MCP9509/10

Resistor-Programmable Temperature Switches

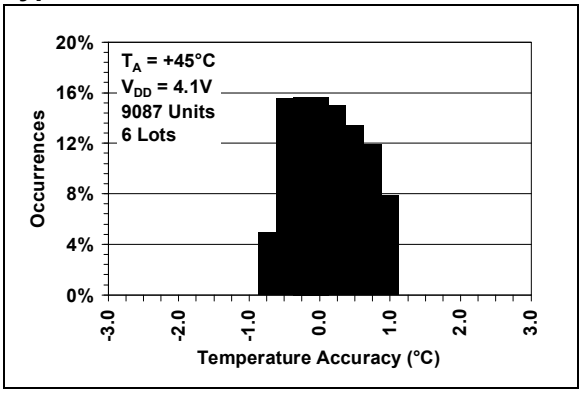
Features

- Resistor-Programmable Temperature Switch
- Wide Operating Voltage Range: 2.7V to 5.5V
- Low Supply Current: 30 µA (typical)
- Temperature Switch Accuracy:
  - ±0.5°C (typical) at +25°C, +45°C
  - ±1°C (typical) 0°C to +70°C
  - ±3.5°C (maximum) 0°C to +125°C
  - ±4.5°C (maximum) -20°C to +125°C
  - ±2°C (typical) -40°C to +125°C
- Sensor Options available:
  - Switch for rising temperature: Cold to Hot (H)
  - Switch for falling temperature: Hot to Cold (C)
- Output Configurations:
  - Open-Drain:
    - – External Pull-up Resistor: MCP9509
    - – Internal Pull-up Resistor: MCP9510
  - Active-Low, Push-Pull: MCP9510
  - Active-High, Push-Pull: MCP9510
- User Selectable Hysteresis: 2°C or 10°C (typical)
- Space-Saving SOT-23-5, SOT-23-6 Packages

Applications

- Power Supply Thermal Shutdown
- Temperature Alarm
- Thermostat Control
- Fan Control
- Base-Stations
- Automotive

Typical Performance

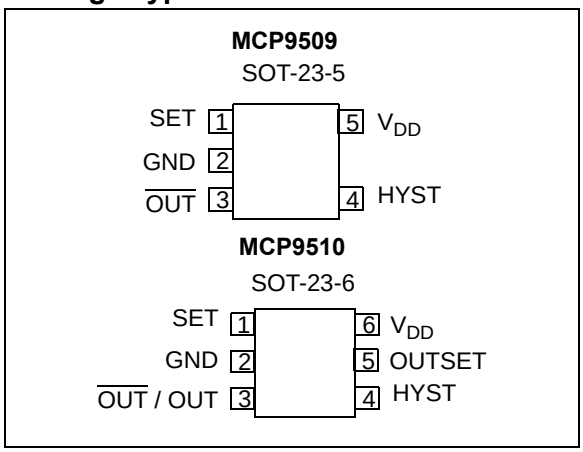


Description

Microchip Technology's MCP9509/10 devices are programmable logic output temperature switches. The temperature switch threshold can be programmed with a single external resistor, which provides high design flexibility and simplicity. In addition, this family of devices provide user programmable features such as 2°C and 10°C (typical) switch hysteresis and output structure configuration. The MCP9509 provides an open drain output, whereas the MCP9510 is offered in three different user selectable output configurations: Active-low/Active-high push pull and Active-Low Open-Drain output with an internal 100 kΩ pull-up resistor.

The MCP9509/10 operate from 2.7V to 5.5V. This family is capable of triggering for temperatures -40°C to +125°C with high accuracy.

Package Types



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NOTES:

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1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings †

V_{DD}..... 6.0V
Voltage at all Input/Output pins ..... GND – 0.3V to 6.0V
Input/Output Current .....20 mA
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/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.

DC CHARACTERISTICS

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

Parameters	Sym	Min	Typ	Max	Unit	Conditions
Sensor Accuracy						
T_A = +25°C, +45°C	T_{ACY}	—	±0.5	—	°C	**Note 1**
0°C ≤ T_A ≤ +125°C		-3.5	±1	+3.5	°C	
-20°C ≤ T_A ≤ +125°C		-4.5	±1	+4.5	°C	
-40°C ≤ T_A ≤ +125°C		—	±2	—	°C	
Power Supply						
Operating Voltage	V_{DD}	2.7	—	5.5	V	
Operating Current (MCP9509)	I_{DD}	—	30	50	µA	
Operating Current (MCP9510)	I_{DD}	—	50	80	µA	OUTSET = GND or V_{DD}
		—	100	165	µA	OUTSET = Unconnected
Hysteresis						
Trip Point Hysteresis	T_{HYST}	—	+2	—	°C	HYST = GND
		—	+10	—	°C	HYST = V_{DD}
Hysteresis Select:	V_{IH}	V_{DD} - 0.4	—	—	V	
Input (HYST) Thresholds	V_{IL}	—	—	0.4	V	
Hysteresis Input (HYST) Leakage	I_{Leak}	—	1	—	µA	
MCP9510 Output Control Input (OUTSET Input)						
OUTSET Input Voltage Threshold and Output Configuration						
Push-Pull, Active Low	V_{OSET}	GND	—	$0.2V_{DD}$	V	
Open-Drain with R_{OUT}, Active Low		$0.45V_{DD}$	—	$0.7V_{DD}$	V	or OUTSET Unconnected
Push-Pull, Active High		$0.85V_{DD}$	—	V_{DD}	V	
OUTSET Input Leakage and Output Configuration						
Push-Pull, Active Low	I_{Leak}	—	10	—	µA	GND ≤ V_{OSET} ≤ $0.2V_{DD}$
Open-Drain, Active Low		—	0	—	µA	Unconnected (i.e. open)
		—	7	—	µA	$0.4V_{DD}$ ≤ V_{OSET} ≤ $0.7V_{DD}$
Push-Pull, Active High		—	-10	—	µA	0.85 ≤ V_{OSET} ≤ V_{DD}
OUTSET Input Impedance	Z_{OUTSET}	—	500	—	kΩ	

Note 1: This specification is tested at mid supply of 4.1V for optimum operation across the supply voltage range of 2.7V to 5.5V.

DC CHARACTERISTICS (CONTINUED)

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

Parameters	Sym	Min	Typ	Max	Unit	Conditions
Outputs (OUT, $\overline{OUT}$)						
Output Voltage High, MCP9510	V_{OH}	V_{DD} - 0.55	—	V_{DD}	V	I_{OUT} = 5 mA OUTSET = V_{DD} or GND
Output Voltage Low, MCP9510	V_{OL}	GND	—	0.3	V	
Output Voltage Low, MCP9509	V_{OL}	GND	—	0.3	V	I_{OUT} = 5 mA
Internal Output Pull-up (MCP9510)	R_{OUT}	60	100	140	kΩ	OUTSET Unconnected
Open-Drain Output Leakage	I_{Leak}	—	1	—	µA	MCP9509/10
Power Supply Rejection	PSR	—	0.05	—	°C/V	
Thermal Response						
SOT23-5, SOT23-6	t_{RES}	—	1.7	—	s	Time to 63% (88°C). +25°C (Air) to +125°C (oil bath)

Note 1: This specification is tested at mid supply of 4.1V for optimum operation across the supply voltage range of 2.7V to 5.5V.

TEMPERATURE CHARACTERISTICS

Electrical Specifications: Unless otherwise indicated, V_{DD} = 2.7V to 5.5V, T_A = -40°C to +125°C, 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, 5L-SOT23	θ_{JA}	—	220.7	—	°C/Ω	
Thermal Resistance, 6L-SOT23	θ_{JA}	—	190.5	—	°C/Ω	

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

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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, T_A = -40°C to +125°C, GND = Ground, $R_{PULL-UP}$ = 10 kΩ (MCP9509 only) and 0.1 µf bypass capacitor.

