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# MCP9501/2/3/4

## Temperature Switch with Selectable Hysteresis

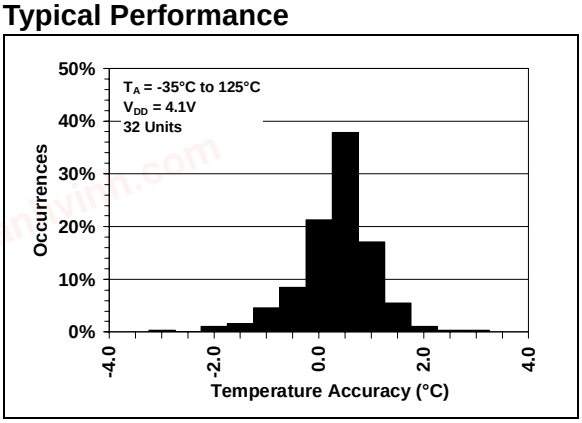
### Features

- Factory Set Temperature Switch
- Available Temperature Switch Thresholds:
  - $T_{SET}$ = -35°C,-25°C, -15°C, -5°C, 5°C, 15°C, 25°C, 35°C, 45°C, 55°C, 65°C, 75°C, 85°C, 95°C, 105°C, 115°C, 125°C
- Wide Operating Voltage Range: 2.7V to 5.5V
- Low Supply Current: 25 µA (typical)
- Temperature Switch Accuracy:
  - ±1°C (typical)
  - ±4°C (maximum) -15°C to +75°C
  - ±6°C (maximum) -40°C to +125°C
- Switch Threshold Options (Hot/Cold):
  - Rising Temp.: MCP9501/2 (Hot Option)
  - Falling Temp.: MCP9503/4 (Cold Option)
- Output Configuration Options:
  - Active Low, Open-Drain Output: MCP9501/3
    – Uses External Pull-up Resistor
  - Active-High, Push-Pull Output: MCP9502/4
- User Selectable Hysteresis: 2°C or 10°C (typical)
- 5-lead SOT-23 package

### Applications

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

### Typical Performance




### Description

Microchip Technology's MCP9501/2/3/4 family of devices are temperature switches with ±1°C (typical) accurate factory set output thresholds. These devices are ideal for high power supply systems where an overtemperature protection circuit is needed. These devices do not require external components, consume 25 µA (typical), and the factory set thresholds provide simplicity.

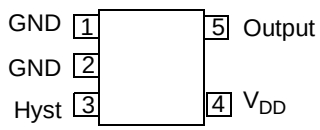
In addition, this family of devices provide user selectable 2°C and 10°C (typical) switch hysteresis, and various output configurations. The MCP9501/2 outputs switch for rising temperatures while the MCP9503/4 switch for falling temperature, with the relative hysteresis at the set thresholds. This family of devices is also available with Active-High Push-Pull and Active-Low Open-Drain outputs, the MCP9502/4 and the MCP9501/3, respectively. The Push-Pull output is ideal for a microcontroller interface while the Open-Drain output can be used for level shifting, wired-OR configuration, or as a heater on/off switch.

The MCP9501/2/3/4 operate from 2.7V to 5.5V supply. This family is available with space saving 5-lead SOT-23 package.

### Package Types

**MCP9501/2/3/4**

SOT-23-5



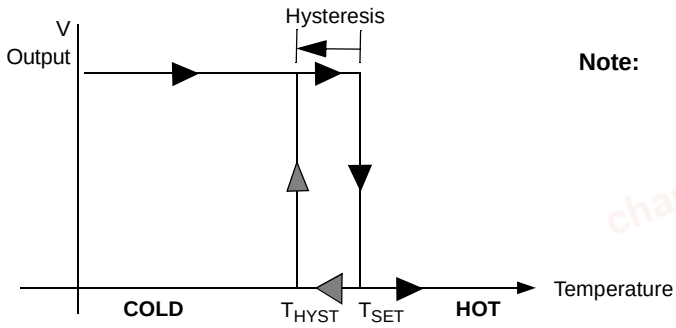

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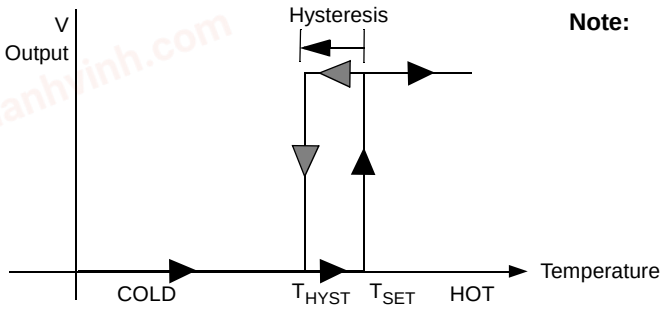
## OUTPUT FUNCTIONAL DESCRIPTION

