MCP9509/10

Resistor Programmable Temperature Switches

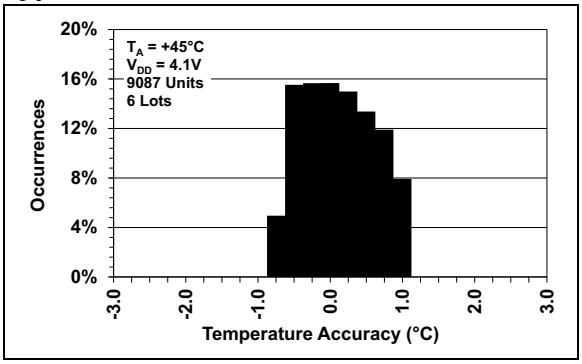
Features

- Resistor Programmable Temperature Switch
- Wide Operating Voltage Range: 2.7V to 5.5V
- Low Supply Current: 30 µA (typical)
- Qualification: AEC-Q100 Rev. G, Grade 1 (-40°C to +125°C)
- Temperature Switch Accuracy:
  - ±0.5°C (typical) at +25°C, +45°C
  - ±1°C (typical) between 0°C to +70°C
  - ±3.5°C (maximum) between 0°C to +125°C
  - ±4.5°C (maximum) between -20°C to +125°C
  - ±2°C (typical) between -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 5-Lead SOT-23 and 6-Lead SOT-23 Packages

Applications

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

Typical Performance



Description

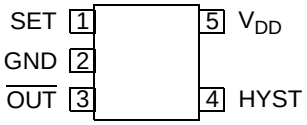
Microchip Technology's MCP9509/10 devices are programmable logic output temperature switches. The temperature switch threshold can be programmed with a single external resistor, which provides high design flexibility and simplicity. In addition, this family of devices provides user-programmable features, 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 push-pull, active-high push-pull and active-low open-drain output with an internal 100 kΩ pull-up resistor.

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

Package Types

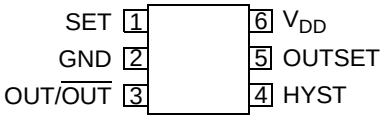
MCP9509

5-Lead SOT-23



MCP9510

6-Lead SOT-23



NOTES:

1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings†

V_{DD} 6.0V
Voltage on All Input/Output Pins – GND ..... 0.3V to 6.0V
Input/Output Current ..... 20 mA
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 ..... 4 kV
MM 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, GND = Ground.

Parameters	Symbol	Min.	Typ.	Max.	Unit	Conditions
Sensor Accuracy	T_{ACY} (Note 1)	—	±0.5	—	°C	T_A = +25°C, +45°C
		-3.5	±1	+3.5	°C	0°C ≤ T_A ≤ +125°C
		-4.5	±1	+4.5	°C	-20°C ≤ T_A ≤ +125°C
		—	±2	—	°C	-40°C ≤ T_A ≤ +125°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	—	0.2 V_{DD}	V	
Open-Drain with R_{OUT}, Active-Low		0.45 V_{DD}	—	0.7 V_{DD}	V	or OUTSET is unconnected
Push-Pull, Active-High		0.85 V_{DD}	—	V_{DD}	V	

Note 1: This specification is tested at a 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, GND = Ground.						
Parameters	**Symbol**	**Min.**	**Typ.**	**Max.**	**Unit**	**Conditions**
OUTSET Input Leakage and Output Configuration						
Push-Pull, Active-Low	I_{LEAK}	—	10	—	µA	$GND \le V_{OSET} \le 0.2\ V_{DD}$
Open-Drain, Active-Low		—	0	—	µA	Unconnected (i.e., open)
		—	7	—	µA	$0.4\ V_{DD} \le V_{OSET} \le 0.7\ V_{DD}$
Push-Pull, Active-High		—	-10	—	µA	$0.85 \le V_{OSET} \le V_{DD}$
OUTSET Input Impedance	Z_{OUTSET}	—	500	—	kΩ	
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 is unconnected
Open-Drain Output Leakage (**MCP9509/10)**	I_{LEAK}	—	1	—	µA	
Power Supply Rejection	PSR	—	0.05	—	°C/V	
Thermal Response						
Response Time to Thermal Shock: 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 a 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, GND = Ground.						
Parameters	**Symbol**	**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 (**MCP9509**)	θ_{JA}	—	220.7	—	°C/W	
Thermal Resistance (**MCP9510**)	θ_{JA}	—	190.5	—	°C/W	

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

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.

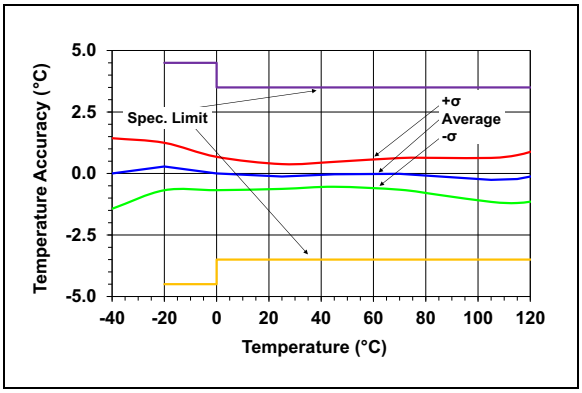


FIGURE 2-1: *Temperature Accuracy (MCP9509CT, MCP9509HT, MCP9510CT and MCP9510HT).*

