# ANALOG DEVICES

# Airflow and Temperature Sensor

# TMP12*

## FEATURES
**Temperature Sensor Includes 100 Ω Heater**
**Heater Provides Power IC Emulation**
**Accuracy ±3°C typ. from −40°C to +100°C**
**Operation to +150°C**
**5 mV/°C Internal Scale-Factor**
**Resistor Programmable Temperature Setpoints**
**20 mA Open-Collector Setpoint Outputs**
**Programmable Thermal Hysteresis**
**Internal 2.5 V Reference**
**Single 5 V Operation**
**400 µA Quiescent Current (Heater OFF)**
**Minimal External Components**

## APPLICATIONS
**System Airflow Sensor**
**Equipment Over-Temperature Sensor**
**Over-Temperature Protection**
**Power Supply Thermal Sensor**
**Low-Cost Fan Controller**

## FUNCTIONAL BLOCK DIAGRAM



## PINOUTS
### DIP And SO



## GENERAL DESCRIPTION

The TMP12 is a silicon-based airflow and temperature sensor designed to be placed in the same airstream as heat generating components that require cooling. Fan cooling may be required continuously, or during peak power demands, e.g. for a power supply, and if the cooling systems fails, system reliability and/or safety may be impaired. By monitoring temperature while emulating a power IC, the TMP12 can provide a warning of cooling system failure.
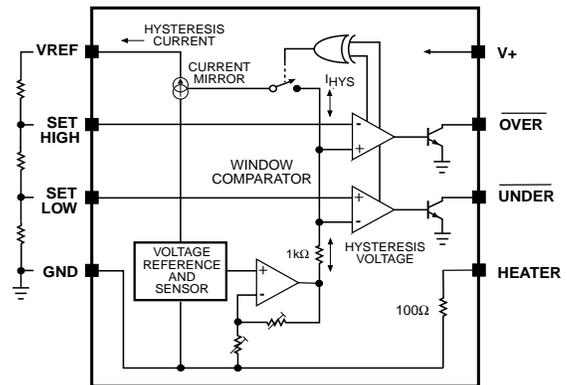
The TMP12 generates an internal voltage that is linearly proportional to Celsius (Centigrade) temperature, nominally +5 mV/°C. The linearized output is compared with voltages from an external resistive divider connected to the TMP12's 2.5 V precision reference. The divider sets up one or two reference voltages, as required by the user, providing one or two temperature setpoints. Comparator outputs are open-collector transistors able to sink over 20 mA. There is an on-board hysteresis generator provided to speed up the temperature-setpoint output transitions, this also reduces erratic output transitions in noisy environments. Hysteresis is programmed by the external resistor chain and is determined by the total current drawn from the 2.5 V reference. The TMP12 airflow sensor also incorporates a precision, low temperature coefficient 100 Ω heater resistor that may be connected directly to an external 5 V supply. When the heater is activated it raises the die temperature in
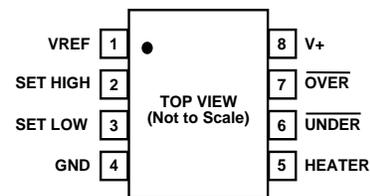
the DIP package approximately 20°C above ambient (in still air). The purpose of the heater in the TMP12 is to emulate a power IC, such as a regulator or Pentium CPU which has a high internal dissipation.

When subjected to a fast airflow, the package and die temperatures of the power device and the TMP12 (if located in the same airstream) will be reduced by an amount proportional to the rate of airflow. The internal temperature rise of the TMP12 may be reduced by placing a resistor in series with the heater, or reducing the heater voltage.

The TMP12 is intended for single 5 V supply operation, but will operate on a 12 V supply. The heater is designed to operate from 5 V only. Specified temperature range is from −40°C to +125°C, operation extends to +150°C at 5 V with reduced accuracy.

The TMP12 is available in 8-pin plastic DIP and SO packages.

**\*Protected by U.S. Patent No. 5,195,827.**

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# TMP12–SPECIFICATIONS ($V_S$ = +5 V, $-40°C \leq T_A \leq +125°C$ unless otherwise noted.)

