

SM72480 SolarMagic 1.6V, WSON-6 Factory Preset Temperature Switch and Temperature Sensor

Check for Samples: [SM72480](#)

FEATURES

- Renewable Energy Grade
- Low 1.6V Operation
- Latching Function: Device Can Latch the Over Temperature Condition
- Push-pull and Open-Drain Temperature Switch Outputs
- Very Linear Analog V_{TEMP} Temperature Sensor Output
- V_{TEMP} Output Short-circuit Protected
- 2.2 mm by 2.5 mm (typ) WSON-6 Package
- Excellent Power Supply Noise Rejection

APPLICATIONS

- PV Power Optimizers
- Wireless Transceivers
- Battery Management
- Automotive
- Disk Drives

KEY SPECIFICATIONS

- Supply Voltage 1.6V to 5.5V
- Supply Current 8 μ A (typ)
- Accuracy, Trip Point Temperature 0°C to 150°C $\pm 2.2^\circ$ C
- Accuracy, V_{TEMP} 0°C to 150°C $\pm 2.3^\circ$ C
- V_{TEMP} Output Drive ± 100 μ A
- Operating Temperature -50° C to 150°C
- Hysteresis Temperature 4.5°C to 5.5°C

Connection Diagram

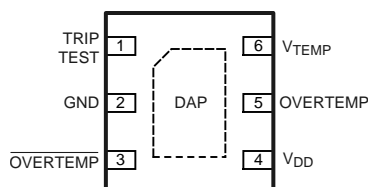


Figure 1. WSON-6 - Top View
See Package Number NGF0006A

DESCRIPTION

The SM72480 is a low-voltage, precision, dual-output, low-power temperature switch and temperature sensor. The temperature trip point (T_{TRIP}) is set at the factory to be 120°C. Built-in temperature hysteresis (T_{HYST}) keeps the output stable in an environment of temperature instability.

In normal operation the SM72480 temperature switch outputs assert when the die temperature exceeds T_{TRIP} . The temperature switch outputs will reset when the temperature falls below a temperature equal to ($T_{TRIP} - T_{HYST}$). The OVERTEMP digital output, is active-high with a push-pull structure, while the OVERTEMP digital output, is active-low with an open-drain structure.

The analog output, V_{TEMP} , delivers an analog output voltage with Negative Temperature Coefficient — NTC.

Driving the TRIP TEST input high: (1) causes the digital outputs to be asserted for in-situ verification and, (2) causes the threshold voltage to appear at the V_{TEMP} output pin, which could be used to verify the temperature trip point.

The SM72480's low minimum supply voltage makes it ideal for 1.8 volt system designs. Its wide operating range, low supply current, and excellent accuracy provide a temperature switch solution for a wide range of commercial and industrial applications.



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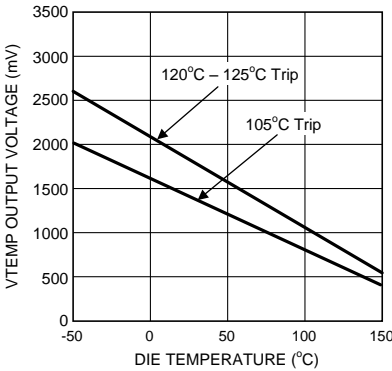
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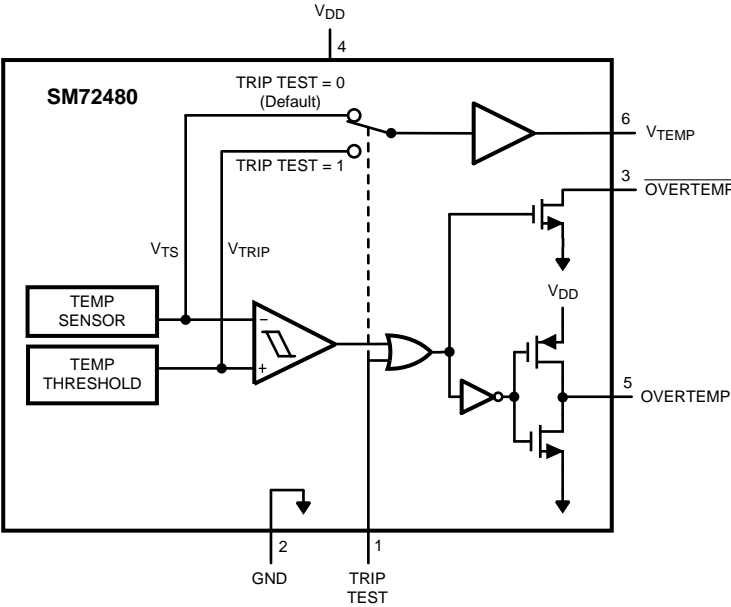
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Typical Transfer Characteristic

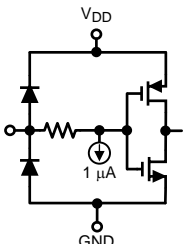
Figure 2. V_{TEMP} Analog Voltage vs Die Temperature



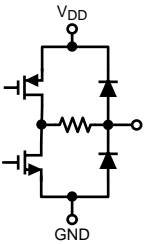
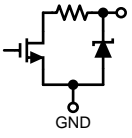
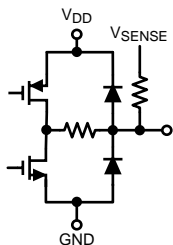
Block Diagram



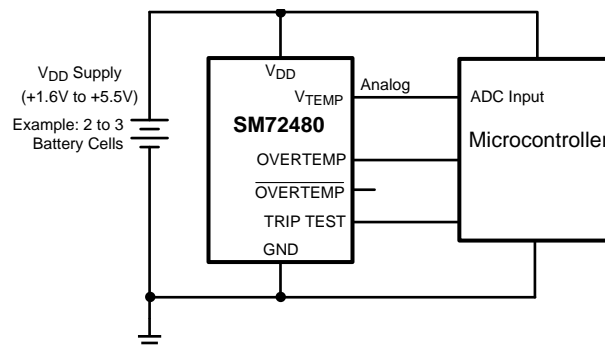
PIN DESCRIPTIONS

| Pin No. | Name | Type | Equivalent Circuit | Description |
|---------|-----------|---------------|---|---|
| 1 | TRIP TEST | Digital Input |  | TRIP TEST pin. Active High input. If TRIP TEST = 0 (Default) then: $V_{TEMP} = V_{TS}$, Temperature Sensor Output Voltage If TRIP TEST = 1 then: $\overline{OVERTEMP}$ and $\overline{OVERTEMP}$ outputs are asserted and $V_{TEMP} = V_{TRIP}$, Temperature Trip Voltage. This pin may be left open if not used. |

PIN DESCRIPTIONS (continued)

| Pin No. | Name | Type | Equivalent Circuit | Description |
|---------|------------------------------|----------------|--|---|
| 5 | OVERTEMP | Digital Output |  | Over Temperature Switch output Active High, Push-Pull Asserted when the measured temperature exceeds the Trip Point Temperature or if TRIP TEST = 1 This pin may be left open if not used. |
| 3 | $\overline{\text{OVERTEMP}}$ | Digital Output |  | Over Temperature Switch output Active Low, Open-drain (See OVERTEMP OPEN-DRAIN DIGITAL OUTPUT regarding required pull-up resistor.) Asserted when the measured temperature exceeds the Trip Point Temperature or if TRIP TEST = 1 This pin may be left open if not used. |
| 6 | V _{TEMP} | Analog Output |  | V _{TEMP} Analog Voltage Output If TRIP TEST = 0 then V _{TEMP} = V _{TS} , Temperature Sensor Output Voltage If TRIP TEST = 1 then V _{TEMP} = V _{TRIP} , Temperature Trip Voltage This pin may be left open if not used. |
| 4 | V _{DD} | Power | | Positive Supply Voltage |
| 2 | GND | Ground | | Power Supply Ground |
| DAP | Die Attach Pad | | | The best thermal conductivity between the device and the PCB is achieved by soldering the DAP of the package to the thermal pad on the PCB. The thermal pad can be a floating node. However, for improved noise immunity the thermal pad should be connected to the circuit GND node, preferably directly to pin 2 (GND) of the device. |