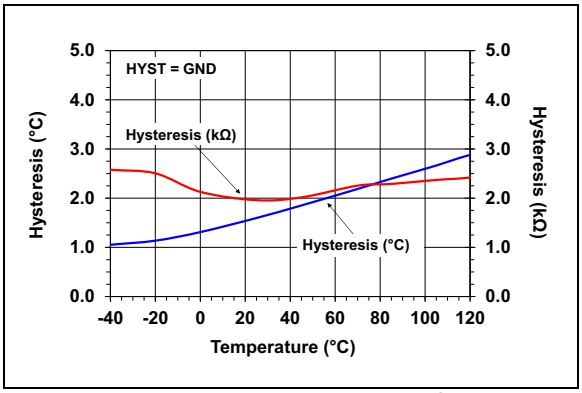


FIGURE 2-2: *Output Hysteresis vs. Temperature.*

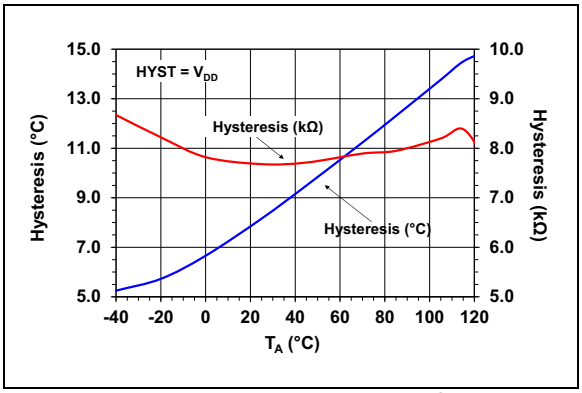


FIGURE 2-3: *Output Hysteresis vs. Temperature.*

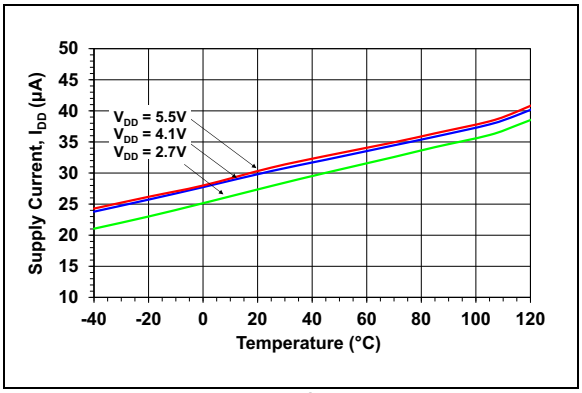


FIGURE 2-4: *Supply Current vs. Temperature (MCP9509CT, MCP9509HT).*

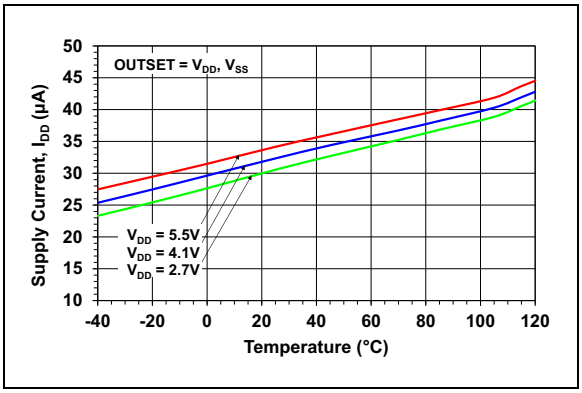


FIGURE 2-5: *Supply Current vs. Temperature (MCP9510CT, MCP9510HT).*

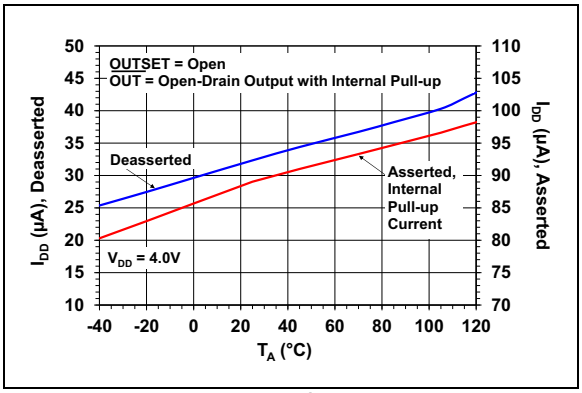


FIGURE 2-6: *Supply Current vs. Temperature (MCP9510CT, MCP9510HT).*

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.

