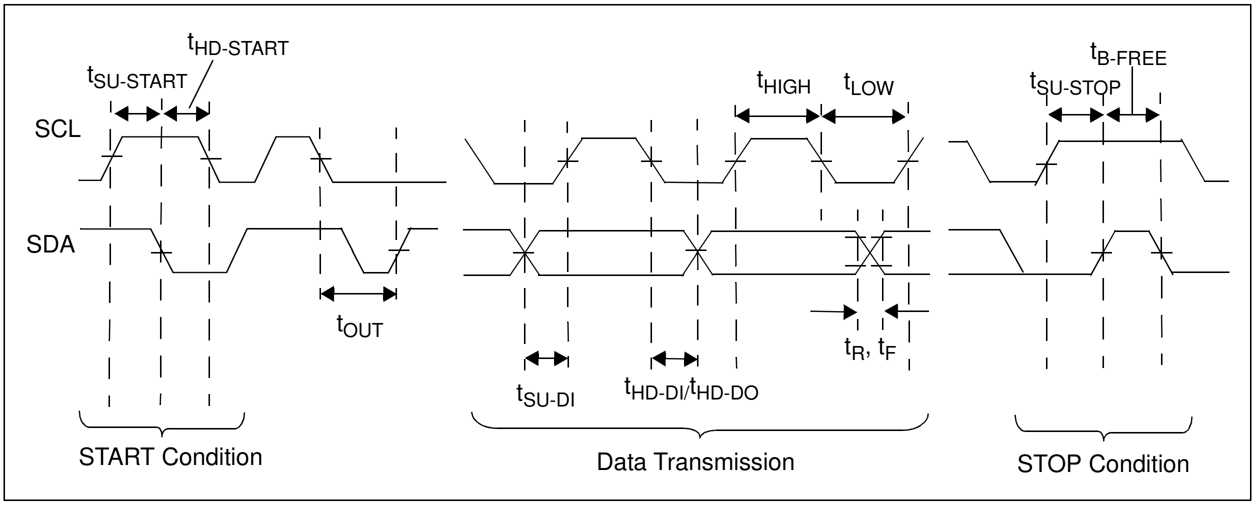
2: If $t_{LOW} > t_{OUT}$ or $t_{HIGH} > t_{OUT}$, the temperature sensor I²C interface will time-out. A Repeat Start command is required for communication.

3: This device can be used in a Standard mode I²C bus system, but the requirement, $t_{SU\text{-}DI} \geq 100$ ns, must be met. This device does not stretch the SCL Low time.

4: As a transmitter, the device provides internal minimum delay time, $t_{HD\text{-}DO\ MIN}$, to bridge the undefined region (min. 200 ns) of the falling edge of SCL, $t_{F\ MAX}$, to avoid unintended generation of Start or Stop conditions.

5: As a receiver, SDA should not be sampled at the falling edge of SCL. SDA can transition $t_{HD\text{-}DI}$ 0 ns after SCL toggles Low.

TIMING DIAGRAM



NOTES:

2.0 TYPICAL PERFORMANCE CURVES

Note: The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only. The performance characteristics listed herein are not tested or guaranteed. In some graphs or tables, the data presented may be outside the specified operating range (e.g., outside specified power supply range) and therefore outside the warranted range.

Note: Unless otherwise indicated, V_{DD} = 2.7V to 5.5V, GND = Ground, SDA/SCL pulled-up to V_{DD} and T_A = -40°C to +125°C.