Typical Application



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

Absolute Maximum Ratings⁽¹⁾

| | | |
|--|----------------------|--|
| Supply Voltage | | -0.3V to +6.0V |
| Voltage at $\overline{\text{OVERTEMP}}$ pin | | -0.3V to +6.0V |
| Voltage at $\overline{\text{OVERTEMP}}$ and V_{TEMP} pins | | -0.3V to ($V_{\text{DD}} + 0.5\text{V}$) |
| TRIP TEST Input Voltage | | -0.3V to ($V_{\text{DD}} + 0.5\text{V}$) |
| Output Current, any output pin | | $\pm 7\text{ mA}$ |
| Input Current at any pin ⁽²⁾ | | 5 mA |
| Storage Temperature | | -65°C to +150°C |
| Maximum Junction Temperature | $T_{\text{J(MAX)}}$ | +155°C |
| ESD Susceptibility ⁽³⁾ | Human Body Model | 4500V |
| | Machine Model | 300V |
| | Charged Device Model | 1000V |
| For soldering specifications: see www.ti.com/lit/SNOA549 | | |

- (1) Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not ensure specific performance limits. For ensured specifications and test conditions, see the Electrical Characteristics. The ensured specifications apply only for the test conditions listed. Some performance characteristics may degrade when the device is not operated under the listed test conditions.
- (2) When the input voltage (V_I) at any pin exceeds power supplies ($V_I < \text{GND}$ or $V_I > V_{\text{DD}}$), the current at that pin should be limited to 5 mA.
- (3) The Human Body Model (HBM) is a 100 pF capacitor charged to the specified voltage then discharged through a 1.5 k Ω resistor into each pin. The Machine Model (MM) is a 200 pF capacitor charged to the specified voltage then discharged directly into each pin. The Charged Device Model (CDM) is a specified circuit characterizing an ESD event that occurs when a device acquires charge through some triboelectric (frictional) or electrostatic induction processes and then abruptly touches a grounded object or surface.

Operating Ratings⁽¹⁾

| | | |
|---|-------------------------|---|
| Specified Temperature Range | | $T_{\text{MIN}} \leq T_A \leq T_{\text{MAX}}$ |
| SM72480 | | -50°C $\leq T_A \leq$ +150°C |
| Supply Voltage Range (V_{DD}) | | +1.6 V to +5.5 V |
| Thermal Resistance (θ_{JA}) ⁽²⁾⁽³⁾ | WS0N-6 (Package SDB06A) | 152 °C/W |

- (1) Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not ensure specific performance limits. For ensured specifications and test conditions, see the Electrical Characteristics. The ensured specifications apply only for the test conditions listed. Some performance characteristics may degrade when the device is not operated under the listed test conditions.
- (2) The junction to ambient temperature resistance (θ_{JA}) is specified without a heat sink in still air.
- (3) Changes in output due to self heating can be computed by multiplying the internal dissipation by the temperature resistance.

Accuracy Characteristics Trip Point Accuracy

| Parameter | Conditions | | Limits ⁽¹⁾ | Units (Limit) |
|------------------------------------|-------------|--------------------------------|-----------------------|---------------|
| Trip Point Accuracy ⁽²⁾ | 0°C – 150°C | $V_{\text{DD}} = 5.0\text{ V}$ | ± 2.2 | °C (max) |

- (1) Limits are ensured to AOQL (Average Outgoing Quality Level).
- (2) Accuracy is defined as the error between the measured and reference output voltages, tabulated in the Conversion Table at the specified conditions of supply gain setting, voltage, and temperature (expressed in °C). Accuracy limits include line regulation within the specified conditions. Accuracy limits do not include load regulation; they assume no DC load.

Accuracy Characteristics V_{TEMP} Analog Temperature Sensor Output Accuracy

The limits do not include DC load regulation. The stated accuracy limits are with reference to the values in the SM72480 Conversion Table.

| Parameter | Conditions | | | Limits ⁽¹⁾ | Units (Limit) |
|--|------------------------------|--|----------------------------------|-----------------------------|--|
| V_{TEMP} Temperature Accuracy ⁽²⁾ | Trip Point 125°C or 120°C | $T_A = 20^\circ\text{C}$ to 40°C | $V_{DD} = 2.3$ to 5.5 V | ± 1.8 | $^\circ\text{C}$ (max) ⁽²⁾ |
| | | $T_A = 0^\circ\text{C}$ to 70°C | $V_{DD} = 2.5$ to 5.5 V | ± 2.0 | |
| | | $T_A = 0^\circ\text{C}$ to 90°C | $V_{DD} = 2.5$ to 5.5 V | ± 2.1 | |
| | | $T_A = 0^\circ\text{C}$ to 120°C | $V_{DD} = 2.5$ to 5.5 V | ± 2.2 | |
| | | $T_A = 0^\circ\text{C}$ to 150°C | $V_{DD} = 2.5$ to 5.5 V | ± 2.3 | |
| | | $T_A = -50^\circ\text{C}$ to 0°C | $V_{DD} = 3.0$ to 5.5 V | ± 1.7 | |
| V_{TEMP} Temperature Accuracy | Trip Point 105°C | $T_A = 20^\circ\text{C}$ to 40°C | $V_{DD} = 1.8$ to 5.5 V | ± 1.8 | $^\circ\text{C}$ (max) |
| | | $T_A = 0^\circ\text{C}$ to 70°C | $V_{DD} = 1.9$ to 5.5 V | ± 2.0 | |
| | | $T_A = 0^\circ\text{C}$ to 90°C | $V_{DD} = 1.9$ to 5.5 V | ± 2.1 | |
| | | $T_A = 0^\circ\text{C}$ to 120°C | $V_{DD} = 1.9$ to 5.5 V | ± 2.2 | |
| | | $T_A = 0^\circ\text{C}$ to 150°C | $V_{DD} = 1.9$ to 5.5 V | ± 2.3 | |
| | | $T_A = -50^\circ\text{C}$ to 0°C | $V_{DD} = 2.3$ to 5.5 V | ± 1.7 | |

(1) Limits are ensured to AOQL (Average Outgoing Quality Level).

(2) Accuracy is defined as the error between the measured and reference output voltages, tabulated in the Conversion Table at the specified conditions of supply gain setting, voltage, and temperature (expressed in $^\circ\text{C}$). Accuracy limits include line regulation within the specified conditions. Accuracy limits do not include load regulation; they assume no DC load.

Electrical Characteristics

Unless otherwise noted, these specifications apply for $+V_{DD} = +1.6\text{V}$ to $+5.5\text{V}$. **Boldface limits apply for $T_A = T_J = T_{MIN}$ to T_{MAX}** ; all other limits $T_A = T_J = 25^\circ\text{C}$.

| Symbol | Parameter | Conditions | | Typical ⁽¹⁾ | Limits ⁽²⁾ | Units (Limit) |
|--|--------------------------------|------------------------|-----------------|------------------------|-------------------------|----------------------|
| GENERAL SPECIFICATIONS | | | | | | |
| I _S | Quiescent Power Supply Current | | | 8 | 16 | μA (max) |
| | Hysteresis | | | 5 | 5.5 4.5 | °C (max) °C (Min) |
| OVERTEMP DIGITAL OUTPUT | | ACTIVE HIGH, PUSH-PULL | | | | |
| V _{OH} | Logic "1" Output Voltage | V _{DD} ≥ 1.6V | Source ≤ 340 μA | | V _{DD} – 0.2V | V (min) |
| | | V _{DD} ≥ 2.0V | Source ≤ 498 μA | | | |
| | | V _{DD} ≥ 3.3V | Source ≤ 780 μA | | | |
| | | V _{DD} ≥ 1.6V | Source ≤ 600 μA | | V _{DD} – 0.45V | V (min) |
| | | V _{DD} ≥ 2.0V | Source ≤ 980 μA | | | |
| | | V _{DD} ≥ 3.3V | Source ≤ 1.6 mA | | | |
| BOTH OVERTEMP and OVERTEMP DIGITAL OUTPUTS | | | | | | |
| V _{OL} | Logic "0" Output Voltage | V _{DD} ≥ 1.6V | Sink ≤ 385 μA | | 0.2 | V (max) |
| | | V _{DD} ≥ 2.0V | Sink ≤ 500 μA | | | |
| | | V _{DD} ≥ 3.3V | Sink ≤ 730 μA | | | |
| | | V _{DD} ≥ 1.6V | Sink ≤ 690 μA | | 0.45 | |
| | | V _{DD} ≥ 2.0V | Sink ≤ 1.05 mA | | | |
| | | V _{DD} ≥ 3.3V | Sink ≤ 1.62 mA | | | |

(1) Typicals are at $T_J = T_A = 25^\circ\text{C}$ and represent most likely parametric norm.