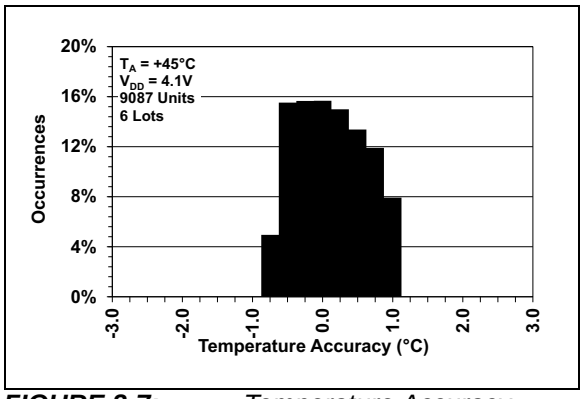


FIGURE 2-7: *Temperature Accuracy Histogram at +45°C.*

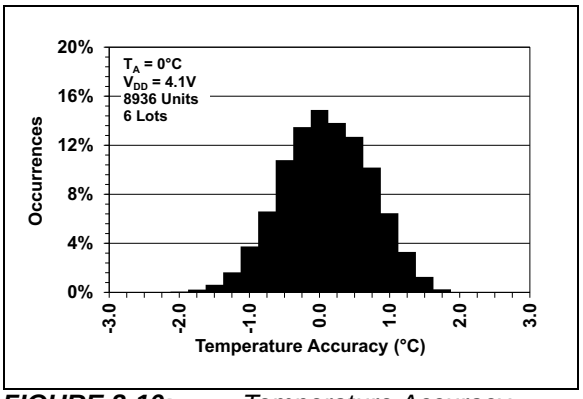


FIGURE 2-10: *Temperature Accuracy Histogram at 0°C.*

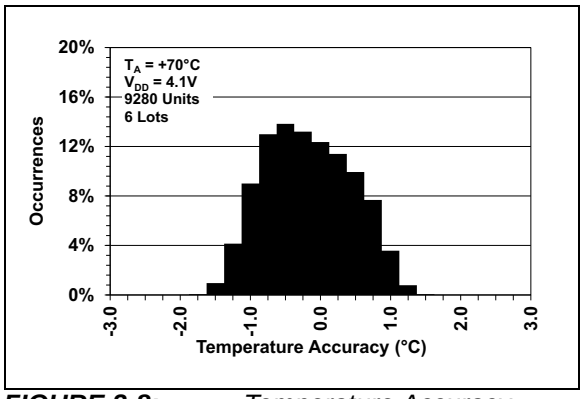


FIGURE 2-8: *Temperature Accuracy Histogram at +70°C.*

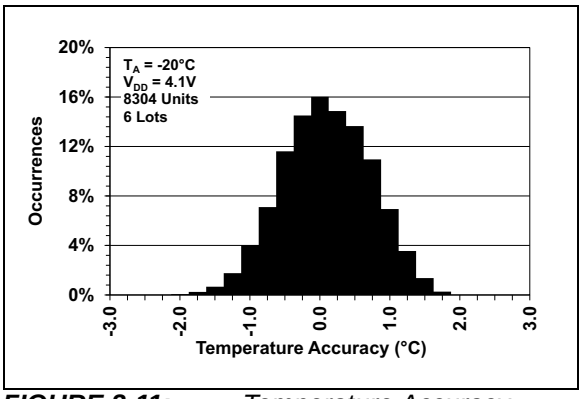


FIGURE 2-11: *Temperature Accuracy Histogram at -20°C.*

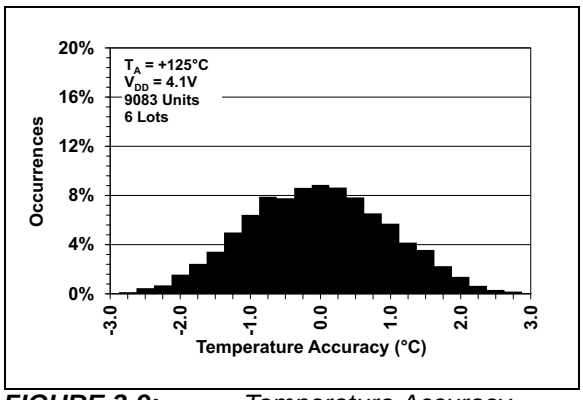


FIGURE 2-9: *Temperature Accuracy Histogram at +125°C.*

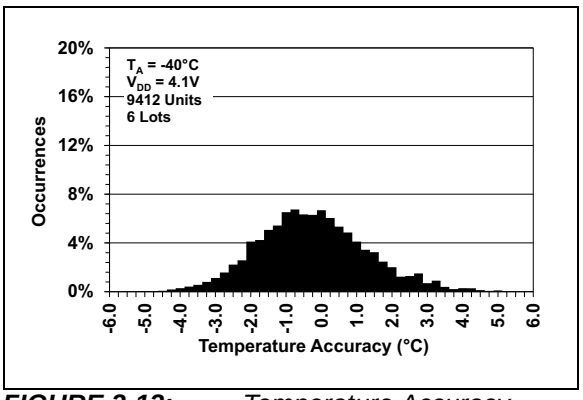


FIGURE 2-12: *Temperature Accuracy Histogram at -40°C.*

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.

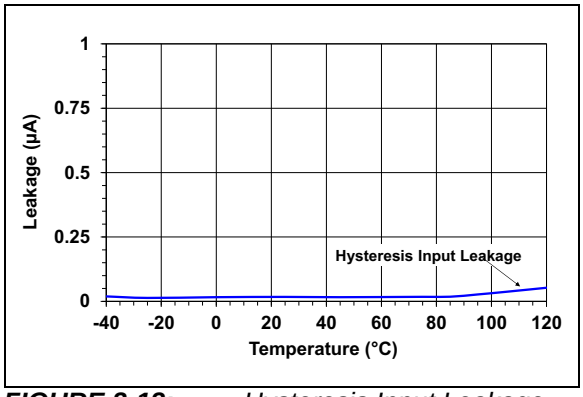


FIGURE 2-13: *Hysteresis Input Leakage vs, Temperature.*

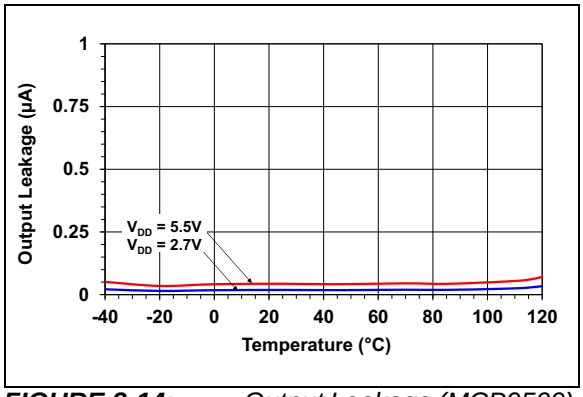


FIGURE 2-14: *Output Leakage (MCP9509) vs. Temperature.*

NOTES:

3.0 PIN DESCRIPTION

The description of the pins is listed in Table 3-1.

TABLE 3-1: PIN FUNCTION TABLE

MCP9509	MCP9510	Symbol	Description
5-LD SOT-23	6-LD SOT-23		
1	1	SET	External Trip Temperature Resistor (R_{SET}) Input Pin
2	2	GND	Ground Pin
3	—	$\overline{OUT}$	Open-Drain Output Pin
—	3	OUT/$\overline{OUT}$	Selectable Output Pin (function set by OUTSET pin)
4	4	HYS	Hysteresis Input Pin HYS = GND, Hysteresis is +2°C HYS = V_{DD}, Hysteresis is +10°C
5	6	V_{DD}	Power Pin
—	5	OUTSET	Output Control Pin 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 Pin (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 look-up table shown in Table 4-2.

3.2 Ground Pin (GND)

The GND pin is the system ground pin.

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

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

3.4 Selectable Output Pin (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.

3.5 Hysteresis Input Pin (HYS)

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

3.6 Power Pin (V_{DD})

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

3.7 Output Control Pin (OUTSET) (MCP9510)

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

TABLE 3-2: 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)

NOTES:

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) and active-high push-pull output configurations. In addition, this device provides a 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} (Figure 4-1). The voltage across R_{SET} and V_{SET} is compared to an internal thermal diode.

