MCP9808

±0.5°C Maximum Accuracy Digital Temperature Sensor

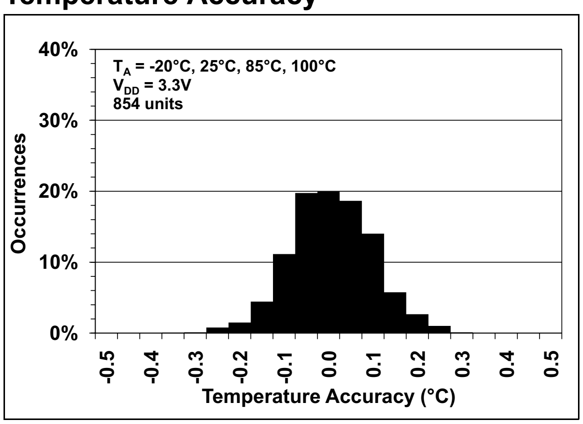
Features

- 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



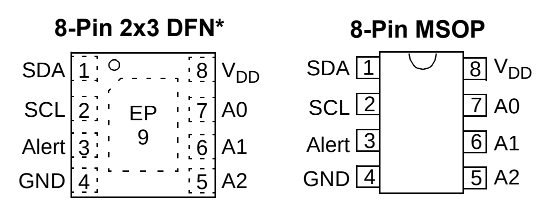
Description

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.

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

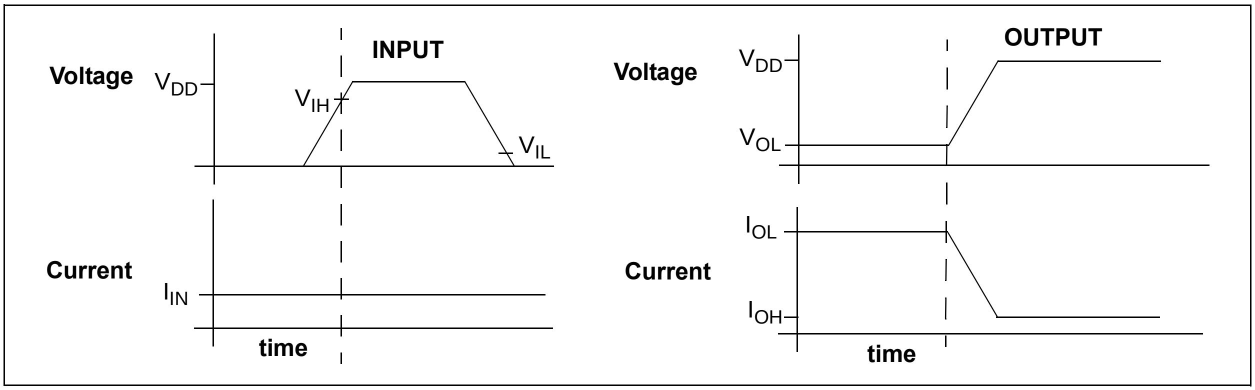
Electrical Specifications: Unless otherwise indicated, V_{DD} = 2.7V to 5.5V, GND = Ground and T_A = -40°C to +125°C.

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	Δ°C/ΔV_{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

Parameters	Sym	Min	Typ	Max	Units	Conditions
Electrical Specifications: Unless otherwise indicated, V_{DD} = 2.7V to 5.5V, GND = Ground and T_A = -40°C to +125°C.						
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

Parameters	Sym	Min	Typ	Max	Units	Conditions
Electrical Specifications: Unless otherwise indicated, V_{DD} = 2.7V to 5.5V and GND = Ground.						
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.