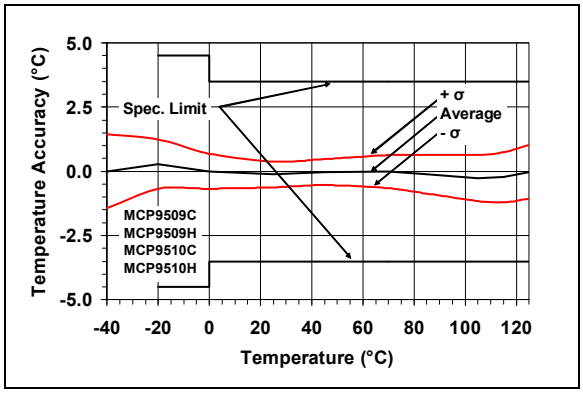


FIGURE 2-1: *Temperature Accuracy.*

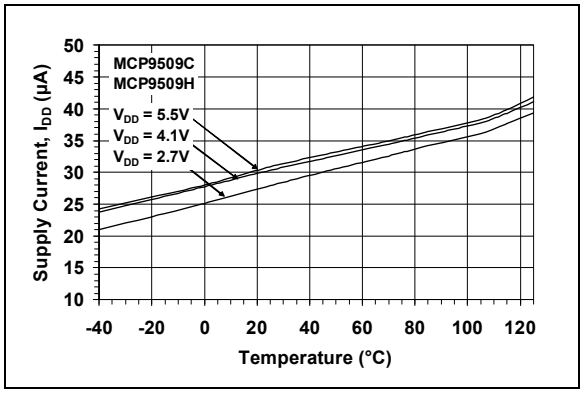


FIGURE 2-4: *Supply Current vs. Temperature (MCP9509).*

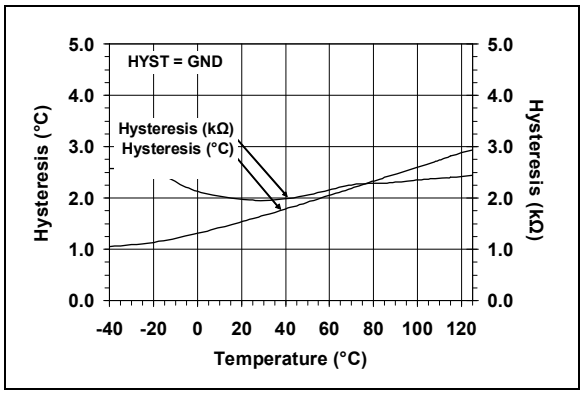


FIGURE 2-2: *Output Hysteresis vs. Temperature.*

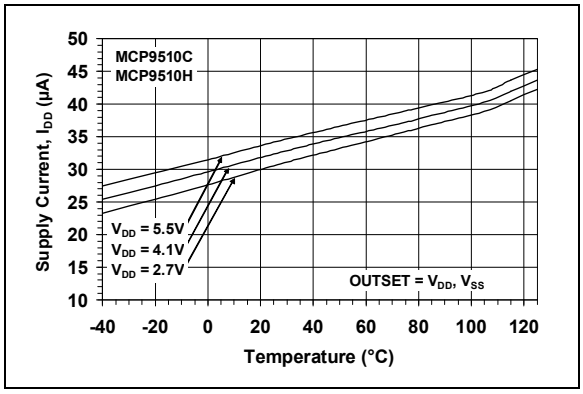


FIGURE 2-5: *Supply Current vs. Temperature OUTSET = V_{DD}, V_{SS} (MCP9510).*

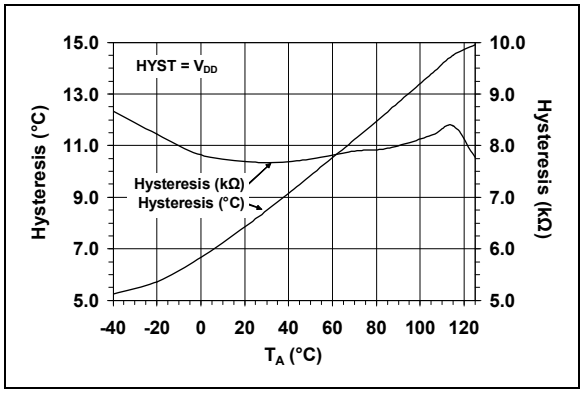


FIGURE 2-3: *Output Hysteresis vs. Temperature.*

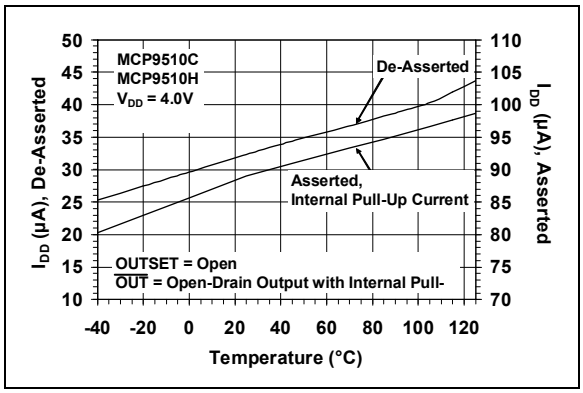


FIGURE 2-6: *Supply Current vs. Temperature OUTSET = Unconnected, Open (MCP9510).*

Note: Unless otherwise indicated, V_{DD} = 2.7V to 5.5V, T_A = -40°C to +125°C, GND = Ground, $R_{PULL-UP}$ = 10 kΩ (MCP9509 only) and 0.1 µf bypass capacitor.