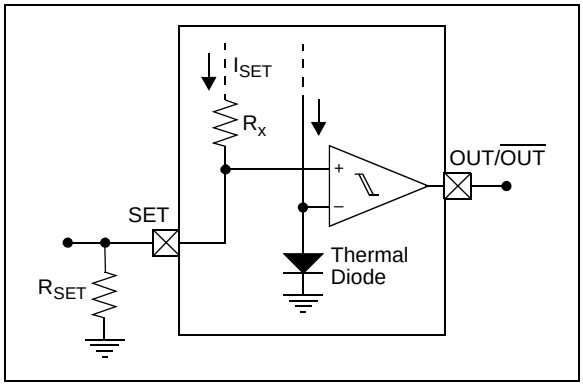


FIGURE 4-1: *SET Input.*

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 OUTSET Input Pin (MCP9510)

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 as a 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 the OUTSET level threshold. Figure 4-2 shows the circuit configuration. The OUTSET input resistance must be carefully considered for leakage current when connecting the voltage source to change the output configuration.

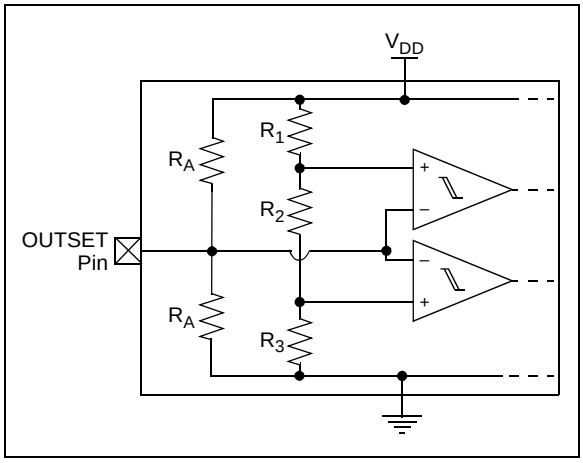


FIGURE 4-2: *OUTSET Input Structure (MCP9510).*

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 the temperature exceeds +100°C ± T_{ACY}. The output remains asserted low until the temperature falls below T_{HYST}, +98°C (HYST = GND) or +90°C (HYST = V_{DD}).

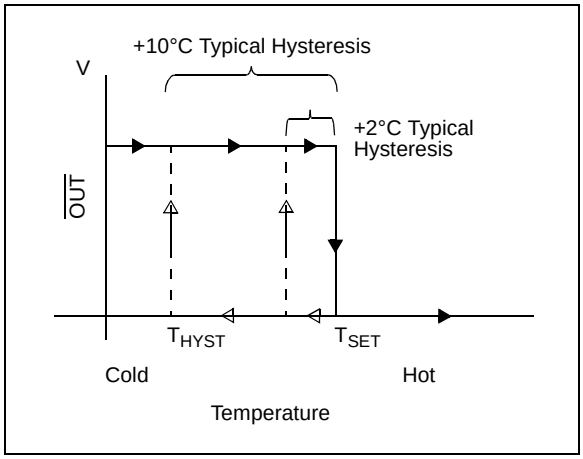


FIGURE 4-3: *Output Hysteresis.*

4.4 Sensor Hot/Cold Options

MCP9509/10 devices are 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 deasserts when temperature falls below T_{HYST}. The output of the Cold option asserts when temperature falls below T_{SET} and deasserts when temperature rises above T_{HYST}.

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

4.5 R_{SET} vs. Temperature

The relationship between the user-selectable external resistor, R_{SET}, and the output trigger threshold limit, T_{SET}, is described as shown in Equation 4-1 and Equation 4-2. The equation coefficients vary depending on the device output options, H or C. Table 4-1 shows the corresponding coefficients.

TABLE 4-1: COEFFICIENTS/VARIABLES

Coef.	MCP9509/10HT	MCP9509/10CT	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

$$R_{SET} = C_{R1}T_{SET}(T_{SET}-T_1)(T_{SET}-T_2) + C_{R2}(T_{SET_{T0}}-T_1)(T_{SET}-T_2) + C_{R3}(T_{SET}-T_1) + R_2$$

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:

$C_{T1,2,3}$ = 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} relationship for Hot and Cold options.