### MCP9501, Hot-Option (Open-Drain, Active-Low)



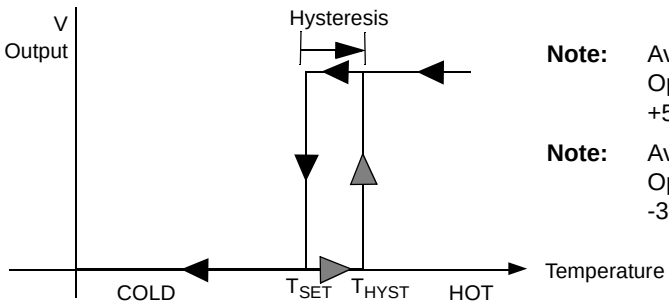

**Note:** Available temperature thresholds for Option P or for rising temperature only: +5°C, +15°C, +25°C, +35°C, +45°C, +55°C, +65°C, +75°C, +85°C, +95°C, +105°C, +115°C, +125°.

### MCP9502, Hot-Option (Push-Pull, Active-High)




**Note:** Available temperature thresholds for Option P or for rising temperature only: +5°C, +15°C, +25°C, +35°C, +45°C, +55°C, +65°C, +75°C, +85°C, +95°C, +105°C, +115°C, +125°.

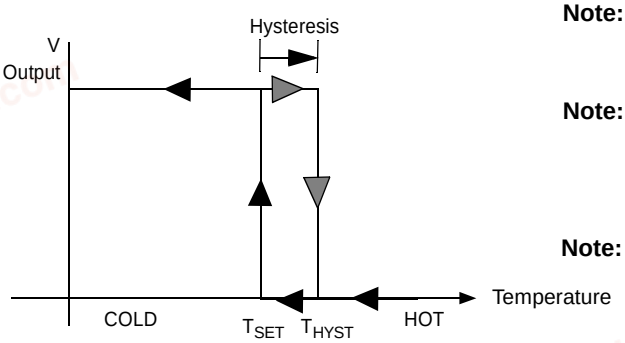
### MCP9503, Cold-Option (Open-Drain, Active-Low)




**Note:** Available temperature thresholds for Option P or for rising temperature only: +5°C, +15°C, +25°C.

**Note:** Available temperature thresholds for Option N or for falling temperature only: -35°C, -25°C, -15°C, -5°C.

### MCP9504, Cold-Option (Push-Pull, Active-High)




**Note:** Available temperature thresholds for Option P or for rising temperature only: +5°C, +15°C, +25°C.

**Note:** Available temperature thresholds for Option N or for falling temperature only: -35°C, -25°C, -15°C, -5°C.

**Note:** Contact Microchip for all other threshold options.


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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** | | | | | | |
| -15°C ≤ $T_A$ ≤ +75°C | | -4 | ±1 | +4 | °C | Note 1 |
| -40°C ≤ $T_A$ ≤ +125°C | | -6 | ±2 | 6 | °C | |
| **Power Supply** | | | | | | |
| Operating Voltage | $V_{DD}$ | 2.7 | — | 5.5 | V | |
| Operating Current | $I_{DD}$ | — | 25 | 40 | µA | |
| Line-Regulation | Δ°C/ΔV | — | 0.2 | — | °C/V | $V_{DD}$ = 2.7V to 5.5V |
| **Hysteresis** | | | | | | |
| Trip Point Hysteresis | $T_{HYST}$ | — | 2 | — | °C | HYST = GND |
| | | — | 10 | — | °C | HYST = $V_{DD}$ |
| Hysteresis Select Input | $V_{IH}$ | 0.8$V_{DD}$ | — | — | V | |
| | $V_{IL}$ | — | — | 0.2$V_{DD}$ | V | |
| | $I_{Leak}$ | — | 0.1 | — | µA | |
| Open-Drain Output Leakage | $I_{Leak}$ | — | 0.1 | 10 | µA | MCP9501/3 |
| Output Voltage High | $V_{OH}$ | 0.8$V_{DD}$ | — | — | V | $I_{OUT}$ = 5 mA (MCP9502/4) |
| Output Voltage Low | $V_{OL}$ | — | — | 0.2$V_{DD}$ | V | $I_{OUT}$ = 5 mA |
| Turn On Time | $T_{ON}$ | — | 1 | — | ms | |
| SOT23-5 | $t_{RES}$ | — | 1.7 | — | s | Time to 63% (89°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 | $\theta_{JA}$ | — | 220.7 | — | °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 (MCP9501/3 only) and 0.1 µF bypass capacitor.

