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MCP9843/98243

Memory Module Temperature Sensor w/ EEPROM for SPD

Features

- Meets JEDEC Specification
  - MCP9843 - JC42.4-TSE3000B3 Temperature Sensor
  - MCP98243 --> JC42.4-TSE2002B3 Temperature Sensor with 2 Kbit Serial EEPROM for Serial Presence Detect (SPD)
- 2-wire I^2C™/SMBus Interface
- Available Packages:
  - DFN-8, TDFN-8, UDFN-8, TSSOP-8

Temperature Sensor Features

- Temperature-to-Digital Converter
- Sensor Accuracy (Grade B):
  - **±0.2°C/±1°C (typ./max.) → +75°C to +95°C**
  - ±0.5°C/±2°C (typ./max.) → +40°C to +125°C
  - ±1°C/±3°C (typ./max.) → -20°C to +125°C
- Specified V_{DD} Range: 3.0V to 3.6V
- Operating Current: 200 µA (typical)
- Operating V_{DD} Range: 2.7V to 5.5V

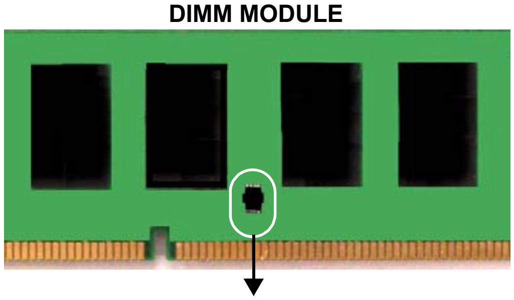
Serial EEPROM Features (MCP98243)

- Specified V_{DD} Range: 1.8V to 5.5V
- Operating Current:
  - Write → 1.1 mA (typical) for 3.5 ms (typical)
  - Read → 100 µA (typical)
- Permanent and Reversible Software Write Protect
- Software Write Protection for the lower 1 Kbit
- Organized as 1 block of 256 x 8-bit (2 Kbit)

Typical Applications

- DIMM Modules for Servers, PCs, and Laptops
- General Purpose Temperature Datalog

DIMM MODULE



MCP9843/98243

Description

Microchip Technology Inc.'s MCP9843/98243 digital temperature sensors convert temperature from -40°C and +125°C to a digital word. These sensors meet JEDEC Specification JC42.4-TSE3000B3 and JC42.4-TSE2002B3 Memory Module Thermal Sensor Component. It provides an accuracy of ±0.2°C/±1°C (typical/maximum) from +75°C to +95°C. In addition, MCP98243 has an internal 256 Byte EEPROM which can be used to store memory module and vendor information.

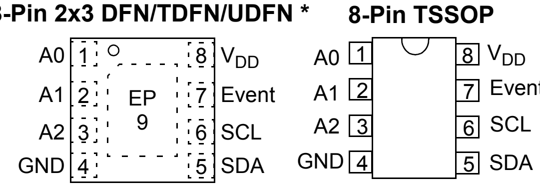
The MCP9843/98243 digital temperature sensor comes with user-programmable registers that provide flexibility for DIMM temperature-sensing applications. The registers allow user-selectable settings such as Shutdown or Low-Power modes and the specification of temperature Event boundaries. When the temperature changes beyond the specified Event boundary limits, the MCP9843/98243 outputs an Alert signal at the Event pin. The user has the option of setting the temperature Event output signal polarity as either an active-low or active-high comparator output for thermostat operation, or as a temperature Event interrupt output for microprocessor-based systems.

The MCP98243 EEPROM is designed specifically for DRAM DIMMs (Dual In-line Memory Modules) Serial Presence Detect (SPD). The lower 128 Bytes (address 0x00 to 0x7F) can be Permanent Write Protected (PWP) or Software Reversible Write Protected (SWP). This allows DRAM vendor and product information to be stored and write protected. The upper 128 bytes (address 0x80 to 0xFF) can be used for general purpose data storage. These addresses are not write protected.

This sensor has an industry standard 2-wire, I^2C compatible serial interface, allowing up to eight devices to be controlled in a single serial bus.

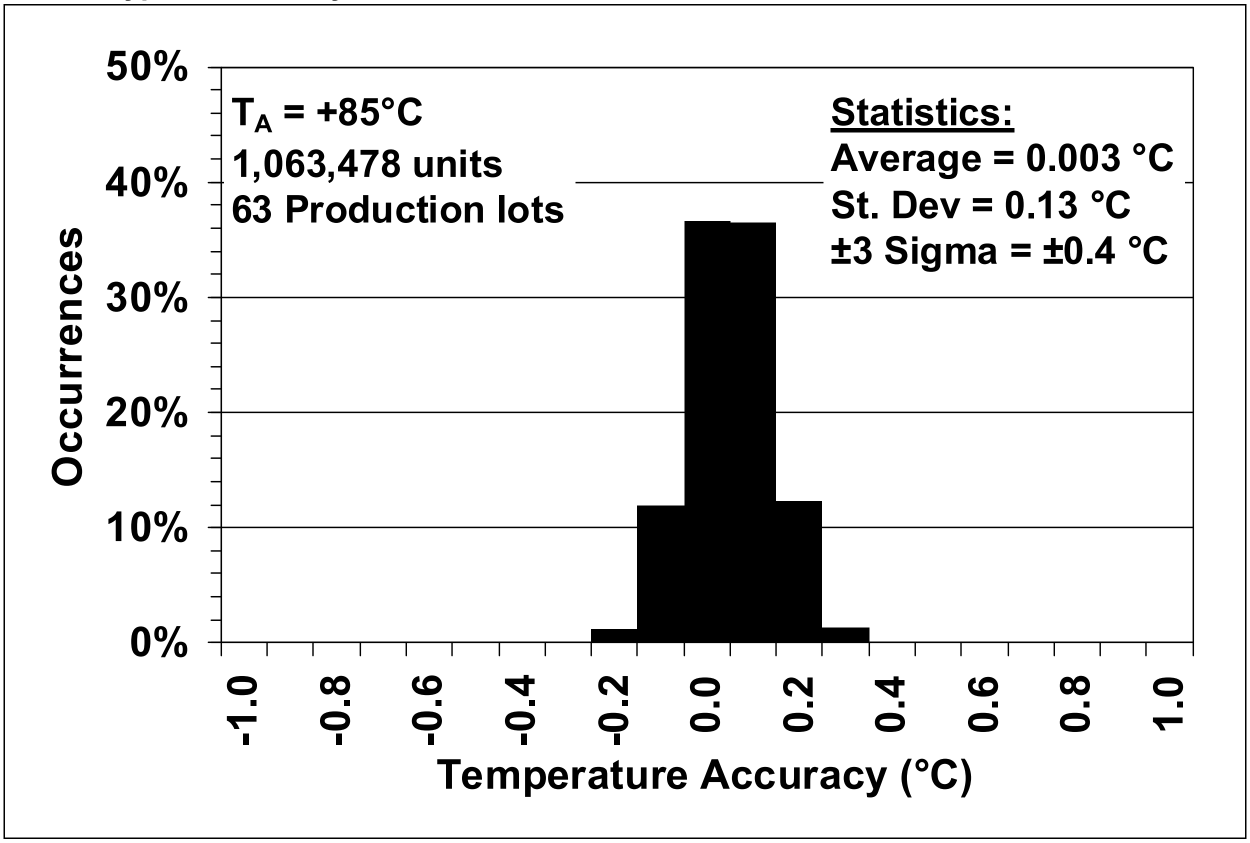
Package Types

8-Pin 2x3 DFN/TDFN/UDFN * **8-Pin TSSOP**



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

Sensor Typical Accuracy Performance



Note:	This accuracy data from the production system represents the typical accuracy performance of the MCP98242 Memory Module Temperature Sensor. The MCP98242 production methodology is also used for the MCP9843/98243 to achieve the same typical accuracy performance.