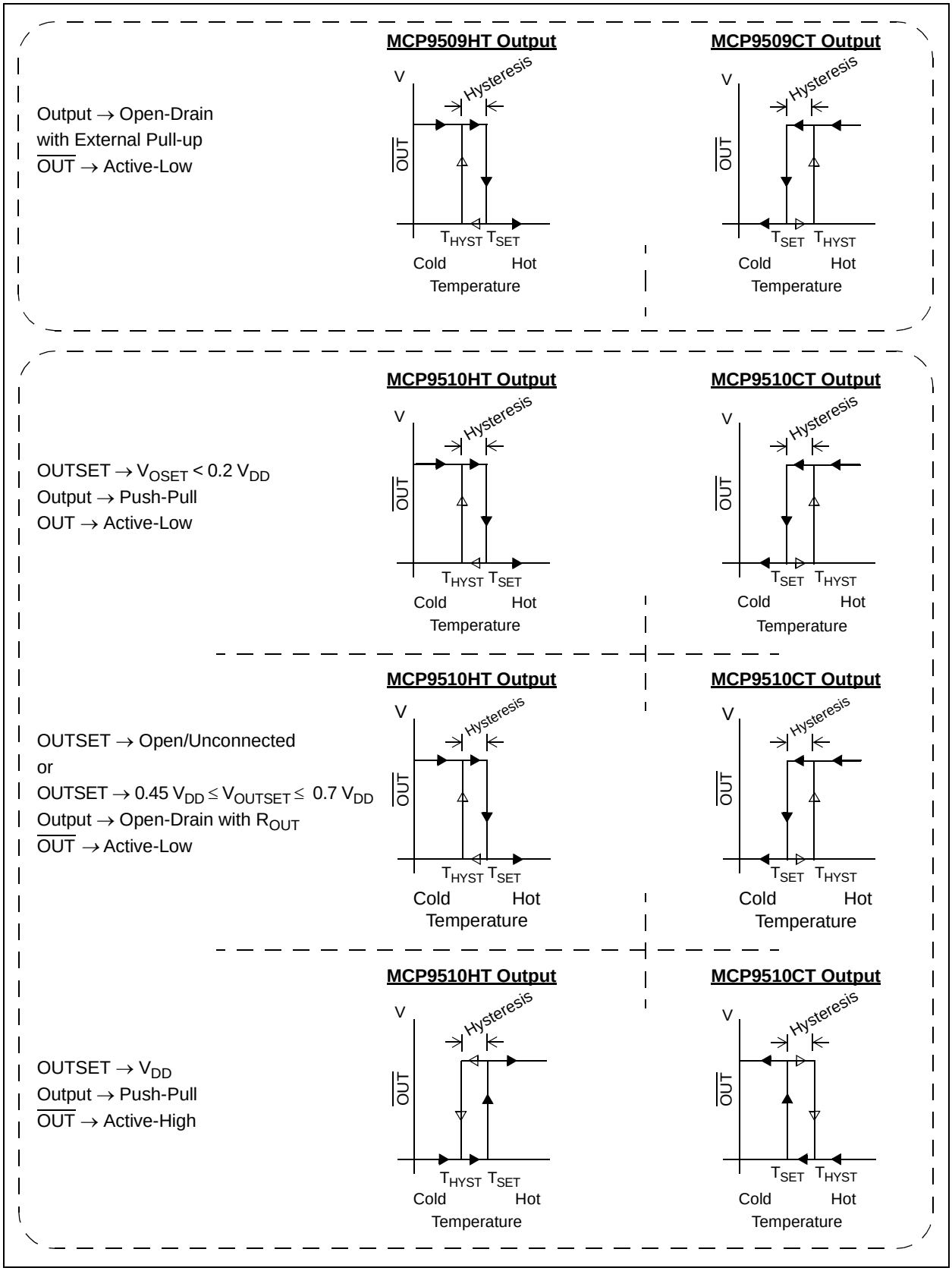


FIGURE 4-4: *MCP9509/10 OUT/$\overline{OUT}$ Output Configuration.*

TABLE 4-2: T_{SET} TO R_{SET} CONVERSION TABLE FOR MCP9509/MCP9510HT (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		

TABLE 4-3: T_{SET} TO R_{SET} CONVERSION TABLE FOR MCP9509/MCP9510CT (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-programmable 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 deasserts when the diode voltage drops below V_{SET} and the user-selected hysteresis level.

The MCP9509/10 devices provide an 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 5 V_{DD} and the controller or processor is powered with 3 V_{DD}, the external resistor can be level shifted by connecting 3 V_{DD} to the pull-up resistor, as shown in Figure 4-5. The MCP9510 eliminates 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.

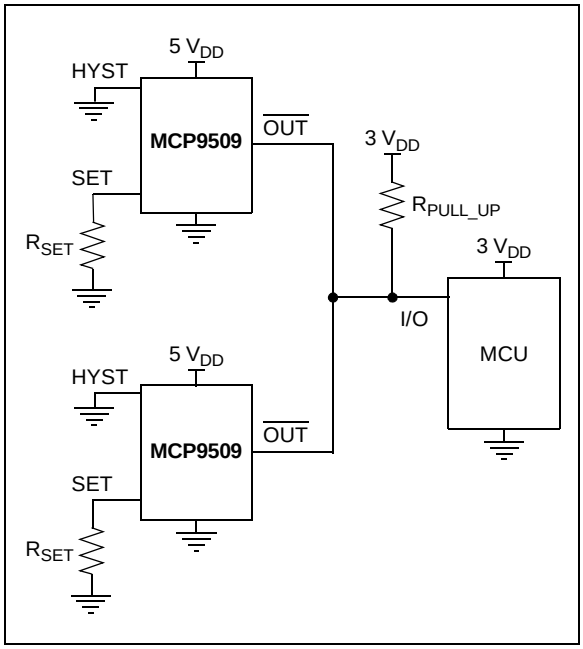


FIGURE 4-5: *MCP9509 Wired-OR Output Configuration with Level Shift.*

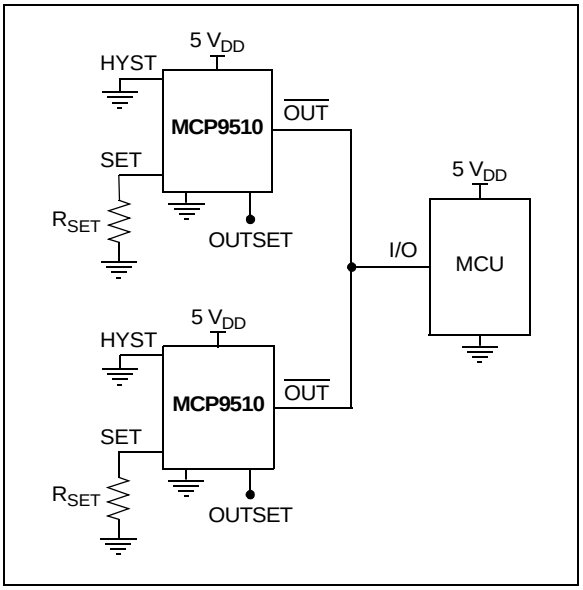


FIGURE 4-6: *MCP9510 Wired-OR Output Configuration with Internal Pull-up Resistor.*

4.6.1 LAYOUT CONSIDERATION AND THERMAL CONSIDERATION

This family of sensors measures 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 decoupling 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

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 DC Characteristics), 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 may be some leakage current due to impedance mismatch (Figure 4-2).

4.6.3 POWER SUPPLY REJECTION

The MCP9509/10 family of sensors is designed to prevent a 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.

