



# Low-Cost, +2.7V to +5.5V, Micropower Temperature Switches in SOT23 and TO-220

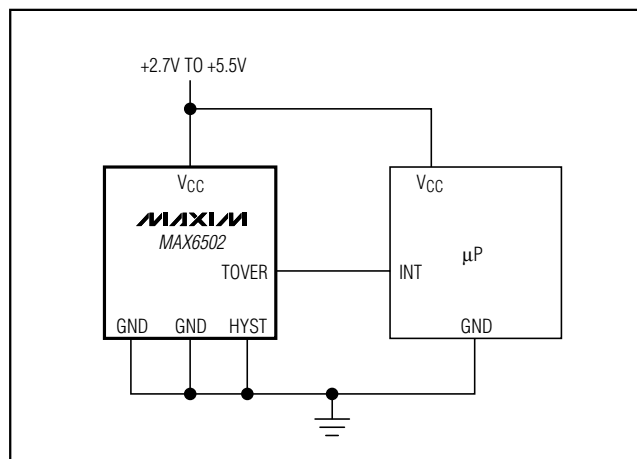
## General Description

The MAX6501–MAX6504 low-cost, fully integrated temperature switches assert a logic signal when their die temperature crosses a factory-programmed threshold. Operating from a +2.7V to +5.5V supply, these devices feature two on-chip, temperature-dependent voltage references and a comparator. They are available with factory-trimmed temperature trip thresholds from -45°C to +115°C in 10°C increments, and are accurate to  $\pm 0.5^\circ\text{C}$  (typ) or  $\pm 6^\circ\text{C}$  (max). These devices require no external components and typically consume 30 $\mu\text{A}$  supply current. Hysteresis is pin-selectable at +2°C or +10°C.

The MAX6501/MAX6503 have an active-low, open-drain output intended to interface with a microprocessor ( $\mu\text{P}$ ) reset input. The MAX6502/MAX6504 have an active-high, push-pull output intended to directly drive fan-control logic. The MAX6501/MAX6502 are offered with hot-temperature thresholds (+35°C to +115°C), asserting when the temperature is above the threshold. The MAX6503/MAX6504 are offered with cold-temperature thresholds (-45°C to +15°C), asserting when the temperature is below the threshold.

The MAX6501–MAX6504 are offered in eight standard temperature versions; contact the factory for pricing and availability of nonstandard temperature versions. They are available in 5-pin SOT23 and 7-pin TO-220 packages.

## Typical Operating Circuit



Selector Guide and Pin Configurations appear at end of data sheet.

† Patents Pending



## Features

- ◆  $\pm 0.5^\circ\text{C}$  (typical) Threshold Accuracy Over Full Temperature Range
- ◆ No External Components Required
- ◆ Low Cost
- ◆ 30 $\mu\text{A}$  Supply Current
- ◆ Factory-Programmed Thresholds from -45°C to +115°C in 10°C Increments
- ◆ Open-Drain Output (MAX6501/MAX6503)  
Push-Pull Output (MAX6502/MAX6504)
- ◆ Pin-Selectable +2°C or +10°C Hysteresis
- ◆ SOT23-5 and TO220-7 Packages

## Ordering Information

| PART*           | TEMP. RANGE     | PIN-PACKAGE |
|-----------------|-----------------|-------------|
| MAX6501UK____-T | -55°C to +125°C | 5 SOT23-5   |
| MAX6501CM____-T | -55°C to +125°C | 7 TO-220-7  |
| MAX6502UK____-T | -55°C to +125°C | 5 SOT23-5   |
| MAX6502CM____-T | -55°C to +125°C | 7 TO-220-7  |
| MAX6503UK____-T | -55°C to +125°C | 5 SOT23-5   |
| MAX6503CM____-T | -55°C to +125°C | 7 TO-220-7  |
| MAX6504UK____-T | -55°C to +125°C | 5 SOT23-5   |
| MAX6504CM____-T | -55°C to +125°C | 7 TO-220-7  |

\*These parts are offered in eight standard temperature versions with a minimum order of 2,500 pieces. To complete the suffix information, add P or N for positive or negative trip temperature, and select an available trip point in degrees centigrade. For example, the MAX6501UKP065-T describes a MAX6501 in a SOT23-5 package with a +65°C threshold. Contact the factory for pricing and availability of nonstandard temperature versions (minimum order 10,000 pieces).

## Applications

$\mu\text{P}$  Temperature Monitoring in High-Speed Computers  
Temperature Control  
Temperature Alarms  
Fan Control

MAX6501–MAX6504†

# Low-Cost, +2.7V to +5.5V, Micropower Temperature Switches in SOT23 and TO-220

## ABSOLUTE MAXIMUM RATINGS

|                               |                                     |                                                                           |                                               |
|-------------------------------|-------------------------------------|---------------------------------------------------------------------------|-----------------------------------------------|
| Supply Voltage ( $V_{CC}$ )   | -0.3V to +7V                        | Output Current (all pins)                                                 | 20mA                                          |
| $\overline{TOVER}$ (MAX6501)  | -0.3V to +7V                        | Continuous Power Dissipation ( $T_A = +70^\circ\text{C}$ )                |                                               |
| $\overline{TOVER}$ (MAX6502)  | -0.3V to ( $V_{CC} + 0.3\text{V}$ ) | 5-Pin SOT23-5 (derate 7.1mW/ $^\circ\text{C}$ above $+70^\circ\text{C}$ ) | 571mW                                         |
| $\overline{TUNDER}$ (MAX6503) | -0.3V to +7V                        | Operating Temperature Range                                               | -55 $^\circ\text{C}$ to +125 $^\circ\text{C}$ |
| $\overline{TUNDER}$ (MAX6504) | -0.3V to ( $V_{CC} + 0.3\text{V}$ ) | Storage Temperature Range                                                 | -65 $^\circ\text{C}$ to +165 $^\circ\text{C}$ |
| All Other Pins                | -0.3V to ( $V_{CC} + 0.3\text{V}$ ) | Lead Temperature (soldering, 10sec)                                       | +300 $^\circ\text{C}$                         |
| Input Current (all pins)      | 20mA                                |                                                                           |                                               |