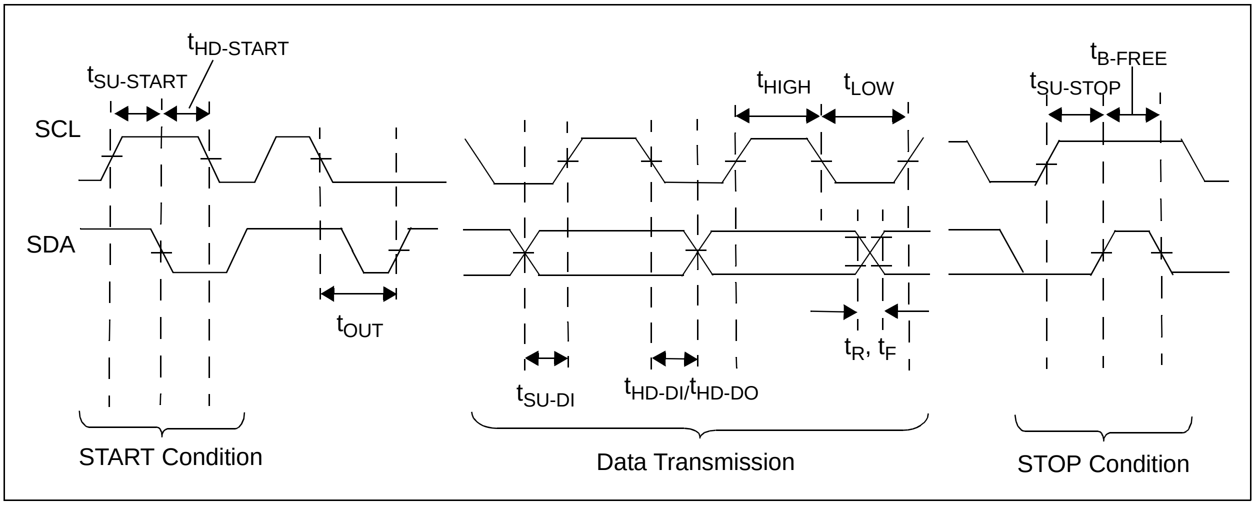
2: If $t_{LOW} > t_{OUT}$ or $t_{HIGH} > t_{OUT}$, the temperature sensor I²C interface will time-out. A Repeat Start command is required for communication.

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



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.