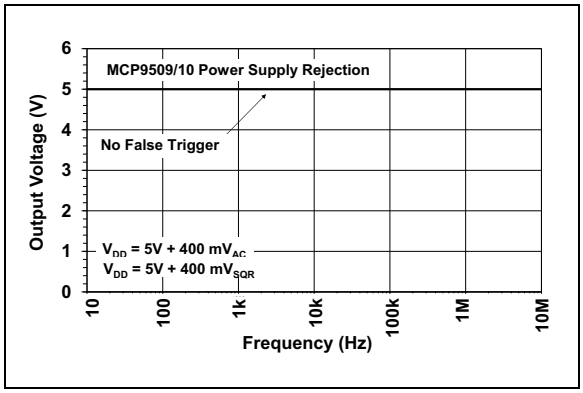


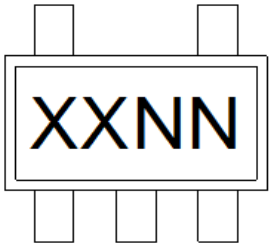
FIGURE 4-7: *Power Supply Rejection (PSR).*

NOTES:

5.0 PACKAGING INFORMATION

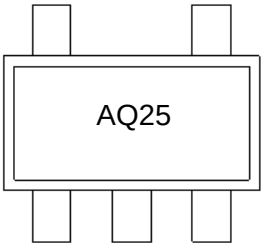
5.1 Package Marking Information

5-Lead SOT-23

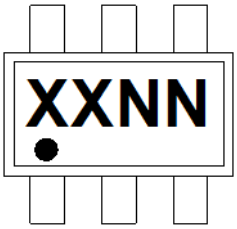


Part Number	Code
MCP9509CT-E/OT	AQNN
MCP9509HT-E/OT	BPNN

Example

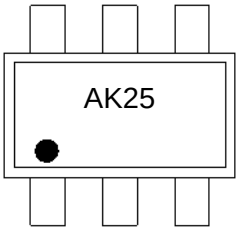


6-Lead SOT-23



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

Example

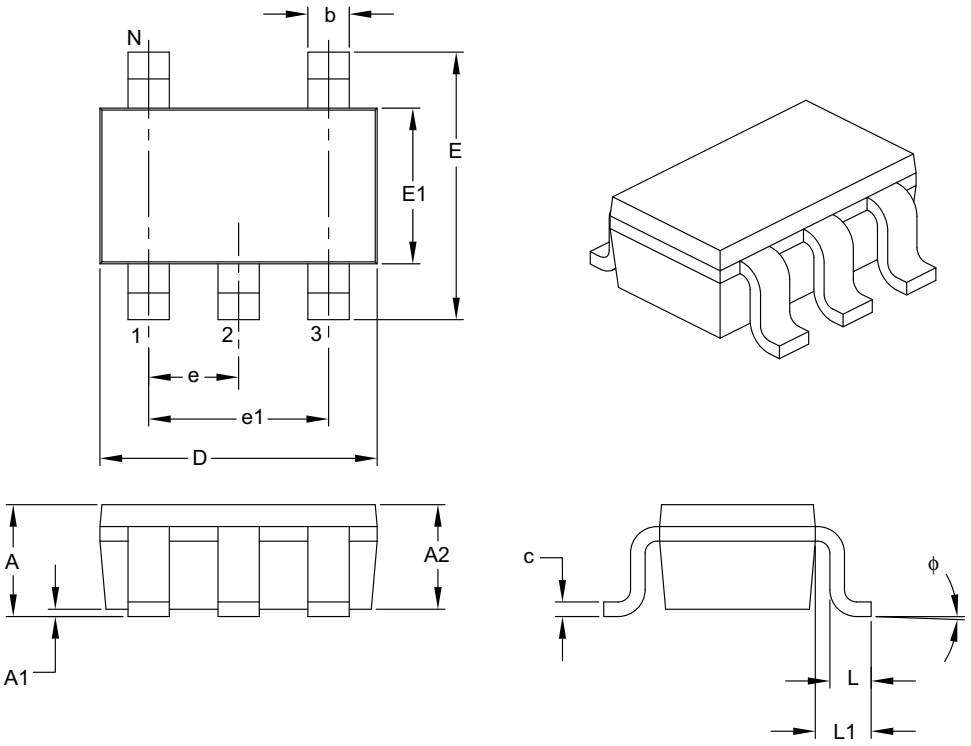


Legend:	XX...X	Customer-specific information
	Y	Year code (last digit of calendar year)
	YY	Year code (last 2 digits of calendar year)
	WW	Week code (week of January 1 is week ‘01’)
	NNN	Alphanumeric traceability code
	(e3)	Pb-free JEDEC® designator for Matte Tin (Sn)
	*	This package is Pb-free. The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

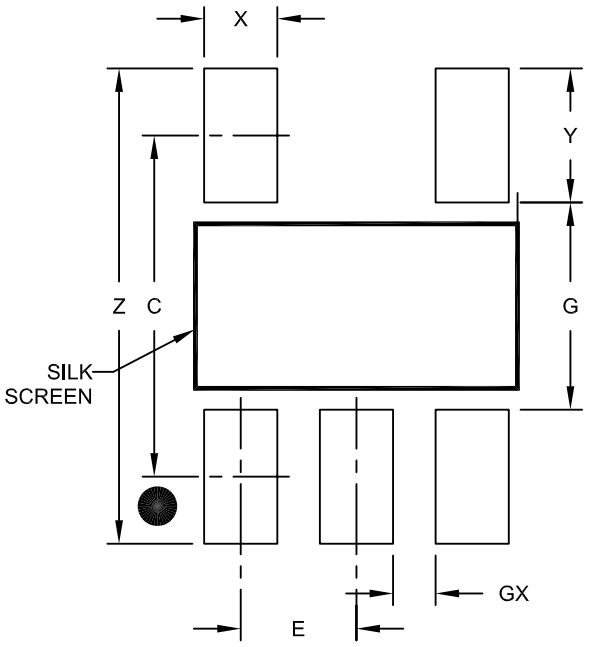
1. Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.127 mm per side.
2. Dimensioning and tolerancing per ASME Y14.5M.