MCP98243 VS. MCP98242

Feature	MCP98243	MCP98242
Event Output in Shutdown Mode	Event Output De-asserts	Event Output Remains in previous state. If the output asserts before shutdown command, it remains asserted during shutdown
I^2C communication Timeout Range	t_{OUT} = 25 ms to 35 ms	t_{OUT} = 20 ms to 50 ms
I^2C Maximum Bus Frequency	400 kHz	100 kHz
I^2C SCL & SDA V_{IL}/V_{IH} voltage levels	V_{IL_MAX}=0.3*V_{DD}, V_{IH_MIN}=0.7*V_{DD}	V_{IL_MAX} = 0.8V, V_{IH_MIN} = 2.1V
$V_{HV\ A0}$ range	7V to 12V	8V to 12V
I^2C Spike Supression	50 ns	—
I^2C input hysteresis	0.05V_{DD}	0.5V
Device/Revision ID Register	0x2101 (hex)	0x2001

1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings †

V_{DD} 6.0V
Voltage at all Input/Output pins .... GND – 0.3V to 6.0V
Pin A0 .... GND – 0.3V to 12.5V
Storage temperature .... -65°C to +150°C
Ambient temp. with power applied .... -40°C to +125°C
Junction Temperature (T_J) .... +150°C
ESD protection on all pins (HBM:MM) .... (4 kV:300V)
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} = 3.0V to 3.6V, GND = Ground, and T_A = -20°C to +125°C.

Parameters	Sym	Min	Typ	Max	Unit	Conditions
Temperature Sensor Accuracy						
+75°C < T_A ≤ +95°C	T_{ACY}	-1.0	±0.2	+1.0	°C	JC42.4 - TSE2002B3 Grade B Accuracy Specification
+40°C < T_A ≤ +125°C		-2.0	±0.5	+2.0	°C	
-20°C < T_A ≤ +125°C		-3.0	±1	+3.0	°C	
T_A = -40°C		—	-1	—	°C	
Temperature Conversion Time						
0.25°C/bit	t_{CONV}	—	65	125	ms	15 s/sec (typical) (See **Section 5.2.4**)
Power Supply						
Specified Voltage Range	V_{DD}	3.0	—	3.6	V	JC42.4 Specified Voltage Range
Operating Voltage Range	V_{DD}	2.7	—	5.5	V	**Note 1**
Operating Current	I_{DD_TS}	—	200	500	µA	EEPROM Inactive
Shutdown Current - **MCP9843**	I_{SHDN}	—	1	2	µA	EEPROM Inactive, I^2C Bus Inactive
MCP98243		—	1	3	µA	
Power On Reset (POR)	V_{POR_TS}	—	2.2	—	V	Threshold for falling V_{DD} voltage
Power Supply Rejection,	$\Delta°C/\Delta V_{DD}$	—	±0.3	—	°C/V	V_{DD} = 2.7V to 5.5V
T_A = +25°C		—	±0.15	—	°C	V_{DD} = 3.3V+150 $mV_{PP\ AC}$ (0 to 1 MHz)
Event Output (Open-Drain output, external pull-up or pull-down resistor required), see Section 5.2.3						
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)
Low-level Current (leakage)	I_{OL}	—	—	1	µA	V_{OL} = V_{SS} (Active-High, Pull-down Resistor)
High-level Voltage	V_{OH}	—	—	V_{DD}-0.5	V	I_{OH}= 3 mA (Active-High, Pull-down Resistor)
Thermal Response, from +25°C (Air) to +125°C (oil bath)						
DFN/UDFN/TDFN-8	t_{RES}	—	0.7	—	s	Time to 63% (89°C)
TSSOP-8		—	1.4	—	s	

Note 1: Characterized but not production tested. Also, see **Section 2.0 “Typical Performance Curves”**.

MCP98243 EEPROM DC CHARACTERISTICS

Electrical Specifications: Unless otherwise indicated, V_{DD} = 1.8V to 5.5V, GND = Ground, and T_A = -20°C to +125°C.						
Parameters	**Sym**	**Min**	**Typ**	**Max**	**Unit**	**Conditions**
Power Supply						
Operating Voltage Range	V_{DD}	1.8	—	5.5	V	
Current, EEPROM write	I_{DD_EE}	—	1100	2000	µA	Sensor in Shutdown Mode (for t_{WC}), (**Note 1**)
Current, EEPROM read	I_{DD_EE}	—	100	500	µA	Sensor in Shutdown Mode (**Note 1**)
Power On Reset (POR)	V_{POR_EE}	—	1.6	—	V	EEPROM
Write Cycle time (byte/page)	t_{WC}	—	3	5	ms	
Endurance T_A = +25°C	—	—	1M	—	cycles	Number of Write Cycles, V_{DD} = 5V **(Note 2)**
EEPROM Write Temperature	EE_{WRITE}	0	—	85	°C	
EEPROM Read Temperature	EE_{READ}	-40	—	125	°C	For minimum read temperature, see **Note 2**
Write Protect Voltage						
SWP and CWP Voltage	V_{HV}	7	—	12	V	Applied at A0 pin **(Note 3)**
PWP Voltage		—	V_{DD}	—	V	

Note 1: For V_{DD} ranges of 1.8V to the temperature sensor V_{POR_TS}, the temperature sensor becomes partially biased and consumes 80 µA (typical) until the sensor POR resets and acknowledges a shutdown command. See Figure 2-15.

2: Characterized but not production tested. For endurance estimates in a specific application, please consult the Total Endurance™ Model which can be obtained from Microchip's web site at www.microchip.com.

3: The range of voltage applied at A0 pin for Permanent Write Protect is GND to V_{DD} + 1V. See Figure 2-13 and **Section 5.3.3 "Write Protection"**.

INPUT/OUTPUT PIN DC CHARACTERISTICS (NOTE 1)

Electrical Specifications: Unless otherwise indicated, V_{DD} = 1.8V to 5.5V, GND = Ground and T_A = -20°C to +125°C.						
Parameters	**Sym**	**Min**	**Typ**	**Max**	**Units**	**Conditions**
Serial Input/Output (SCL, SDA, A0, A1, A2) (Note 2)						
Input						
High-level Voltage	V_{IH}	$0.7V_{DD}$	—	—	V	
Low-level Voltage	V_{IL}	—	—	$0.3V_{DD}$	V	
Input Current	I_{IN}	—	—	±5	µA	SDA and SCL only
Input Impedance (A0, A1, A2)	Z_{IN}	—	1	—	MΩ	$V_{IN} > V_{IH}$
Input Impedance (A0, A1, A2)	Z_{IN}	—	200	—	kΩ	$V_{IN} < V_{IL}$
Output (SDA only)						
Low-level Voltage	V_{OL}	—	—	0.4	V	I_{OL}= 3 mA
High-level Current (leakage)	I_{OH}	—	—	1	µA	$V_{OH} = V_{DD}$
Low-level Current	I_{OL}	6	—	—	mA	V_{OL} = 0.6V
Capacitance	C_{IN}	—	5	—	pF	
SDA and SCL Inputs						
Hysteresis	V_{HYST}	—	$0.05V_{DD}$	—	V	V_{DD} > 2V
		—	$0.1V_{DD}$	—	V	V_{DD} < 2V
Spike Supression	T_{SP}	—	—	50	ns	

Note 1: These specifications apply for the Temperature Sensor and EEPROM.

2: For V_{DD} ranges of 1.8V to the temperature sensor V_{POR_TS}, the temperature sensor becomes partially biased and consumes 80 µA (typical) until the sensor POR resets and acknowledges a shutdown command. See Figure 2-15.