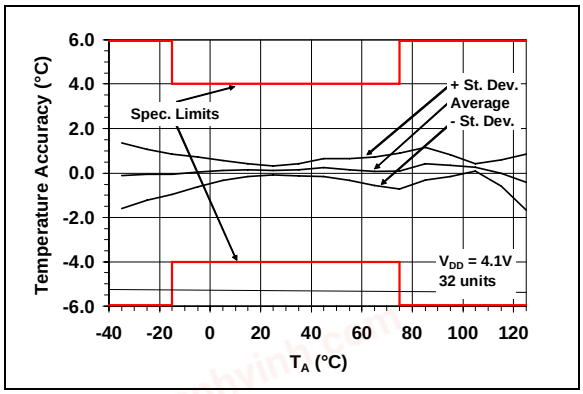



***FIGURE 2-1:*** *Temperature Accuracy.*

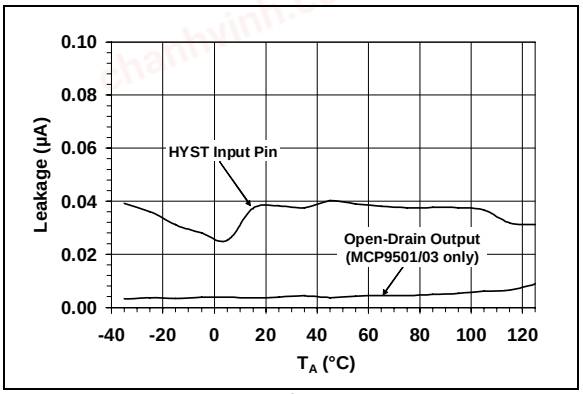



***FIGURE 2-4:*** *Leakage vs. Temperature.*

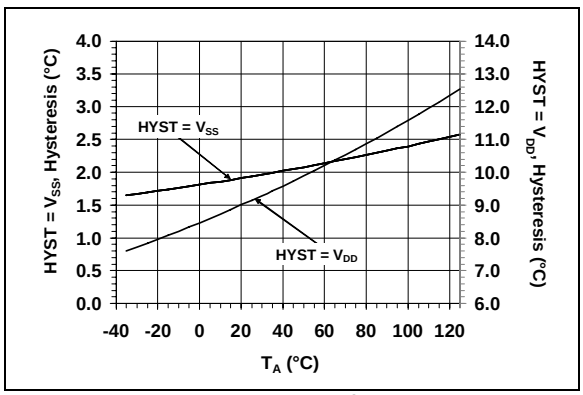



***FIGURE 2-2:*** *Hysteresis vs. Temperature.*

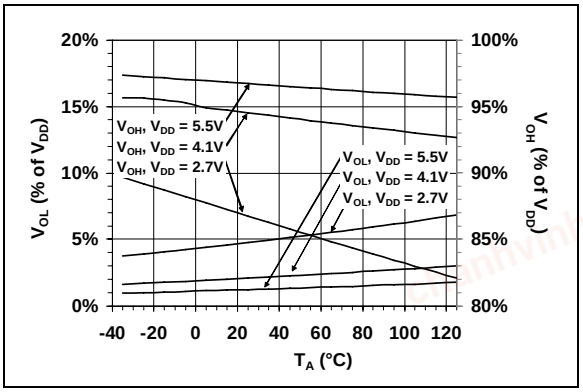



***FIGURE 2-5:*** *$V_{OL}$,$V_{OH}$ vs. Temperature.*

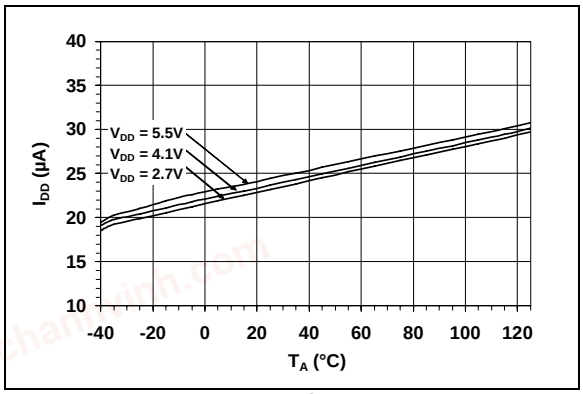



***FIGURE 2-3:*** *Supply Current vs. Temperature.*

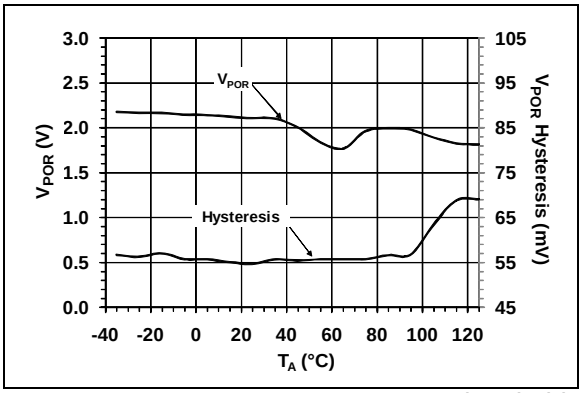



***FIGURE 2-6:*** *Power On Reset Threshold vs. Temperature.*


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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 (MCP9501 only) and 0.1 µF bypass capacitor.