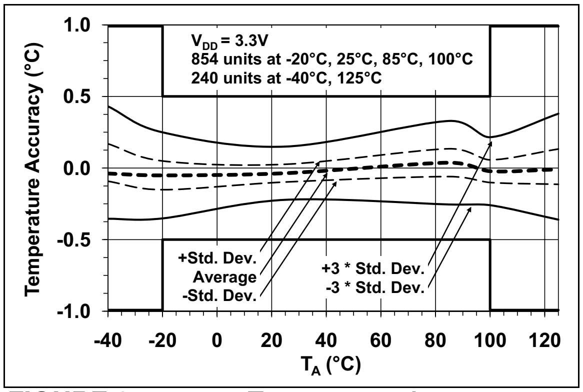


FIGURE 2-1: *Temperature Accuracy.*

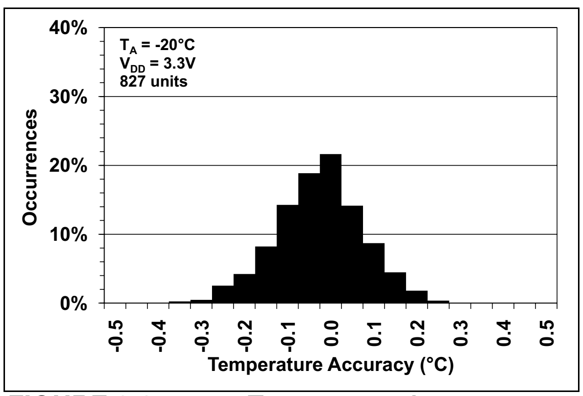


FIGURE 2-2: *Temperature Accuracy Histogram, T_A = -20°C.*

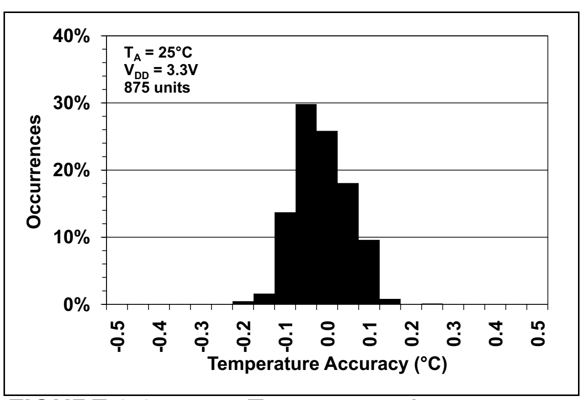


FIGURE 2-3: *Temperature Accuracy Histogram, T_A = +25°C.*

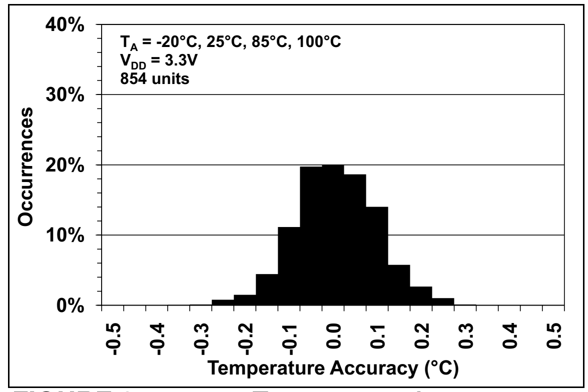


FIGURE 2-4: *Temperature Accuracy Histogram.*

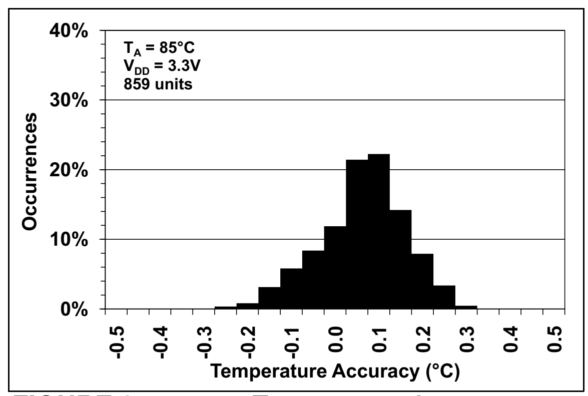


FIGURE 2-5: *Temperature Accuracy Histogram, T_A = +85°C.*

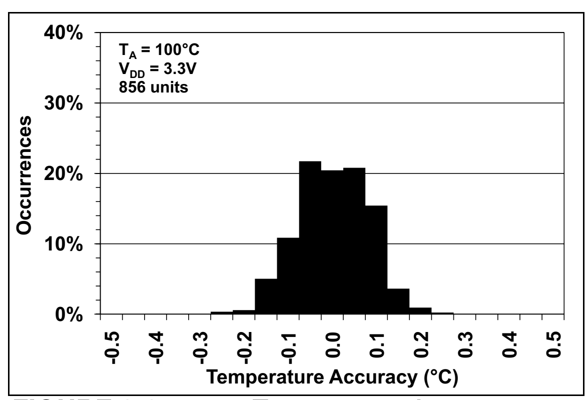


FIGURE 2-6: *Temperature Accuracy Histogram, T_A = +100°C.*

Note: Unless otherwise indicated, V_{DD} = 2.7V to 5.5V, GND = Ground, SDA/SCL pulled-up to V_{DD} and T_A = -40°C to +125°C.

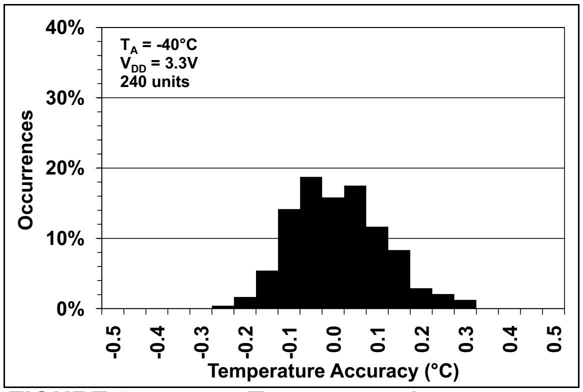


FIGURE 2-7: *Temperature Accuracy Histogram, T_A = -40°C.*

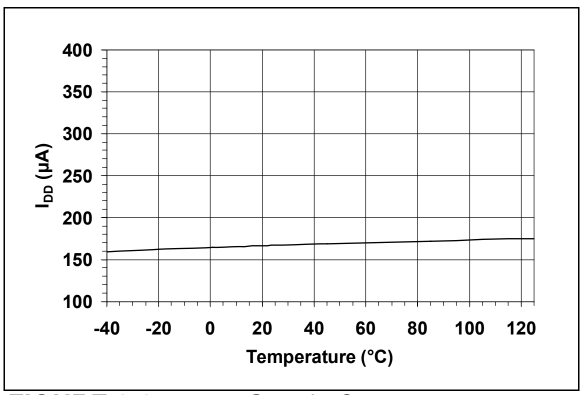


FIGURE 2-8: *Supply Current vs. Temperature.*

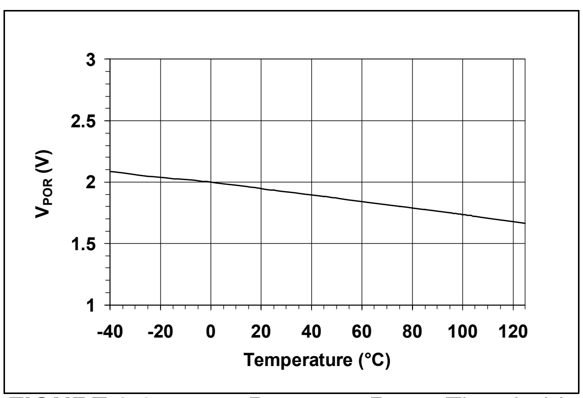


FIGURE 2-9: *Power-on Reset Threshold Voltage vs. Temperature.*

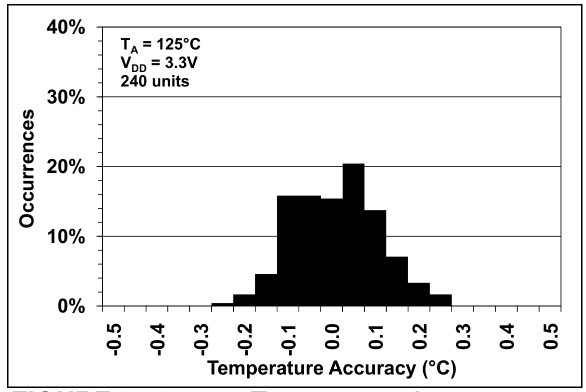


FIGURE 2-10: *Temperature Accuracy Histogram, T_A = +125°C.*

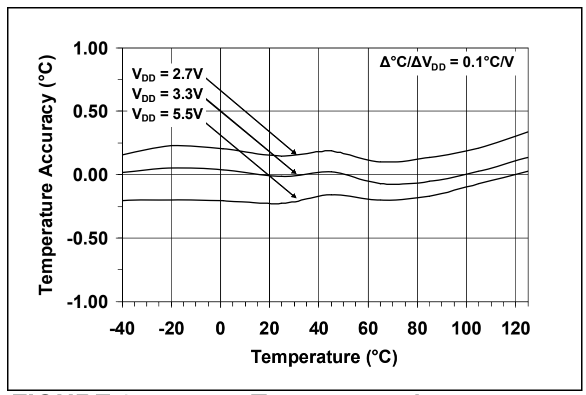


FIGURE 2-11: *Temperature Accuracy vs Supply Voltage.*

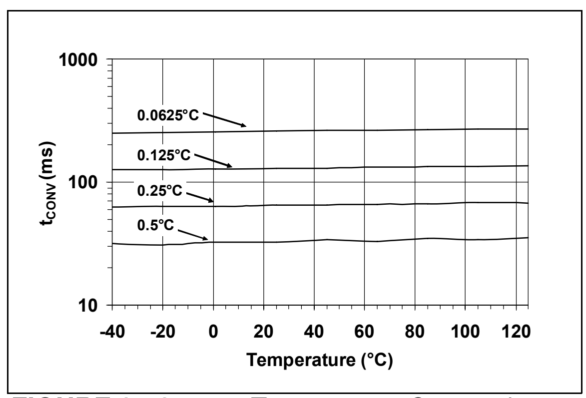


FIGURE 2-12: *Temperature Conversion Time vs. Temperature.*

Note: Unless otherwise indicated, V_{DD} = 2.7V to 5.5V, GND = Ground, SDA/SCL pulled-up to V_{DD} and T_A = -40°C to +125°C.