SENSOR AND EEPROM SERIAL INTERFACE TIMING SPECIFICATIONS

Electrical Specifications: Unless otherwise indicated, GND = Ground, T_A = -20°C to +125°C, and C_L = 80 pF (**Note 1, 5**).							
		V_{DD}= 1.8V to 5.5V		V_{DD}= 2.2V to 5.5V			
Parameters	**Sym**	**Min**	**Max**	**Min**	**Max**	**Units**	**Conditions**
2-Wire I²C Interface							
Serial port frequency	f_{SCL}	10	100	10	400	kHz	**Note 2, 4**
Low Clock	t_{LOW}	4700	—	1300	—	ns	**Note 2**
High Clock	t_{HIGH}	4000	—	600	—	ns	**Note 2**
Rise time	t_R	—	1000	20	300	ns	
Fall time	t_F	20	300	20	300	ns	
Data in Setup time	$t_{SU:DI}$	250	—	100	—	ns	**Note 3**
Data in Hold time	$t_{HD:DI}$	0	—	0	—	ns	**Note 6**
Data out Hold time	$t_{HD:DO}$	200	900	200	900	ns	**Note 4**
Start Condition Setup time	$t_{SU:STA}$	4700	—	600	—	ns	
Start Condition Hold time	$t_{HD:STA}$	4000	—	600	—	ns	
Stop Condition Setup time	$t_{SU:STO}$	4000	—	600	—	ns	
Bus idle	$t_{B:FREE}$	4700	—	1300	—	ns	
Time out (Sensor Only)	t_{OUT}	—	—	25	35	ms	V_{DD}= 3.0V to 3.6V
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 $t_{SU:DAT} \geq 250$ ns must be met. This device does not stretch SCL Low time. It outputs the next data bit to the SDA line within $t_{R\ MAX} + t_{SU:DI\ MIN}$ = 1000 ns + 250 ns = 1250 ns (according to the Standard-mode I²C-bus specification) before the SCL line is released.

4: As a transmitter, the device provides internal minimum delay time $t_{HD:DAT\ MIN}$ to bridge the undefined region (min. 300 ns) of the falling edge of SCL $t_{F\ MAX}$ to avoid unintended generation of Start or Stop conditions.

5: For V_{DD} ranges of 1.8V to the temperature sensor V_{POR_TS}, the temperature sensor becomes partially biased and consumes 100 µA (typical) until the sensor POR resets and acknowledges a shutdown command.

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

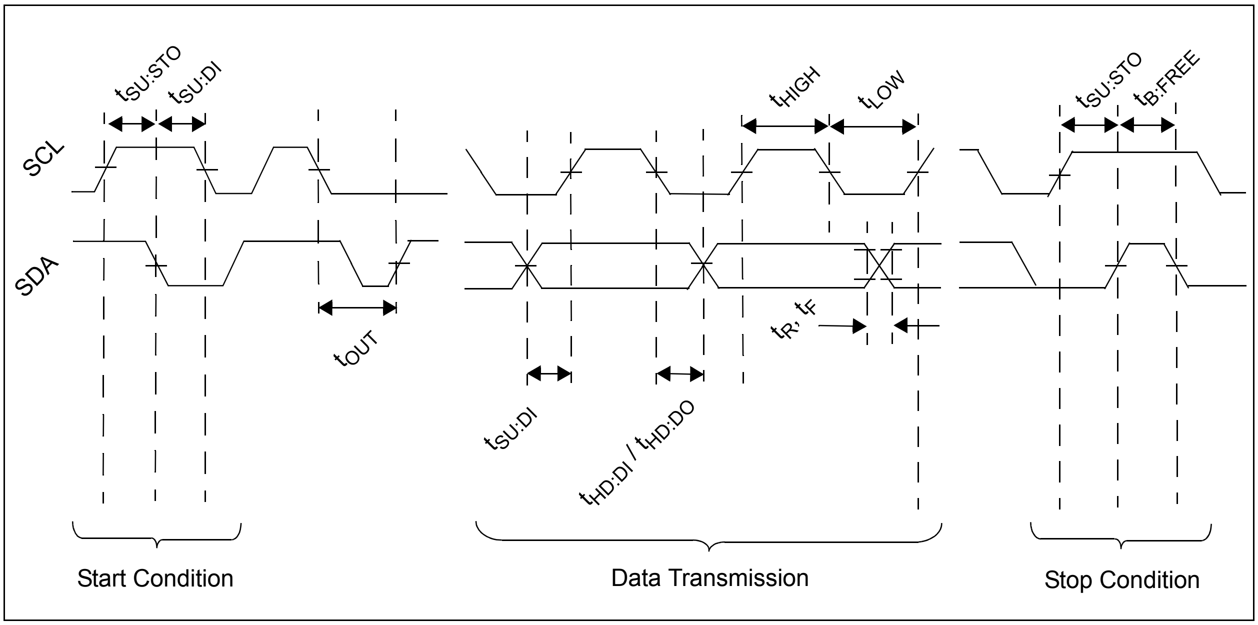
TEMPERATURE CHARACTERISTICS

Electrical Specifications: Unless otherwise indicated, V_{DD} = 1.8V to 5.5V for the EEPROM, V_{DD} = 3.0V to 3.6V for the Temperature Sensor, and GND = Ground.

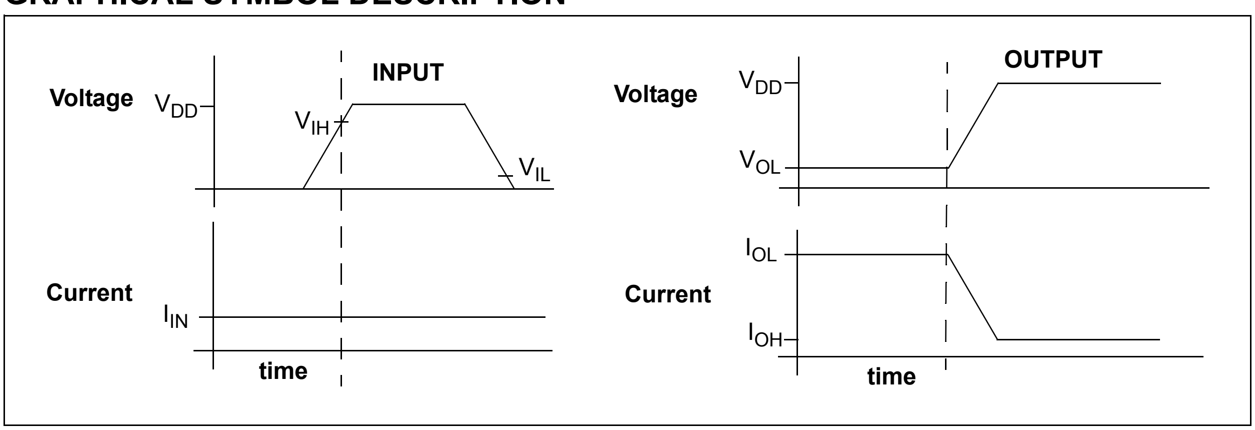
Parameters	Sym	Min	Typ	Max	Units	Conditions
Temperature Ranges						
Specified Temperature Range	T_A	-20	—	+125	°C	**Note 1**
Operating Temperature Range	T_A	-40	—	+125	°C	
Storage Temperature Range	T_A	-65	—	+150	°C	
Thermal Package Resistances						
Thermal Resistance, 8L-DFN	θ_{JA}	—	68	—	°C/W	
Thermal Resistance, 8L-TDFN	θ_{JA}	—	52.5	—	°C/W	
Thermal Resistance, 8L-TSSOP	θ_{JA}	—	139	—	°C/W	
Thermal Resistance, 8L-UDFN	θ_{JA}	—	41	—	°C/W	

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

TIMING DIAGRAM



GRAPHICAL SYMBOL DESCRIPTION



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.