(2) Limits are ensured to AOQL (Average Outgoing Quality Level).

Electrical Characteristics (continued)

Unless otherwise noted, these specifications apply for $+V_{DD} = +1.6V$ to $+5.5V$. **Boldface limits apply for $T_A = T_J = T_{MIN}$ to T_{MAX}** ; all other limits $T_A = T_J = 25^\circ C$.

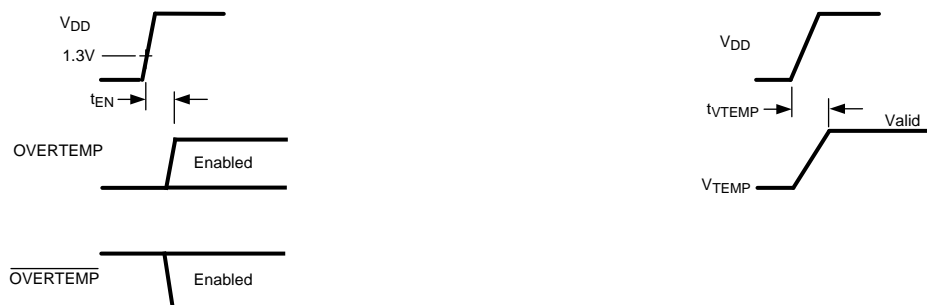
| Symbol | Parameter | Conditions | Typical ⁽¹⁾ | Limits ⁽²⁾ | Units (Limit) | |
|--|--|---|--|-----------------------|------------------|----------|
| OVERTEMP DIGITAL OUTPUT | | ACTIVE LOW, OPEN DRAIN | | | | |
| I _{OH} | Logic "1" Output Leakage Current ⁽³⁾ | T _A = 30 °C | 0.001 | 1 | µA (max) | |
| | | T _A = 150 °C | 0.025 | | | |
| V _{TEMP} ANALOG TEMPERATURE SENSOR OUTPUT | | | | | | |
| | V _{TEMP} Sensor Gain | Trip Point = 105°C | -7.7 | | mV/°C | |
| | | Trip Point = 125°C or 120°C | -10.3 | | mV/°C | |
| | V _{TEMP} Load Regulation ⁽⁴⁾ | 1.6V ≤ V _{DD} < 1.8V | Source ≤ 90 µA (V _{DD} – V _{TEMP}) ≥ 200 mV | -0.1 | -1 | mV (max) |
| | | | Sink ≤ 100 µA V _{TEMP} ≥ 260 mV | 0.1 | 1 | mV (max) |
| | | V _{DD} ≥ 1.8V | Source ≤ 120 µA (V _{DD} – V _{TEMP}) ≥ 200 mV | -0.1 | -1 | mV (max) |
| | | | Sink ≤ 200 µA V _{TEMP} ≥ 260 mV | 0.1 | 1 | mV (max) |
| | | Source or Sink = 100 µA | | 1 | | Ohm |
| | V _{DD} Supply- to-V _{TEMP} DC Line Regulation ⁽⁵⁾ | V _{DD} = +1.6V to +5.5V | 0.29 | | mV | |
| | | | 74 | | µV/V | |
| | | | -82 | | dB | |
| C _L | V _{TEMP} Output Load Capacitance | Without series resistor. See CAPACITIVE LOADS . | 1100 | | pF (max) | |
| TRIP TEST DIGITAL INPUT | | | | | | |
| V _{IH} | Logic "1" Threshold Voltage | | | V _{DD} – 0.5 | V (min) | |
| V _{IL} | Logic "0" Threshold Voltage | | | 0.5 | V (max) | |
| I _{IH} | Logic "1" Input Current | | 1.5 | 2.5 | µA (max) | |
| I _{IL} | Logic "0" Input Current ⁽³⁾ | | 0.001 | 1 | µA (max) | |
| TIMING | | | | | | |
| t _{EN} | Time from Power On to Digital Output Enabled. See definition below. | | 1.1 | 2.3 | ms (max) | |
| t _V | Time from Power On to Analog Temperature Valid. See definition below. | V _{TEMP} C _L = 0 pF to 1100 pF | 1.0 | 2.9 | ms (max) | |

(3) The 1 μA limit is based on a testing limitation and does not reflect the actual performance of the part. Expect to see a doubling of the current for every $15^\circ C$ increase in temperature. For example, the 1 nA typical current at $25^\circ C$ would increase to 16 nA at $85^\circ C$.

(4) Source currents are flowing out of the SM72480. Sink currents are flowing into the SM72480.

(5) Line regulation (DC) is calculated by subtracting the output voltage at the highest supply voltage from the output voltage at the lowest supply voltage. The typical DC line regulation specification does not include the output voltage shift discussed in [VOLTAGE SHIFT](#).

Definitions of t_{EN} and t_v



The curves shown represent typical performance under worst-case conditions. Performance improves with larger overhead ($V_{DD} - V_{TEMP}$), larger V_{DD} , and lower temperatures.

The curves shown represent typical performance under worst-case conditions. Performance improves with larger V_{TEMP} , larger V_{DD} and lower temperatures.

Typical Performance Characteristics

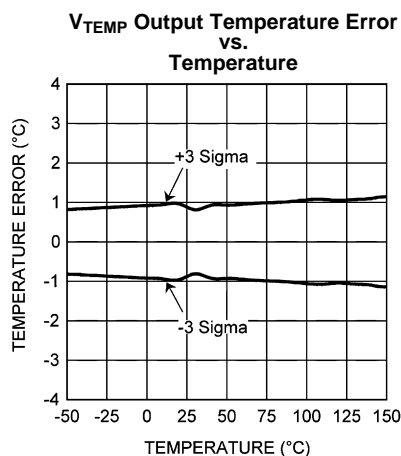


Figure 3.

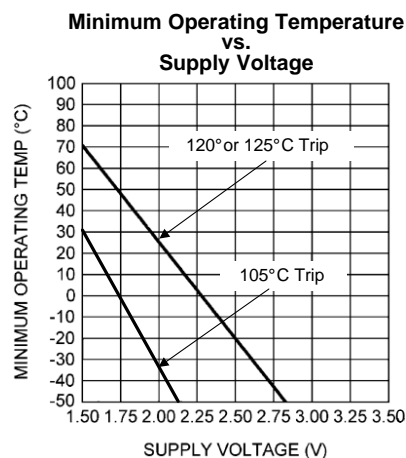


Figure 4.

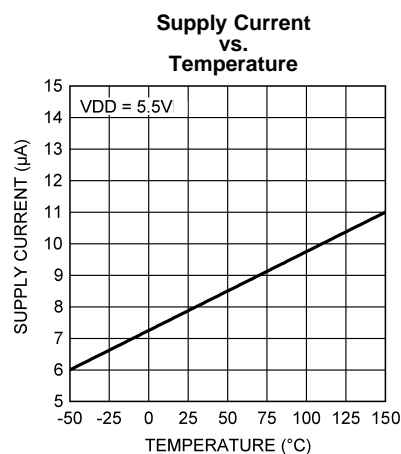


Figure 5.