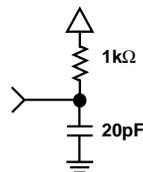| Parameter | Symbol | Conditions | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| **ACCURACY** | | | | | | |
| Accuracy (High, Low Setpoints) | | $T_A$ = +25°C | | ±2 | ±3 | °C |
| Accuracy (High, Low Setpoints) | | $T_A$ = −40°C to +100°C | | ±3 | ±5 | °C |
| Internal Scale Factor | | $T_A$ = −40°C to +100°C | +4.9 | +5 | +5.1 | mV/°C |
| Power Supply Rejection Ratio | PSRR | 4.5 V ≤ +$V_S$ ≤ 5.5 V | | 0.1 | 0.5 | °C/V |
| Linearity | | $T_A$ = −40°C to +125°C | | 0.5 | | °C |
| Repeatability | | $T_A$ = −40°C to +125°C | | 0.3 | | °C |
| Long Term Stability | | $T_A$ = +125°C for 1 k Hrs | | 0.3 | | °C |
| **SETPOINT INPUTS** | | | | | | |
| Offset Voltage | $V_{OS}$ | | | 0.25 | | mV |
| Output Voltage Drift | $TCV_{OS}$ | | | 3 | | μV/°C |
| Input Bias Current | $I_B$ | | | 25 | 100 | nA |
| **VREF OUTPUT** | | | | | | |
| Output Voltage | VREF | $T_A$ = +25°C, No Load | 2.49 | 2.50 | 2.51 | V |
| Output Voltage | VREF | $T_A$ = −40°C to +100°C, No Load | | 2.5 ±0.015 | | V |
| Output Drift | $TC_{VREF}$ | | | −10 | | ppm/°C |
| Output Current, Zero Hysteresis | $I_{VREF}$ | | | 7 | | μA |
| Hysteresis Current Scale Factor | $SF_{HYS}$ | | | 5 | | μA/°C |
| **OPEN-COLLECTOR OUTPUTS** | | | | | | |
| Output Low Voltage | $V_{OL}$ | $I_{SINK}$ = 1.6 mA | | 0.25 | 0.4 | V |
| Output Low Voltage | $V_{OL}$ | $I_{SINK}$ = 20 mA | | 0.6 | | V |
| Output Leakage Current | $I_{OH}$ | $V_S$ = 12 V | | 1 | 100 | μA |
| Fall Time | $t_{HL}$ | See Test Load | | 40 | | ns |
| **HEATER** | | | | | | |
| Resistance | $R_H$ | $T_A$ = +25°C | 97 | 100 | 103 | Ω |
| Temperature Coefficient | | $T_A$ = −40°C to +125°C | | 100 | | ppm/°C |
| Maximum Continuous Current | $I_H$ | See Note 1 | | | 60 | mA |
| **POWER SUPPLY** | | | | | | |
| Supply Range | +$V_S$ | | 4.5 | | 5.5 | V |
| Supply Current | $I_{SY}$ | Unloaded at +5 V | | 400 | 600 | μA |
| Supply Current | $I_{SY}$ | Unloaded at +12 V[2] | | 450 | | μA |

NOTES

[1]Guaranteed but not tested.

[2]TMP12 is specified for operation from a 5 V supply. However, operation is allowed up to a 12 V supply, but not tested at 12 V. Maximum heater supply is 6 V.

Specifications subject to change without notice.

**TEST LOAD**



−2−

## WAFER TEST LIMITS ($V_S$ = +5 V, GND = 0 V, $T_A$ = +25°C, unless otherwise noted.)

| Parameter | Symbol | Conditions | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| ACCURACY | | | | | | |
| Accuracy (High, Low Setpoints) | | $T_A$ = +25°C | | | ±3 | °C |
| Internal Scale Factor | | $T_A$ = +25°C | +4.9 | +5 | +5.1 | mV/°C |
| SETPOINT INPUTS | | | | | | |
| Input Bias Current | $I_B$ | | | | 100 | nA |
| VREF OUTPUT | | | | | | |
| Output Voltage | VREF | $T_A$ = +25°C, No Load | 2.49 | | 2.51 | V |
| OPEN-COLLECTOR OUTPUTS | | | | | | |
| Output Low Voltage | $V_{OL}$ | $I_{SINK}$ = 1.6 mA | | | 0.4 | V |
| Output Leakage Current | $I_{OH}$ | $V_S$ = 12 V | | | 100 | µA |
| HEATER | | | | | | |
| Resistance | $R_H$ | $T_A$ = +25°C | 97 | 100 | 103 | Ω |
| POWER SUPPLY | | | | | | |
| Supply Range | +$V_S$ | | 4.5 | | 5.5 | V |
| Supply Current | $I_{SY}$ | Unloaded at +5 V | | | 600 | µA |

**NOTE**
Electrical tests are performed at wafer probe to the limits shown. Due to variations in assembly methods and normal yield loss, yield after packaging is not guaranteed for standard product dice. Consult factory to negotiate specifications based on dice lot qualification through sample lot assembly and testing.

**DICE CHARACTERISTICS**
Die Size 0.078 × 0.071 inch, 5,538 sq. mils
(1.98 × 1.80 mm, 3.57 sq. mm)
Transistor Count: 105
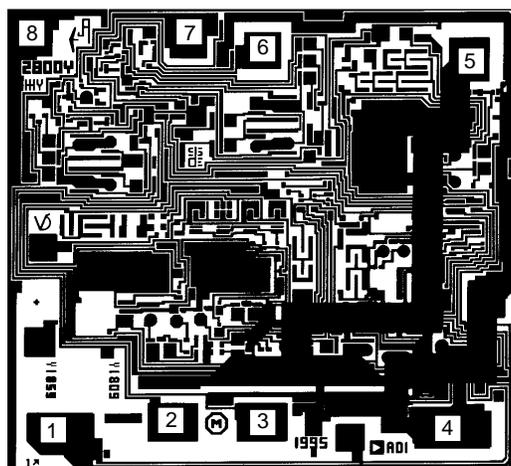


1. **VREF**

2. **SET HIGH INPUT**

3. **SET LOW INPUT**

4. **GND**

5. **HEATER**

6. **UNDER OUTPUT**

7. **OVER OUTPUT**

8. **V+**

For additional DICE ordering information, refer to databook.