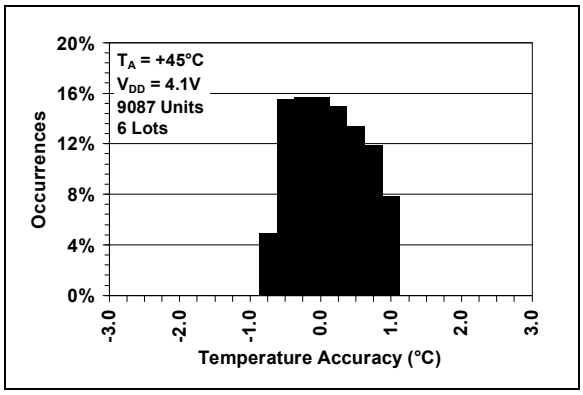


FIGURE 2-7: *Temperature Accuracy Histogram at +45°C.*

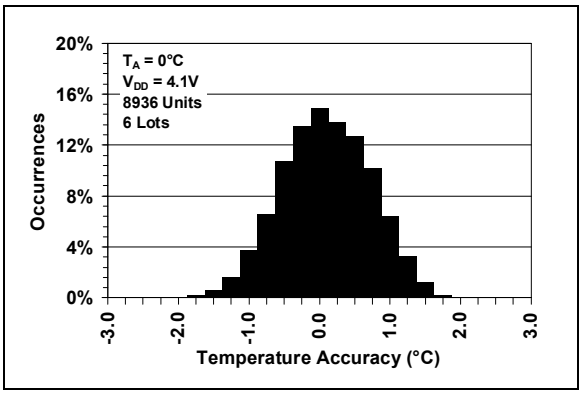


FIGURE 2-10: *Temperature Accuracy Histogram at 0°C.*

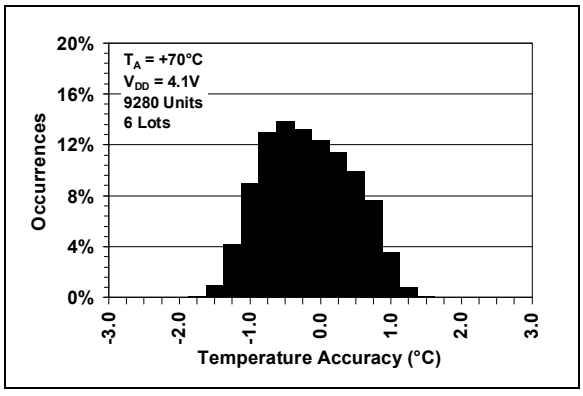


FIGURE 2-8: *Temperature Accuracy Histogram at +70°C.*

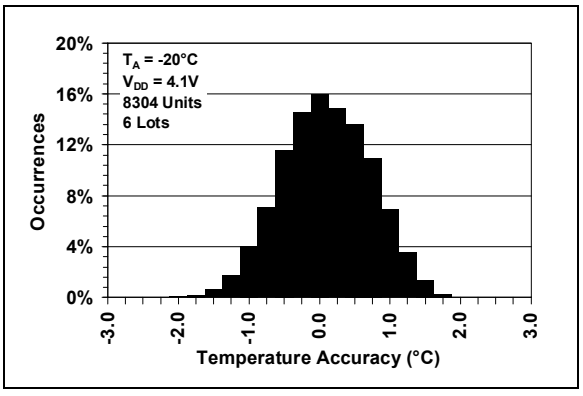


FIGURE 2-11: *Temperature Accuracy Histogram at -20°C.*

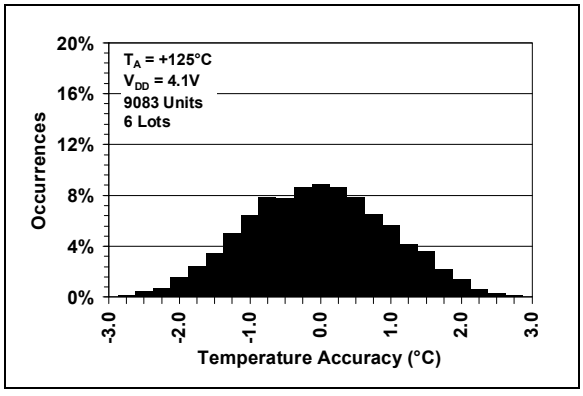


FIGURE 2-9: *Temperature Accuracy Histogram at +125°C.*

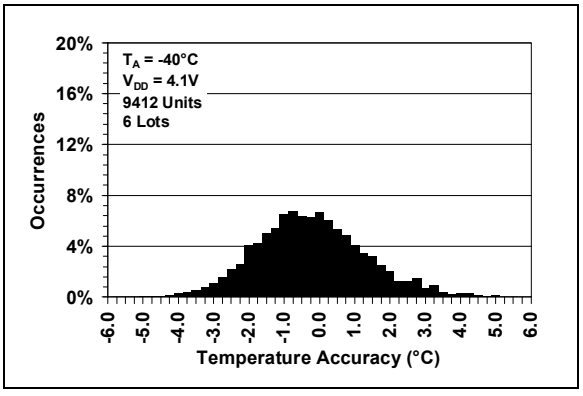


FIGURE 2-12: *Temperature Accuracy Histogram at -40°C.*

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Note: Unless otherwise indicated, V_{DD} = 2.7V to 5.5V, T_A = -40°C to +125°C, GND = Ground, $R_{PULL-UP}$ = 10 kΩ (MCP9509 only) and 0.1 µf bypass capacitor.

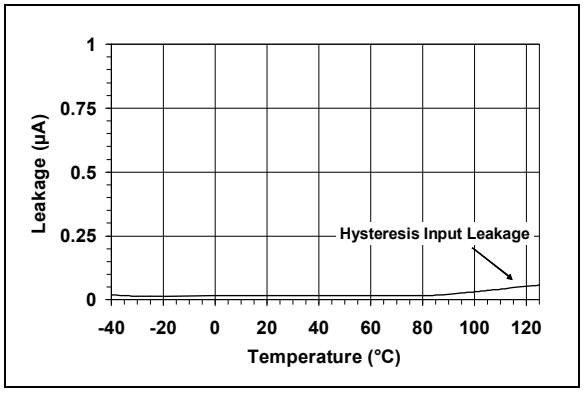


FIGURE 2-13: *Hysteresis Input Leakage vs, Temperature.*

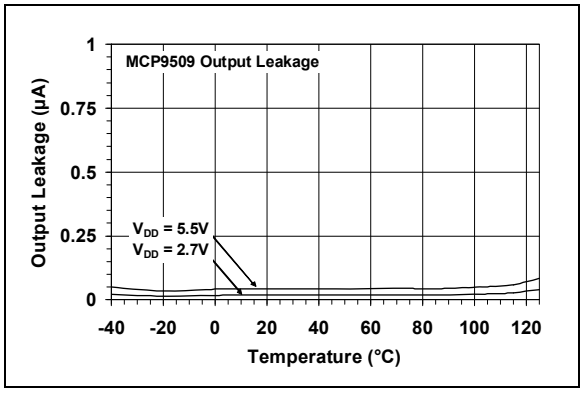


FIGURE 2-14: *Output Leakage vs. Temperature.*

NOTES:

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3.0 PIN DESCRIPTIONS

TABLE 3-1: PIN FUNCTION TABLE

MCP9509	MCP9510	Symbol	Description
SOT-23-5	SOT-23-6		
1	1	SET	External Trip Temperature Resistor (R_{SET}) input
2	2	GND	Ground
3	—	$\overline{OUT}$	Open-drain output
—	3	OUT, $\overline{OUT}$	Selectable Output pin, function set by OUTSET pin
4	4	HYS	Hysteresis Input HYS = GND, hysteresis is 2°C HYS = V_{DD}, hysteresis is 10°C
5	6	V_{DD}	Power pin
—	5	OUTSET	Output Control OUTSET = GND, Active-Low, Push-Pull OUTSET = V_{DD}, Active-High, Push-Pull OUTSET = Unconnected, Active-Low, Open-Drain with an internal pull-up

3.1 External Resistor Input (SET)

This pin is used to connect a resistor between the SET and GND pins to select the temperature trip point (T_{SET}). The resistor value can be determined either from Equation 4-2 or the lookup table shown in Table 4-2.

3.2 Ground (GND)

The GND pin is the system ground pin.

3.3 Hysteresis Input (HYS)

This is an input pin which can be connected to V_{DD} or GND to select output hysteresis. Either 2°C (HYS = GND) or 10°C (HYS = V_{DD}) of hysteresis can be selected.

3.4 Power Pin (V_{DD})

The operating voltage range, as specified in the DC electrical specification table, is applied on this pin.

3.5 Open-Drain Output ($\overline{OUT}$) (MCP9509)

This output is triggered when temperature exceeds the programmed trip temperature. This pin requires a pull-up resistor.

3.6 Selectable Output (OUT, $\overline{OUT}$) (MCP9510)

The output pin can be configured as either a Push-Pull Active-High, Push-Pull Active-Low, or an Open-drain Output with an internal pull-up resistor. The three output options of the MCP9510 are selected by the OUTSET pin.

3.7 Output Control (OUTSET) (MCP9510)

The OUTSET pin is used to select the desired configuration of the OUT or $\overline{OUT}$ pin.

TABLE 3-1: OUTSET SELECTABLE OUTPUTS

OUTSET Pin	OUT / $\overline{OUT}$ Pin
GND	Push-Pull, Active-Low
V_{DD}	Push-Pull, Active-High
unconnected (i.e. open)	Open-Drain output with an internal pull-up resistor of 100 kΩ (typical)

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NOTES:

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4.0 FUNCTIONAL DESCRIPTION

The MCP9509/10 integrates a temperature switch with a user programmable threshold. The temperature switch threshold or alert limit is programmed using an external resistor R_{SET}. A logic signal is asserted when the die temperature crosses the programmed alert limit. The MCP9509 has an Open-Drain output which requires an external pull-up resistor for operation. The MCP9510 output can be configured to three user selectable output configurations. The OUTSET pin is used to select Active-Low Push-Pull, Active-Low Open-Drain (with internal 100 kΩ pull-up resistor), Active-High Push-Pull output configurations. In addition, this device provides user selectable hysteresis of 2°C and 10°C (typical).

4.1 SET Input Pin

The SET input pin is used to connect an external resistor R_{SET}. The resistor sets the alert threshold. The SET pin outputs a constant current I_{SET} (~5 µA) to bias R_{SET} (Shown in Figure 4-1). The voltage across R_{SET}, V_{SET}, is compared to an internal thermal diode.

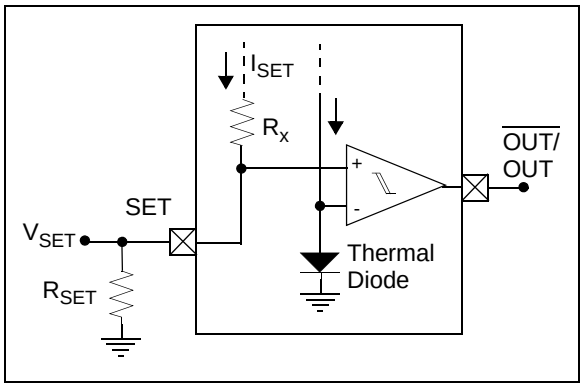


FIGURE 4-1: *SET input.*

When the thermal diode voltage exceeds V_{SET}, the sensor output asserts. The assert polarity is determined by the state of the OUTSET pin.

4.2 MCP9510 OUTSET Input Pin

This pin is used to select the device output configuration. This feature enables in-circuit device output configuration by driving this pin with a microcontroller I/O pin to Output-HIGH, Output-LOW, or High-Impedance input. Figure 4-4 shows the configuration and output conditions.

The input structure of this pin consists of a resistor ladder and comparators to determine OUTSET level threshold. Figure 4-2 shows the circuit configuration. The OUTSET input resistance must be carefully considered for leakage current when connecting voltage source to change output configuration.