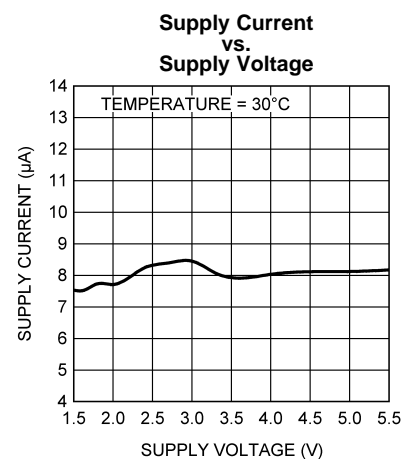


Figure 6.

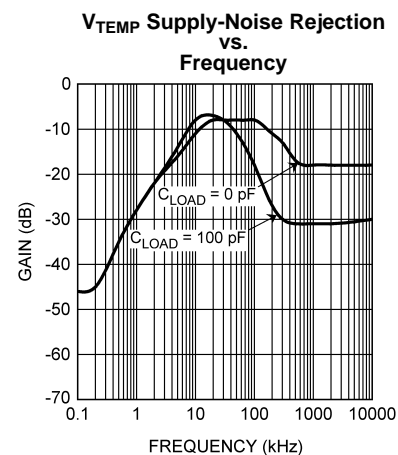


Figure 7.

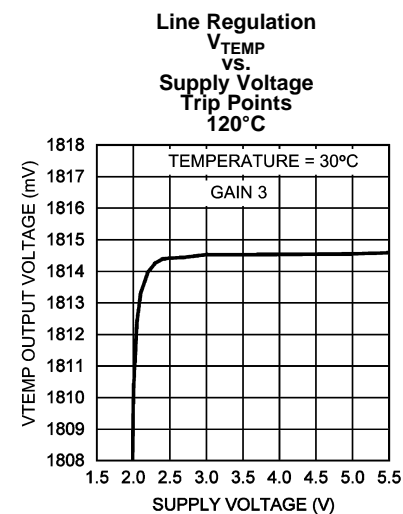


Figure 8.

SM72480 V_{TEMP} VS DIE TEMPERATURE CONVERSION TABLE

The SM72480 has a factory-set gain, which is dependent on the Temperature Trip Point. The V_{TEMP} temperature sensor voltage, in millivolts, at each discrete die temperature over the complete operating range is shown in the conversion table below.

Table 1. V_{TEMP} Temperature Sensor Output Voltage vs Die Temperature Conversion Table⁽¹⁾

| Die Temp., °C | V_{TEMP} , Analog Output Voltage, mV | |
|------------------|--|----------------------------------|
| | $T_{TRIP} = 125 \text{ or } 120^{\circ}\text{C}$ | $T_{TRIP} = 105^{\circ}\text{C}$ |
| -50 | 2623 | 1967 |
| -49 | 2613 | 1960 |
| -48 | 2603 | 1952 |
| -47 | 2593 | 1945 |
| -46 | 2583 | 1937 |
| -45 | 2573 | 1930 |
| -44 | 2563 | 1922 |
| -43 | 2553 | 1915 |
| -42 | 2543 | 1908 |
| -41 | 2533 | 1900 |
| -40 | 2523 | 1893 |
| -39 | 2513 | 1885 |
| -38 | 2503 | 1878 |
| -37 | 2493 | 1870 |
| -36 | 2483 | 1863 |
| -35 | 2473 | 1855 |
| -34 | 2463 | 1848 |
| -33 | 2453 | 1840 |
| -32 | 2443 | 1833 |
| -31 | 2433 | 1825 |
| -30 | 2423 | 1818 |
| -29 | 2413 | 1810 |
| -28 | 2403 | 1803 |
| -27 | 2393 | 1795 |
| -26 | 2383 | 1788 |
| -25 | 2373 | 1780 |
| -24 | 2363 | 1773 |
| -23 | 2353 | 1765 |
| -22 | 2343 | 1757 |
| -21 | 2333 | 1750 |
| -20 | 2323 | 1742 |
| -19 | 2313 | 1735 |
| -18 | 2303 | 1727 |
| -17 | 2293 | 1720 |
| -16 | 2283 | 1712 |
| -15 | 2272 | 1705 |
| -14 | 2262 | 1697 |
| -13 | 2252 | 1690 |
| -12 | 2242 | 1682 |

(1) The V_{TEMP} temperature sensor output voltage, in mV, vs Die Temperature, in °C for the gain corresponding to the temperature trip point. $V_{DD} = 5.0\text{V}$.

Table 1. V_{TEMP} Temperature Sensor Output Voltage vs Die Temperature Conversion Table⁽¹⁾ (continued)

| Die Temp., °C | V_{TEMP} , Analog Output Voltage, mV | |
|------------------|--|----------------------------------|
| | $T_{TRIP} = 125 \text{ or } 120^{\circ}\text{C}$ | $T_{TRIP} = 105^{\circ}\text{C}$ |
| -11 | 2232 | 1674 |
| -10 | 2222 | 1667 |
| -9 | 2212 | 1659 |
| -8 | 2202 | 1652 |
| -7 | 2192 | 1644 |
| -6 | 2182 | 1637 |
| -5 | 2171 | 1629 |
| -4 | 2161 | 1621 |
| -3 | 2151 | 1614 |
| -2 | 2141 | 1606 |
| -1 | 2131 | 1599 |
| 0 | 2121 | 1591 |
| 1 | 2111 | 1583 |
| 2 | 2101 | 1576 |
| 3 | 2090 | 1568 |
| 4 | 2080 | 1561 |
| 5 | 2070 | 1553 |
| 6 | 2060 | 1545 |
| 7 | 2050 | 1538 |
| 8 | 2040 | 1530 |
| 9 | 2029 | 1522 |
| 10 | 2019 | 1515 |
| 11 | 2009 | 1507 |
| 12 | 1999 | 1499 |
| 13 | 1989 | 1492 |
| 14 | 1978 | 1484 |
| 15 | 1968 | 1477 |
| 16 | 1958 | 1469 |
| 17 | 1948 | 1461 |
| 18 | 1938 | 1454 |
| 19 | 1927 | 1446 |
| 20 | 1917 | 1438 |
| 21 | 1907 | 1431 |
| 22 | 1897 | 1423 |
| 23 | 1886 | 1415 |
| 24 | 1876 | 1407 |
| 25 | 1866 | 1400 |
| 26 | 1856 | 1392 |
| 27 | 1845 | 1384 |
| 28 | 1835 | 1377 |
| 29 | 1825 | 1369 |
| 30 | 1815 | 1361 |
| 31 | 1804 | 1354 |
| 32 | 1794 | 1346 |
| 33 | 1784 | 1338 |
| 34 | 1774 | 1331 |

Table 1. V_{TEMP} Temperature Sensor Output Voltage vs Die Temperature Conversion Table⁽¹⁾ (continued)

| Die Temp., °C | V_{TEMP} , Analog Output Voltage, mV | |
|------------------|--|----------------------------------|
| | $T_{TRIP} = 125 \text{ or } 120^{\circ}\text{C}$ | $T_{TRIP} = 105^{\circ}\text{C}$ |
| 35 | 1763 | 1323 |
| 36 | 1753 | 1315 |
| 37 | 1743 | 1307 |
| 38 | 1732 | 1300 |
| 39 | 1722 | 1292 |
| 40 | 1712 | 1284 |
| 41 | 1701 | 1276 |
| 42 | 1691 | 1269 |
| 43 | 1681 | 1261 |
| 44 | 1670 | 1253 |
| 45 | 1660 | 1245 |
| 46 | 1650 | 1238 |
| 47 | 1639 | 1230 |
| 48 | 1629 | 1222 |
| 49 | 1619 | 1214 |
| 50 | 1608 | 1207 |
| 51 | 1598 | 1199 |
| 52 | 1588 | 1191 |
| 53 | 1577 | 1183 |
| 54 | 1567 | 1176 |
| 55 | 1557 | 1168 |
| 56 | 1546 | 1160 |
| 57 | 1536 | 1152 |
| 58 | 1525 | 1144 |
| 59 | 1515 | 1137 |
| 60 | 1505 | 1129 |
| 61 | 1494 | 1121 |
| 62 | 1484 | 1113 |
| 63 | 1473 | 1105 |
| 64 | 1463 | 1098 |
| 65 | 1453 | 1090 |
| 66 | 1442 | 1082 |
| 67 | 1432 | 1074 |
| 68 | 1421 | 1066 |
| 69 | 1411 | 1059 |
| 70 | 1400 | 1051 |
| 71 | 1390 | 1043 |
| 72 | 1380 | 1035 |
| 73 | 1369 | 1027 |
| 74 | 1359 | 1019 |
| 75 | 1348 | 1012 |
| 76 | 1338 | 1004 |
| 77 | 1327 | 996 |
| 78 | 1317 | 988 |
| 79 | 1306 | 980 |
| 80 | 1296 | 972 |