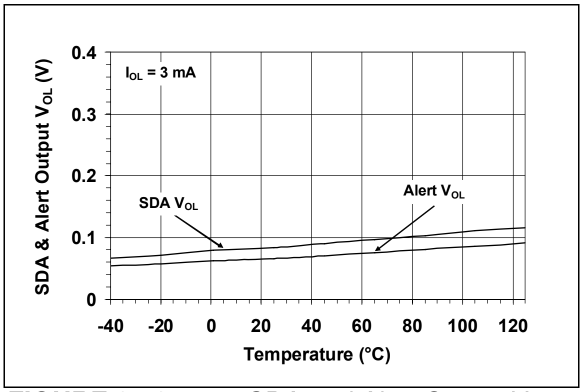


FIGURE 2-13: *SDA and Alert Output V_{OL} vs. Temperature.*

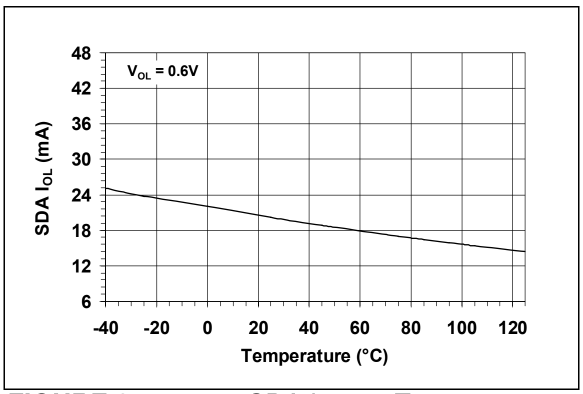


FIGURE 2-14: *SDA I_{OL} vs. Temperature.*

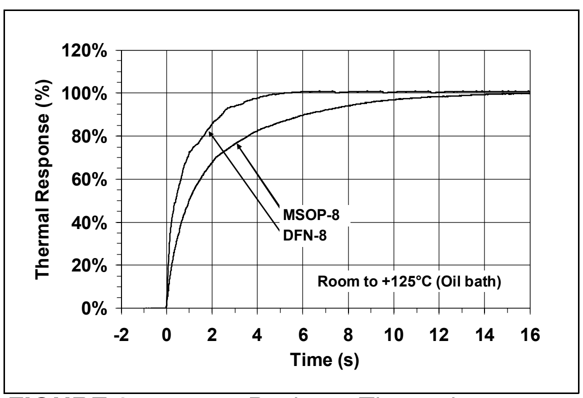


FIGURE 2-15: *Package Thermal Response.*

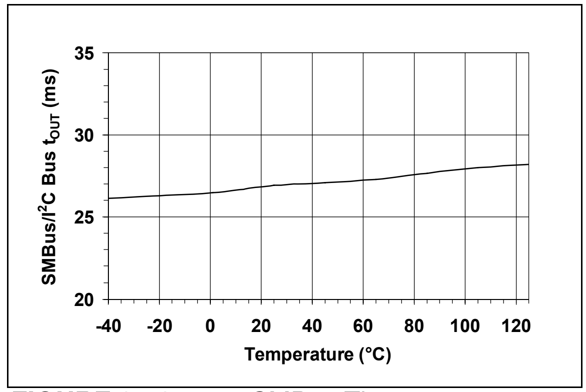


FIGURE 2-16: *SMBus Time-out vs. Temperature.*

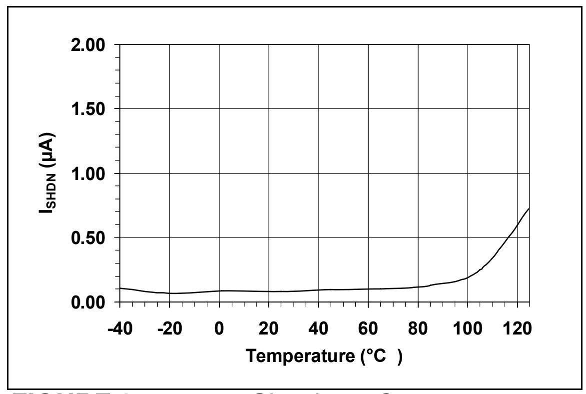


FIGURE 2-17: *Shutdown Current vs Temperature.*

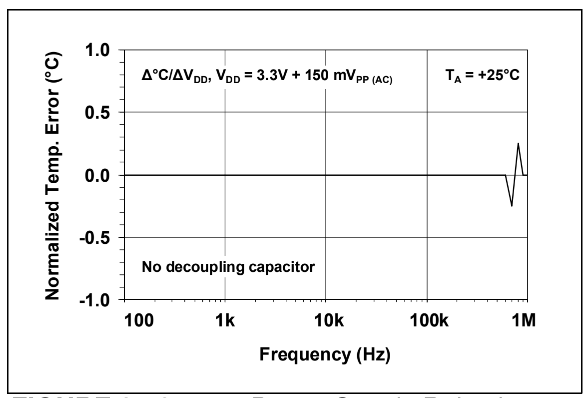


FIGURE 2-18: *Power Supply Rejection vs. Frequency.*

NOTES:

3.0 PIN DESCRIPTION

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

TABLE 3-1: PIN FUNCTION TABLE

DFN	MSOP	Symbol	Pin Function
1	1	SDA	Serial Data Line
2	2	SCL	Serial Clock Line
3	3	Alert	Temperature Alert Output
4	4	GND	Ground
5	5	A2	Slave Address
6	6	A1	Slave Address
7	7	A0	Slave Address
8	8	V_{DD}	Power Pin
9	—	EP	Exposed Thermal Pad (EP); must be connected to GND

3.1 Serial Data Line (SDA)

SDA is a bidirectional input/output pin, used to serially transmit data to/from the host controller. This pin requires a pull-up resistor. (See **Section 4.0 "Serial Communication"**.)

3.2 Serial Clock Line (SCL)

The SCL is a clock input pin. All communication and timing is relative to the signal on this pin. The clock is generated by the host or master controller on the bus. (See **Section 4.0 "Serial Communication"**.)

3.3 Temperature Alert, Open-Drain Output (Alert)

The MCP9808 temperature Alert output pin is an open-drain output. The device outputs a signal when the ambient temperature goes beyond the user-programmed temperature limit. (See **Section 5.2.3 "Alert Output Configuration"**).

3.4 Ground Pin (GND)

The GND pin is the system ground pin.

3.5 Address Pins (A0, A1, A2)

These pins are device address input pins.

The address pins correspond to the Least Significant bits (LSbs) of the address bits and the Most Significant bits (MSbs): A6, A5, A4, A3. This is illustrated in Table 3-2.

TABLE 3-2: MCP9808 ADDRESS BYTE

Device	Address Code				Slave Address		
	A6	A5	A4	A3	A2	A1	A0
MCP9808	0	0	1	1	x(1)	x	x
MCP9808(2)	1	0	0	1	x	x	x

Note 1: User-selectable address is shown by 'x'. A2, A1 and A0 must match the corresponding device pin configuration.

2: Contact factory for this address code.

3.6 Power Pin (V_{DD})

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

3.7 Exposed Thermal Pad (EP)

There is an internal electrical connection between the Exposed Thermal Pad (EP) and the GND pin. The EP may be connected to the system ground on the Printed Circuit Board (PCB).