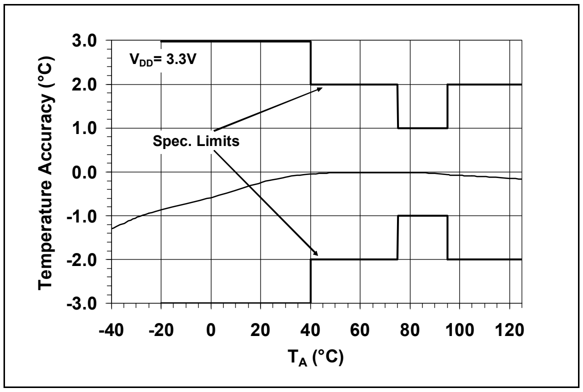


FIGURE 2-1: *Average Temperature Accuracy.*

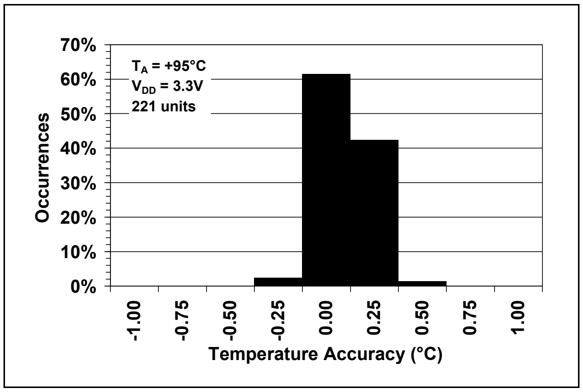


FIGURE 2-2: *Temperature Accuracy Histogram, T_A = +95°C.*

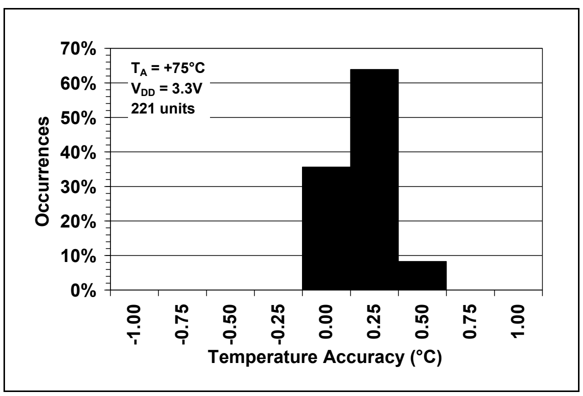


FIGURE 2-3: *Temperature Accuracy Histogram, T_A = +75°C.*

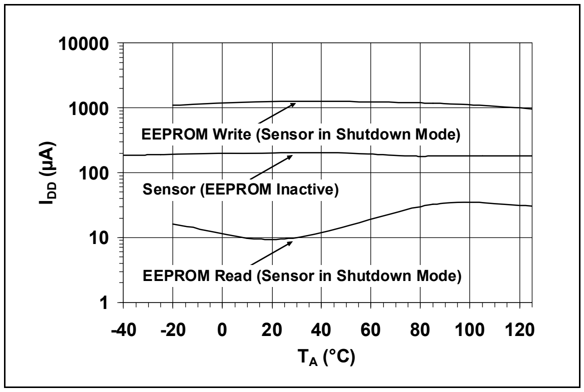


FIGURE 2-4: *Supply Current vs. Temperature.*

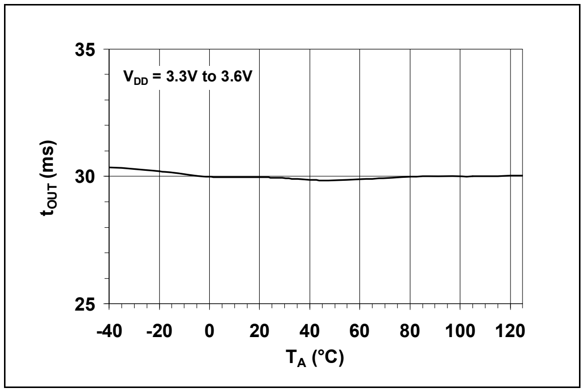


FIGURE 2-5: *Serial Bus Time-Out vs. Temperature.*

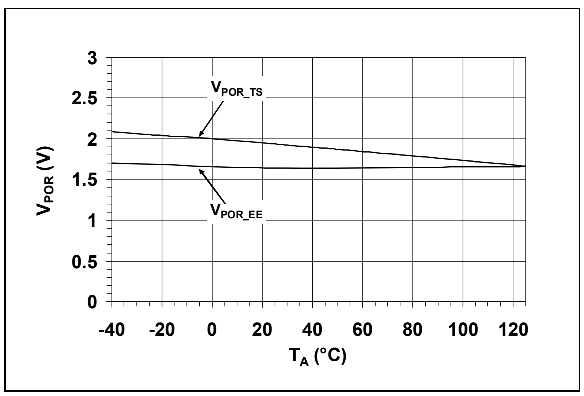


FIGURE 2-6: *Power-on Reset Threshold Voltage vs. Temperature.*

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.

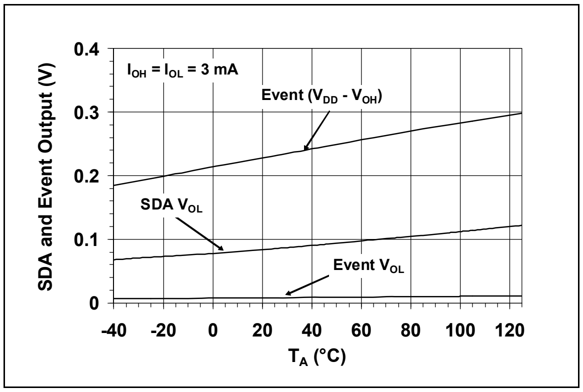


FIGURE 2-7: *Event and SDA V_{OL} vs. Temperature.*

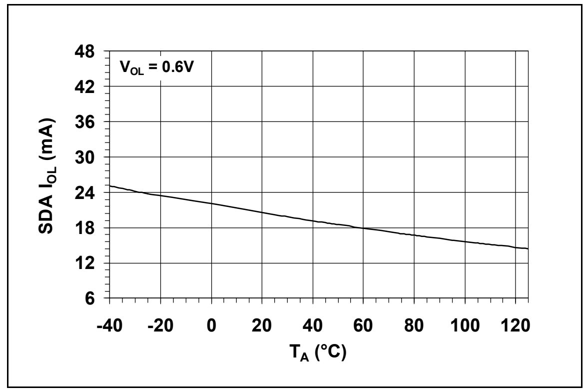


FIGURE 2-10: *SDA I_{OL} vs. Temperature.*

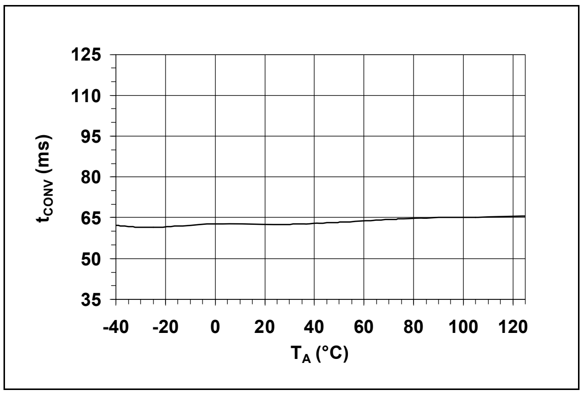


FIGURE 2-8: *Conversion Rate vs. Temperature.*

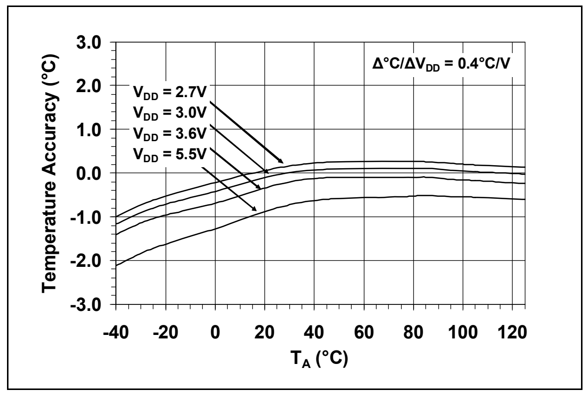


FIGURE 2-11: *Temperature Accuracy vs. V_{DD}.*

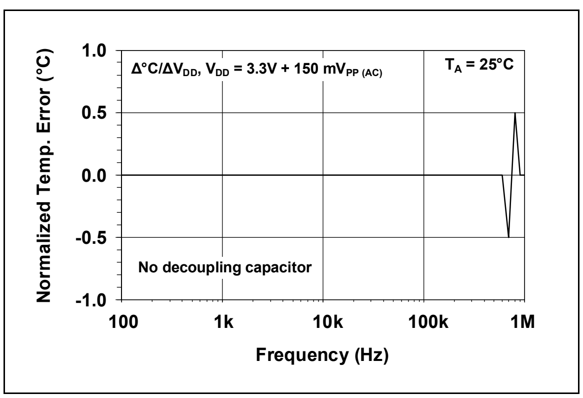


FIGURE 2-9: *Power Supply Rejection vs. Frequency.*

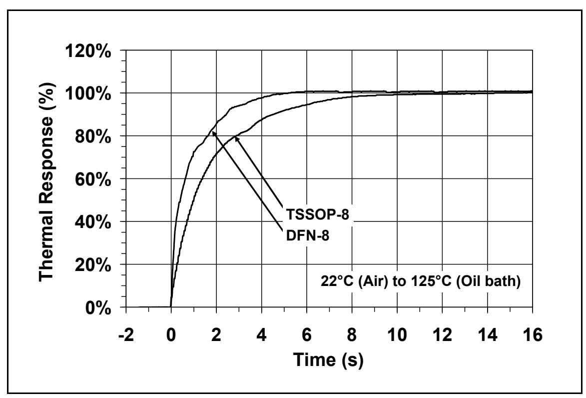


FIGURE 2-12: *Package Thermal Response.*

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.