Table 1. V_{TEMP} Temperature Sensor Output Voltage vs Die Temperature Conversion Table⁽¹⁾ (continued)

| Die Temp., °C | V_{TEMP} , Analog Output Voltage, mV | |
|------------------|--|--------------------------------|
| | $T_{TRIP} = 125 \text{ or } 120^\circ\text{C}$ | $T_{TRIP} = 105^\circ\text{C}$ |
| 81 | 1285 | 964 |
| 82 | 1275 | 957 |
| 83 | 1264 | 949 |
| 84 | 1254 | 941 |
| 85 | 1243 | 933 |
| 86 | 1233 | 925 |
| 87 | 1222 | 917 |
| 88 | 1212 | 909 |
| 89 | 1201 | 901 |
| 90 | 1191 | 894 |
| 91 | 1180 | 886 |
| 92 | 1170 | 878 |
| 93 | 1159 | 870 |
| 94 | 1149 | 862 |
| 95 | 1138 | 854 |
| 96 | 1128 | 846 |
| 97 | 1117 | 838 |
| 98 | 1106 | 830 |
| 99 | 1096 | 822 |
| 100 | 1085 | 814 |
| 101 | 1075 | 807 |
| 102 | 1064 | 799 |
| 103 | 1054 | 791 |
| 104 | 1043 | 783 |
| 105 | 1032 | 775 |
| 106 | 1022 | 767 |
| 107 | 1011 | 759 |
| 108 | 1001 | 751 |
| 109 | 990 | 743 |
| 110 | 979 | 735 |
| 111 | 969 | 727 |
| 112 | 958 | 719 |
| 113 | 948 | 711 |
| 114 | 937 | 703 |
| 115 | 926 | 695 |
| 116 | 916 | 687 |
| 117 | 905 | 679 |
| 118 | 894 | 671 |
| 119 | 884 | 663 |
| 120 | 873 | 655 |
| 121 | 862 | 647 |
| 122 | 852 | 639 |
| 123 | 841 | 631 |
| 124 | 831 | 623 |
| 125 | 820 | 615 |
| 126 | 809 | 607 |

Table 1. V_{TEMP} Temperature Sensor Output Voltage vs Die Temperature Conversion Table⁽¹⁾ (continued)

| Die Temp., °C | V _{TEMP} , Analog Output Voltage, mV | |
|------------------|---|---------------------------|
| | T _{TRIP} = 125 or 120°C | T _{TRIP} = 105°C |
| 127 | 798 | 599 |
| 128 | 788 | 591 |
| 129 | 777 | 583 |
| 130 | 766 | 575 |
| 131 | 756 | 567 |
| 132 | 745 | 559 |
| 133 | 734 | 551 |
| 134 | 724 | 543 |
| 135 | 713 | 535 |
| 136 | 702 | 527 |
| 137 | 691 | 519 |
| 138 | 681 | 511 |
| 139 | 670 | 503 |
| 140 | 659 | 495 |
| 141 | 649 | 487 |
| 142 | 638 | 479 |
| 143 | 627 | 471 |
| 144 | 616 | 463 |
| 145 | 606 | 455 |
| 146 | 595 | 447 |
| 147 | 584 | 438 |
| 148 | 573 | 430 |
| 149 | 562 | 422 |
| 150 | 552 | 414 |

V_{TEMP} vs DIE TEMPERATURE APPROXIMATIONS

The SM72480's V_{TEMP} analog temperature output is very linear. The Conversion Table above and the equation in [The Second-Order Equation \(Parabolic\)](#) represent the most accurate typical performance of the V_{TEMP} voltage output vs Temperature.

The Second-Order Equation (Parabolic)

The data from the Conversion Table, or the equation below, when plotted, has an umbrella-shaped parabolic curve. V_{TEMP} is in mV.

$$\begin{aligned}
 V_{(TEMP=120 \text{ or } 125)} &= 1814.6 - 10.270 \times (T_{DIE} - 30^{\circ}\text{C}) - 2.12\text{e-}3 \times (T_{DIE} - 30^{\circ}\text{C})^2 \\
 V_{(TEMP=105)} &= 1361.4 - 7.701 \times (T_{DIE} - 30^{\circ}\text{C}) - 1.60\text{e-}3 \times (T_{DIE} - 30^{\circ}\text{C})^2
 \end{aligned}
 \tag{1}$$

The First-Order Approximation (Linear)

For a quicker approximation, although less accurate than the second-order, over the full operating temperature range the linear formula below can be used. Using this formula, with the constant and slope in the following set of equations, the best-fit V_{TEMP} vs Die Temperature performance can be calculated with an approximation error less than 18 mV. V_{TEMP} is in mV.

$$\begin{aligned}
 V_{(TEMP=120 \text{ or } 125)} &= 2119 - 10.36 \times T_{DIE} \\
 V_{(TEMP=105)} &= 1590 - 7.77 \times T_{DIE}
 \end{aligned}
 \tag{2}$$

First-Order Approximation (Linear) over Small Temperature Range

For a linear approximation, a line can easily be calculated over the desired temperature range from the Conversion Table using the two-point equation:

$$V - V_1 = \left(\frac{V_2 - V_1}{T_2 - T_1} \right) \times (T - T_1) \quad (3)$$

Where V is in mV, T is in $^{\circ}\text{C}$, T_1 and V_1 are the coordinates of the lowest temperature, T_2 and V_2 are the coordinates of the highest temperature.

$$V - 2396 \text{ mV} = (-12.8 \text{ mV}/^{\circ}\text{C}) \times (T - 20^{\circ}\text{C}) \quad (4)$$

$$V = (-12.8 \text{ mV}/^{\circ}\text{C}) \times (T - 20^{\circ}\text{C}) + 2396 \text{ mV} \quad (5)$$

Using this method of linear approximation, the transfer function can be approximated for one or more temperature ranges of interest.

OVERTEMP and $\overline{\text{OVERTEMP}}$ Digital Outputs

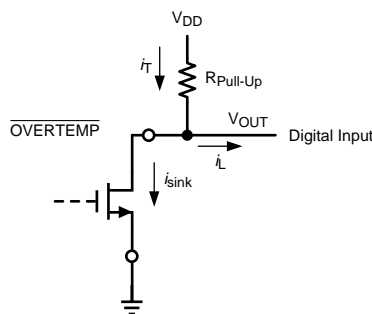
The OVERTEMP Active High, Push-Pull Output and the $\overline{\text{OVERTEMP}}$ Active Low, Open-Drain Output both assert at the same time whenever the Die Temperature reaches the factory preset Temperature Trip Point. They also assert simultaneously whenever the TRIP TEST pin is set high. Both outputs de-assert when the die temperature goes below the Temperature Trip Point - Hysteresis. These two types of digital outputs enable the user the flexibility to choose the type of output that is most suitable for his design.

Either the OVERTEMP or the $\overline{\text{OVERTEMP}}$ Digital Output pins can be left open if not used.

$\overline{\text{OVERTEMP}}$ OPEN-DRAIN DIGITAL OUTPUT

The $\overline{\text{OVERTEMP}}$ Active Low, Open-Drain Digital Output, if used, requires a pull-up resistor between this pin and V_{DD} . The following section shows how to determine the pull-up resistor value.