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

Microchip Technology Drawing C04-091B

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



RECOMMENDED LAND PATTERN

Units		MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Contact Pitch	E		0.95 BSC	
Contact Pad Spacing	C		2.80	
Contact Pad Width (X5)	X			0.60
Contact Pad Length (X5)	Y			1.10
Distance Between Pads	G	1.70		
Distance Between Pads	GX	0.35		
Overall Width	Z			3.90

Notes:

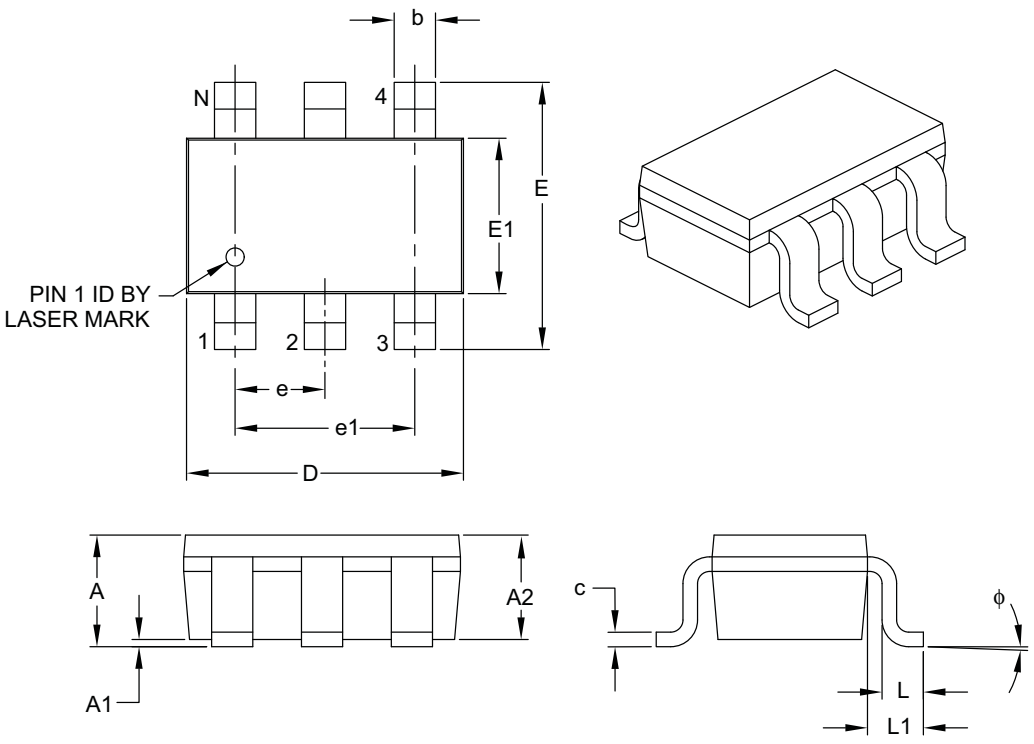
1. Dimensioning and tolerancing per ASME Y14.5M

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

Microchip Technology Drawing No. C04-2091A

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:

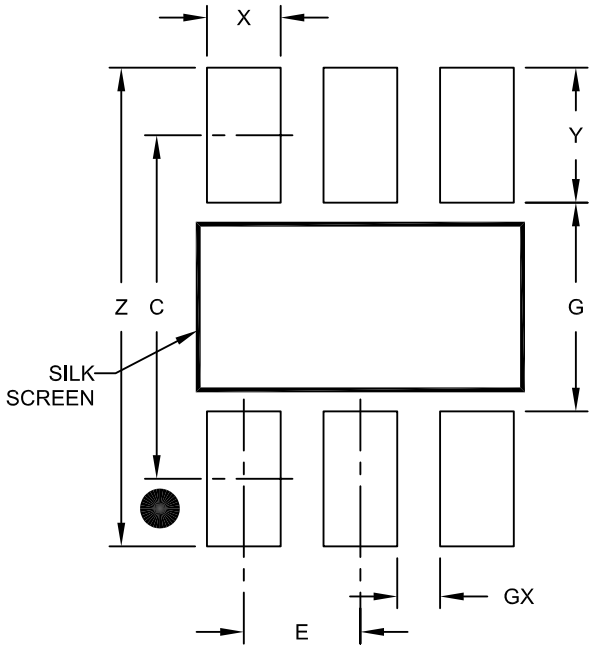
1. Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.127 mm per side.
2. Dimensioning and tolerancing per ASME Y14.5M.

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

Microchip Technology Drawing C04-028B

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



RECOMMENDED LAND PATTERN

Units		MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Contact Pitch	E		0.95 BSC	
Contact Pad Spacing	C		2.80	
Contact Pad Width (X6)	X			0.60
Contact Pad Length (X6)	Y			1.10
Distance Between Pads	G	1.70		
Distance Between Pads	GX	0.35		
Overall Width	Z			3.90

Notes:

1. Dimensioning and tolerancing per ASME Y14.5M

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

Microchip Technology Drawing No. C04-2028A

NOTES:

APPENDIX A: REVISION HISTORY

Revision B (July 2016)

- Added text referencing the AEC-Q100 qualification (automotive) in the Features section.
- Added ‘Recommended Land Pattern’ in **Section 5.0 “Packaging Information”**.

Revision A (November 2008)

- Original release of this document.

NOTES:

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](1)	X	/XX
Device	Tape and Reel Option	Temperature Range	Package

Device:	MCP9509CT:	Resistor Programmable Temperature Switch, Cold Option
	MCP9509HT:	Resistor Programmable Temperature Switch, Hot Option
	MCP9510CT:	Resistor Programmable Temperature Switch, Cold Option
	MCP9510HT:	Resistor Programmable Temperature Switch, Hot Option
Tape and Reel Option:	Blank =	Standard Packaging (tube or tray)
	T =	Tape and Reel(1)
Temperature Range:	E =	-40°C to +125°C
Package:	OT =	Plastic Small Outline Transistor (SOT-23), 5-Lead (**MCP9509**)
	CH =	Plastic Small Outline Transistor (SOT-23), 6-Lead (**MCP9510**)

Examples:

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

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

c) MCP9510CT-E/CH: Cold Option, Extended Temp., 6LD SOT-23 package.

d) MCP9510HT-E/CH: Hot Option, Extended Temp., 6-LD SOT-23 package.