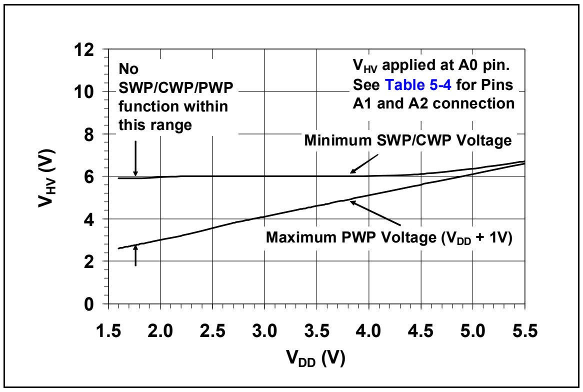


FIGURE 2-13: *SWP/CWP/PWP High Voltage Range.*

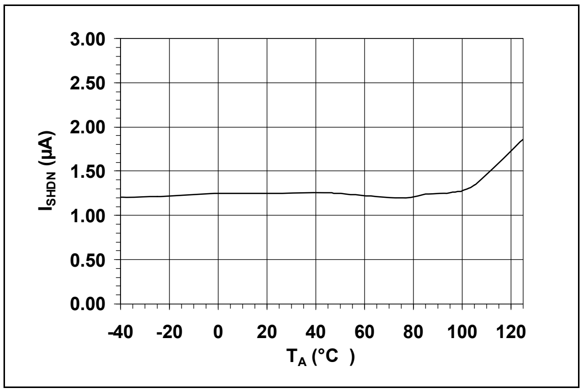


FIGURE 2-14: *Shutdown Current vs. Temperature.*

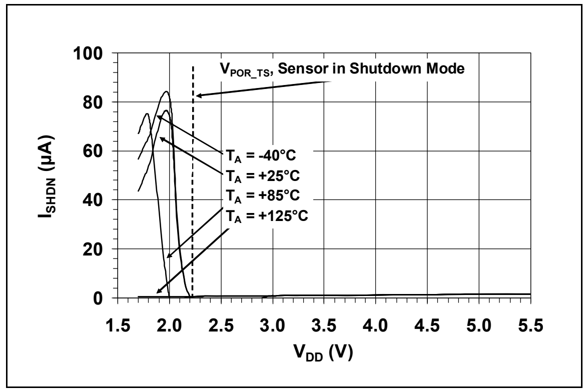


FIGURE 2-15: *Shutdown Current vs. V_{DD}.*

NOTES:

3.0 PIN DESCRIPTION

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

TABLE 3-1: PIN FUNCTION TABLES

MCP9843/98243		Symbol	Description
DFN, TDFN, UDFN	TSSOP		
1	1	A0	Slave Address and EEPROM Software Write Protect high voltage input (V_{HV})
2	2	A1	Slave Address
3	3	A2	Slave Address
4	4	GND	Ground
5	5	SDA	Serial Data Line
6	6	SCL	Serial Clock Line
7	7	Event	Temperature Alert Output
8	8	V_{DD}	Power Pin
9	—	EP	Exposed Thermal Pad (EP); can be connected to GND.

3.1 Address Pins (A0, A1, A2)

These pins are device address input pins.

The address pins correspond to the Least Significant bits (LSb) of address bits. The Most Significant bits (MSb) (A6, A5, A4, A3). This is shown in Table 3-2.

TABLE 3-2: MCP9843/98243 ADDRESS BYTE

Device	Address Code				Slave Address		
	A6	A5	A4	A3	A2	A1	A0
Sensor	0	0	1	1	X	X	X
EEPROM	1	0	1	0			
EEPROM Write Protect	0	1	1	0			

Note: User-selectable address is shown by X.

The A0 Address pin is a multi-function pin. This input pin is also used for high voltge input V_{HV} to enable the EEPROM Software Write Protect feature, see **Section 5.3.3 "Write Protection"**.

All address pin have an internal pull-down resistors.

3.2 Ground Pin (GND)

The GND pin is the system ground pin.

3.3 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"**).

3.4 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"**).

3.5 Temperature Alert, Open-Drain Output (Event)

The MCP9843/98243 temperature Event 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 "Event Output Configuration"**).

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; they can be connected to the same potential on the Printed Circuit Board (PCB). This provides better thermal conduction from the PCB to the die.

NOTES:

4.0 SERIAL COMMUNICATION

4.1 2-Wire Standard Mode I²C™ Protocol-Compatible Interface

The MCP9843/98243 serial clock input (SCL) and the bidirectional serial data line (SDA) form a 2-wire bidirectional Standard mode I²C compatible communication port (refer to the **Input/Output Pin DC Characteristics (Note 1)** Table and **Sensor And EEPROM Serial Interface Timing Specifications** Table).

The following bus protocol has been defined:

TABLE 4-1: MCP9843/98243 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 MCP9843/98243.
Transmitter	Device sending data to the bus.
Receiver	Device receiving data from the bus.
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 MCP9843/98243 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 MCP9843/98243 retain the previously selected register. Therefore, they output 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 MCP9843/98243 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 MCP9843/98243 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 MCP9843/98243. The address for the MCP9843/98243 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 MCP9843/98243 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).

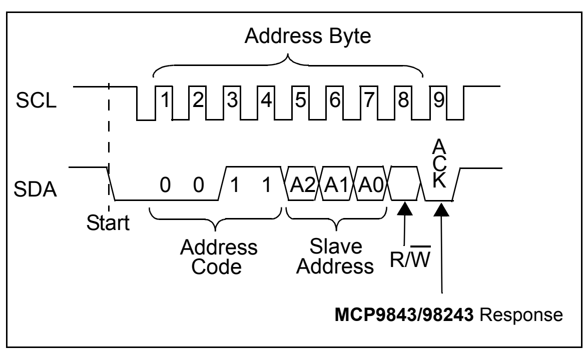


FIGURE 4-1: *Device Addressing.*

4.1.5 DATA VALID

After the Start condition, each bit of data in transmission needs to be settled for a time specified by $t_{SU\text{-}DATA}$ before SCL toggles from low-to-high (see **"Sensor And EEPROM Serial Interface Timing Specifications" on Page 5**).

4.1.6 ACKNOWLEDGE (ACK/NAK)

Each receiving device, when addressed, is obliged to 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 (MCP9843/98243, SENSOR ONLY)

If the SCL stays low or high for time specified by t_{OUT}, the MCP9843/98243 temperature sensor resets the serial interface. This dictates the minimum clock speed as specified in the specification. However, the EEPROM does not reset the serial interface. Therefore, the master can hold the clock indefinitely to process data from the EEPROM.

5.0 FUNCTIONAL DESCRIPTION

The MCP9843/98243 temperature sensors consists of a band-gap type temperature sensor, a Delta-Sigma Analog-to-Digital Converter (ΣΔ ADC), user-programmable registers and a 2-wire I²C protocol compatible serial interface. Figure 5-1 shows a block diagram of the register structure.