# TMP12

**ABSOLUTE MAXIMUM RATINGS***

Supply Voltage. . . . . . . . . . . . . . . . . . . . . . . . −0.3 V to +15 V
Heater Voltage . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . +6 V
Setpoint Input Voltage. . . . . . . . . . . −0.3 V to [(V+) +0.3 V]
Reference Output Current . . . . . . . . . . . . . . . . . . . . . . 2 mA
Open-Collector Output Current . . . . . . . . . . . . . . . . . 50 mA
Open-Collector Output Voltage . . . . . . . . . . . . . . . . . +15 V
Operating Temperature Range . . . . . . . . . . −55°C to +150°C
Dice Junction Temperature . . . . . . . . . . . . . . . . . . . +175°C
Storage Temperature Range . . . . . . . . . . . . −65°C to +160°C
Lead Temperature(Soldering, 60 sec) . . . . . . . . . . . . . +300°C

| Package Type | $\Theta_{JA}$ | $\Theta_{JC}$ | Units |
|---|---|---|---|
| 8-Pin Plastic DIP  (P) | 103[1] | 43 | °C/W |
| 8-Lead SOIC  (S) | 158[2] | 43 | °C/W |

**NOTES**
[1]$\Theta$JA is specified for device in socket (worst case conditions).
[2]$\Theta$JA is specified for device mounted on PCB.

**CAUTION**
1. Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation at or above this specification is not implied. Exposure to the above maximum rating conditions for extended periods may affect device reliability.

2. Digital inputs and outputs are protected, however, permanent damage may occur on unprotected units from high-energy electrostatic fields. Keep units in conductive foam or packaging at all times until ready to use. Use proper antistatic handling procedures.
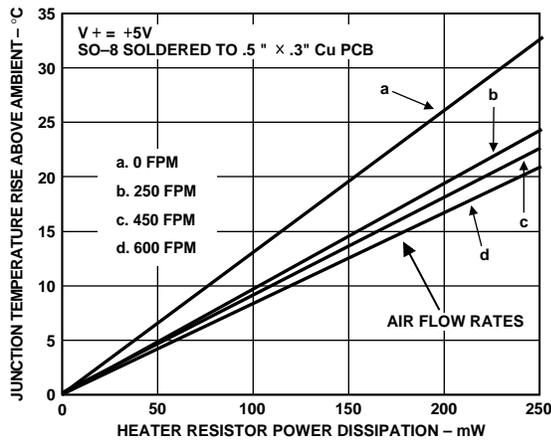
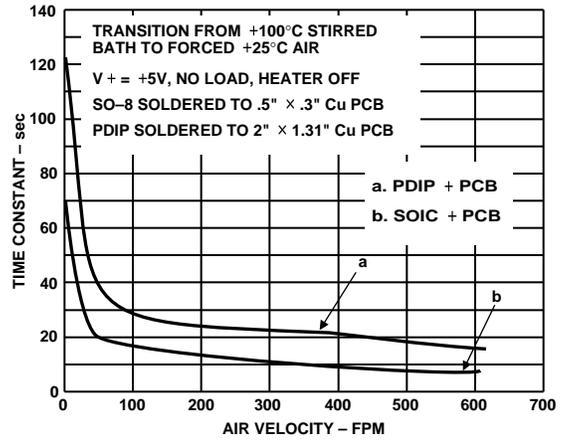**Figure 1. SOIC Junction Temperature Rise vs. Heater Dissipation**

**Figure 2. PDIP Junction Temperature Rise vs. Heater Dissipation**

**Figure 3. Junction Temperature Rise in Still Air**

**Figure 4. Package Thermal Time Constant in Forced Air**

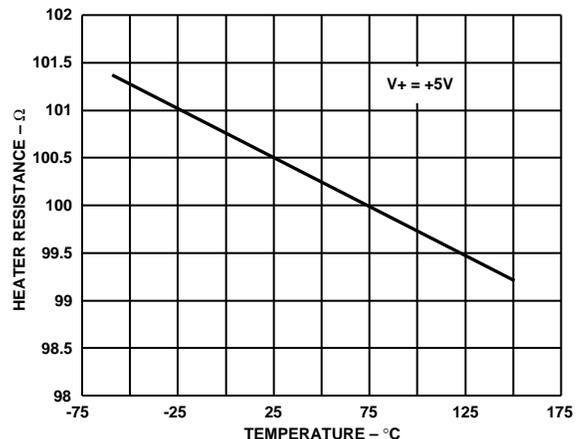**Figure 5. Thermal Response Time in Stirred Oil Bath**

**Figure 6. Heater Resistance vs. Temperature**

# TMP12
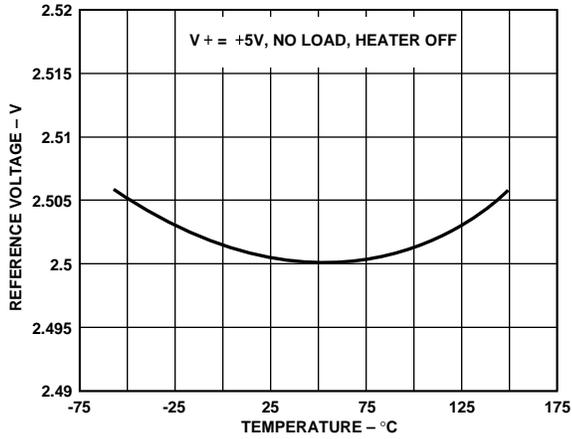


Figure 7. Reference Voltage vs. Temperature



Figure 8. Start-up Voltage vs. Temperature



Figure 9. Supply Current vs. Temperature



Figure 10. Accuracy Error vs. Temperature
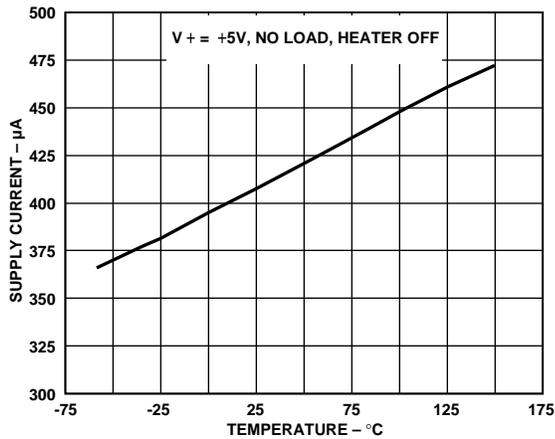