Figure 9. Determining the Pull-up Resistor Value



The Pull-up resistor value is calculated at the condition of maximum total current, i_T , through the resistor. The total current is:

$$i_T = i_L + i_{\text{sink}}$$

where

- i_T is the maximum total current through the Pull-up Resistor at V_{OL} .
- i_L is the load current, which is very low for typical digital inputs.
- V_{OUT} is the Voltage at the $\overline{\text{OVERTEMP}}$ pin. Use V_{OL} for calculating the Pull-up resistor.
- $V_{DD(\text{Max})}$ is the maximum power supply voltage to be used in the customer's system.

The pull-up resistor maximum value can be found by using the following formula:

$$R_{\text{pull-up}} = \frac{V_{DD(\text{Max})} - V_{OL}}{i_T} \quad (7)$$

EXAMPLE CALCULATION

Suppose we have, for our example, a V_{DD} of $3.3 \text{ V} \pm 0.3 \text{ V}$, a CMOS digital input as a load, a V_{OL} of 0.2 V .

1. We see that for V_{OL} of 0.2 V the electrical specification for $\overline{OVERTEMP}$ shows a maximum i_{sink} of 385 μA .
2. Let $i_L = 1 \mu A$, then i_T is about 386 μA max. If we select 35 μA as the current limit then i_T for the calculation becomes 35 μA
3. We notice that $V_{DD(Max)}$ is $3.3V + 0.3V = 3.6V$ and then calculate the pull-up resistor as $R_{Pull-up} = (3.6 - 0.2)/35 \mu A = 97k$
4. Based on this calculated value, we select the closest resistor value in the tolerance family we are using.

In our example, if we are using 5% resistor values, then the next closest value is 100 k Ω .

NOISE IMMUNITY

The SM72480 is virtually immune from false triggers on the $OVERTEMP$ and $\overline{OVERTEMP}$ digital outputs due to noise on the power supply. Test have been conducted showing that, with the die temperature within 0.5°C of the temperature trip point, and the severe test of a 3 Vpp square wave "noise" signal injected on the V_{DD} line, over the V_{DD} range of 2V to 5V, there were no false triggers.

TRIP TEST Digital Input

The TRIP TEST pin simply provides a means to test the $OVERTEMP$ and $\overline{OVERTEMP}$ digital outputs electronically by causing them to assert, at any operating temperature, as a result of forcing the TRIP TEST pin high.

When the TRIP TEST pin is pulled high the V_{TEMP} pin will be at the V_{TRIP} voltage.

If not used, the TRIP TEST pin may either be left open or grounded.

V_{TEMP} Analog Temperature Sensor Output

The V_{TEMP} push-pull output provides the ability to sink and source significant current. This is beneficial when, for example, driving dynamic loads like an input stage on an analog-to-digital converter (ADC). In these applications the source current is required to quickly charge the input capacitor of the ADC. See the [Applications Circuits](#) section for more discussion of this topic. The SM72480 is ideal for this and other applications which require strong source or sink current.

NOISE CONSIDERATIONS

The SM72480's supply-noise rejection (the ratio of the AC signal on V_{TEMP} to the AC signal on V_{DD}) was measured during bench tests. It's typical attenuation is shown in the [Typical Performance Characteristics](#) section. A load capacitor on the output can help to filter noise.

For operation in very noisy environments, some bypass capacitance should be present on the supply within approximately 2 inches of the SM72480.

CAPACITIVE LOADS

The V_{TEMP} Output handles capacitive loading well. In an extremely noisy environment, or when driving a switched sampling input on an ADC, it may be necessary to add some filtering to minimize noise coupling. Without any precautions, the V_{TEMP} can drive a capacitive load less than or equal to 1100 pF as shown in [Figure 10](#). For capacitive loads greater than 1100 pF, a series resistor is required on the output, as shown in [Figure 11](#), to maintain stable conditions.

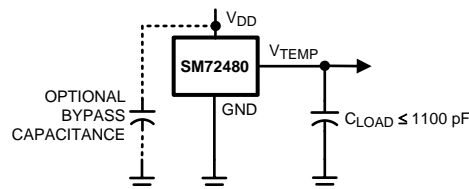


Figure 10. SM72480 No Decoupling Required for Capacitive Loads Less than 1100 pF.

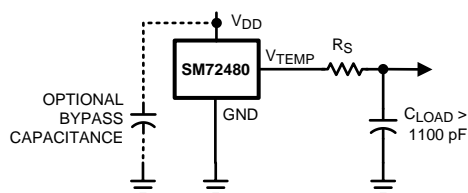


Figure 11.

| C_{LOAD} | Minimum R_S |
|------------------|----------------|
| 1.1 nF to 99 nF | 3 k Ω |
| 100 nF to 999 nF | 1.5 k Ω |
| 1 μ F | 800 Ω |

VOLTAGE SHIFT

The SM72480 is very linear over temperature and supply voltage range. Due to the intrinsic behavior of an NMOS/PMOS rail-to-rail buffer, a slight shift in the output can occur when the supply voltage is ramped over the operating range of the device. The location of the shift is determined by the relative levels of V_{DD} and V_{TEMP} . The shift typically occurs when $V_{DD} - V_{TEMP} = 1.0V$.

This slight shift (a few millivolts) takes place over a wide change (approximately 200 mV) in V_{DD} or V_{TEMP} . Since the shift takes place over a wide temperature change of 5°C to 20°C, V_{TEMP} is always monotonic. The accuracy specifications in the [Electrical Characteristics](#) table already includes this possible shift.

Mounting and Temperature Conductivity

The SM72480 can be applied easily in the same way as other integrated-circuit temperature sensors. It can be glued or cemented to a surface.

The best thermal conductivity between the device and the PCB is achieved by soldering the DAP of the package to the thermal pad on the PCB. The temperatures of the lands and traces to the other leads of the SM72480 will also affect the temperature reading.

Alternatively, the SM72480 can be mounted inside a sealed-end metal tube, and can then be dipped into a bath or screwed into a threaded hole in a tank. As with any IC, the SM72480 and accompanying wiring and circuits must be kept insulated and dry, to avoid leakage and corrosion. This is especially true if the circuit may operate at cold temperatures where condensation can occur. If moisture creates a short circuit from the V_{TEMP} output to ground or V_{DD} , the V_{TEMP} output from the SM72480 will not be correct. Printed-circuit coatings are often used to ensure that moisture cannot corrode the leads or circuit traces.

The thermal resistance junction-to-ambient (θ_{JA}) is the parameter used to calculate the rise of a device junction temperature due to its power dissipation. The equation used to calculate the rise in the SM72480's die temperature is

$$T_J = T_A + \theta_{JA} [(V_{DD} I_Q) + (V_{DD} - V_{TEMP}) I_L] \quad (8)$$

where T_A is the ambient temperature, I_Q is the quiescent current, I_L is the load current on the output, and V_O is the output voltage. For example, in an application where $T_A = 30^\circ\text{C}$, $V_{DD} = 5\text{ V}$, $I_{DD} = 9\text{ }\mu\text{A}$, Gain 4, $V_{TEMP} = 2231\text{ mV}$, and $I_L = 2\text{ }\mu\text{A}$, the junction temperature would be 30.021°C , showing a self-heating error of only 0.021°C . Since the SM72480's junction temperature is the actual temperature being measured, care should be taken to minimize the load current that the V_{TEMP} output is required to drive. If The $\overline{OVERTEMP}$ output is used with a 100 k pull-up resistor, and this output is asserted (low), then for this example the additional contribution is $[(152^\circ\text{C/W}) \times (5\text{V})^2 / 100\text{k}] = 0.038^\circ\text{C}$ for a total self-heating error of 0.059°C . [Table 2](#) shows the thermal resistance of the SM72480.