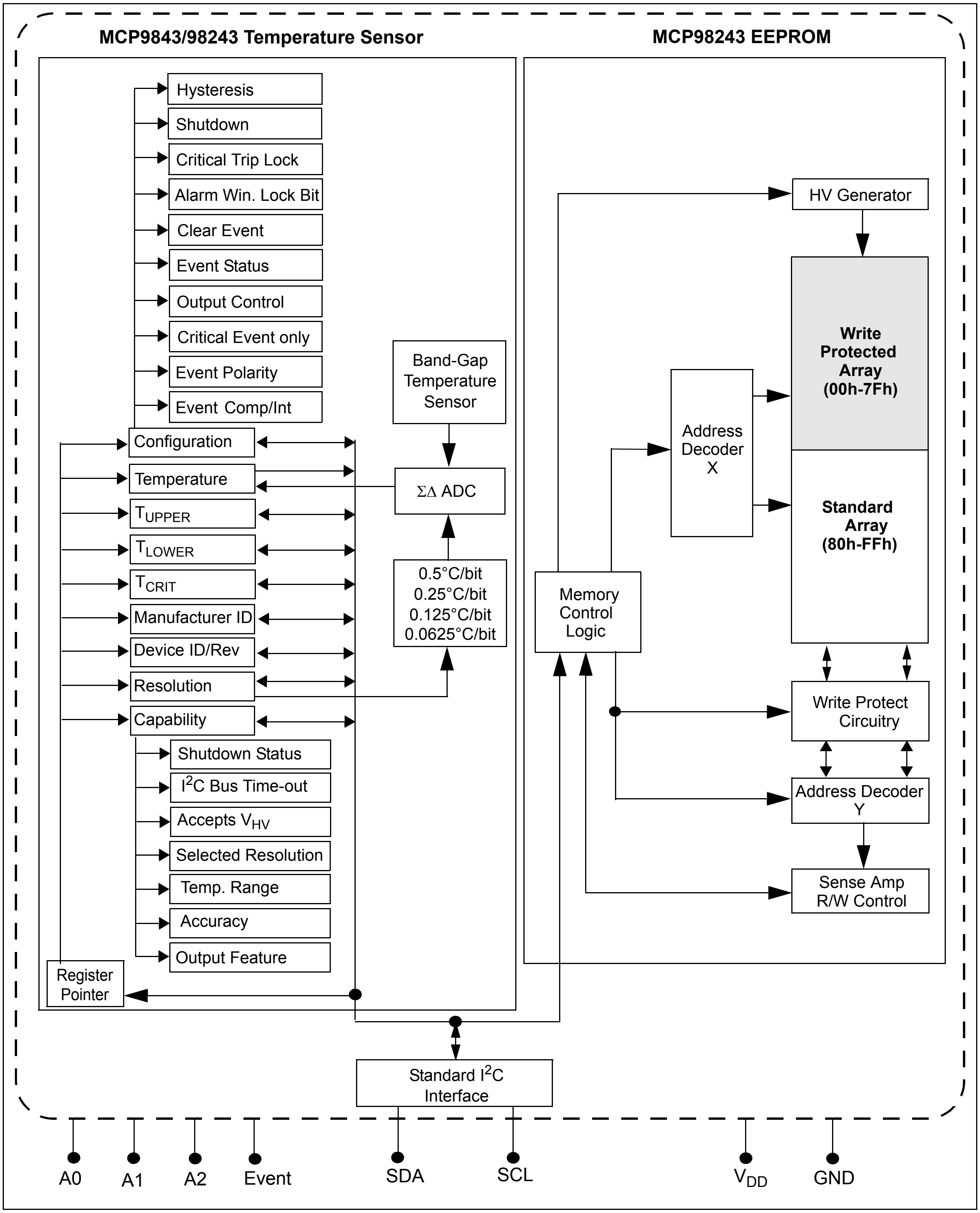


FIGURE 5-1: *Functional Block Diagram.*

5.1 Registers

The MCP9843/98243 device has several registers that are user-accessible. These registers include the Capability register, Configuration register, Event Temperature Upper-Boundary and Lower-Boundary Trip registers, Critical Temperature Trip register, Temperature register, Manufacturer Identification register and Device Identification register.

The Temperature register is read-only, used to access the ambient temperature data. The data is loaded in parallel to this register after t_{CONV}. The Event Temperature Upper-Boundary and Lower-Boundary Trip registers are read/writes. If the ambient temperature drifts beyond the user-specified limits, the MCP9843/98243 device outputs a signal using the Event pin (refer to **Section 5.2.3 "Event Output Configuration"**). In addition, the Critical Temperature Trip register is used to provide an additional critical temperature limit.

The Capability register is used to provide bits describing the MCP9843/98243's capability in measurement resolution, measurement range and device accuracy. The device Configuration register provides access to configure the MCP9843/98243'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 MCP9843/98243 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 (bits 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 **Writable Bits:** Write '0"

bit 3-0 **Pointer Bits:**

- 0000 = Capability register
- 0001 = Configuration register (CONFIG)
- 0010 = Event Temperature Upper-Boundary Trip register (T_{UPPER})
- 0011 = Event 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 (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.)

TABLE 5-1: BIT ASSIGNMENT SUMMARY FOR ALL TEMPERATURE SENSOR REGISTERS (SEE SECTION 5.4)

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	SHDN Status	t_{OUT} Range	V_{HV}	Resolution		Range	Accuracy	Event
0x01	MSB	0	0	0	0	0	Hysteresis		SHDN
	LSB	Crt Loc	Win Loc	Int Clr	Evt Stat	Evt Cnt	Evt Sel	Evt Pol	Evt 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 **MCP98243**	MSB	0	0	1	0	0	0	0	1
	LSB	0	0	0	0	0	0	0	1
0x07 **MCP9843**	MSB	0	0	0	0	0	0	0	0
	LSB	0	0	0	0	0	0	0	1
0x08	LSB	0	0	0	0	0	0	0	1

5.1.1 CAPABILITY REGISTER

This is a read-only register used to identify the temperature sensor capability. For example, the MCP9843/98243 device is capable of providing temperature at 0.25°C resolution, measuring temperature below and above 0°C, providing ±1°C and ±2°C accuracy over the active and monitor temperature ranges (respectively) and providing user-programmable temperature event boundary trip limits. Register 5-2 describes the Capability register. These functions are described in further detail in the following sections.

REGISTER 5-2: CAPABILITY REGISTER (READ-ONLY) → ADDRESS '0000 0000'b

U-0	U-0	U-0	U-0	U-0	U-0	U-0	U-0
—	—	—	—	—	—	—	—
bit 15							bit 8

R-1	R-1	R-1	R-0	R-1	R-1	R-1	R-1
SHDN Status	t_{OUT} Range	V_{HV}	Resolution		Meas Range	Accuracy	Temp Alarm
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 15-8 **Unimplemented:** Read as '0'

bit 7 **Event output status during Shutdown (SHDN Status):**
- 0 = Event output remains in previous state. If the output asserts before shutdown command, it remains asserted during shutdown.
- 1 = Event output de-asserts during shutdown. After shutdown, it takes t_{CONV} to re-assert the Event output (power-up default)

bit 6 **I^2C Bus time-out (t_{OUT} Range):**
- 0 = Bus time-out range is 10 ms to 60 ms
- 1 = Bus time-out range is 25 ms to 35 ms (power-up default)

bit 5 **High Voltage Input**
- 0 = Pin A0 does not accept High Voltage
- 1 = Pin A0 accepts High Voltage for the EEPROM Write Protect feature (power-up default)

bit 4-3 **Resolution:**
- 00 = 0.5°C
- 01 = 0.25°C (power up default)
- 10 = 0.125°C
- 11 = 0.0625°C

These bits reflect the selected resolution (see **Section 5.2.4 "Temperature Resolution"**)

bit 2 **Temperature Measurement Range (Meas. Range):**
- 0 = T_A = 0 (decimal) for temperature below 0°C
- 1 = The part can measure temperature below 0°C (power-up default)

REGISTER 5-2: CAPABILITY REGISTER (READ-ONLY) → ADDRESS ‘0000 0000’b (CONTINUED)

bit 1 **Accuracy:**

`0` = Accuracy → ±2°C from +75°C to +95°C (Active Range) and ±3°C from +40°C to +125°C (Monitor Range)

`1` = Accuracy → ±1°C from +75°C to +95°C (Active Range) and ±2°C from +40°C to +125°C (Monitor Range)

bit 0 **Temperature Alarm:**

`0` = No defined function (This bit will never be cleared or set to ‘0’)

`1` = The part has temperature boundary trip limits (T_{UPPER}/T_{LOWER}/T_{CRIT} registers) and a temperautre event output (JC 42.4 required feature)