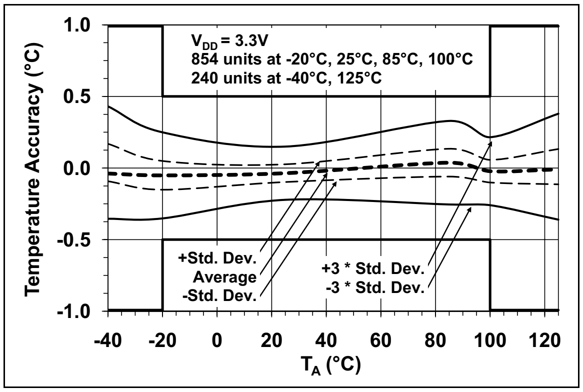


FIGURE 2-1: *Temperature Accuracy.*

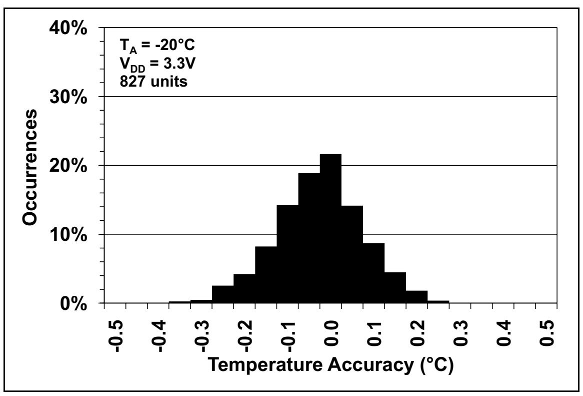


FIGURE 2-2: *Temperature Accuracy Histogram, T_A = -20°C.*

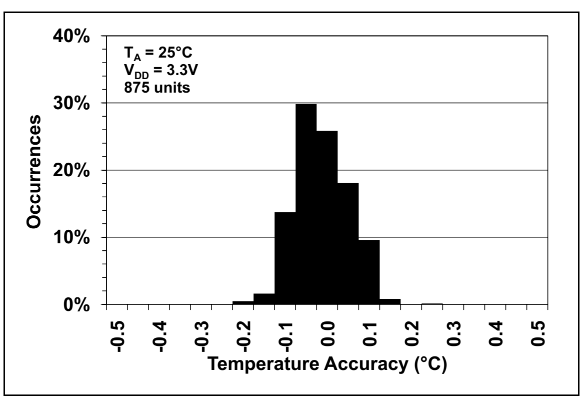


FIGURE 2-3: *Temperature Accuracy Histogram, T_A = +25°C.*

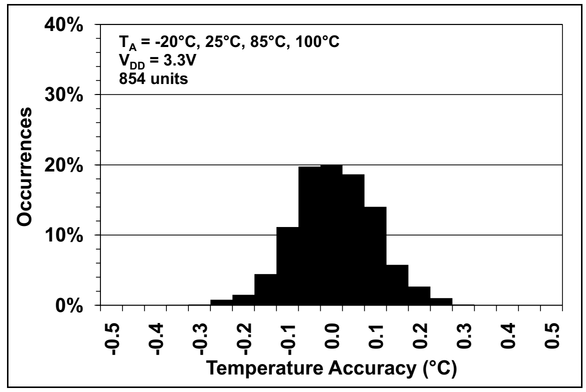


FIGURE 2-4: *Temperature Accuracy Histogram.*

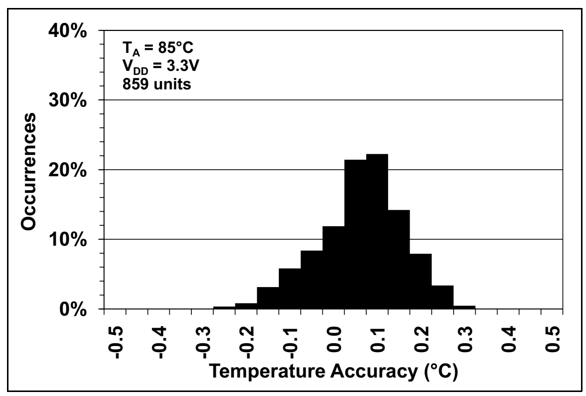


FIGURE 2-5: *Temperature Accuracy Histogram, T_A = +85°C.*

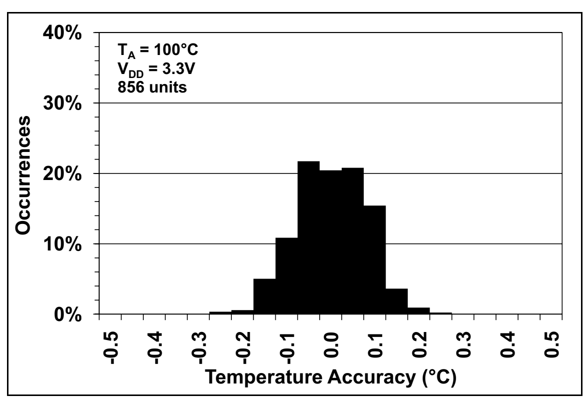


FIGURE 2-6: *Temperature Accuracy Histogram, T_A = +100°C.*

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.

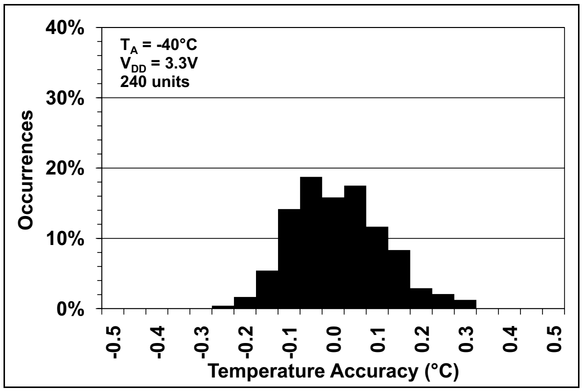


FIGURE 2-7: Temperature Accuracy Histogram, T_A = -40°C.

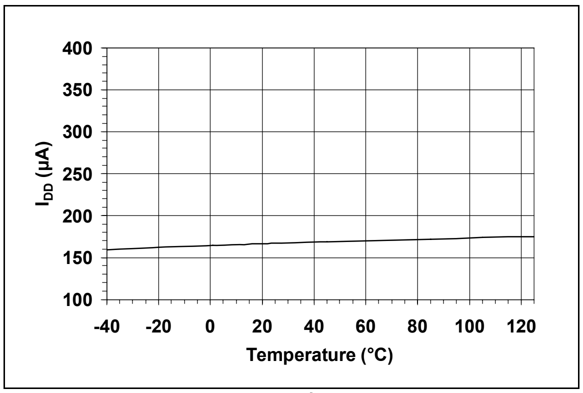


FIGURE 2-8: Supply Current vs. Temperature.