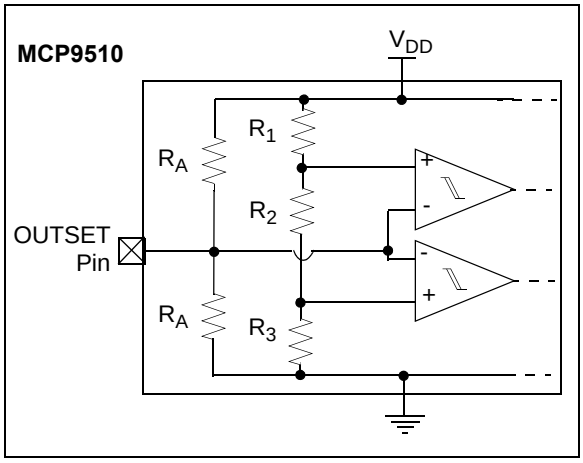


FIGURE 4-2: *MCP9510 OUTSET Input Structure.*

The OUTSET pin input impedance Z_{OUTSET} is set by the internal resistance R_A = 1 MΩ (typical). The input structure is a voltage divider network from V_{DD}. Therefore, the leakage current on the OUTSET pin is a function of change in V_{DD} and the V_{OSET}.

4.3 HYST Input Pin (Hysteresis Select)

The MCP9509/10 family has a user selectable hysteresis input pin HYST. Hysteresis can be externally selected to either 2°C (HYST = GND) or 10°C (HYST = V_{DD}). Figure 4-3 shows graphical description of change in hysteresis.

For example, if the alert temperature threshold is set to T_{SET} = 100°C (R_{SET} = 16.1 kΩ) with an Active-Low output configuration, the output asserts Low when temperature exceeds 100°C ± T_{ACY}. The output remains asserted Low until temperautre falls below T_{HYST}, 98°C (HYST = GND) or 90°C (HYST = V_{DD}).

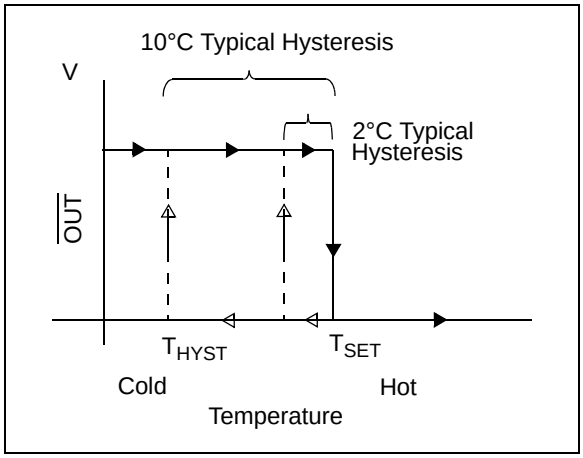


FIGURE 4-3: *Output Hysteresis.*

4.4 Sensor Hot/Cold Options

MCP9509/10 is available with Hot (H) and Cold (C) options. The MCP9509/10 Hot option detects rising temperature while the Cold option detects falling temperature. The output of the Hot option asserts when temperature rises above T_{SET} and de-asserts when temperature falls below T_{HYST}. The output of the Cold option asserts when temperature falls below T_{SET} and de-asserts when temperature rises above T_{HYST}.

For example, if T_{SET} = 100°C for Hot option (Active-Low Configuration, HYST = V_{DD}), output asserts Low when temperature is greater than 100°C ± T_{ACY}. The output de-asserts High when temperature is below 90°C. For the Cold option, output asserts Low when temperature is less than 100°C ± T_{ACY}, and de-asserts when temperature is greater than 110°C. This operation is shown graphically in Figure 4-4.

4.5 R_{SET} vs. Temperature

The relation between the user selectable external resistor R_{SET} and the output trigger threshold limit T_{SET} is described as shown in **EQUATION 4-1: "T_{SET} to R_{set} conversion"** and **EQUATION 4-2: "R_{SET} to T_{set} conversion"**. The equation coeffcients vary depending on the device output options, H or C. Table 4-1 shows the corresponding coefficients.

TABLE 4-1: COEFFICIENTS/VARIABLES

Coef.	MCP9509/10H	MCP9509/10C	Units
C_{R1}	-9.84	-10.00	10^{-6}kΩ/°C^3
C_{R2}	3.355	3.345	10^{-3}kΩ/°C^2
C_{R3}	-0.8648	-0.8610	kΩ/°C
C_{T1}	-20.00	-19.7	10^{-6}°C/kΩ^3
C_{T2}	4.136	4.179	10^{-3}°C/kΩ^2
C_{T3}	-1.1564	-1.1617	°C/kΩ
R_1	94.1	95.1	kΩ
R_2	145.5	146.3	kΩ
R_3	2.77	4.25	kΩ
T_1	-40.0		°C
T_2	125.0		°C

EQUATION 4-1: T_{SET} TO R_{SET} CONVERSION

$$R_{SET} = C_{R1}T_{SET}(T_{SET}-T_1)(T_{SET}-T_2) + C_{R2}(T_{SET}-T_1)(T_{SET}-T_2) + C_{R3}(T_{SET}-T_1) + R_2$$

Where:

- $C_{R1,2,3}$ = 1st, 2nd and 3rd order Temperature to Resistance Conversion Coefficients (Table 4-1)
- R_2 = Resistance (Table 4-1)
- $T_{1,2}$ = Temperature (Table 4-1)

EQUATION 4-2: R_{SET} TO T_{SET} CONVERSION

$$T_{SET} = C_{T1}(R_{SET}-R_1)(R_{SET}-R_2)(R_{SET}-R_3) + C_{T2}(R_{SET}-R_3)(R_{SET}-R_2) + C_{T3}(R_{SET}-R_2) + T_1$$

Where:

- $C_{C1,2,3}$ = 1st, 2nd and 3rd order Resistance to Temperature Conversion Coefficients (Table 4-1)
- $R_{1,2,3}$ = Resistance (Table 4-1)
- T_1 = Temperature (Table 4-1)

The equations can be used to determine the external resistance value for a specified temperature threshold or threshold value for a specified resistance. Table 4-2 and Table 4-3 show a look-up table which can be used to easily identify the T_{SET} to R_{SET} relation for Hot and Cold options.

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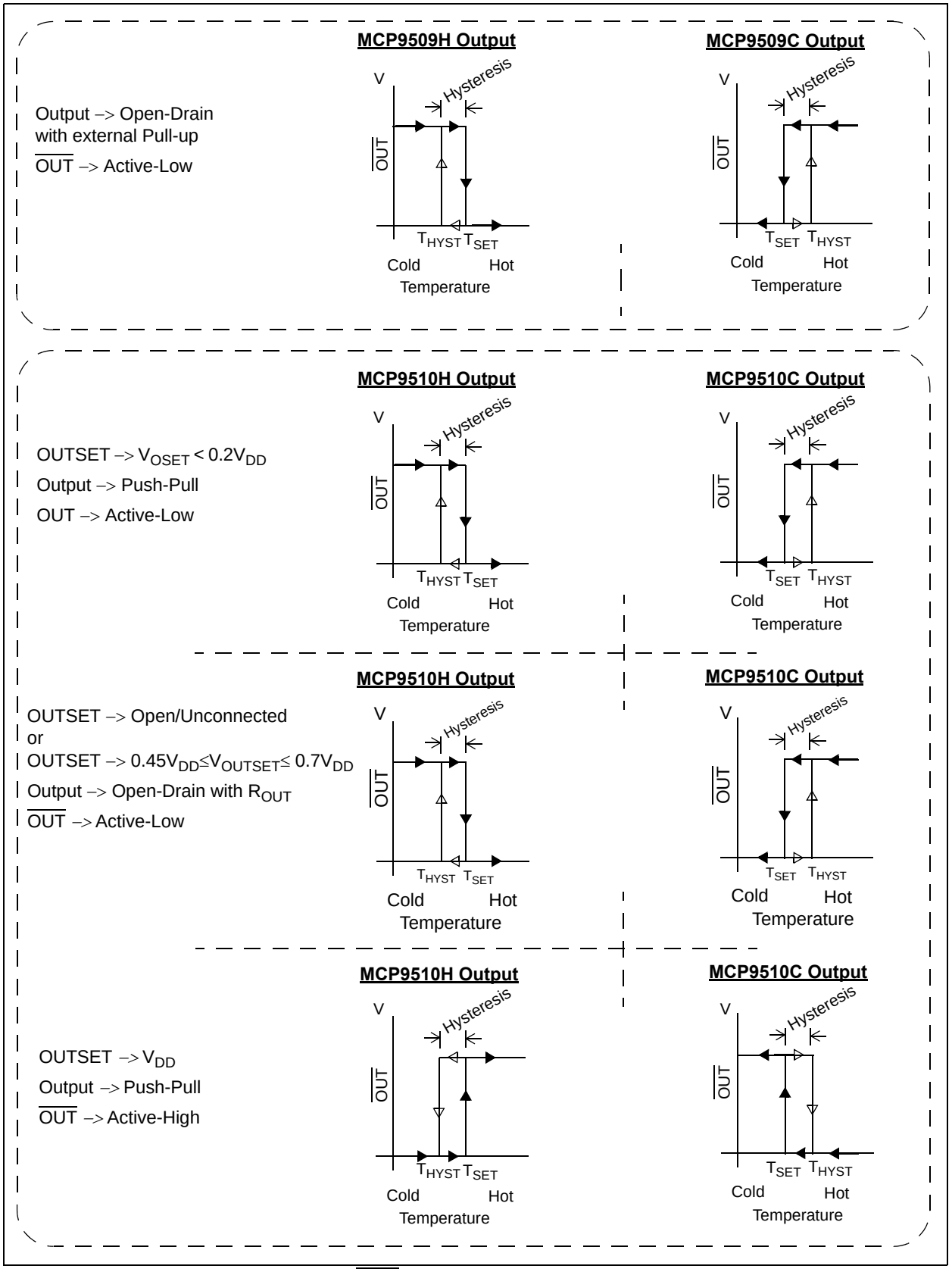