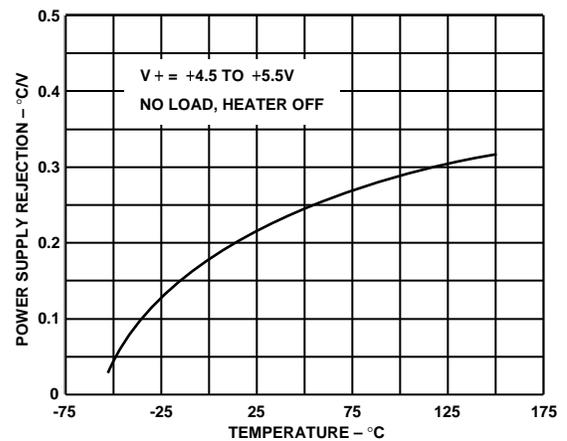Figure 11. Supply Current vs. Supply Voltage



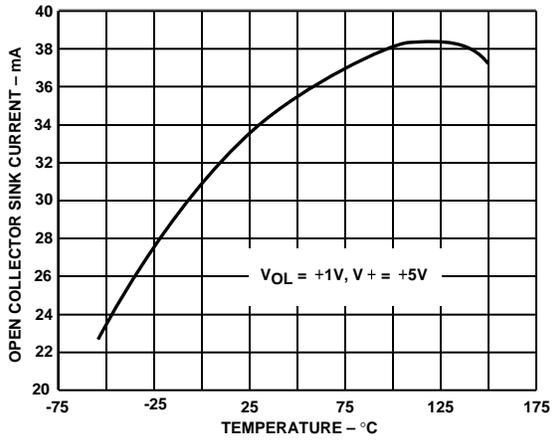Figure 12. VPTAT Power Supply Rejection vs. Temperature

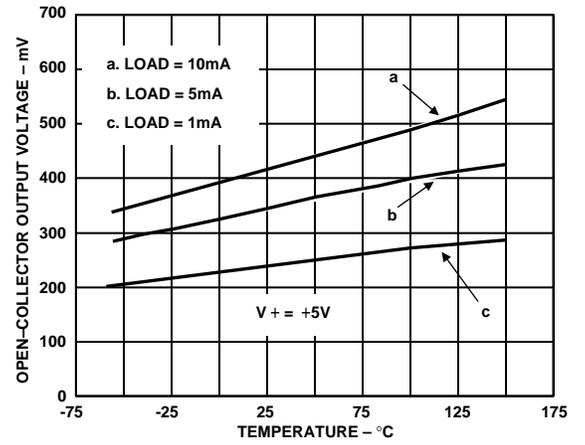Figure 13. Open-Collector Output Sink Current vs. Temperature



Figure 14. Open-Collector Voltage vs. Temperature

**APPLICATIONS INFORMATION**

# TMP12

LOW, deactivating the open-collector output and disabling the hysteresis current buffer output. The scale factor for the programmed hysteresis current is:

$$I = I_{VREF} = 5 \ \mu A/°C + 7 \ \mu A$$

Thus, since VREF = 2.5 V, a reference load resistance of 357 kΩ or greater (output current of 7 μA or less) will produce a temperature setpoint hysteresis of zero degrees. For more details, see the temperature programming discussion below. Larger values of load resistance will only decrease the output current below 7 μA, but will have no effect on the operation of the device. The amount of hysteresis is determined by selecting an appropriate value of load resistance for VREF, as shown below.

## Programming the TMP12

The basic thermal monitoring application only requires a simple three-resistor ladder voltage divider to set the high and low setpoints and the hysteresis. These resistors are programmed in the following sequence:

1. Select the desired hysteresis temperature.

2. Calculate the hysteresis current, $I_{VREF}$

3. Select the desired setpoint temperatures.

4. Calculate the individual resistor divider ladder values needed to develop the desired comparator setpoint voltages at the Set High and Set Low inputs.

The hysteresis current is readily calculated, as shown above. For example, to produce 2 degrees of hysteresis $I_{VREF}$ should be set to 17 μA. Next, the setpoint voltages $V_{SETHIGH}$ and $V_{SETLOW}$ are determined using the VPTAT scale factor of 5 mV/K = 5 mV/(°C + 273.15), which is 1.49 V for +25°C. Finally, the divider resistors are calculated, based on the setpoint voltages.