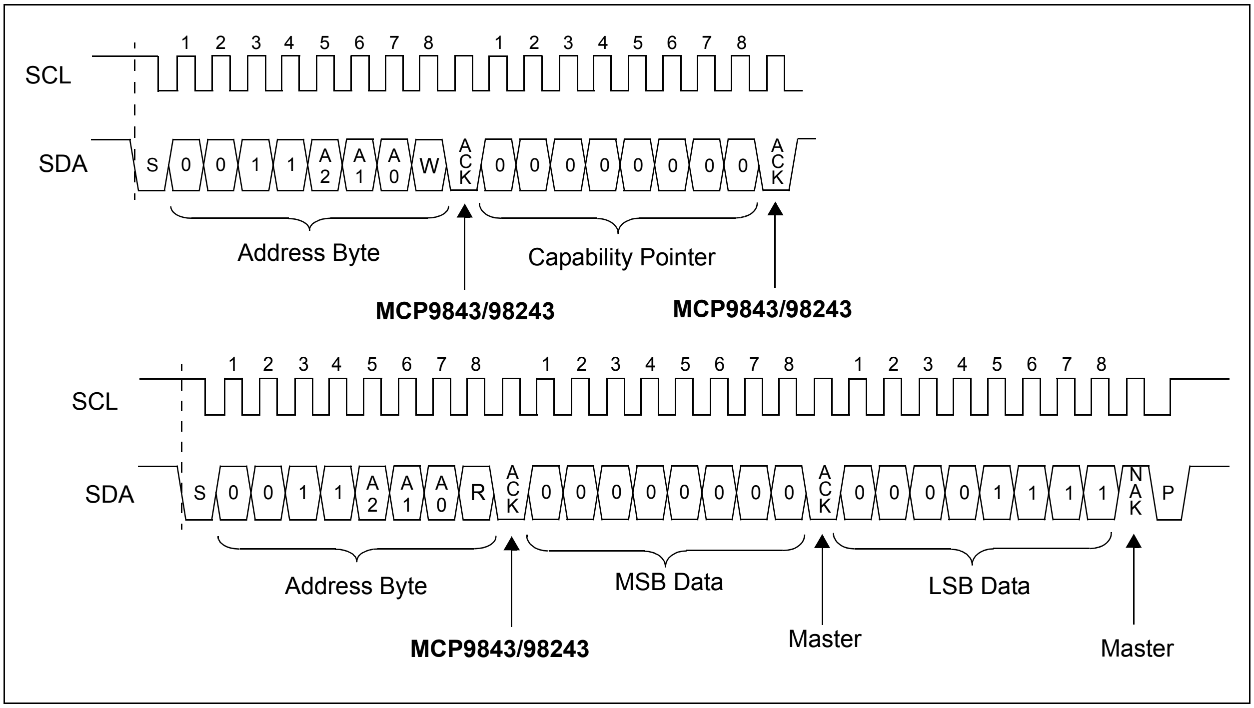


FIGURE 5-2: *Timing Diagram for Reading the Capability Register (See **Section 4.0 “Serial Communication”**).*

5.1.2 SENSOR CONFIGURATION REGISTER (CONFIG)

The MCP9843/98243 device has a 16-bit Configuration register (CONFIG) that allows the user to set various functions for a robust temperature monitoring system. Bits 10 thru 0 are used to select Event output boundary hysteresis, device Shutdown or Low-Power mode, temperature boundary and critical temperature lock, temperature Event output enable/disable. In addition, the user can select the Event output condition (output set for T_{UPPER} and T_{LOWER} temperature boundary or T_{CRIT} only), read Event output status and set Event output polarity and mode (Comparator Output or Interrupt Output mode).

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 successfully converted 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. Bits 5 thru 0 are used to configure the temperature Event output pin. All functions are described in Register 5-3 (see **Section 5.2.3 "Event Output Configuration"**).

REGISTER 5-3: CONFIGURATION REGISTER (CONFIG) → 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	Event Stat.	Event Cnt.	Event Sel.	Event Pol.	Event 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_{UPPER} and T_{LOWER} Limit Hysteresis (T_{HYST}):**

00 = 0°C (power-up default)
01 = 1.5°C
10 = 3.0°C
11 = 6.0°C

(Refer to **Section 5.2.3 "Event 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 **Shutdown Mode (SHDN):**

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. Event output will de-assert.

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

REGISTER 5-3: CONFIGURATION REGISTER (CONFIG) → ADDRESS `0000 0001'b

bit 7 **T_{CRIT} Lock Bit (Crit. Lock):**

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 '1' or locked until cleared by internal reset (**Section 5.4 "Summary of Power-on Default"**). This bit does not require a double-write.

This bit can be programmed in shutdown mode.

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

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 '1' or locked until cleared by power-on Respell (**Section 5.4 "Summary of Power-on Default"**). This bit does not require a double-write.

This bit can be programmed in shutdown mode.

bit 5 **Interrupt Clear (Int. Clear) Bit:**

0 = No effect (power-up default)
1 = Clear interrupt output. When read this bit returns '0'

This bit clears the Interrupt flag which de-asserts Event output. In shutdown mode, the Event output is always de-asserted. Therefore, setting this bit in shutdown mode clears the interrupt after the device returns to normal operation.

bit 4 **Event Output Status (Event Stat.) Bit:**

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

In shutdown mode this bit will clear because Event output is always de-asserted in shutdown mode.

bit 3 **Event Output Control (Event Cnt.) Bit:**

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

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

This bit can be programmed in shutdown mode, but Event output will remain de-asserted.

bit 2 **Event Output Select (Event Sel.) Bit:**

0 = Event output for T_{UPPER}, T_{LOWER} and T_{CRIT} (power-up default)
1 = $T_A \geq T_{CRIT}$ 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 Event output will remain de-asserted.

bit 1 **Event Output Polarity (Event Pol.) Bit:**

0 = Active low (power-up default. Pull-up resistor required) See **Section 5.2.3 "Event Output Configuration"**
1 = Active-high (Pull-down resistor required) See **Section 5.2.3 "Event Output Configuration"**

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

This bit can be programmed in shutdown mode, but Event output will remain de-asserted.

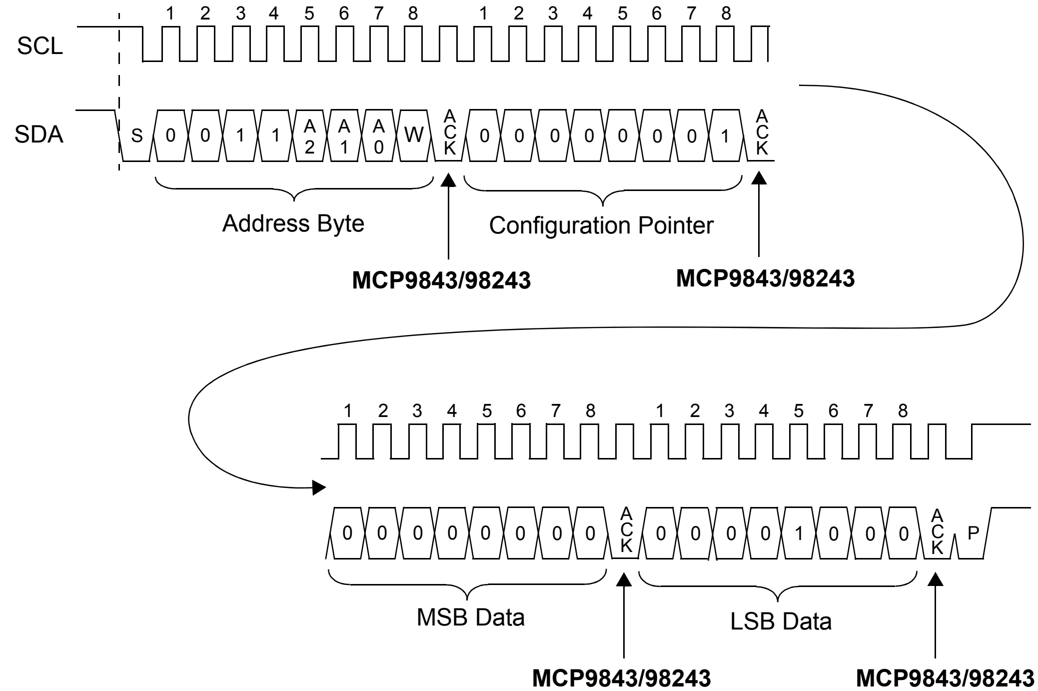
bit 0 **Event Output Mode (Event Mod.) Bit:**

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

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

This bit can be programmed in shutdown mode, but Event output will remain de-asserted.