FIGURE 4-4: *MCP9509/10 OUT/$\overline{OUT}$ Output Configuration.*

TABLE 4-2: T_{SET} TO R_{SET} CONVERSION TABLE FOR MCP9509/MCP9510H (HOT)

T_{SET} (°C)	R_{SET} (kΩ)	T_{SET} (°C)	R_{SET} (kΩ)	T_{SET} (°C)	R_{SET} (kΩ)	T_{SET} (°C)	R_{SET} (kΩ)	T_{SET} (°C)	R_{SET} (kΩ)	T_{SET} (°C)	R_{SET} (kΩ)	T_{SET} (°C)	R_{SET} (kΩ)	T_{SET} (°C)	R_{SET} (kΩ)	T_{SET} (°C)	R_{SET} (kΩ)
-40.0	145.5	-20.0	117.9	0.0	94.1	20.0	73.7	40.0	56.2	60.0	41.1	80.0	27.9	100.0	16.1	120.0	5.4
-39.5	144.8	-19.5	117.3	0.5	93.6	20.5	73.2	40.5	55.8	60.5	40.7	80.5	27.5	100.5	15.9	120.5	5.1
-39.0	144.0	-19.0	116.6	1.0	93.0	21.0	72.8	41.0	55.4	61.0	40.3	81.0	27.2	101.0	15.6	121.0	4.9
-38.5	143.3	-18.5	116.0	1.5	92.5	21.5	72.3	41.5	55.0	61.5	40.0	81.5	26.9	101.5	15.3	121.5	4.6
-38.0	142.6	-18.0	115.4	2.0	91.9	22.0	71.8	42.0	54.6	62.0	39.7	82.0	26.6	102.0	15.0	122.0	4.4
-37.5	141.8	-17.5	114.7	2.5	91.4	22.5	71.4	42.5	54.2	62.5	39.3	82.5	26.3	102.5	14.7	122.5	4.1
-37.0	141.1	-17.0	114.1	3.0	90.9	23.0	70.9	43.0	53.8	63.0	39.0	83.0	26.0	103.0	14.5	123.0	3.8
-36.5	140.4	-16.5	113.5	3.5	90.3	23.5	70.5	43.5	53.4	63.5	38.6	83.5	25.7	103.5	14.2	123.5	3.6
-36.0	139.7	-16.0	112.9	4.0	89.8	24.0	70.0	44.0	53.0	64.0	38.3	84.0	25.4	104.0	13.9	124.0	3.3
-35.5	138.9	-15.5	112.2	4.5	89.3	24.5	69.5	44.5	52.6	64.5	37.9	84.5	25.1	104.5	13.6	124.5	3.1
-35.0	138.2	-15.0	111.6	5.0	88.7	25.0	69.1	45.0	52.2	65.0	37.6	85.0	24.8	105.0	13.4	125.0	2.8
-34.5	137.5	-14.5	111.0	5.5	88.2	25.5	68.6	45.5	51.8	65.5	37.2	85.5	24.5	105.5	13.1		
-34.0	136.8	-14.0	110.4	6.0	87.7	26.0	68.2	46.0	51.4	66.0	36.9	86.0	24.2	106.0	12.8		
-33.5	136.1	-13.5	109.8	6.5	87.2	26.5	67.7	46.5	51.0	66.5	36.6	86.5	23.9	106.5	12.6		
-33.0	135.4	-13.0	109.2	7.0	86.6	27.0	67.3	47.0	50.6	67.0	36.2	87.0	23.6	107.0	12.3		
-32.5	134.7	-12.5	108.6	7.5	86.1	27.5	66.8	47.5	50.2	67.5	35.9	87.5	23.3	107.5	12.0		
-32.0	134.0	-12.0	108.0	8.0	85.6	28.0	66.4	48.0	49.9	68.0	35.6	88.0	23.0	108.0	11.7		
-31.5	133.3	-11.5	107.4	8.5	85.1	28.5	65.9	48.5	49.5	68.5	35.2	88.5	22.7	108.5	11.5		
-31.0	132.6	-11.0	106.8	9.0	84.6	29.0	65.5	49.0	49.1	69.0	34.9	89.0	22.4	109.0	11.2		
-30.5	131.9	-10.5	106.2	9.5	84.0	29.5	65.1	49.5	48.7	69.5	34.6	89.5	22.1	109.5	10.9		
-30.0	131.2	-10.0	105.6	10.0	83.5	30.0	64.6	50.0	48.3	70.0	34.2	90.0	21.8	110.0	10.7		
-29.5	130.5	-9.5	105.0	10.5	83.0	30.5	64.2	50.5	48.0	70.5	33.9	90.5	21.5	110.5	10.4		
-29.0	129.8	-9.0	104.4	11.0	82.5	31.0	63.7	51.0	47.6	71.0	33.6	91.0	21.3	111.0	10.1		
-28.5	129.1	-8.5	103.8	11.5	82.0	31.5	63.3	51.5	47.2	71.5	33.3	91.5	21.0	111.5	9.9		
-28.0	128.5	-8.0	103.2	12.0	81.5	32.0	62.9	52.0	46.8	72.0	32.9	92.0	20.7	112.0	9.6		
-27.5	127.8	-7.5	102.6	12.5	81.0	32.5	62.4	52.5	46.5	72.5	32.6	92.5	20.4	112.5	9.3		
-27.0	127.1	-7.0	102.0	13.0	80.5	33.0	62.0	53.0	46.1	73.0	32.3	93.0	20.1	113.0	9.1		
-26.5	126.4	-6.5	101.5	13.5	80.0	33.5	61.6	53.5	45.7	73.5	32.0	93.5	19.8	113.5	8.8		
-26.0	125.8	-6.0	100.9	14.0	79.5	34.0	61.2	54.0	45.4	74.0	31.6	94.0	19.5	114.0	8.5		
-25.5	125.1	-5.5	100.3	14.5	79.0	34.5	60.7	54.5	45.0	74.5	31.3	94.5	19.2	114.5	8.3		
-25.0	124.4	-5.0	99.7	15.0	78.5	35.0	60.3	55.0	44.6	75.0	31.0	95.0	19.0	115.0	8.0		
-24.5	123.8	-4.5	99.2	15.5	78.0	35.5	59.9	55.5	44.3	75.5	30.7	95.5	18.7	115.5	7.7		
-24.0	123.1	-4.0	98.6	16.0	77.6	36.0	59.5	56.0	43.9	76.0	30.4	96.0	18.4	116.0	7.5		
-23.5	122.4	-3.5	98.0	16.5	77.1	36.5	59.1	56.5	43.5	76.5	30.0	96.5	18.1	116.5	7.2		
-23.0	121.8	-3.0	97.5	17.0	76.6	37.0	58.6	57.0	43.2	77.0	29.7	97.0	17.8	117.0	7.0		
-22.5	121.1	-2.5	96.9	17.5	76.1	37.5	58.2	57.5	42.8	77.5	29.4	97.5	17.5	117.5	6.7		
-22.0	120.5	-2.0	96.4	18.0	75.6	38.0	57.8	58.0	42.5	78.0	29.1	98.0	17.2	118.0	6.4		
-21.5	119.8	-1.5	95.8	18.5	75.1	38.5	57.4	58.5	42.1	78.5	28.8	98.5	17.0	118.5	6.2		
-21.0	119.2	-1.0	95.2	19.0	74.7	39.0	57.0	59.0	41.8	79.0	28.5	99.0	16.7	119.0	5.9		
-20.5	118.5	-0.5	94.7	19.5	74.2	39.5	56.6	59.5	41.4	79.5	28.2	99.5	16.4	119.5	5.7		
-20.0	117.9	0.0	94.1	20.0	73.7	40.0	56.2	60.0	41.1	80.0	27.9	100.0	16.1	120.0	5.4		