Note 1: Tape and Reel identifier only appears in the catalog part number description. This identifier is used for ordering purposes and is not printed on the device package. Check with your Microchip Sales Office for package availability with the Tape and Reel option.

NOTES:

Note the following details of the code protection feature on Microchip devices:

- Microchip products meet the specification contained in their particular Microchip Data Sheet.
- Microchip believes that its family of products is one of the most secure families of its kind on the market today, when used in the intended manner and under normal conditions.
- There are dishonest and possibly illegal methods used to breach the code protection feature. All of these methods, to our knowledge, require using the Microchip products in a manner outside the operating specifications contained in Microchip's Data Sheets. Most likely, the person doing so is engaged in theft of intellectual property.
- Microchip is willing to work with the customer who is concerned about the integrity of their code.
- Neither Microchip nor any other semiconductor manufacturer can guarantee the security of their code. Code protection does not mean that we are guaranteeing the product as "unbreakable."

Code protection is constantly evolving. We at Microchip are committed to continuously improving the code protection features of our products. Attempts to break Microchip's code protection feature may be a violation of the Digital Millennium Copyright Act. If such acts allow unauthorized access to your software or other copyrighted work, you may have a right to sue for relief under that Act.

Microchip received ISO/TS-16949:2009 certification for its worldwide headquarters, design and wafer fabrication facilities in Chandler and Tempe, Arizona; Gresham, Oregon and design centers in California and India. The Company's quality system processes and procedures are for its PIC® MCUs and dsPIC® DSCs, KEELOQ® code hopping devices, Serial EEPROMs, microperipherals, nonvolatile memory and analog products. In addition, Microchip's quality system for the design and manufacture of development systems is ISO 9001:2000 certified.

QUALITY MANAGEMENT SYSTEM
CERTIFIED BY DNV
═ ISO/TS 16949 ═

Trademarks

ISBN: 978-1-5224-0756-0

Worldwide Sales and Service

AMERICAS

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

Atlanta
Duluth, GA
Tel: 678-957-9614
Fax: 678-957-1455

Austin, TX
Tel: 512-257-3370

Boston
Westborough, MA
Tel: 774-760-0087
Fax: 774-760-0088

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

Cleveland
Independence, OH
Tel: 216-447-0464
Fax: 216-447-0643

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

Detroit
Novi, MI
Tel: 248-848-4000

Houston, TX
Tel: 281-894-5983

Indianapolis
Noblesville, IN
Tel: 317-773-8323
Fax: 317-773-5453

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

New York, NY
Tel: 631-435-6000

San Jose, CA
Tel: 408-735-9110

Canada - Toronto
Tel: 905-695-1980
Fax: 905-695-2078

ASIA/PACIFIC

Asia Pacific Office
Suites 3707-14, 37th Floor
Tower 6, The Gateway
Harbour City, Kowloon

Hong Kong
Tel: 852-2943-5100
Fax: 852-2401-3431

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

China - Beijing
Tel: 86-10-8569-7000
Fax: 86-10-8528-2104

China - Chengdu
Tel: 86-28-8665-5511
Fax: 86-28-8665-7889

China - Chongqing
Tel: 86-23-8980-9588
Fax: 86-23-8980-9500

China - Dongguan
Tel: 86-769-8702-9880

China - Guangzhou
Tel: 86-20-8755-8029

China - Hangzhou
Tel: 86-571-8792-8115
Fax: 86-571-8792-8116

China - Hong Kong SAR
Tel: 852-2943-5100
Fax: 852-2401-3431

China - Nanjing
Tel: 86-25-8473-2460
Fax: 86-25-8473-2470

China - Qingdao
Tel: 86-532-8502-7355
Fax: 86-532-8502-7205

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

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

China - Shenzhen
Tel: 86-755-8864-2200
Fax: 86-755-8203-1760

China - Wuhan
Tel: 86-27-5980-5300
Fax: 86-27-5980-5118

China - Xian
Tel: 86-29-8833-7252
Fax: 86-29-8833-7256

ASIA/PACIFIC

China - Xiamen
Tel: 86-592-2388138
Fax: 86-592-2388130

China - Zhuhai
Tel: 86-756-3210040
Fax: 86-756-3210049

India - Bangalore
Tel: 91-80-3090-4444
Fax: 91-80-3090-4123

India - New Delhi
Tel: 91-11-4160-8631
Fax: 91-11-4160-8632

India - Pune
Tel: 91-20-3019-1500

Japan - Osaka
Tel: 81-6-6152-7160
Fax: 81-6-6152-9310

Japan - Tokyo
Tel: 81-3-6880- 3770
Fax: 81-3-6880-3771

Korea - Daegu
Tel: 82-53-744-4301
Fax: 82-53-744-4302

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

Malaysia - Kuala Lumpur
Tel: 60-3-6201-9857
Fax: 60-3-6201-9859

Malaysia - Penang
Tel: 60-4-227-8870
Fax: 60-4-227-4068

Philippines - Manila
Tel: 63-2-634-9065
Fax: 63-2-634-9069

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

Taiwan - Hsin Chu
Tel: 886-3-5778-366
Fax: 886-3-5770-955

Taiwan - Kaohsiung
Tel: 886-7-213-7828

Taiwan - Taipei
Tel: 886-2-2508-8600
Fax: 886-2-2508-0102

Thailand - Bangkok
Tel: 66-2-694-1351
Fax: 66-2-694-1350

EUROPE

Austria - Wels
Tel: 43-7242-2244-39
Fax: 43-7242-2244-393

Denmark - Copenhagen
Tel: 45-4450-2828
Fax: 45-4485-2829

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

Germany - Dusseldorf
Tel: 49-2129-3766400

Germany - Karlsruhe
Tel: 49-721-625370

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

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

Italy - Venice
Tel: 39-049-7625286

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

Poland - Warsaw
Tel: 48-22-3325737

Spain - Madrid
Tel: 34-91-708-08-90
Fax: 34-91-708-08-91

Sweden - Stockholm
Tel: 46-8-5090-4654

UK - Wokingham
Tel: 44-118-921-5800
Fax: 44-118-921-5820

06/23/16