NOTES:

4.0 SERIAL COMMUNICATION

4.1 2-Wire Standard Mode I²C™ Protocol Compatible Interface

The MCP9808 Serial Clock (SCL) input and the bidirectional Serial Data (SDA) line form a 2-wire bidirectional, Standard mode, I²C compatible communication port (refer to the **Digital Input/Output Pin Characteristics** and **Sensor Serial Interface Timing Specifications** tables).

The following bus protocol has been defined:

TABLE 4-1: MCP9808 SERIAL BUS PROTOCOL DESCRIPTIONS

Term	Description
Master	The device that controls the serial bus, typically a microcontroller.
Slave	The device addressed by the master, such as the MCP9808.
Transmitter	Device sending data to the bus.
Receiver	Device receiving data from the bus.
START	A unique signal from the 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 MCP9808 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 SCL remain high.
Data Valid	SDA must remain stable before SCL becomes high in order for a data bit to be considered valid. During normal data transfers, SDA only changes state while SCL is low.

4.1.1 DATA TRANSFER

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

Repeated communication is initiated after $t_{B\text{-}FREE}$.

This device does not support sequential register read/write. Each register needs to be addressed using the Register Pointer.

This device supports the receive protocol. The register can be specified using the pointer for the initial read. Each repeated read or receive begins with a Start condition and address byte. The MCP9808 retains the previously selected register. Therefore, it outputs data from the previously specified register (repeated pointer specification is not necessary).

4.1.2 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 MCP9808 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.

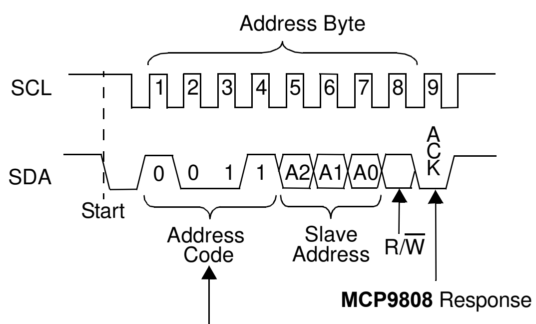
4.1.3 START/STOP CONDITION

A high-to-low transition of the SDA line (while SCL is high) is the Start condition. All data transfers must be preceded by a Start condition from the master. A low-to-high transition of the SDA line (while SCL is high) signifies a Stop condition.

If a Start or Stop condition is introduced during data transmission, the MCP9808 releases the bus. All data transfers are ended by a Stop condition from the master.

4.1.4 ADDRESS BYTE

Following the Start condition, the host must transmit an 8-bit address byte to the MCP9808. The address for the MCP9808 temperature sensor is '0011,A2,A1,A0' in binary, where the A2, A1 and A0 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 MCP9808 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 (see Figure 4-1).



See Table 3-2.

FIGURE 4-1: *Device Addressing.*

4.1.5 DATA VALID

After the Start condition, each bit of data in the transmission needs to be settled for a time specified by $t_{SU\text{-}DATA}$ before SCL toggles from low-to-high (see the Sensor Serial Interface Timing Specifications section).

4.1.6 ACKNOWLEDGE (ACK/NAK)

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

The Acknowledging device pulls down the SDA line for $t_{SU\text{-}DATA}$ before the low-to-high transition of SCL from the master. SDA also needs to remain pulled down for $t_{H\text{-}DATA}$ after a high-to-low transition of SCL.

During read, the master must signal an End-of-Data (EOD) to the slave, by not generating an ACK bit (NAK), 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.

4.1.7 TIME-OUT

If the SCL stays low or high for the time specified by t_{OUT}, the MCP9808 temperature sensor resets the serial interface. This dictates the minimum clock speed as outlined in the specification.

5.0 FUNCTIONAL DESCRIPTION

The MCP9808 temperature sensors consist of a band-gap-type temperature sensor, a Delta-Sigma Analog-to-Digital Converter (ΔΣ ADC), user-programmable registers and a 2-wire SMBus/I^{2}C protocol compatible serial interface. Figure 5-1 shows a block diagram of the register structure.

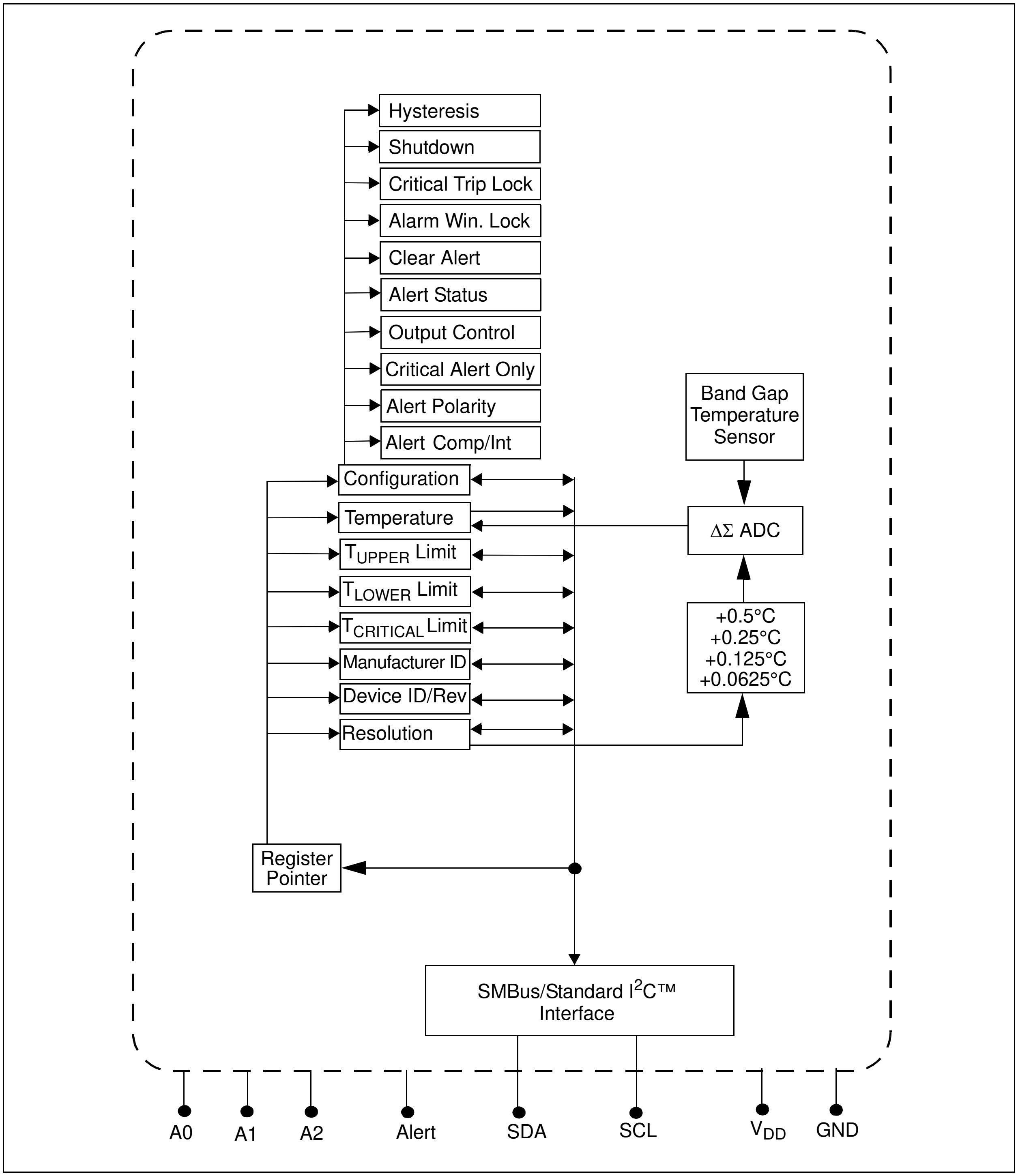


FIGURE 5-1: *Functional Block Diagram.*

5.1 Registers

The MCP9808 has several registers that are user-accessible. These registers include the Temperature register, Configuration register, Temperature Alert Upper Boundary and Lower Boundary Limit registers, Critical Temperature Limit register, Manufacturer Identification register and Device Identification register.