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TABLE 4-3: T_{SET} TO R_{SET} CONVERSION TABLE FOR MCP9509/MCP9510C (COLD)

T_{SET} (°C)	R_{SET} (kΩ)	T_{SET} (°C)	R_{SET} (kΩ)	T_{SET} (°C)	R_{SET} (kΩ)	T_{SET} (°C)	R_{SET} (kΩ)	T_{SET} (°C)	R_{SET} (kΩ)	T_{SET} (°C)	R_{SET} (kΩ)	T_{SET} (°C)	R_{SET} (kΩ)	T_{SET} (°C)	R_{SET} (kΩ)	T_{SET} (°C)	R_{SET} (kΩ)
-40.0	146.3	-20.0	118.8	0.0	95.1	20.0	74.8	40.0	57.4	60.0	42.4	80.0	29.2	100.0	17.6	120.0	6.8
-39.5	145.6	-19.5	118.2	0.5	94.6	20.5	74.4	40.5	57.0	60.5	42.0	80.5	28.9	100.5	17.3	120.5	6.6
-39.0	144.8	-19.0	117.5	1.0	94.0	21.0	73.9	41.0	56.6	61.0	41.7	81.0	28.6	101.0	17.0	121.0	6.3
-38.5	144.1	-18.5	116.9	1.5	93.5	21.5	73.4	41.5	56.2	61.5	41.3	81.5	28.3	101.5	16.7	121.5	6.0
-38.0	143.4	-18.0	116.3	2.0	93.0	22.0	73.0	42.0	55.8	62.0	41.0	82.0	28.0	102.0	16.4	122.0	5.8
-37.5	142.6	-17.5	115.6	2.5	92.4	22.5	72.5	42.5	55.4	62.5	40.6	82.5	27.7	102.5	16.2	122.5	5.5
-37.0	141.9	-17.0	115.0	3.0	91.9	23.0	72.0	43.0	55.0	63.0	40.3	83.0	27.4	103.0	15.9	123.0	5.3
-36.5	141.2	-16.5	114.4	3.5	91.4	23.5	71.6	43.5	54.6	63.5	39.9	83.5	27.1	103.5	15.6	123.5	5.0
-36.0	140.5	-16.0	113.8	4.0	90.8	24.0	71.1	44.0	54.2	64.0	39.6	84.0	26.8	104.0	15.3	124.0	4.8
-35.5	139.8	-15.5	113.2	4.5	90.3	24.5	70.7	44.5	53.8	64.5	39.3	84.5	26.5	104.5	15.1	124.5	4.5
-35.0	139.0	-15.0	112.5	5.0	89.8	25.0	70.2	45.0	53.4	65.0	38.9	85.0	26.2	105.0	14.8	125.0	4.2
-34.5	138.3	-14.5	111.9	5.5	89.2	25.5	69.8	45.5	53.0	65.5	38.6	85.5	25.9	105.5	14.5		
-34.0	137.6	-14.0	111.3	6.0	88.7	26.0	69.3	46.0	52.7	66.0	38.2	86.0	25.6	106.0	14.3		
-33.5	136.9	-13.5	110.7	6.5	88.2	26.5	68.9	46.5	52.3	66.5	37.9	86.5	25.3	106.5	14.0		
-33.0	136.2	-13.0	110.1	7.0	87.7	27.0	68.4	47.0	51.9	67.0	37.6	87.0	25.0	107.0	13.7		
-32.5	135.5	-12.5	109.5	7.5	87.2	27.5	68.0	47.5	51.5	67.5	37.2	87.5	24.7	107.5	13.4		
-32.0	134.8	-12.0	108.9	8.0	86.6	28.0	67.5	48.0	51.1	68.0	36.9	88.0	24.4	108.0	13.2		
-31.5	134.1	-11.5	108.3	8.5	86.1	28.5	67.1	48.5	50.7	68.5	36.6	88.5	24.1	108.5	12.9		
-31.0	133.4	-11.0	107.7	9.0	85.6	29.0	66.7	49.0	50.4	69.0	36.2	89.0	23.8	109.0	12.6		
-30.5	132.7	-10.5	107.1	9.5	85.1	29.5	66.2	49.5	50.0	69.5	35.9	89.5	23.5	109.5	12.4		
-30.0	132.0	-10.0	106.5	10.0	84.6	30.0	65.8	50.0	49.6	70.0	35.6	90.0	23.2	110.0	12.1		
-29.5	131.4	-9.5	105.9	10.5	84.1	30.5	65.3	50.5	49.2	70.5	35.3	90.5	23.0	110.5	11.8		
-29.0	130.7	-9.0	105.3	11.0	83.6	31.0	64.9	51.0	48.9	71.0	34.9	91.0	22.7	111.0	11.6		
-28.5	130.0	-8.5	104.8	11.5	83.1	31.5	64.5	51.5	48.5	71.5	34.6	91.5	22.4	111.5	11.3		
-28.0	129.3	-8.0	104.2	12.0	82.6	32.0	64.1	52.0	48.1	72.0	34.3	92.0	22.1	112.0	11.0		
-27.5	128.6	-7.5	103.6	12.5	82.1	32.5	63.6	52.5	47.7	72.5	34.0	92.5	21.8	112.5	10.8		
-27.0	128.0	-7.0	103.0	13.0	81.6	33.0	63.2	53.0	47.4	73.0	33.6	93.0	21.5	113.0	10.5		
-26.5	127.3	-6.5	102.4	13.5	81.1	33.5	62.8	53.5	47.0	73.5	33.3	93.5	21.2	113.5	10.2		
-26.0	126.6	-6.0	101.9	14.0	80.6	34.0	62.4	54.0	46.6	74.0	33.0	94.0	20.9	114.0	10.0		
-25.5	126.0	-5.5	101.3	14.5	80.1	34.5	61.9	54.5	46.3	74.5	32.7	94.5	20.7	114.5	9.7		
-25.0	125.3	-5.0	100.7	15.0	79.6	35.0	61.5	55.0	45.9	75.0	32.4	95.0	20.4	115.0	9.4		
-24.5	124.6	-4.5	100.1	15.5	79.1	35.5	61.1	55.5	45.6	75.5	32.0	95.5	20.1	115.5	9.2		
-24.0	124.0	-4.0	99.6	16.0	78.6	36.0	60.7	56.0	45.2	76.0	31.7	96.0	19.8	116.0	8.9		
-23.5	123.3	-3.5	99.0	16.5	78.2	36.5	60.3	56.5	44.8	76.5	31.4	96.5	19.5	116.5	8.7		
-23.0	122.7	-3.0	98.5	17.0	77.7	37.0	59.8	57.0	44.5	77.0	31.1	97.0	19.2	117.0	8.4		
-22.5	122.0	-2.5	97.9	17.5	77.2	37.5	59.4	57.5	44.1	77.5	30.8	97.5	19.0	117.5	8.1		
-22.0	121.4	-2.0	97.3	18.0	76.7	38.0	59.0	58.0	43.8	78.0	30.5	98.0	18.7	118.0	7.9		
-21.5	120.7	-1.5	96.8	18.5	76.2	38.5	58.6	58.5	43.4	78.5	30.2	98.5	18.4	118.5	7.6		
-21.0	120.1	-1.0	96.2	19.0	75.8	39.0	58.2	59.0	43.1	79.0	29.9	99.0	18.1	119.0	7.3		
-20.5	119.4	-0.5	95.7	19.5	75.3	39.5	57.8	59.5	42.7	79.5	29.5	99.5	17.8	119.5	7.1		
-20.0	118.8	0.0	95.1	20.0	74.8	40.0	57.4	60.0	42.4	80.0	29.2	100.0	17.6	120.0	6.8		

4.6 Application Information

The MCP9509/10 temperature switch integrates a temperature sensor and a comparator circuit which outputs an alert signal when the user programmed temperature threshold is exceeded. The external resistor value to set the output threshold can be determined using Table 4-2. A constant current source I_{SET} = 5 µA (typical) biases the external resistor R_{SET}. A thermal diode is used to measure ambient temperature. When the voltage across the thermal diode exceeds the voltage across R_{SET}, V_{SET}, the sensor output asserts. The sensor output de-asserts when the diode voltage drops below V_{SET} and the user selected hysteresis level.