- Writing to the CONFIG Register to Enable the Event Output pin <0000 0000 0000 1000>b.

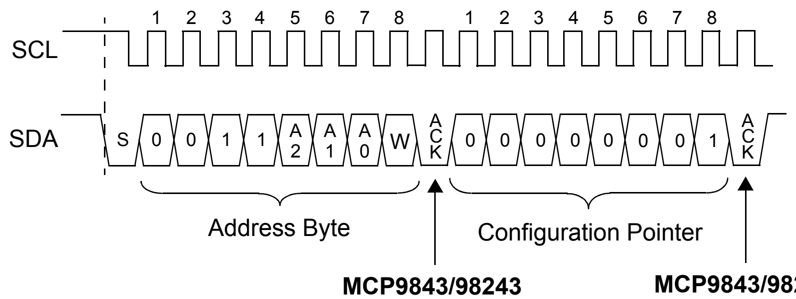


Note: this is an example routine:

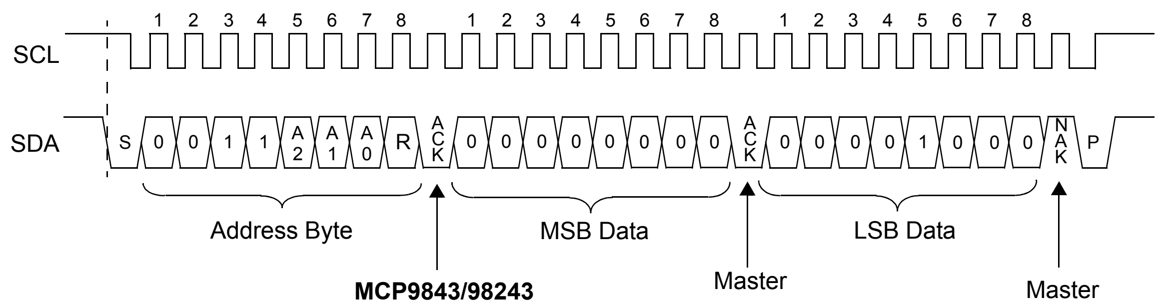
```
i2c_start();                    // send START command
i2c_write(AddressByte & 0xFE);  //WRITE Command
                                //also, make sure bit 0 is cleared '0'
i2c_write(0x01);                // Write CONFIG Register
i2c_write(0x00);                // Write data
i2c_write(0x08);                // Write data
i2c_stop();                     // send STOP command
```

FIGURE 5-3: *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:

```
i2c_start();                      // send START command
i2c_write(AddressByte & 0xFE);    //WRITE Command
                                  //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 5-4: *Timing Diagram for Reading from the Configuration Register (See **Section 4.0 "Serial Communication"**).*

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

The MCP9843/98243 device has a 16-bit read/write Event output Temperature Upper-Boundary Trip register (T_{UPPER}), a 16-bit Lower-Boundary Trip register (T_{LOWER}) and a 16-bit Critical Boundary Trip register (T_{CRIT}) that contains 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 5.1.2 "Sensor Configuration Register (CONFIG)"**) and the ambient temperature exceeds the specified boundary or window, the MCP9843/98243 asserts an Event output. (Refer to **Section 5.2.3 "Event Output Configuration"**).

REGISTER 5-4: UPPER/LOWER/CRITICAL TEMPERATURE LIMIT REGISTER ($T_{UPPER}/T_{LOWER}/T_{CRIT}$) → ADDRESS `'0000 0010'b`/`'0000 0011'b`/`'0000 0100'b` (NOTE 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:**
- 0 = $T_A \geq 0$°C
- 1 = $T_A < 0$°C

bit 11-2 **$T_{UPPER}/T_{LOWER}/T_{CRIT}$:**
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.

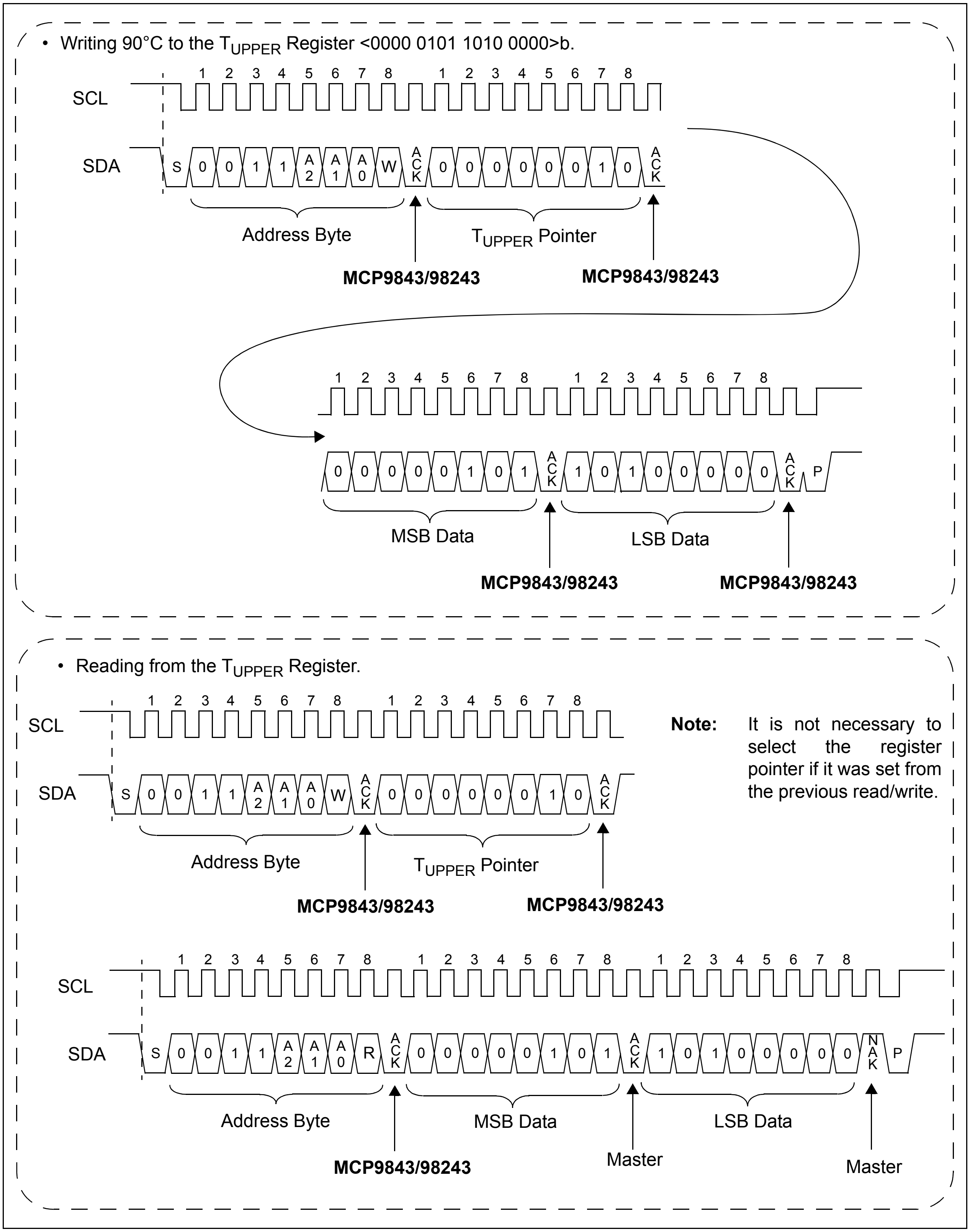


FIGURE 5-5: *Timing Diagram for Writing and Reading from the T_{UPPER} Register (See **Section 4.0 "Serial Communication"**).*