The Temperature register is read-only, used to access the ambient temperature data. This register is double-buffered and it is updated every t_{CONV}. The Temperature Alert Upper Boundary and Lower Boundary Limit registers are read/write registers. If the ambient temperature drifts beyond the user-specified limits, the MCP9808 outputs a signal using the Alert pin (refer to **Section 5.2.3 "Alert Output Configuration"**). In addition, the Critical Temperature Limit register is used to provide an additional critical temperature limit.

The Configuration register provides access to configure the MCP9808 device's various features. These registers are described in further detail in the following sections.

The registers are accessed by sending a Register Pointer to the MCP9808, using the serial interface. This is an 8-bit write-only pointer. However, the four Least Significant bits are used as pointers and all unused bits (Register Pointer<7:4>) need to be cleared or set to '0'. Register 5-1 describes the pointer or the address of each register.

REGISTER 5-1: REGISTER POINTER (WRITE-ONLY)

W-0	W-0	W-0	W-0	W-0	W-0	W-0	W-0
—	—	—	—	Pointer bits			
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

bit 7-4 **W:** Writable bits
Write '0'.
Bits 7-4 must always be cleared or written to '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.

bit 3-0 **Pointer bits**
- `0000` = RFU, Reserved for Future Use (Read-Only register)
- `0001` = Configuration register (CONFIG)
- `0010` = Alert Temperature Upper Boundary Trip register (T_{UPPER})
- `0011` = Alert Temperature Lower Boundary Trip register (T_{LOWER})
- `0100` = Critical Temperature Trip register (T_{CRIT})
- `0101` = Temperature register (T_A)
- `0110` = Manufacturer ID register
- `0111` = Device ID/Revision register
- `1000` = Resolution register
- `1xxx` = Reserved[1]

Note 1: Some registers contain calibration codes and should not be accessed.

TABLE 5-1: BIT ASSIGNMENT SUMMARY FOR ALL REGISTERS (See Section 5.3 “Summary of Power-on Default” for Power-on Defaults)

Register Pointer (Hex)	MSB/ LSB	Bit Assignment							
		7	6	5	4	3	2	1	0
0x00	MSB	0	0	0	0	0	0	0	0
	LSB	0	0	0	1	1	1	1	1
0x01	MSB	0	0	0	0	0	Hysteresis		SHDN
	LSB	Crt Loc	Win Loc	Int Clr	Alt Stat	Alt Cnt	Alt Sel	Alt Pol	Alt Mod
0x02	MSB	0	0	0	SIGN	2^{7}°C	2^{6}°C	2^{5}°C	2^{4}°C
	LSB	2^{3}°C	2^{2}°C	2^{1}°C	2^{0}°C	2^{-1}°C	2^{-2}°C	0	0
0x03	MSB	0	0	0	SIGN	2^{7}°C	2^{6}°C	2^{5}°C	2^{4}°C
	LSB	2^{3}°C	2^{2}°C	2^{1}°C	2^{0}°C	2^{-1}°C	2^{-2}°C	0	0
0x04	MSB	0	0	0	SIGN	2^{7}°C	2^{6}°C	2^{5}°C	2^{4}°C
	LSB	2^{3}°C	2^{2}°C	2^{1}°C	2^{0}°C	2^{-1}°C	2^{-2}°C	0	0
0x05	MSB	$T_A \geq T_{CRIT}$	$T_A > T_{UPPER}$	$T_A < T_{LOWER}$	SIGN	2^{7}°C	2^{6}°C	2^{5}°C	2^{4}°C
	LSB	2^{3}°C	2^{2}°C	2^{1}°C	2^{0}°C	2^{-1}°C	2^{-2}°C	2^{-3}°C	2^{-4}°C
0x06	MSB	0	0	0	0	0	0	0	0
	LSB	0	1	0	1	0	1	0	0
0x07	MSB	0	0	0	0	0	1	0	0
	LSB	0	0	0	0	0	0	0	0
0x08	LSB	0	0	0	0	0	0	1	1

5.1.1 SENSOR CONFIGURATION REGISTER (CONFIG)

The MCP9808 has a 16-bit Configuration register (CONFIG) that allows the user to set various functions for a robust temperature monitoring system. Bits 10 through 0 are used to select the temperature alert output hysteresis, device shutdown or Low-Power mode, temperature boundary and critical temperature lock, and temperature Alert output enable/disable. In addition, Alert output condition (output set for T_{UPPER} and T_{LOWER} temperature boundary or T_{CRIT} only), Alert output status and Alert output polarity and mode (Comparator Output or Interrupt Output mode) are user-configurable.

The temperature hysteresis bits 10 and 9 can be used to prevent output chatter when the ambient temperature gradually changes beyond the user-specified temperature boundary (see **Section 5.2.2 "Temperature Hysteresis (T_{HYST})"**. The Continuous Conversion or Shutdown mode is selected using bit 8. In Shutdown mode, the band gap temperature sensor circuit stops converting temperature and the Ambient Temperature register (T_A) holds the previous temperature data (see **Section 5.2.1 "Shutdown Mode"**). Bits 7 and 6 are used to lock the user-specified boundaries T_{UPPER}, T_{LOWER} and T_{CRIT} to prevent an accidental rewrite. The Lock bits are cleared by resetting the power. Bits 5 through 0 are used to configure the temperature Alert output pin. All functions are described in Register 5-2 (see **Section 5.2.3 "Alert Output Configuration"**).

REGISTER 5-2: CONFIG: CONFIGURATION REGISTER (→ ADDRESS `0000 0001'b)

U-0	U-0	U-0	U-0	U-0	R/W-0	R/W-0	R/W-0
—	—	—	—	—	T_{HYST}		SHDN
bit 15							bit 8

R/W-0	R/W-0	R/W-0	R-0	R/W-0	R/W-0	R/W-0	R/W-0
Crit. Lock	Win. Lock	Int. Clear	Alert Stat.	Alert Cnt.	Alert Sel.	Alert Pol.	Alert Mod.
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

bit 15-11 **Unimplemented:** Read as '0'

bit 10-9 **T_{HYST}:** T_{UPPER} and T_{LOWER} Limit Hysteresis bits
- 00 = 0°C (power-up default)
- 01 = +1.5°C
- 10 = +3.0°C
- 11 = +6.0°C

(Refer to **Section 5.2.3 "Alert Output Configuration"**.)