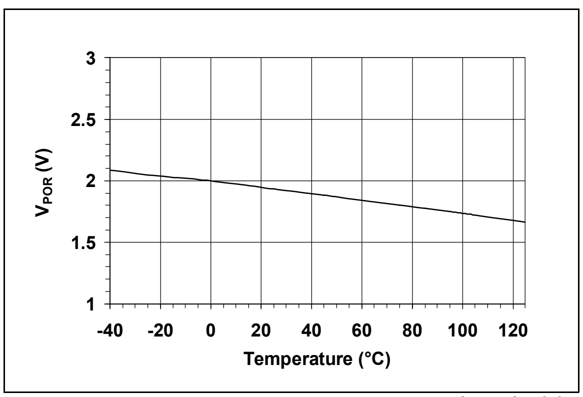


FIGURE 2-9: Power-on Reset Threshold Voltage vs. Temperature.

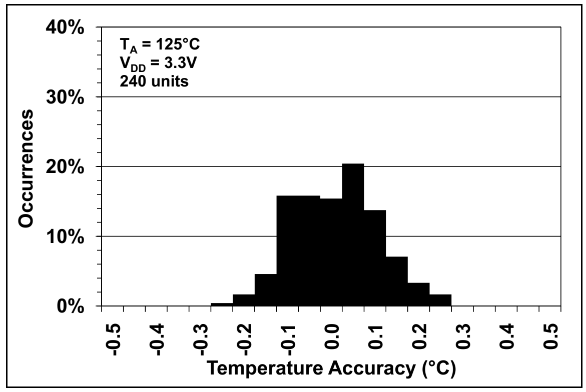


FIGURE 2-10: Temperature Accuracy Histogram, T_A = +125°C.

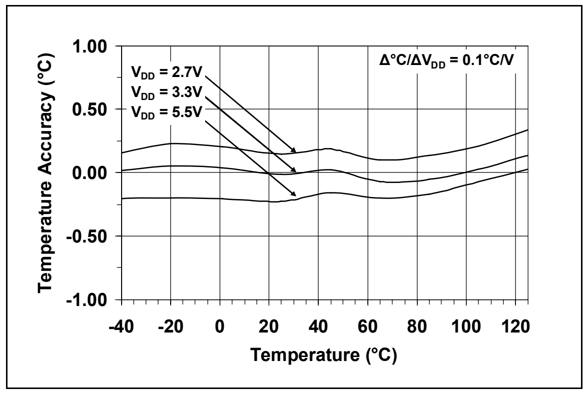


FIGURE 2-11: Temperature Accuracy vs Supply Voltage.

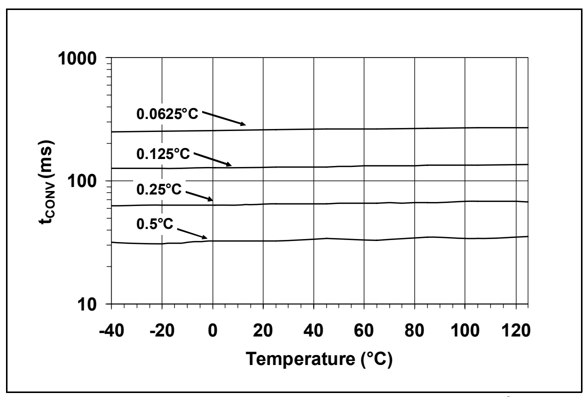


FIGURE 2-12: Temperature Conversion Time vs. Temperature.

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.