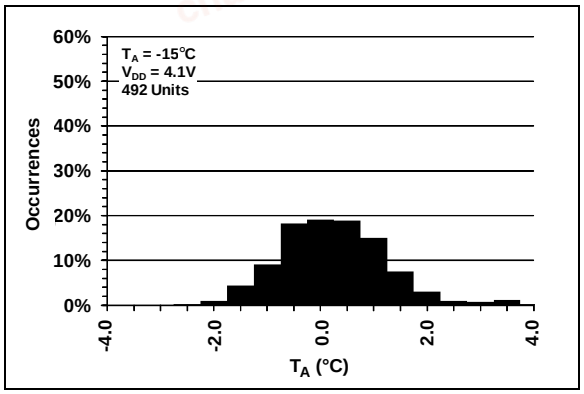



***FIGURE 2-7:*** *Temperature Accuracy Distribution at -15°C.*

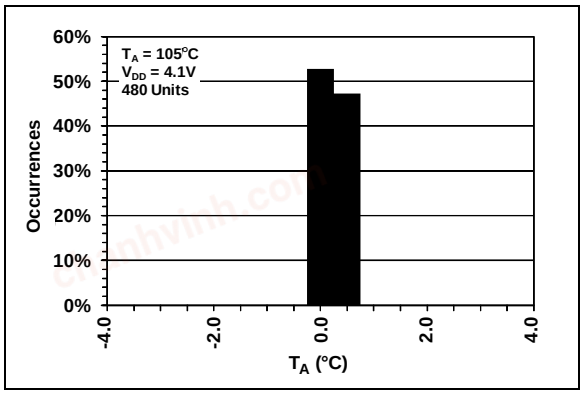



***FIGURE 2-10:*** *Temperature Accuracy Distribution at 105°C.*

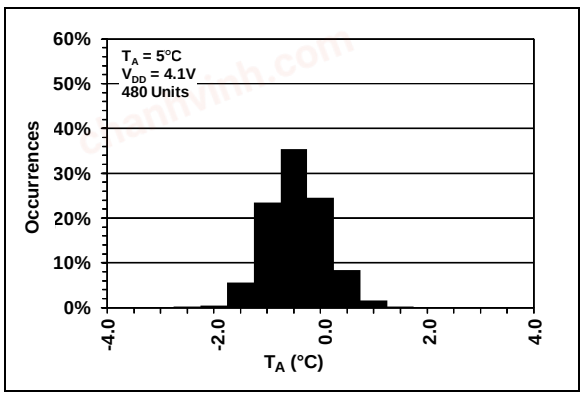



***FIGURE 2-8:*** *Temperature Accuracy Distribution at 5°C.*

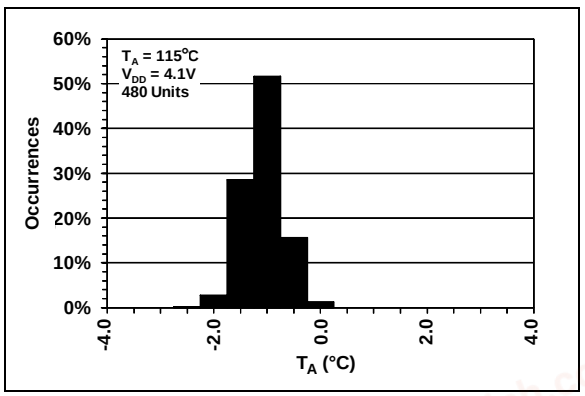



***FIGURE 2-11:*** *Temperature Accuracy Distribution at 115°C.*

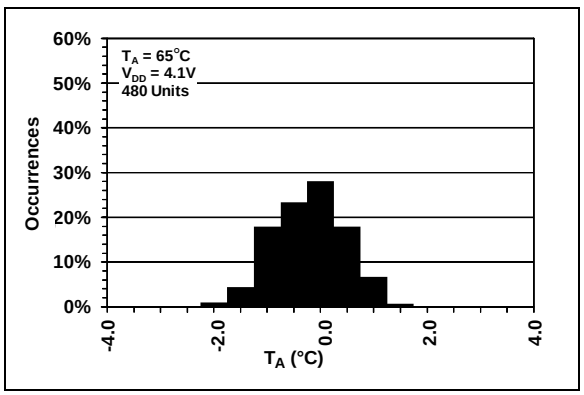



***FIGURE 2-9:*** *Temperature Accuracy Distribution at 65°C.*

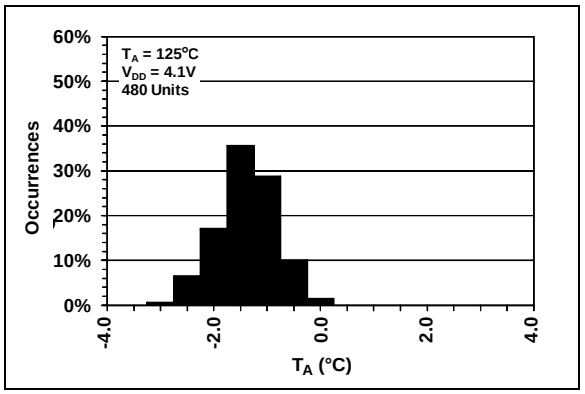



***FIGURE 2-12:*** *Temperature Accuracy Distribution at 125°C.*

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## 3.0 PIN DESCRIPTIONS

**TABLE 3-1: PIN FUNCTION TABLE**

| MCP9501/2/3/4 SOT-23-5 | Symbol | Description |
|---|---|---|
| 1 | GND | Ground |
| 2 | GND | Ground (must be connected to ground) |
| 3 | HYST | Hysteresis Selection Input:<br>HYST = GND → Hysteresis is 2°C (typical)<br>HYST = $V_{DD}$ → Hysteresis is 10°C (typical) |
| 4 | $V_{DD}$ | Power pin |
| 5 | Output | Output Options:<br>MCP9501 → Open-Drain, Active-Low Output (Hot-Option)<br>MCP9502 → Push-Pull, Active-High Output (Hot-Option)<br>MCP9503 → Open-Drain, Active-Low Output (Cold-Option)<br>MCP9504 → Push-Pull, Active-High Output (Cold-Option) |