The setpoint voltages are calculated from the equation:

$$V_{SET} = (T_{SET} + 273.15)(5 \ mV/°C)$$

This equation is used to calculate both the $V_{SETHIGH}$ and the $V_{SETLOW}$ values. A simple 3-resistor network, as shown in Figure 18, determines the setpoints and hysteresis value. The equations used to calculate the resistors are:

$$R1 \ (k\Omega) = (V_{REF} - V_{SETHIGH})/I_{VREF} = (2.5 \ V - V_{SETHIGH})/I_{VREF}$$

$$R2 \ (k\Omega) = (V_{SETHIGH} - V_{SETLOW})/I_{VREF}$$

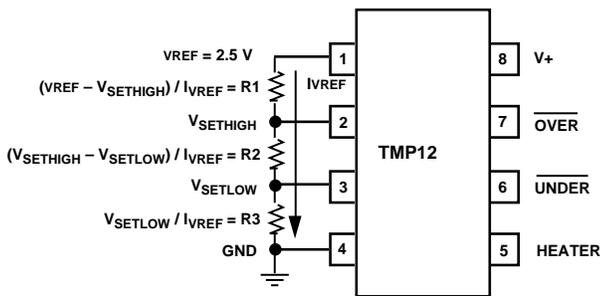$$R3 \ (k\Omega) = V_{SETLOW}/I_{VREF}$$

For example, setting the high setpoint for +80°C, the low setpoint for +55°C, and hysteresis for 3°C produces the following values:

$$I_{HYS} = I_{VREF} = (3°C \times 5 \ \mu A/°C) + 7 \ \mu A = 15 \ \mu A + 7 \ \mu A = 22 \ \mu A$$

$$V_{SETHIGH} = (T_{SETHIGH} + 273.15)(5 \ mV/°C) = (80°C + 273.15)(5 \ mV/°C) = 1.766 \ V$$

$$V_{SETLOW} = (T_{SETLOW} + 273.15)(5 \ mV/°C) = (55°C + 273.15)(5 \ mV/°C) = 1.641 \ V$$

$$R1 \ (k\Omega) = (VREF - V_{SETHIGH})/I_{VREF} = (2.5 \ V - 1.766 \ V)/22 \ \mu A = 33.36 \ k\Omega$$

$$R2 \ (k\Omega) = (V_{SETHIGH} - V_{SETLOW})/I_{VREF} = (1.766 \ V - 1.641 \ V)/22 \ \mu A = 5.682 \ k\Omega$$

$$R3 \ (k\Omega) = V_{SETLOW}/I_{VREF} = (1.641 \ V)/22 \ \mu A = 74.59 \ k\Omega$$

The total of R1 + R2 + R3 is equal to the load resistance needed to draw the desired hysteresis current from the reference, or $I_{VREF}$.

The nomograph of Figure 19 provides an easy method of determining the correct VPTAT voltage for any temperature. Simply locate the desired temperature on the appropriate scale (K, °C or °F) and read the corresponding VPTAT value from the bottom scale.



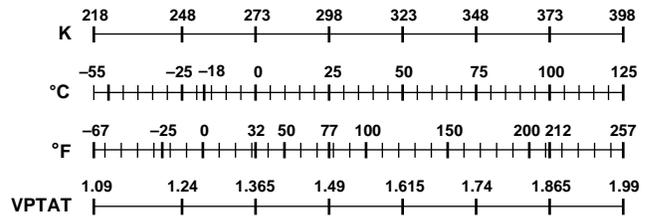Figure 19. Temperature – VPTAT Scale



Figure 18. TMP12 Setpoint Programming

**Measuring the TMP12 Internal Temperature**

As previously mentioned, the TMP12's VPTAT generator represents the chip temperature with a slope of 5 mV/K. In some cases, selecting the setpoints is made easier if the TMP12's internal VPTAT voltage (and therefore the chip temperature) is known. For example, the case temperature of a high power microprocessor can be monitored with a thermistor, thermocouple, or other measurement method. The case temperature can then be correlated with the TMP12's temperature to select the setpoints.

The TMP12's VPTAT voltage is not available externally, so indirect methods must be used. Since the VPTAT voltage is applied to the internal comparators, measuring the voltage at which the digital output changes state will reflect the VPTAT voltage.

A simple method of measuring the TMP12 VPTAT is shown in Figure 20. To measure VPTAT, adjust potentiometer R1 until the LED turns ON. The voltage at Pin 2 of the TMP12 will then match the TMP12's internal VPTAT.



*Figure 20.  Measuring VPTAT with a Potentiometer*

The method described in Figure 20 can be automated by replacing the discrete resistors with a digital potentiometer. The improved circuit, shown in Figure 21, permits the VPTAT voltage to be monitored with a microprocessor or other digital controller. The AD8402-100 provides two 100 kΩ potentiom-

eters which are adjusted to 8-bit resolution via a 3-wire serial interface. The controller simply sweeps the wiper of potentiometer 1 from the A1 terminal to the B1 terminal (digital value = 0), while monitoring the comparator output at Pin 7 of the TMP12. When Pin 7 goes low, the voltage at Pin 2 equals the VPTAT voltage.  This Circuit sweeps Pin 2's voltage from maximum to minimum, so that the TMP12's setpoint o.5 495 428 2.74 Tw
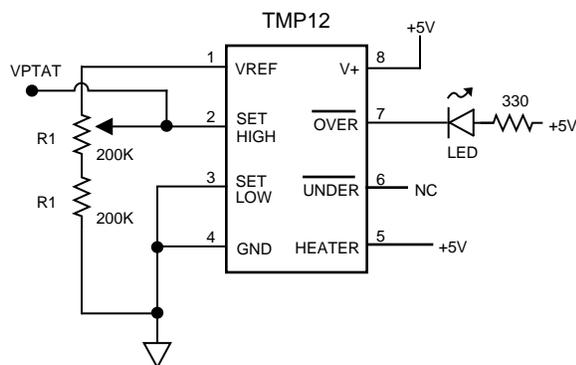
# TMP12

**Understanding Error Sources**

The accuracy of the VPTAT sensor output is well characterized and specified, however preserving this accuracy in a thermal monitoring control system requires some attention to minimizing the various potential error sources. The internal sources of setpoint programming error include the initial tolerances and temperature drifts of the reference voltage VREF, the setpoint comparator input offset voltage and bias current, and the hysteresis current scale factor. When evaluating setpoint programming errors, remember that any VREF error contribution at the comparator inputs is reduced by the resistor divider ratios. Each comparator's input bias current drops to less than 1 nA (typ) when the comparator is tripped. This change accounts for some setpoint voltage error, equal to the change in bias current multiplied by the effective setpoint divider ladder resistance to ground.