This bit can not be altered when either of the Lock bits are set (bit 6 and bit 7).

This bit can be programmed in Shutdown mode.

bit 8 **SHDN:** Shutdown Mode bit
- 0 = Continuous conversion (power-up default)
- 1 = Shutdown (Low-Power mode)

In shutdown, all power-consuming activities are disabled, though all registers can be written to or read.

This bit cannot be set to '1' when either of the Lock bits is set (bit 6 and bit 7). However, it can be cleared to '0' for continuous conversion while locked (refer to **Section 5.2.1 "Shutdown Mode"**).

REGISTER 5-2: CONFIG: CONFIGURATION REGISTER (→ ADDRESS `0000 0001'b)

bit 7 **Crit. Lock:** T_{CRIT} Lock bit

0 = Unlocked. T_{CRIT} register can be written (power-up default)
1 = Locked. T_{CRIT} register can not be written

When enabled, this bit remains set to '1' or locked until cleared by an internal Reset (**Section 5.3 "Summary of Power-on Default"**).

This bit can be programmed in Shutdown mode.

bit 6 **Win. Lock:** T_{UPPER} and T_{LOWER} Window Lock bit

0 = Unlocked; T_{UPPER} and T_{LOWER} registers can be written (power-up default)
1 = Locked; T_{UPPER} and T_{LOWER} registers can not be written

When enabled, this bit remains set to '1' or locked until cleared by a Power-on Reset (**Section 5.3 "Summary of Power-on Default"**).

This bit can be programmed in Shutdown mode.

bit 5 **Int. Clear:** Interrupt Clear bit

0 = No effect (power-up default)
1 = Clear interrupt output; when read, this bit returns to '0'

This bit can not be set to '1' in Shutdown mode, but it can be cleared after the device enters Shutdown mode.

bit 4 **Alert Stat.:** Alert Output Status bit

0 = Alert output is not asserted by the device (power-up default)
1 = Alert output is asserted as a comparator/Interrupt or critical temperature output

This bit can not be set to '1' or cleared to '0' in Shutdown mode. However, if the Alert output is configured as Interrupt mode, and if the host controller clears to '0', the interrupt, using bit 5 while the device is in Shutdown mode, then this bit will also be cleared '0'.

bit 3 **Alert Cnt.:** Alert Output Control bit

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

This bit can not be altered when either of the Lock bits are set (bit 6 and bit 7).

This bit can be programmed in Shutdown mode, but the Alert output will not assert or deassert.

bit 2 **Alert Sel.:** Alert Output Select bit

0 = Alert output for T_{UPPER}, T_{LOWER} and T_{CRIT} (power-up default)
1 = $T_A > T_{CRIT}$ only (T_{UPPER} and T_{LOWER} temperature boundaries are disabled)

When the Alarm Window Lock bit is set, this bit cannot be altered until unlocked (bit 6).

This bit can be programmed in Shutdown mode, but the Alert output will not assert or deassert.

bit 1 **Alert Pol.:** Alert Output Polarity bit

0 = Active-low (power-up default; pull-up resistor required)
1 = Active-high

This bit cannot be altered when either of the Lock bits are set (bit 6 and bit 7).

This bit can be programmed in Shutdown mode, but the Alert output will not assert or deassert.

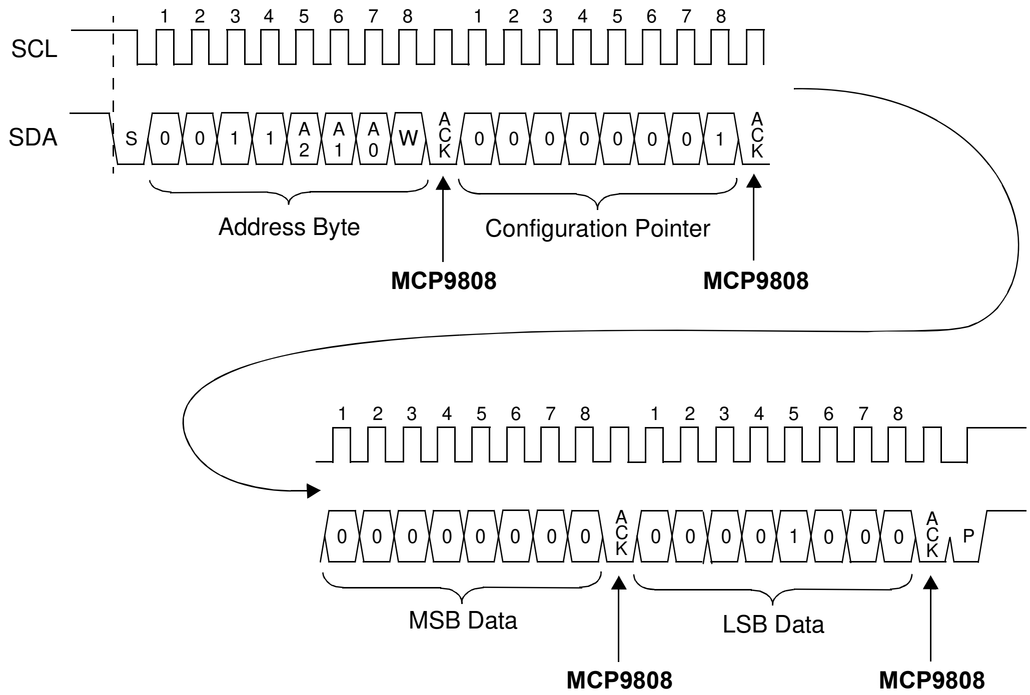
bit 0 **Alert Mod.:** Alert Output Mode bit

0 = Comparator output (power-up default)
1 = Interrupt output

This bit cannot be altered when either of the Lock bits are set (bit 6 and bit 7).

This bit can be programmed in Shutdown mode, but the Alert output will not assert or deassert.

Writing to the CONFIG Register to Enable the Event Output Pin `<0000 0000 0000 1000>b`**:**

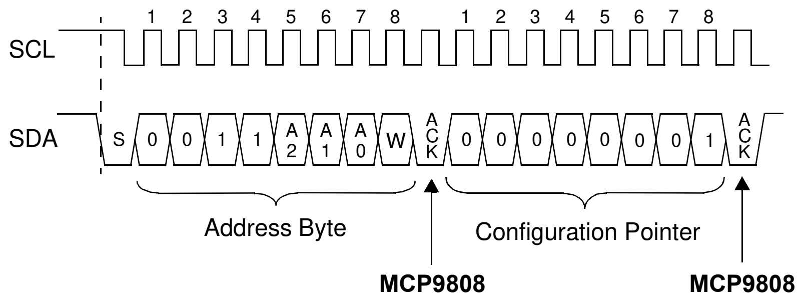


Note: This is an example routine (see **Appendix A: “Source Code”**).