### 3.1 Ground (GND)

The GND pin is the system ground pin. Pin 2 must be connected to system ground. Pin 1 can also be connected to system ground which would provide better thermal conduction to the die.

### 3.2 Hysteresis Input (HYS)

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

### 3.3 Power Pin ($V_{DD}$)

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

### 3.4 Switch Output (Output)

This output is triggered when temperature rises or falls beyond the programmed trip temperature threshold. MCP9501/3 require an external pull-up resistor.


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**NOTES:**

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## 4.0 FUNCTIONAL DESCRIPTION

The MCP9501/2/3/4 temperature switch family integrates a thermal diode, a comparator, and a factory selectable resistive network used to set the temperature thresholds. The available output thresholds range from -35°C to 125°C at 10°C increments. There is no additional configuration required to operate this device. The selectable output hysteresis is controlled using a single input pin. When this pin is connected to ground, the output hysteresis is 2°C (typical) and when connected to $V_{DD}$ the output hysteresis is 10°C (typical). Figure 4-1 shows the functional block diagram.

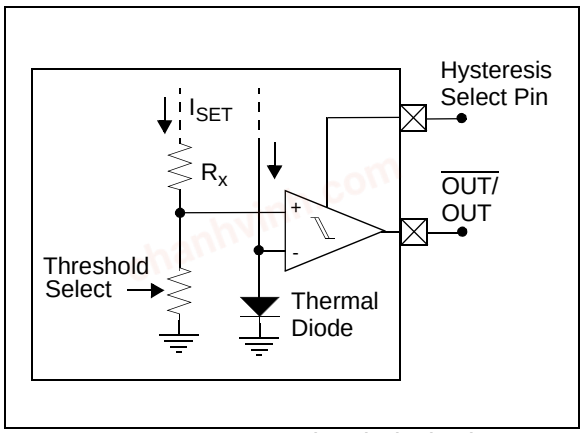



***FIGURE 4-1:*** *Functional Block Diagram.*

There are two output configurations for this family, a push-pull and an open-drain output with active-high and active-low assertions. These assertion options are referred to as Cold and Hot options, primarily due to the direction of selected hysteresis. For the Cold option, temperature has to fall below the threshold for the output to assert High, and de-assert Low when the temperature rises above the threshold plus the hysteresis. For example, a 65°C threshold and 2°C (typical) hysteresis, when temperature falls below 65°C the output asserts High, and the de-asserts Low when temperature rises above 67°C. For the Hot option, the opposite is true. When temperature rises above 65°C, the output asserts Low, and de-asserts High when the temperature falls below 63°C. Figure 4-2 shows a graphical description for the Hot and Cold options.

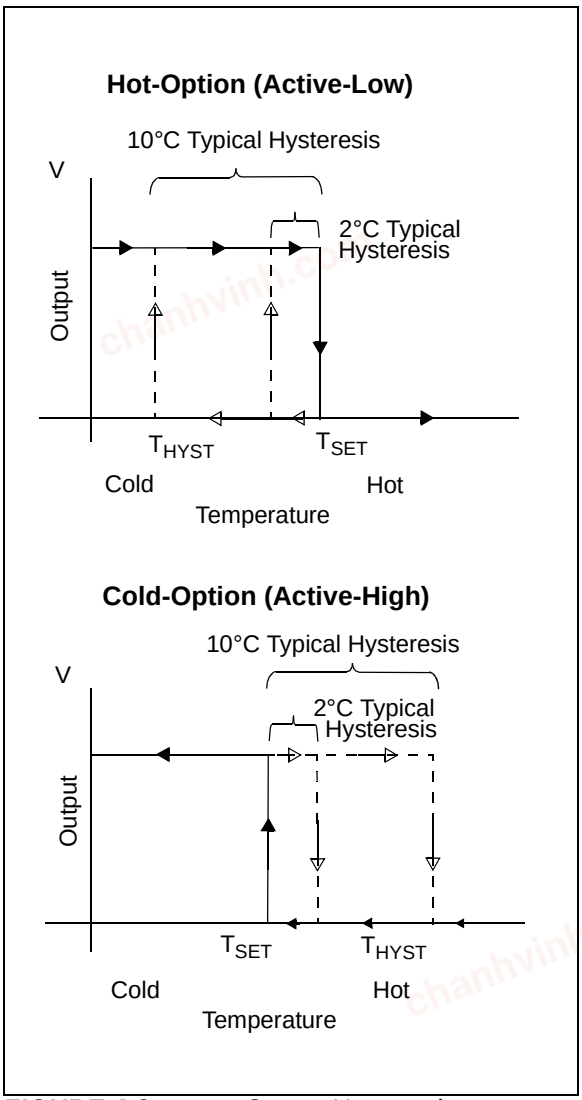



***FIGURE 4-2:*** *Output Hysteresis.*

The Push-Pull output is ideal for a microcontroller interface using an input/output pin or an interrupt input pin. The open-drain option can be used with multiple sensors in a wired-OR configuration or as a level shifter.