The thermal mass of the TMP12 package and the degree of thermal coupling to the surrounding circuitry are the largest factors in determining the rate of thermal settling, which ultimately determines the rate at which the desired temperature measurement accuracy may be reached (see graph in Figure 3). Thus, one must allow sufficient time for the device to reach the final temperature. The typical thermal time constant for the SOIC plastic package is approximately 70 seconds in still air. Therefore, to reach the final temperature accuracy within 1%, for a temperature change of 60 degrees, a settling time of 5 time constants, or 6 minutes, is necessary. Refer to Figure 4.

External error sources to consider are the accuracy of the external programming resistors, grounding error voltages, and thermal gradients. The accuracy of the external programming resistors directly impacts the resulting setpoint accuracy. Thus, in fixed-temperature applications the user should select resistor tolerances appropriate to the desired programming accuracy. Since setpoint resistors are typically located in the same air flow as the TMP12, resistor temperature drift must be taken into account also. This effect can be minimized by selecting good quality components, and by keeping all components in close thermal proximity. Careful circuit board layout and component placement are necessary to minimize common thermal error sources. Also, the user should take care to keep the bottom of the setpoint programming divider ladder as close to GND (Pin 4) as possible to minimize errors

due to IR voltage drops and coupling of external noise sources. In any case, a 0.1 μF capacitor for power supply bypassing is always recommended at the chip.

**Safety Considerations in Heating and Cooling System Design**

Designers should anticipate potential system fault conditions that may result in significant safety hazards which are outside the control of and cannot be corrected by the TMP12-based circuit. Governmental and Industrial regulations regarding safety requirements and standards for such designs should be observed where applicable.

**Self-Heating Effects**

In some applications the user should consider the effects of self-heating due to the power dissipated by the open-collector outputs, which are capable of sinking 20 mA continuously. Under full load, the TMP12 open-collector output device is dissipating:

$$P_{DISS} = 0.6 \ V$$

The on-board VREF output buffer is typically capable of 500 μA output drive into as much as 50 pF load (max). Exceeding this load will affect the accuracy of the reference voltage, could cause thermal sensing errors due to excess heat build-up, and may induce oscillations. External buffering of VREF with a low-drift voltage follower will ensure optimal reference accuracy. Amplifiers which offer low drift, low power consumption, and low cost appropriate to this application include the OP284, and members of the OP113 and OP193 families.

With excellent drift and noise characteristics, VREF offers a good voltage reference for data acquisition and transducer excitation applications as well. Output drift is typically better than $-10$ ppm/°C, with 315 nV/Hz (typ) noise spectral density at 1 kHz.

**Preserving Accuracy Over Wide Temperature Range Operation**
The TMP12 is unique in offering both a wide-range temperature sensor and the associated detection circuitry needed to implement a complete thermostatic control function in one monolithic device. The voltage reference, setpoint comparators, and output buffer amplifiers have been carefully compensated to maintain accuracy over the specified temperature ranges in this application. Since the TMP12 is both sensor and control circuit, in many applications the external components used to program and interface the device are subjected to the same temperature extremes. Thus, it is necessary to place components in close thermal proximity minimizing large temperate differentials, and to account for thermal drift errors where appropriate, such as resistor matching temperature coefficients, amplifier error drift, and the like. Circuit design with the TMP12 requires a slightly different perspective regarding the thermal behavior of electronic components.

**PC Board Layout Considerations**
The TMP12 also requires a different perspective on PC board layout. In many applications, wide traces and generous ground planes are used to extract heat from components. The TMP12 is slightly different, in that ideal path for heat is via the cooling system air flow. Thus, heat paths through the PC traces should be minimized. This constraint implies that minimum pad sizes and trace widths should be specified in order to reduce heat conduction. At the same time, analog performance should not be compromised. In particular, the bottom of the setpoint resistor ladder should be located as close to GND as possible, as discussed in the Understanding Error Sources section of this data sheet.

**Thermal Response Time**
The time required for a temperature sensor to settle to a specified accuracy is a function of the thermal mass of the sensor, and the thermal conductivity between the sensor and the object being sensed. Thermal mass is often considered equivalent to capacitance. Thermal conductivity is commonly specified using the symbol Q, and is the inverse of thermal resistance. It is commonly specified in units of degrees per watt of power transferred across the thermal joint. Figures 3 and 5 illustrate the typical RC time constant response to a step change in ambient temperature. Thus, the time required for the TMP12 to settle to the desired accuracy is dependent on the package selected, the thermal contact established in the particular application, and the equivalent thermal conductivity of the heat source. For most applications, the settling-time is probably best determined empirically.