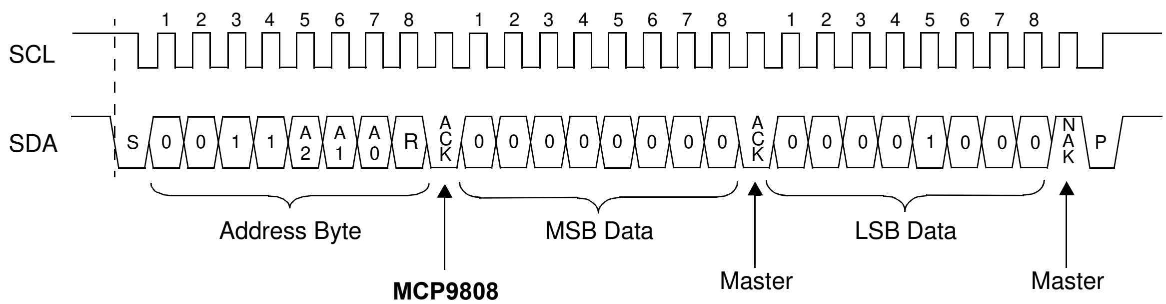
```
i2c_start();                    // send START command
i2c_write(AddressByte & 0xFE);  //WRITE Command (see Section 4.1.4 “Address Byte”)
                                //also, make sure bit 0 is cleared ‘0’
i2c_write(0x01);                // Write CONFIG Register
i2c_write(0x00);                // Write data
i2c_write(0x08);                // Write data
i2c_stop();                     // send STOP command
```

FIGURE 5-2: *Timing Diagram for Writing to the Configuration Register (see* ***Section 4.0 “Serial Communication”****).*

Reading the CONFIG Register:



Note: It is not necessary to select the Register Pointer if it was set from the previous read/write.



Note: This is an example routine (see **Appendix A: “Source Code”**).

```
i2c_start();                      // send START command
i2c_write(AddressByte & 0xFE);    //WRITE Command (see Section 4.1.4 “Address Byte”)
                                  //also, make sure bit 0 is cleared ‘0’
i2c_write(0x01);                  // Write CONFIG Register
i2c_start();                      // send Repeat START command
i2c_write(AddressByte | 0x01);    //READ Command
                                  //also, make sure bit 0 is set ‘1’
UpperByte = i2c_read(ACK);        // READ 8 bits
                                  //and Send ACK bit
LowerByte = i2c_read(NAK);        // READ 8 bits
                                  //and Send NAK bit
i2c_stop();                       // send STOP command
```

FIGURE 5-3: *Timing Diagram for Reading from the Configuration Register (see **Section 4.0 “Serial Communication”**).*

5.1.2 UPPER/LOWER/CRITICAL TEMPERATURE LIMIT REGISTERS ($T_{UPPER}/T_{LOWER}/T_{CRIT}$)

The MCP9808 has a 16-bit read/write Alert Output Temperature Upper Boundary register (T_{UPPER}), a 16-bit Lower Boundary register (T_{LOWER}) and a 16-bit Critical Boundary register (T_{CRIT}) that contain 11-bit data in two's complement format (0.25°C). This data represents the maximum and minimum temperature boundary or temperature window that can be used to monitor ambient temperature. If this feature is enabled (**Section 5.1.1 "Sensor Configuration Register (CONFIG)"**) and the ambient temperature exceeds the specified boundary or window, the MCP9808 asserts an Alert output. (Refer to **Section 5.2.3 "Alert Output Configuration"**).

REGISTER 5-3: $T_{UPPER}/T_{LOWER}/T_{CRIT}$ UPPER/LOWER/CRITICAL TEMPERATURE LIMIT REGISTER (→ ADDRESS `0000 0010'b/`0000 0011'b/`0000 0100'b)(1)

U-0	U-0	U-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
—	—	—	Sign	2^7°C	2^6°C	2^5°C	2^4°C
bit 15							bit 8

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	U-0	U-0
2^3°C	2^2°C	2^1°C	2^0°C	2^{-1}°C	2^{-2}°C	—	—
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

bit 15-13 **Unimplemented:** Read as '0'

bit 12 **Sign:** Sign bit
0 = $T_A \geq 0$°C
1 = $T_A < 0$°C

bit 11-2 **$T_{UPPER}/T_{LOWER}/T_{CRIT}$:** Temperature Boundary bits
Temperature boundary trip data in two's complement format.

bit 1-0 **Unimplemented:** Read as '0'

Note 1: This table shows two 16-bit registers for T_{UPPER}, T_{LOWER} and T_{CRIT}, located at '0000 0010b', '0000 0011b' and '0000 0100b', respectively.