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## 4.1 Application Information

The MCP9501/2/3/4 temperature switch family integrates a temperature sensor and a comparator circuit which outputs an alert signal when the factory set temperature threshold is exceeded. No additional component is required for device operation, which provides simplicity to the system designer. The device output options provide design flexibility for various applications such as overtemperature protection circuit or a closed loop temperature control unit. This device can be interfaced to a closed loop fan controller network without the need for a microcontroller.

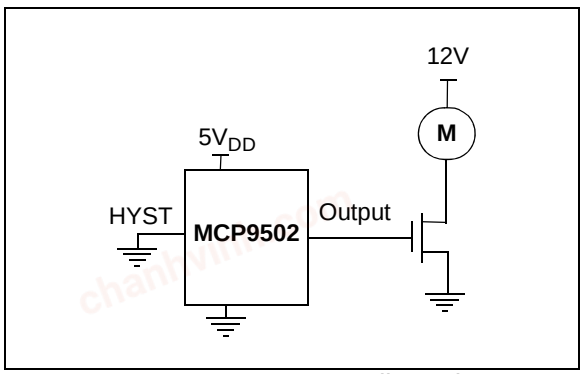



***FIGURE 4-3:*** *Fan Controller Using MCP9502.*

The MCP9501/2/3/4 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 MCP9501 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 4-4.

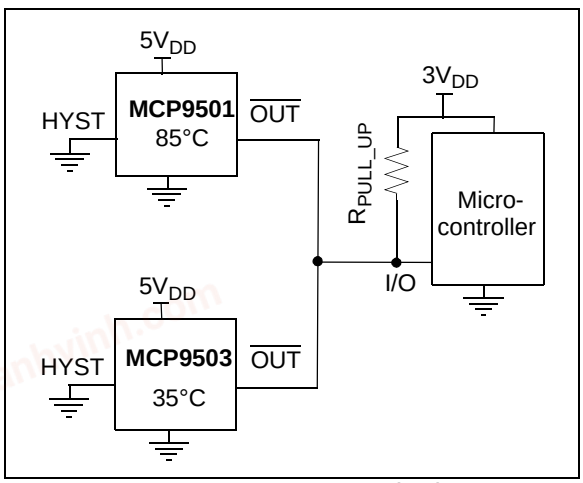



***FIGURE 4-4:*** *MCP9501 Wired-OR Output Configuration with Level-shift.*

### 4.1.1 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.

When connecting an external resistor to the MCP9501/3, the current through the pull-up resistor must be considered to prevent self-heat due to power. This can be determined using Equation 4-1.

**EQUATION 4-1: 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 |
| $\theta_{JA}$ | = | Package Thermal Resistance (220.7 °C/W) |
| $V_{OL}$ | = | Sensor Output Low Voltage |
| $I_{OUT}$ | = | Output Current |

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

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### 4.1.2 POWER SUPPLY REJECTION

The MCP9501/2/3/4 family does not require any additional components. However, it is recommended that a decoupling capacitor of 0.1 µF to 1 µF be used between the $V_{DD}$ and GND pins. A high-frequency ceramic capacitor is recommended. It is necessary for the capacitor to be located as close as possible to the power pins in order to provide effective noise protection.

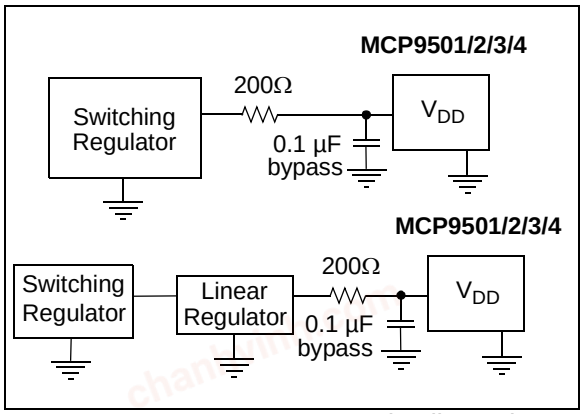



***FIGURE 4-5:*** *Power-supply Filter using a Single Resistor.*

For applications where a switching regulator is used to power the sensor, it is recommended to add a 200Ω resistor in series to $V_{DD}$ to filter out the switcher noise. It is also recommended to add the series resistor in applications where a linear regulator is used to step-down a switching regulator voltage to power the sensor, as shown in Figure 4-5. For example, if a linearly regulated 3.3V from a 5V switching regulator is used to power the sensor, add a 200Ω series resistor.