The MCP9509/10 provide Open-drain output where multiple sensors from multiple PCB hot-spots can be connected to a single processor I/O input with a wired-Or Configuration. The MCP9509 requires an external pull-up resistor which can be used to level-shift the alert signal. For example, if the sensors are powered with $5V_{DD}$ and the controller or processor is powered with $3V_{DD}$, the external resistor can be level-shifted by connecting $3V_{DD}$ to the pull-up resistor as shown in Figure 4-5. The MCP9510 elliminates the need for an external resistor while providing wired-Or function (Figure 4-6). The MCP9510 also provides push-pull output configuration for a direct connection to the processor with Active-Low or Active-High assert polarities.

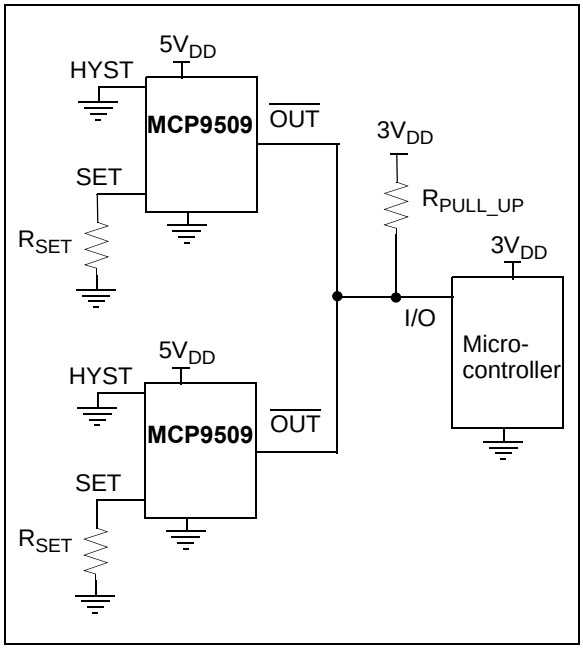


FIGURE 4-5: *MCP9509 Wired-Or Output Configuration with Level-shift.*

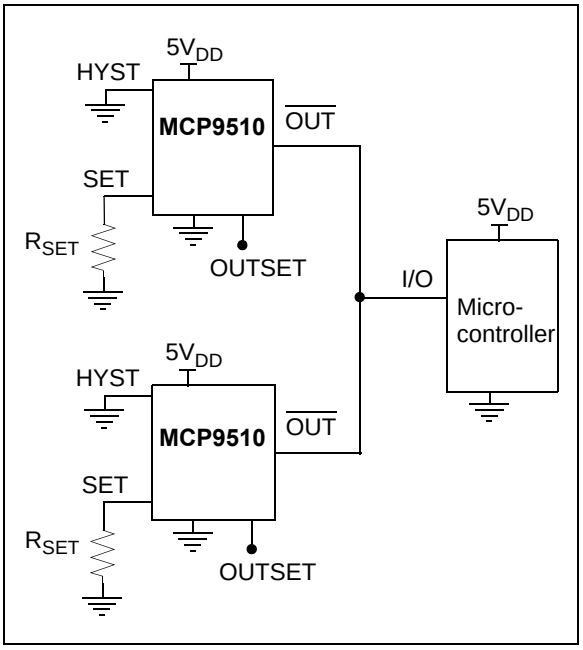


FIGURE 4-6: *MCP9510 Wired-Or Output Configuration with Internal Pull-up Resistor.*

4.6.1 LAYOUT CONSIDERATION AND THERMAL CONSIDERATION

This family of sensors measure temperature by monitoring the voltage level of a thermal diode located in the die. A low-impedance thermal path between the die and the PCB is provided by the pins. Therefore, the sensor effectively monitors PCB temperature. For efficient performance, it is recommended to layout the device as close to the heat source as possible. It is also recommended to use a de-coupling capacitor of 0.1 µF to 1 µF between V_{DD} and GND pins for stability.

When connecting an external resistor to the MCP9509 device, the current through the pull-up resistor must be considered to prevent self-heat due to power. This can be determined using Equation 4-3.

EQUATION 4-3: EFFECT OF SELF-HEATING

$$T_J - T_A = \theta_{JA}(V_{DD} \times I_{DD} + V_{OL} \times I_{OUT})$$

Where:

T_J	=	Junction Temperature
T_A	=	Ambient Temperature
θ_{JA}	=	Package Thermal Resistance (220.7 °C/W)
V_{OL}	=	Sensor Output Low Voltage
I_{OUT}	=	Output Current

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For example, at room temperature, when output asserts Active-Low and maximum I_{DD} = 50 µA, V_{DD} = 5.5V, V_{OL} = 0.3V and I_{OUT} = 5 mA (see specification table), the self heating due to power dissipation (T_J - T_A) is ~0.4°C.

4.6.2 DRIVING OUTSET WITH A MICROCONTROLLER I/O PIN

The OUTSET pin can be controlled using a Microcontroller input/output (I/O) pin. I/O levels HIGH and LOW provide push-pull configuration with Active-High and Active-Low outputs, respectively. The Open-Drain output with internal pull-up resistor can be selected by configuring the I/O pin as a High-Impedance Input. The Open-Drain output can also be selected by forcing voltage level V_{OSET} from a low impedance source. With this configuration, there maybe some leakage current due to impedance mismatch, (See Figure 4-2).

4.6.3 POWER SUPPLY REJECTION

The MCP9509/10 family of sensors are designed to prevent false output trigger due to high frequency power supply or system noise. Figure 4-7 shows device performance with a high frequency signal added on V_{DD}. The output is not triggered due to the signal added on V_{DD}. With some applications, it is recommended to add a bypass capacitor of 0.1 µF to 1 µF.

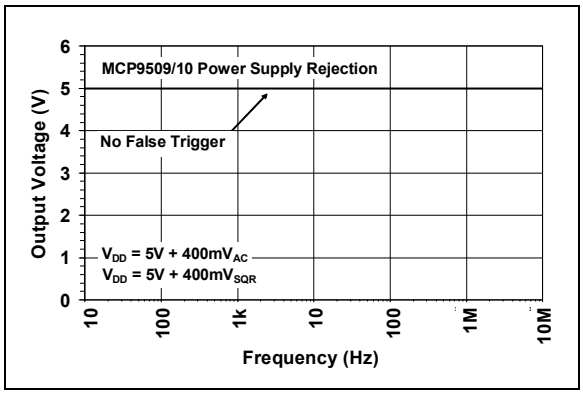


FIGURE 4-7: *Power Supply Rejection (PSR).*

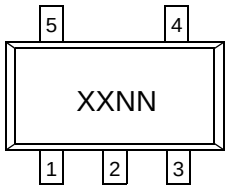
NOTES:

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5.0 PACKAGING INFORMATION

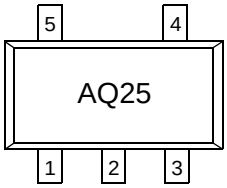
5.1 Package Marking Information

5-Lead SOT-23

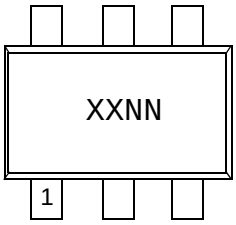


Device	Code
MCP9509CT-E/OT	AQNN
MCP9509HT-E/OT	BPNN

Example:

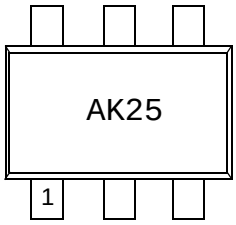


6-Lead SOT-23



Part Number	Code
MCP9510CT-E/CH	AKNN
MCP9510HT-E/CH	ALNN

Example

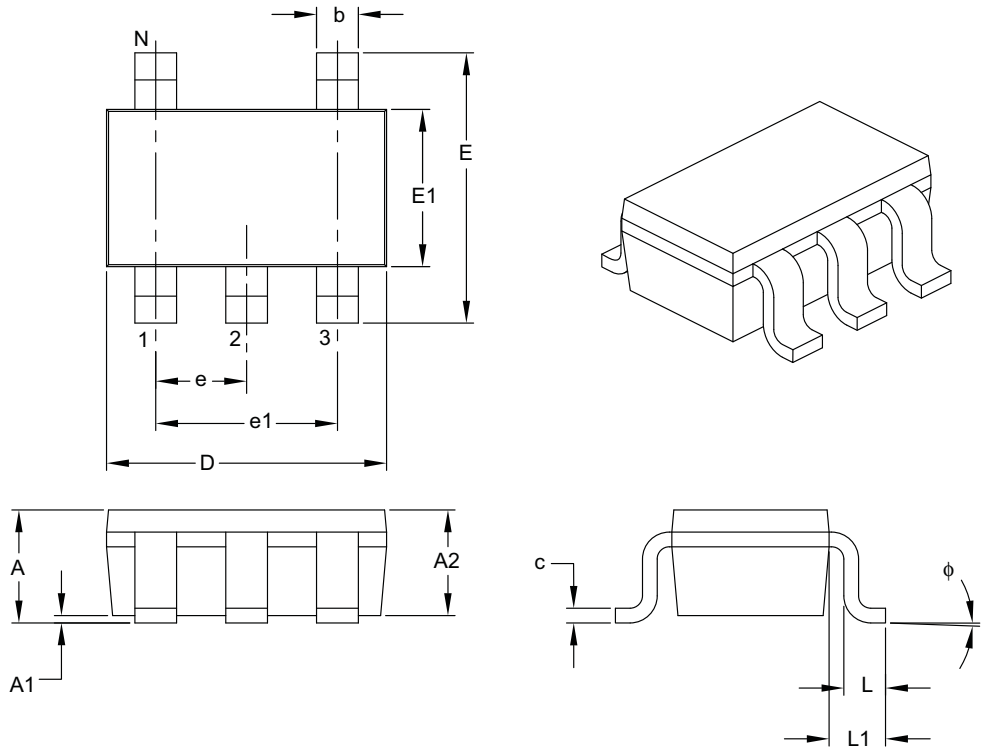


Legend:	XX...X	Customer-specific information
	Y	Year code (last digit of calendar year)
	YY	Year code (last 2 digits of calendar year)
	WW	Week code (week of January 1 is week ‘01’)
	NNN	Alphanumeric traceability code
	(e3)	Pb-free JEDEC designator for Matte Tin (Sn)
	*	This package is Pb-free. The Pb-free JEDEC designator ((e3)) can be found on the outer packaging for this package.

Note: In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line, thus limiting the number of available characters for customer-specific information.

5-Lead Plastic Small Outline Transistor (OT) [SOT-23]

Note: For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



Units		MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Number of Pins	N		5	
Lead Pitch	e		0.95 BSC	
Outside Lead Pitch	e1		1.90 BSC	
Overall Height	A	0.90	–	1.45
Molded Package Thickness	A2	0.89	–	1.30
Standoff	A1	0.00	–	0.15
Overall Width	E	2.20	–	3.20
Molded Package Width	E1	1.30	–	1.80
Overall Length	D	2.70	–	3.10
Foot Length	L	0.10	–	0.60
Footprint	L1	0.35	–	0.80
Foot Angle	ϕ	0°	–	30°
Lead Thickness	c	0.08	–	0.26
Lead Width	b	0.20	–	0.51

Notes:

1. Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.127 mm per side.
2. Dimensioning and tolerancing per ASME Y14.5M.

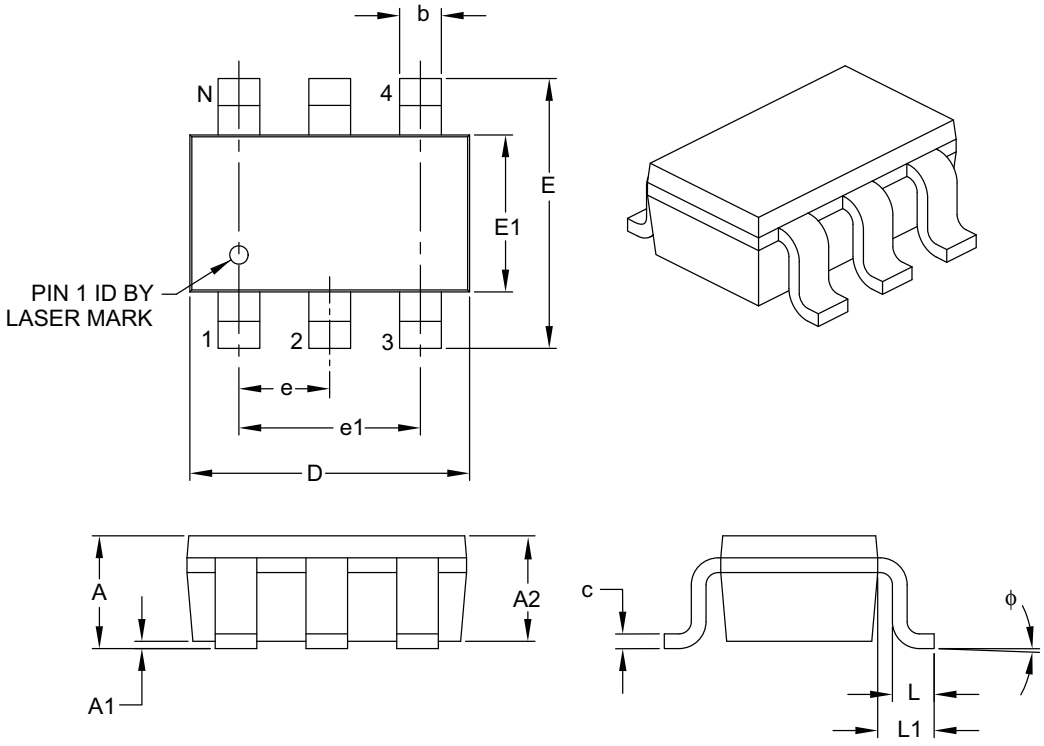
BSC: Basic Dimension. Theoretically exact value shown without tolerances.

Microchip Technology Drawing C04-091B

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6-Lead Plastic Small Outline Transistor (CH) [SOT-23]

Note: For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



Units		MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Number of Pins	N		6	
Pitch	e		0.95 BSC	
Outside Lead Pitch	e1		1.90 BSC	
Overall Height	A	0.90	–	1.45
Molded Package Thickness	A2	0.89	–	1.30
Standoff	A1	0.00	–	0.15
Overall Width	E	2.20	–	3.20
Molded Package Width	E1	1.30	–	1.80
Overall Length	D	2.70	–	3.10
Foot Length	L	0.10	–	0.60
Footprint	L1	0.35	–	0.80
Foot Angle	ϕ	0°	–	30°
Lead Thickness	c	0.08	–	0.26
Lead Width	b	0.20	–	0.51

Notes:

1. Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.127 mm per side.
2. Dimensioning and tolerancing per ASME Y14.5M.

BSC: Basic Dimension. Theoretically exact value shown without tolerances.

Microchip Technology Drawing C04-028B

NOTES:

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APPENDIX A: REVISION HISTORY

Revision A (November 2008)

- Original Release of this Document.

NOTES:

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PRODUCT IDENTIFICATION SYSTEM

To order or obtain information, e.g., on pricing or delivery, refer to the factory or the listed sales office.

PART NO.	-X	/XX
Device	Temperature Range	Package

Device:	MCP9509H:	Resistor Programmable Temperature Switch, Hot Option
	MCP9509C	Resistor Programmable Temperature Switch, Cold Option
	MCP9510H:	Resistor Programmable Temperature Switch, Hot Option
	MCP9510C	Resistor Programmable Temperature Switch, Cold Option
Temperature Range:	E =	-40°C to +125°C
Package:	CH =	Plastic Small Outline Transistor (SOT-23), 6-lead (MCP9510 only)
	OT =	Plastic Small Outline Transistor (SOT-23), 5-lead (MCP9509)

Examples:

a) MCP9509CT-E/OT: Cold option, Extended Temp., 5LD SOT-23 package.

b) MCP9509HT-E/OT: Hot option, Extended Temp., 5LD SOT-23 package.

a) MCP9510C-E/CH: Cold option, Extended Temp., 6LD SOT-23 package.

b) MCP9510H-E/CH: Hot option, Extended Temp., 6LD SOT-23 package.

NOTES:

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