**Switching Loads with the Open-Collector Outputs**
In many temperature sensing and control applications some type of switching is required. Whether it be to turn on a heater when the temperature goes below a minimum value or to turn off a motor that is overheating, the open-collector outputs can be used. For the majority of applications, the switches used need to handle large currents on the order of 1 Amp and above. Because the TMP12 is accurately measuring temperature, the open-collector outputs should handle less than 20 mA of current to minimize self-heating. Clearly, the trip point outputs should not drive the equipment directly. Instead, an external switching device is required to handle the large currents. Some examples of

# TMP12

Power FETs are popular for handling a variety of high current dc loads. Figure 24 shows the TMP12 driving a P-channel MOSFET transistor for a simple heater circuit. When the output transistor turns on, the gate of the MOSFET is pulled down to approximately 0.6 V, turning it on. For most MOSFETs a gate-to-source voltage or Vgs on the order of -2 V to -5 V is sufficient to turn the device on. Figure 25 shows a similar circuit for turning on an N-channel MOSFET, except that now the gate to source voltage is positive. For this reason an external transistor must be used as an inverter so that the MOSFET will turn on when the trip point pulls down.
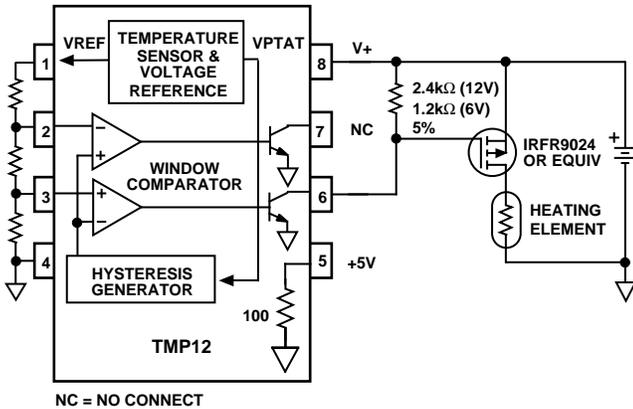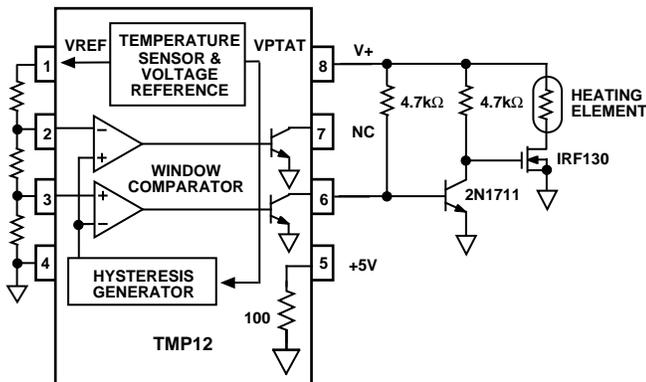


*Figure 24. Driving a P-Channel MOSFET*



*Figure 25. Driving an N-Channel MOSFET*

Isolated Gate Bipolar Transistors (IGBTs) combine many of the benefits of power MOSFETs with bipolar transistors and are used for a variety of high power applications. Because IGBTs have a gate similar to MOSFETs, turning on and off the devices is relatively simple as shown in Figure 26. The turn on voltage for the IGBT shown (IRGB40S) is between 3.0 and 5.5 volts. This part has a continuous collector current rating of 50 A and a maximum collector to emitter voltage of 600 V, enabling it to work in very demanding applications.
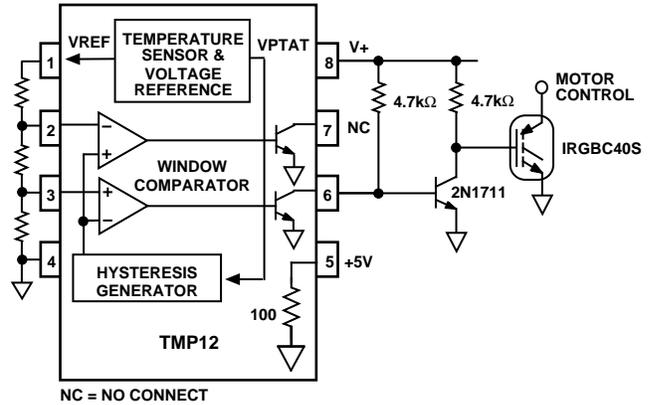


*Figure 26. Driving an IGBT*

The last class of high power devices discussed here are Thyristors, which include SCRs and Triacs. Triacs are a useful alternative to relays for switching ac line voltages. The 2N6073A shown in Figure 27 is rated to handle 4 A (rms). The opto-isolated MOC3021 Triac shown features excellent electrical isolation from the noisy ac line and complete control over the high power Triac with only a few additional components.
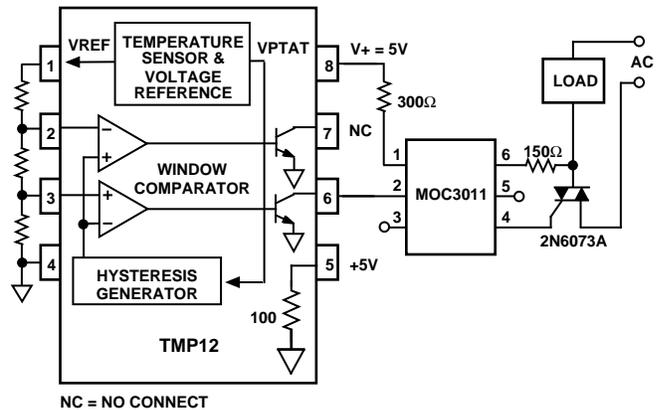