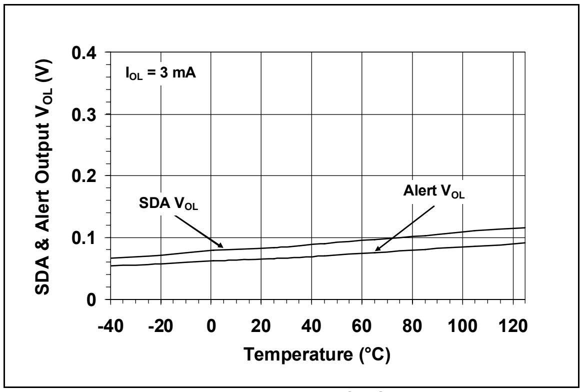


FIGURE 2-13: *SDA and Alert Output V_{OL} vs. Temperature.*

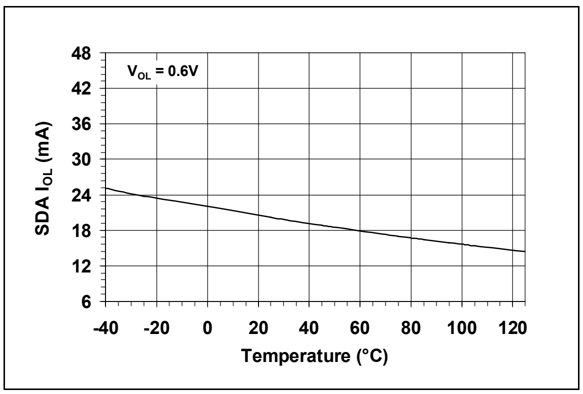


FIGURE 2-14: *SDA I_{OL} vs. Temperature.*

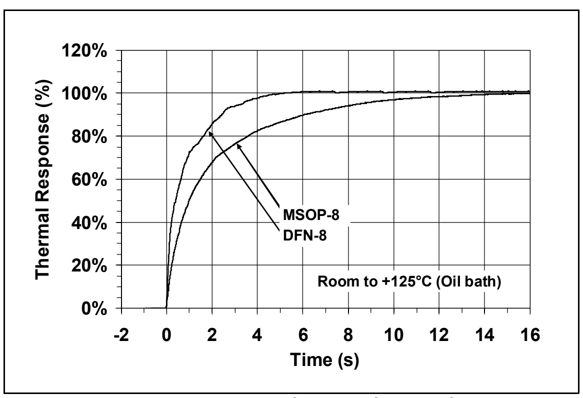


FIGURE 2-15: *Package Thermal Response.*

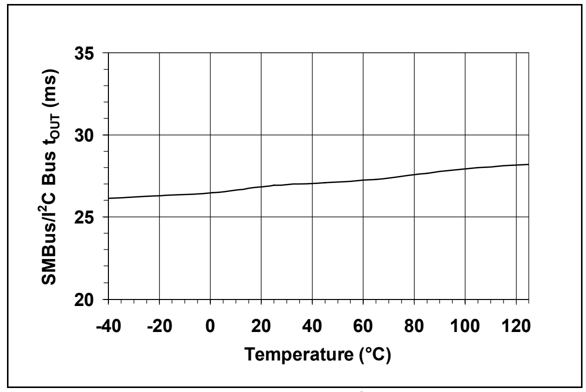


FIGURE 2-16: *SMBus Time-out vs. Temperature.*

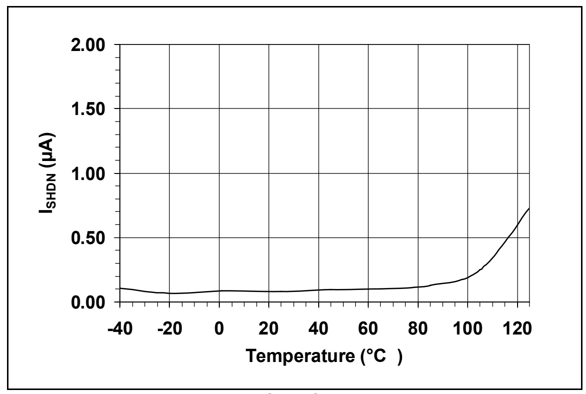


FIGURE 2-17: *Shutdown Current vs Temperature.*

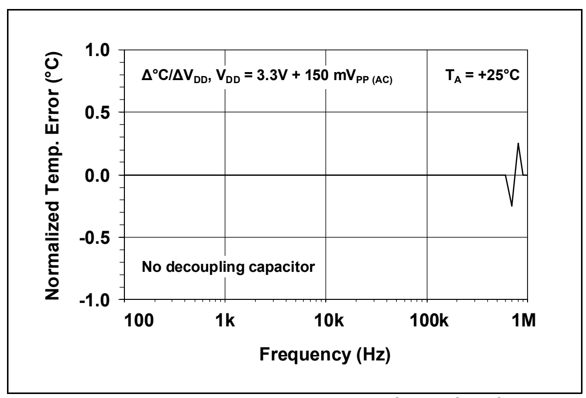


FIGURE 2-18: *Power Supply Rejection vs. Frequency.*

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).

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)
```