Table 2. SM72480 Thermal Resistance

| Device Number | Package Number | Thermal Resistance (θ_{JA}) |
|---------------|----------------|--------------------------------------|
| SM72480SD | SDB06A | 152° C/W |

Applications Circuits

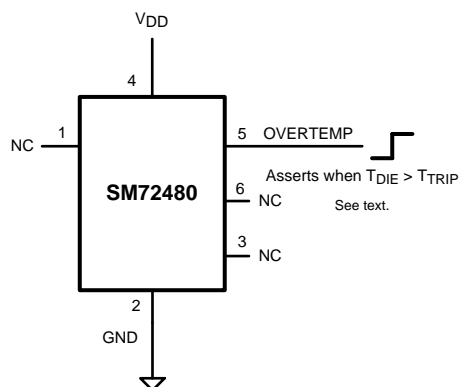


Figure 12. Temperature Switch Using Push-Pull Output

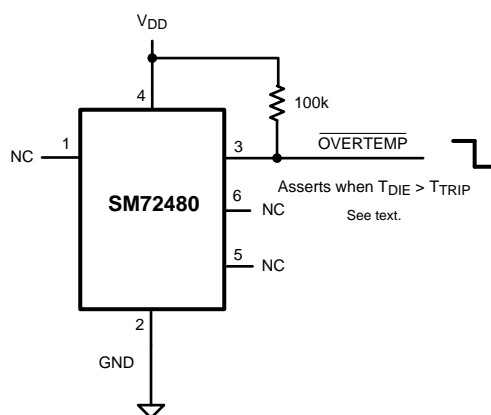


Figure 13. Temperature Switch Using Open-Drain Output

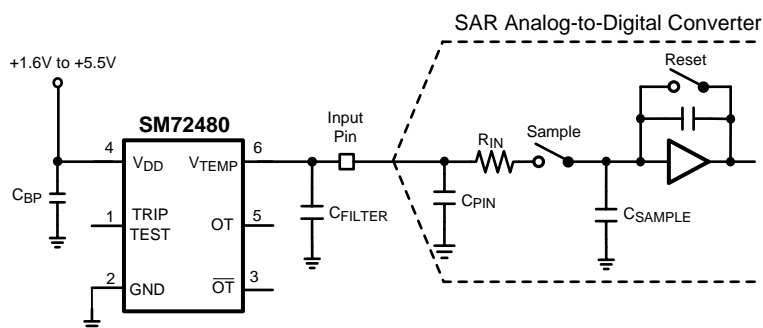


Figure 14. Suggested Connection to a Sampling Analog-to-Digital Converter Input Stage

Most CMOS ADCs found in microcontrollers and ASICs have a sampled data comparator input structure. When the ADC charges the sampling cap, it requires instantaneous charge from the output of the analog source such as the SM72480 temperature sensor and many op amps. This requirement is easily accommodated by the addition of a capacitor (C_{FILTER}). The size of C_{FILTER} depends on the size of the sampling capacitor and the sampling frequency. Since not all ADCs have identical input stages, the charge requirements will vary. This general ADC application is shown as an example only.

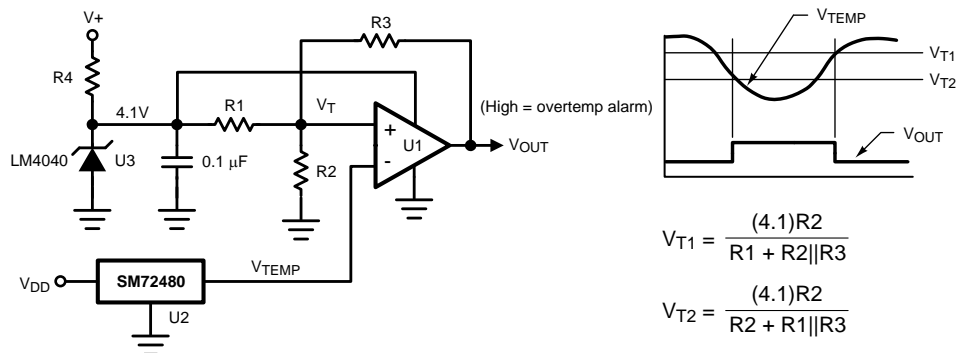


Figure 15. Celsius Temperature Switch

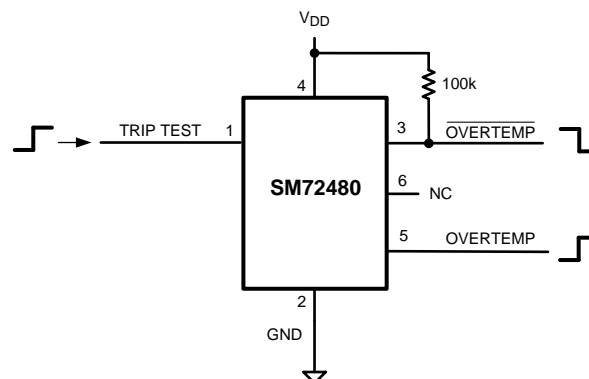


Figure 16. TRIP TEST Digital Output Test Circuit

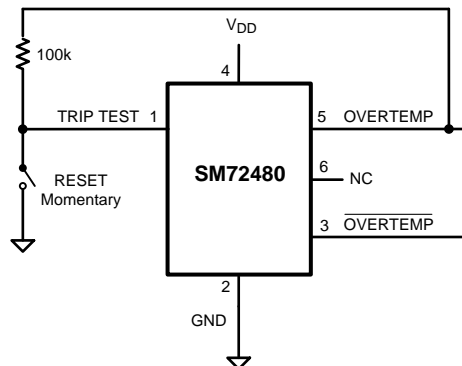


Figure 17. Latch Circuit using OVERTEMP Output

The TRIP TEST pin, normally used to check the operation of the OVERTEMP and $\overline{\text{OVERTEMP}}$ pins, may be used to latch the outputs whenever the temperature exceeds the programmed limit and causes the digital outputs to assert. As shown in the figure, when OVERTEMP goes high the TRIP TEST input is also pulled high and causes OVERTEMP output to latch high and the $\overline{\text{OVERTEMP}}$ output to latch low. The latch can be released by either momentarily pulling the TRIP TEST pin low (GND), or by toggling the power supply to the device. The resistor limits the current out of the OVERTEMP output pin.

REVISION HISTORY

| Changes from Revision B (April 2013) to Revision C | Page |
|--|--------------------|
| • Changed layout of National Data Sheet to TI format | 19 |

PACKAGING INFORMATION

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead finish/ Ball material (6) | MSL Peak Temp (3) | Op Temp (°C) | Device Marking (4/5) | Samples |
|---------------------|---------------|--------------|--------------------|------|----------------|-----------------|--------------------------------------|----------------------|--------------|-------------------------|-------------------------|
| SM72480SD-105/NOPB | ACTIVE | WSO | NGF | 6 | 1000 | RoHS & Green | SN | Level-1-260C-UNLIM | -50 to 150 | 701 | Samples |
| SM72480SD-120/NOPB | ACTIVE | WSO | NGF | 6 | 1000 | RoHS & Green | SN | Level-1-260C-UNLIM | -50 to 150 | S80 | Samples |
| SM72480SD-125/NOPB | ACTIVE | WSO | NGF | 6 | 1000 | RoHS & Green | SN | Level-1-260C-UNLIM | -50 to 150 | 299 | Samples |
| SM72480SDE-105/NOPB | NRND | WSO | NGF | 6 | 250 | RoHS & Green | SN | Level-1-260C-UNLIM | -50 to 150 | 701 | |
| SM72480SDE-120/NOPB | NRND | WSO | NGF | 6 | 250 | RoHS & Green | SN | Level-1-260C-UNLIM | -50 to 150 | S80 | |
| SM72480SDE-125/NOPB | NRND | WSO | NGF | 6 | 250 | RoHS & Green | SN | Level-1-260C-UNLIM | -50 to 150 | 299 | |
| SM72480SDX-105/NOPB | NRND | WSO | NGF | 6 | 4500 | RoHS & Green | SN | Level-1-260C-UNLIM | -50 to 150 | 701 | |
| SM72480SDX-120/NOPB | NRND | WSO | NGF | 6 | 4500 | RoHS & Green | SN | Level-1-260C-UNLIM | -50 to 150 | S80 | |
| SM72480SDX-125/NOPB | NRND | WSO | NGF | 6 | 4500 | RoHS & Green | SN | Level-1-260C-UNLIM | -50 to 150 | 299 | |

(1) The marketing status values are defined as follows:

ACTIVE: Product device recommended for new designs.

LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

PREVIEW: Device has been announced but is not in production. Samples may or may not be available.

OBSOLETE: TI has discontinued the production of the device.

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".

RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.

Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

⁽⁶⁾ Lead finish/Ball material - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

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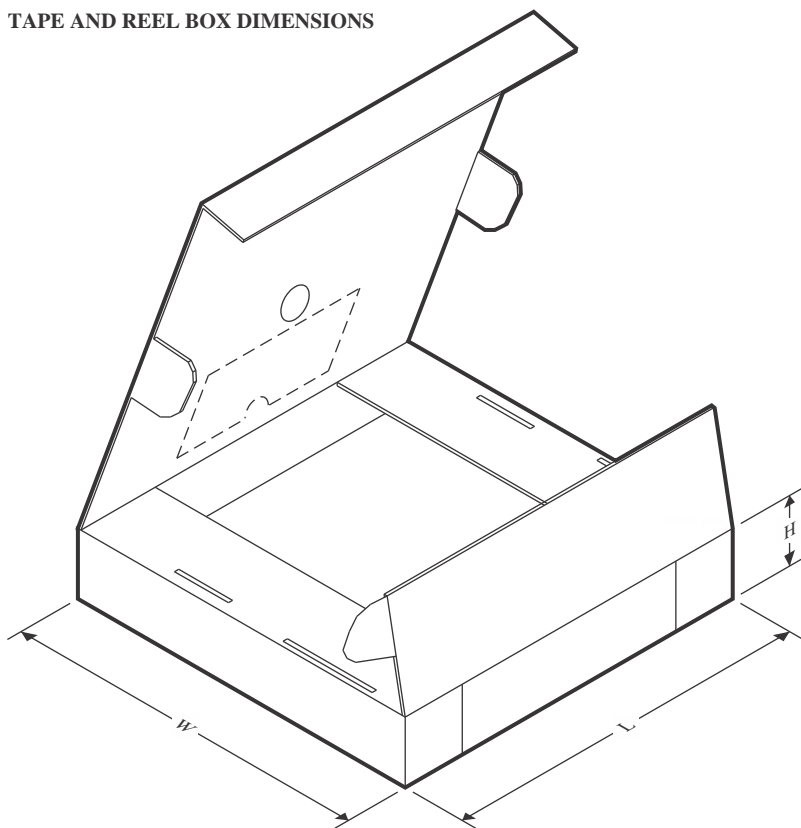
TAPE AND REEL INFORMATION



*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|---------------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| SM72480SD-105/NOPB | WSO | NGF | 6 | 1000 | 178.0 | 12.4 | 2.8 | 2.5 | 1.0 | 8.0 | 12.0 | Q1 |
| SM72480SD-120/NOPB | WSO | NGF | 6 | 1000 | 178.0 | 12.4 | 2.8 | 2.5 | 1.0 | 8.0 | 12.0 | Q1 |
| SM72480SD-125/NOPB | WSO | NGF | 6 | 1000 | 178.0 | 12.4 | 2.8 | 2.5 | 1.0 | 8.0 | 12.0 | Q1 |
| SM72480SDE-105/NOPB | WSO | NGF | 6 | 250 | 178.0 | 12.4 | 2.8 | 2.5 | 1.0 | 8.0 | 12.0 | Q1 |
| SM72480SDE-120/NOPB | WSO | NGF | 6 | 250 | 178.0 | 12.4 | 2.8 | 2.5 | 1.0 | 8.0 | 12.0 | Q1 |
| SM72480SDE-125/NOPB | WSO | NGF | 6 | 250 | 178.0 | 12.4 | 2.8 | 2.5 | 1.0 | 8.0 | 12.0 | Q1 |
| SM72480SDX-105/NOPB | WSO | NGF | 6 | 4500 | 330.0 | 12.4 | 2.8 | 2.5 | 1.0 | 8.0 | 12.0 | Q1 |
| SM72480SDX-120/NOPB | WSO | NGF | 6 | 4500 | 330.0 | 12.4 | 2.8 | 2.5 | 1.0 | 8.0 | 12.0 | Q1 |
| SM72480SDX-125/NOPB | WSO | NGF | 6 | 4500 | 330.0 | 12.4 | 2.8 | 2.5 | 1.0 | 8.0 | 12.0 | Q1 |

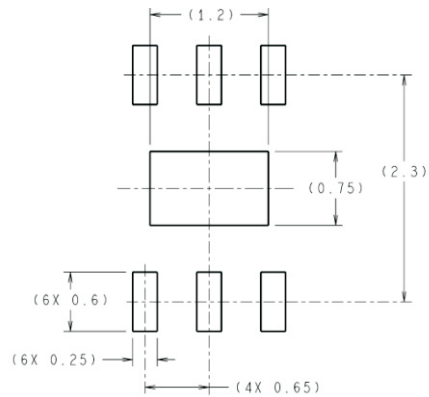
TAPE AND REEL BOX DIMENSIONS



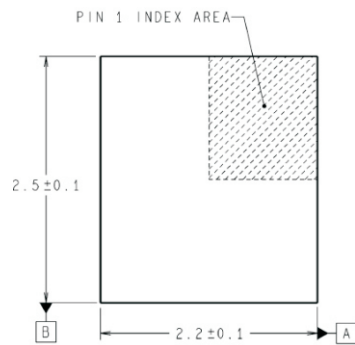
*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|---------------------|--------------|-----------------|------|------|-------------|------------|-------------|
| SM72480SD-105/NOPB | WSN | NGF | 6 | 1000 | 208.0 | 191.0 | 35.0 |
| SM72480SD-120/NOPB | WSN | NGF | 6 | 1000 | 208.0 | 191.0 | 35.0 |
| SM72480SD-125/NOPB | WSN | NGF | 6 | 1000 | 208.0 | 191.0 | 35.0 |
| SM72480SDE-105/NOPB | WSN | NGF | 6 | 250 | 208.0 | 191.0 | 35.0 |
| SM72480SDE-120/NOPB | WSN | NGF | 6 | 250 | 208.0 | 191.0 | 35.0 |
| SM72480SDE-125/NOPB | WSN | NGF | 6 | 250 | 208.0 | 191.0 | 35.0 |
| SM72480SDX-105/NOPB | WSN | NGF | 6 | 4500 | 367.0 | 367.0 | 35.0 |
| SM72480SDX-120/NOPB | WSN | NGF | 6 | 4500 | 367.0 | 367.0 | 35.0 |
| SM72480SDX-125/NOPB | WSN | NGF | 6 | 4500 | 367.0 | 367.0 | 35.0 |

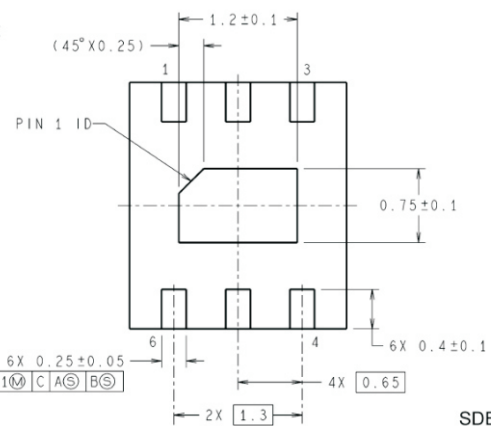
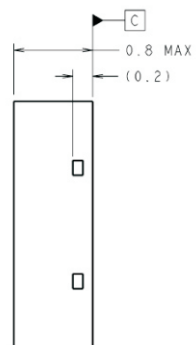
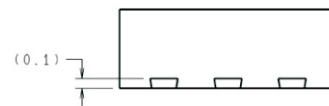
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