The MCP9501/2/3/4 family of sensors is designed to prevent false output trigger due to high frequency power supply or system noise. Figure 4-6 shows the 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.

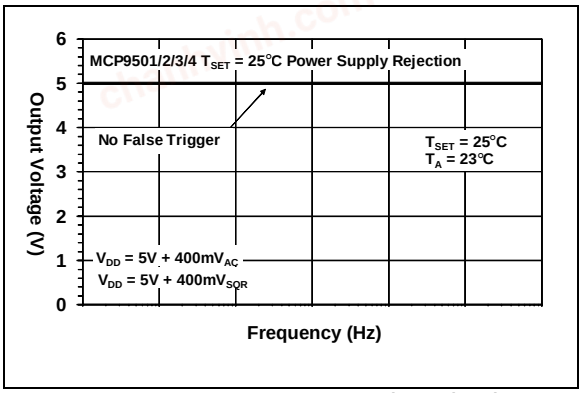



***FIGURE 4-6:*** *Power Supply Rejection.*


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**NOTES:**

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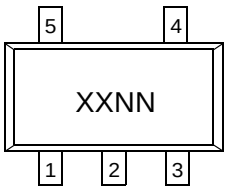
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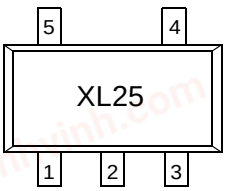
## 5.0 PACKAGING INFORMATION

### 5.1 Package Marking Information

**5-Lead SOT-23**




Example:




| Device | Code | Device | Code |
|---|---|---|---|
| **Hot Options** | | | |
| MCP9501PT-005E/OT | WVNN | MCP9502PT-005E/OT | XLNN |
| MCP9501PT-015E/OT | WWNN | MCP9502PT-015E/OT | XMNN |
| MCP9501PT-025E/OT | WXNN | MCP9502PT-025E/OT | XPNN |
| MCP9501PT-035E/OT | WYNN | MCP9502PT-035E/OT | XQNN |
| MCP9501PT-045E/OT | WZNN | MCP9502PT-045E/OT | XRNN |
| MCP9501PT-055E/OT | X1NN | MCP9502PT-055E/OT | XSNN |
| MCP9501PT-065E/OT | X2NN | MCP9502PT-065E/OT | XTNN |
| MCP9501PT-075E/OT | X3NN | MCP9502PT-075E/OT | XUNN |
| MCP9501PT-085E/OT | X4NN | MCP9502PT-085E/OT | XVNN |
| MCP9501PT-095E/OT | X5NN | MCP9502PT-095E/OT | XWNN |
| MCP9501PT-105E/OT | X6NN | MCP9502PT-105E/OT | XXNN |
| MCP9501PT-115E/OT | X7NN | MCP9502PT-115E/OT | XYNN |
| MCP9501PT-125E/OT | X8NN | MCP9502PT-125E/OT | XZNN |
| MCP9503PT-005E/OT | XHNN | MCP9501PT-005E/OT | Y9NN |
| MCP9503PT-015E/OT | XJNN | MCP9501PT-015E/OT | YANN |
| MCP9503PT-125E/OT | XKNN | MCP9501PT-025E/OT | YBNN |
| **Cold Options** | | | |
| MCP9503NT-005E/OT | XBNN | MCP9501NT-005E/OT | Y3NN |
| MCP9503NT-015E/OT | XCNN | MCP9501NT-015E/OT | Y4NN |
| MCP9503NT-025E/OT | XDNN | MCP9501NT-025E/OT | Y5NN |
| MCP9503NT-035E/OT | XENN | MCP9501NT-035E/OT | Y6NN |

**Note:** Contact Microchip for all other threshold options.

| | | |
|---|---|---|
| **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.