*Figure 27. Controlling the 2N6073A Triac*

**High Current Switching**

As mentioned earlier, internal dissipation due to large loads on the TMP12 outputs will cause some temperature error due to self-heating. External transistors buffer the load from the TMP12 so that virtually no power is dissipated in the internal transistors and minimal self-heating occurs. This section shows several examples using external transistors. The simplest case uses a single transistor on the output to invert the output signal is shown in Figure 28. When the open-collector of the TMP12 turns "ON" and pulls the output down, the external transistor Q1's base will be pulled low, turning off the transistor. Another transistor can be added to re-invert the signal as shown in Figure 29. Now, when the output of the TMP12 is pulled down, the first transistor, Q1, turns off and its collector goes high, which turns Q2 on, pulling its collector low. Thus, the output taken from the collector of Q2 is identical to the output of the TMP12. By picking a transistor that can accommodate large amounts of current, many high power devices can be switched.
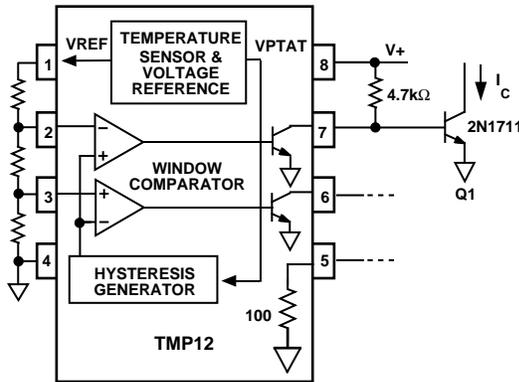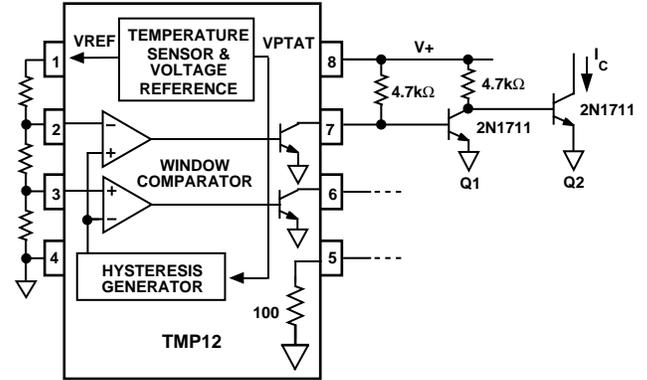


Figure 29. Second Transistor Maintains Polarity of TMP12 Output

An example of a higher power transistor is a standard Darlington configuration as shown in Figure 30. The part chosen, TIP-110, can handle 2 A continuous which is more than enough to control many high power relays. In fact the Darlington itself can be used as the switch, similar to MOSFETs and IGBTs.
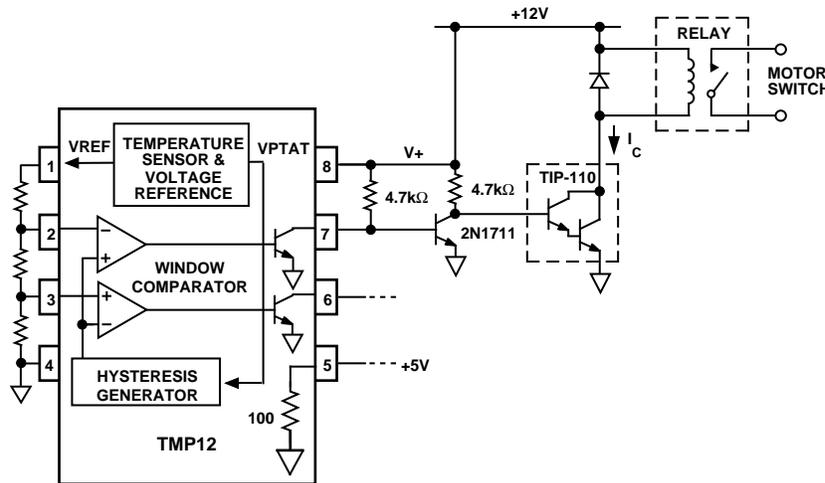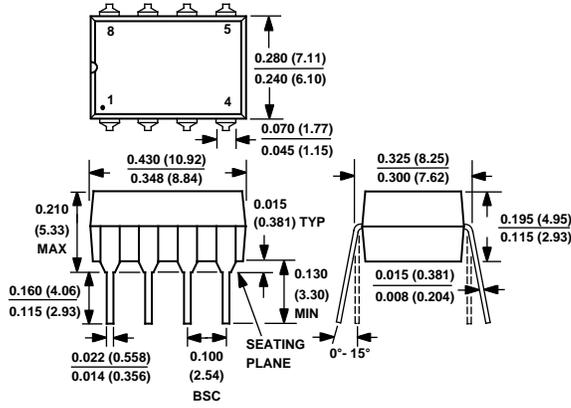


Figure 28. An External Transistor Minimizes Self-Heating



Figure 30. Darlington Transistor Can Handle Large Currents

# TMP12

## OUTLINE DIMENSIONS
Dimensions shown in inches and (mm).

### 8-Pin Epoxy DIP



### 8-Pin SOIC

REV. 0