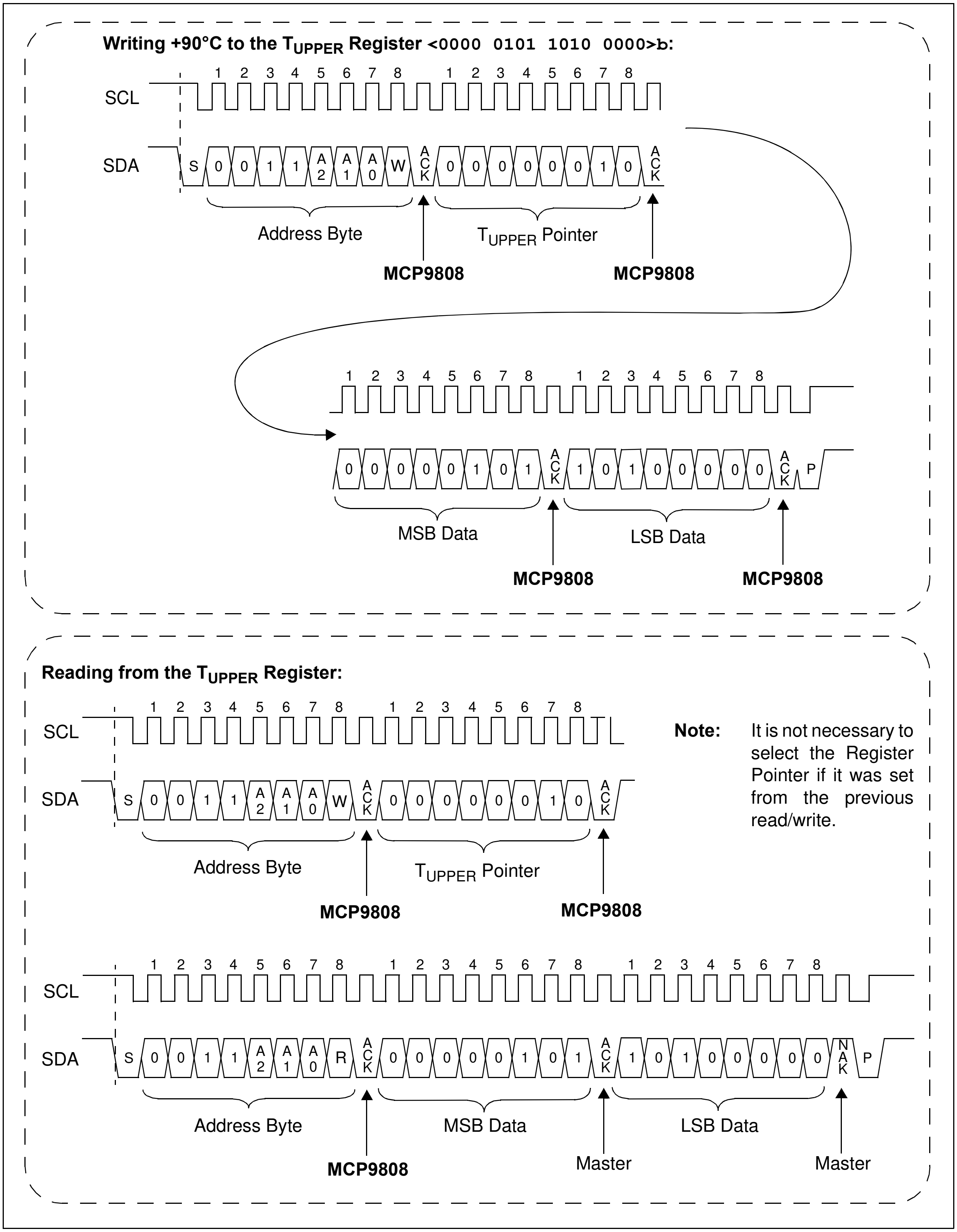


FIGURE 5-4: *Timing Diagram for Writing and Reading from the T_{UPPER} Register (see* ***Section 4.0 "Serial Communication"****).*

5.1.3 AMBIENT TEMPERATURE REGISTER (T_A)

The MCP9808 uses a band gap temperature sensor circuit to output analog voltage proportional to absolute temperature. An internal $\Delta\Sigma$ ADC is used to convert the analog voltage to a digital word. The digital word is loaded to a 16-bit read-only Ambient Temperature register (T_A) that contains 13-bit temperature data in two's complement format.

The T_A register bits (T_A<12:0>) are double-buffered. Therefore, the user can access the register, while in the background, the MCP9808 performs an Analog-to-Digital conversion. The temperature data from the $\Delta\Sigma$ ADC is loaded in parallel to the T_A register at t_{CONV} refresh rate.

In addition, the T_A register uses three bits (T_A<15:13>) to reflect the Alert pin state. This allows the user to identify the cause of the Alert output trigger (see **Section 5.2.3 "Alert Output Configuration"**); bit 15 is set to '1' if T_A is greater than or equal to T_{CRIT}, bit 14 is set to '1' if T_A is greater than T_{UPPER} and bit 13 is set to '1' if T_A is less than T_{LOWER}.

The T_A register bit assignment and boundary conditions are described in Register 5-4.

REGISTER 5-4: T_A: AMBIENT TEMPERATURE REGISTER (→ ADDRESS `0000 0101'b)(1)

R-0	R-0	R-0	R-0	R-0	R-0	R-0	R-0
T_A vs. T_{CRIT}(1)	T_A vs. T_{UPPER}(1)	T_A vs. T_{LOWER}(1)	SIGN	2^7 °C	2^6 °C	2^5 °C	2^4 °C
bit 15							bit 8

R-0	R-0	R-0	R-0	R-0	R-0	R-0	R-0
2^3 °C	2^2 °C	2^1 °C	2^0 °C	2^{-1} °C	2^{-2} °C(2)	2^{-3} °C(2)	2^{-4} °C(2)
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

bit 15 **T_A vs. T_{CRIT} bit(1)**
0 = $T_A < T_{CRIT}$
1 = $T_A \geq T_{CRIT}$

bit 14 **T_A vs. T_{UPPER} bit(1)**
0 = $T_A \leq T_{UPPER}$
1 = $T_A > T_{UPPER}$

bit 13 **T_A vs. T_{LOWER} bit(1)**
0 = $T_A \geq T_{LOWER}$
1 = $T_A < T_{LOWER}$

bit 12 **SIGN bit**
0 = $T_A \geq 0°C$
1 = $T_A < 0°C$

bit 11-0 **T_A:** Ambient Temperature bits(2)
12-bit ambient temperature data in two's complement format.

Note 1: Bits 15, 14 and 13 are not affected by the status of the Alert Output Configuration (CONFIG<5:0> bits, Register 5-2).

2: Bits 2, 1 and 0 may remain clear at '0' depending on the status of the Resolution register (Register 5-7). The power-up default is 0.25°C/bit; bits 1 and 0 remain clear '0'.

5.1.3.1 T_A Bits to Temperature Conversion

To convert the T_A bits to decimal temperature, the upper three boundary bits (T_A<15:13>) must be masked out. Then, determine the SIGN bit (bit 12) to check positive or negative temperature, shift the bits accordingly, and combine the upper and lower bytes of the 16-bit register. The upper byte contains data for temperatures greater than +32°C while the lower byte contains data for temperature less than +32°C, including fractional data. When combining the upper and lower bytes, the upper byte must be right-shifted by 4 bits (or multiply by 2^4) and the lower byte must be left-shifted by 4 bits (or multiply by 2^{-4}). Adding the results of the shifted values provides the temperature data in decimal format (see Equation 5-1).

The temperature bits are in two's compliment format, therefore, positive temperature data and negative temperature data are computed differently. Equation 5-1 shows the temperature computation. The example instruction code, outlined in Example 5-1, shows the communication flow; also see Figure 5-5 for the timing diagram.

EQUATION 5-1: BYTES TO TEMPERATURE CONVERSION

Temperature $T_A \geq 0°C$

$$T_A = (UpperByte \times 2^4 + LowerByte \times 2^{-4})$$

Temperature < 0°C

$$T_A = 256 - (UpperByte \times 2^4 + LowerByte \times 2^{-4})$$

Where:

T_A = Ambient Temperature (°C)

UpperByte = T_A bit 15 to bit 8

LowerByte = T_A bit 7 to bit 0

EXAMPLE 5-1: SAMPLE INSTRUCTION CODE

This example routine assumes the variables and I²C™ communication subroutines are predefined (see Appendix A: "Source Code"):

```
i2c_start();                          // send START command
i2c_write (AddressByte & 0xFE);       //WRITE Command (see Section 4.1.4 "Address Byte")
                                      //also, make sure bit 0 is cleared '0'
i2c_write(0x05);                      // Write TA Register Address
i2c_start();                          //Repeat START
i2c_write(AddressByte | 0x01);        // READ Command (see Section 4.1.4 "Address Byte")
                                      //also, make sure bit 0 is Set '1'
UpperByte = i2c_read(ACK);            // READ 8 bits
                                      //and Send ACK bit
LowerByte = i2c_read(NAK);            // READ 8 bits
                                      //and Send NAK bit
i2c_stop();                           // send STOP command
//Convert the temperature data
//First Check flag bits
if ((UpperByte & 0x80) == 0x80){      //TA ³ TCRIT
}
if ((UpperByte & 0x40) == 0x40){      //TA > TUPPER
}
if ((UpperByte & 0x20) == 0x20){      //TA < TLOWER
}
UpperByte = UpperByte & 0x1F;         //Clear flag bits
if ((UpperByte & 0x10) == 0x10){      //TA < 0°C
    UpperByte = UpperByte & 0x0F;     //Clear SIGN
    Temperature = 256 - (UpperByte x 16 + LowerByte / 16);
}else                                 //TA ³ 0°C
    Temperature = (UpperByte x 16 + LowerByte / 16);
                                      //Temperature = Ambient Temperature (°C)
```