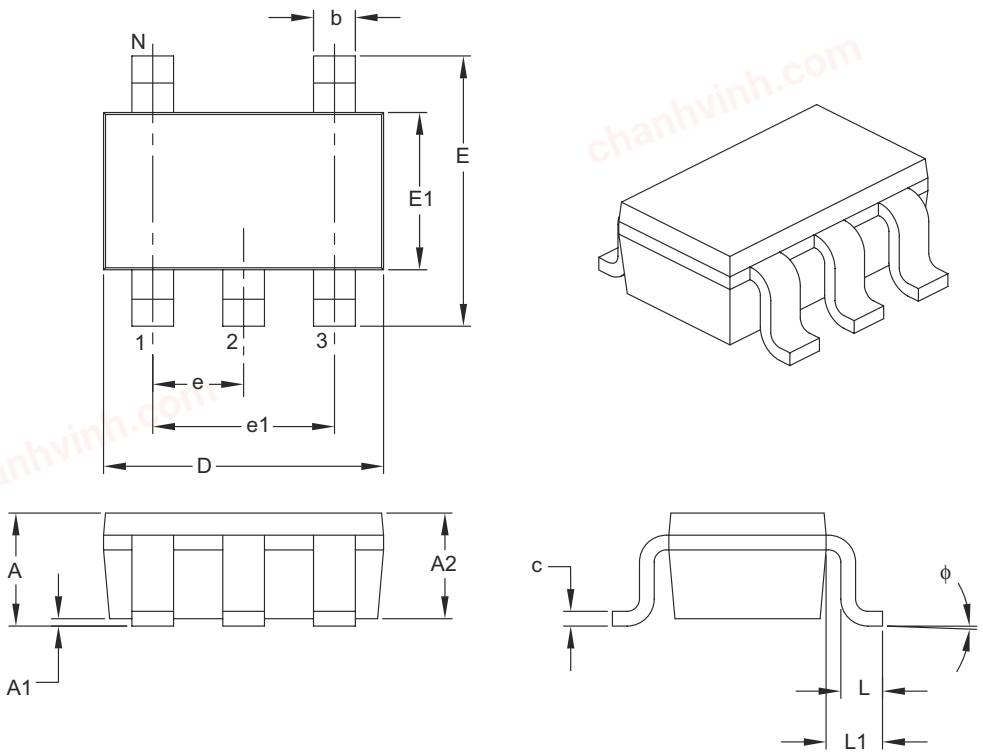

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## 5-Lead Plastic Small Outline Transistor (OT) [SOT-23]

**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.

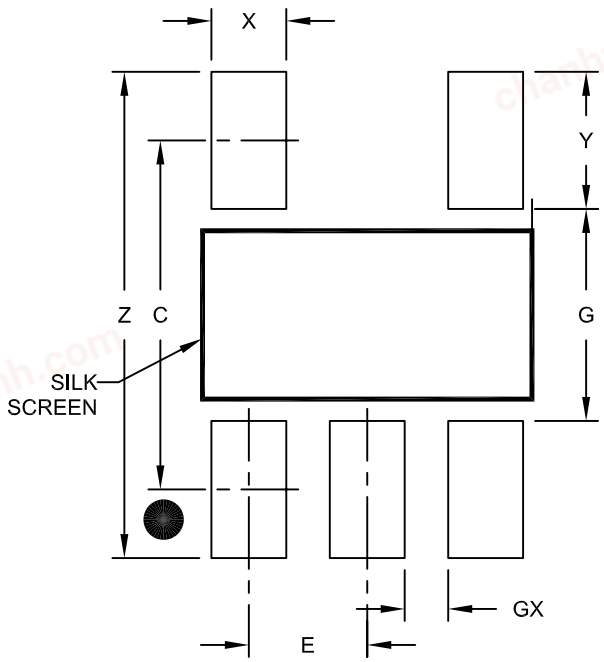
Microchip Technology Drawing C04-091B

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### 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


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# APPENDIX A: REVISION HISTORY

## Revision A (January 2011)

- Original Release of this Document.

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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. | -XXXX | X | /XX |
|---|---|---|---|
| Device | Temperature Switch Threshold | Temperature Range | Package |

| | | |
|---|---|---|
| Device: | MCP9501P: | Resistor Programmable Temperature Switch, Hot Option |
| | MCP9502P | Resistor Programmable Temperature Switch, Hot Option |
| | MCP9503N: | Resistor Programmable Temperature Switch, Cold Option |
| | MCP9504N | Resistor Programmable Temperature Switch, Cold Option |
| Temperature Switch Threshold: | 005, 015, 025, 035, 045, 055, 065, 075, 085, 095, 105, 115, 125 | |
| Temperature Range: | E = -40°C to +125°C | |
| Package: | OT = Plastic Small Outline Transistor (SOT-23), 5-lead | |

**Examples:**

a) MCP9501PT-025E/OT: Active-Low, Open-Drain Output, 25°C Switch Threshold, Hot Option, Extended Temp., 5LD SOT-23 pkg.

b) MCP9502PT-025E/OT: Active-High, Push-Pull Output, 25°C Switch Threshold, Hot Option, Extended Temp., 5LD SOT-23 pkg.

c) MCP9503NT-025E/OT: Active-Low, Open-Drain Output, -25°C Switch Threshold, Cold Option, Extended Temp., 5LD SOT-23 pkg.

d) MCP9504NT-025E/OT: Active-High, Push-Pull Output, -25°C Switch Threshold, Cold Option, Extended Temp., 5LD SOT-23 pkg.

e) MCP9501PT-105E/OT: Active-Low, Open-Drain Output, 105°C Switch Threshold, Hot Option, Extended Temp., 5LD SOT-23 pkg.

f) MCP9502PT-105E/OT: Active-High, Push-Pull Output, 105°C Switch Threshold, Hot Option, Extended Temp., 5LD SOT-23 pkg.

g) MCP9503NT-035E/OT: Active-Low, Open-Drain Output, -35°C Switch Threshold, Cold Option, Extended Temp., 5LD SOT-23 pkg.

h) MCP9504NT-035E/OT: Active-High, Push-Pull Output, -35°C Switch Threshold, Cold Option, Extended Temp., 5LD SOT-23 pkg.

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