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

## ELECTRICAL CHARACTERISTICS

( $V_{CC} = +2.7\text{V}$  to  $+5.5\text{V}$ ,  $R_{PULL-UP} = 100\text{k}\Omega$  (MAX6501/MAX6503 only),  $T_A = T_{MIN}$  to  $T_{MAX}$ , unless otherwise noted. Typical values are at  $T_A = +25^\circ\text{C}$ .) (Note 1)

| PARAMETER                               | SYMBOL          | CONDITIONS                                                                                                               | MIN                 | TYP       | MAX | UNITS            |
|-----------------------------------------|-----------------|--------------------------------------------------------------------------------------------------------------------------|---------------------|-----------|-----|------------------|
| Supply Voltage Range                    | $V_{CC}$        |                                                                                                                          | 2.7                 |           | 5.5 | V                |
| Supply Current                          | $I_{CC}$        |                                                                                                                          |                     | 30        | 85  | $\mu\text{A}$    |
| Temperature Threshold Accuracy (Note 2) | $\Delta T_{TH}$ | -45 $^\circ\text{C}$ to -25 $^\circ\text{C}$                                                                             | -6                  | $\pm 0.5$ | 6   | $^\circ\text{C}$ |
|                                         |                 | -15 $^\circ\text{C}$ to +15 $^\circ\text{C}$                                                                             | -4                  | $\pm 0.5$ | 4   |                  |
|                                         |                 | +35 $^\circ\text{C}$ to +65 $^\circ\text{C}$                                                                             | -4                  | $\pm 0.5$ | 4   |                  |
|                                         |                 | +75 $^\circ\text{C}$ to +115 $^\circ\text{C}$                                                                            | -6                  | $\pm 0.5$ | 6   |                  |
| Temperature Threshold Hysteresis        | $T_{HYST}$      | $\overline{HYST} = \text{GND}$                                                                                           |                     | 2         |     | $^\circ\text{C}$ |
|                                         |                 | $\overline{HYST} = V_{CC}$                                                                                               |                     | 10        |     |                  |
| HYST Input Threshold (Note 3)           | $V_{IH}$        |                                                                                                                          | $0.8 \times V_{CC}$ |           |     | V                |
|                                         | $V_{IL}$        |                                                                                                                          | $0.2 \times V_{CC}$ |           |     |                  |
| Output Voltage High                     | $V_{OH}$        | $I_{SOURCE} = 500\mu\text{A}$ , $V_{CC} > 2.7\text{V}$ (MAX6502/MAX6504 only)                                            | $0.8 \times V_{CC}$ |           |     | V                |
|                                         |                 | $I_{SOURCE} = 800\mu\text{A}$ , $V_{CC} > 4.5\text{V}$ (MAX6502/MAX6504 only)                                            | $V_{CC} - 1.5$      |           |     |                  |
| Output Voltage Low                      | $V_{OL}$        | $I_{SINK} = 1.2\text{mA}$ , $V_{CC} > 2.7\text{V}$                                                                       |                     |           | 0.3 | V                |
|                                         |                 | $I_{SINK} = 3.2\text{mA}$ , $V_{CC} > 4.5\text{V}$                                                                       |                     |           | 0.4 |                  |
| Open-Drain Output Leakage Current       |                 | $V_{CC} = 2.7\text{V}$ , $\overline{V_{TUNDER}} = 5.5\text{V}$ (MAX6503), $\overline{V_{TOVER}} = 5.5\text{V}$ (MAX6501) |                     | 10        |     | nA               |

**Note 1:** 100% production tested at  $T_A = +25^\circ\text{C}$ . Specifications over temperature limits are guaranteed by design.

**Note 2:** The MAX6501-MAX6504 are available with internal, factory-programmed temperature trip thresholds from -45 $^\circ\text{C}$  to +115 $^\circ\text{C}$  in +10 $^\circ\text{C}$  increments (see *Selector Guide*).

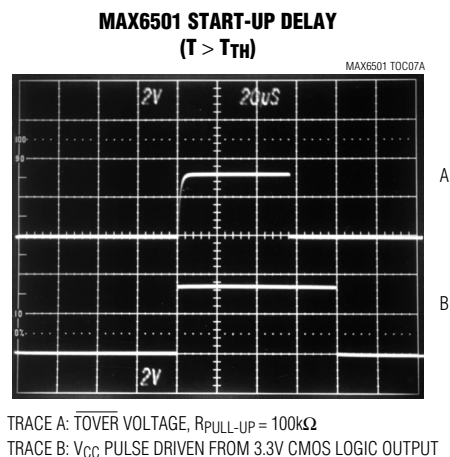
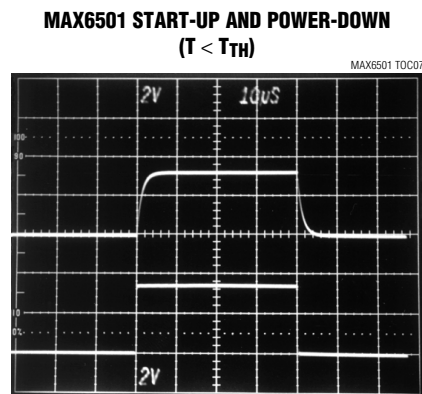
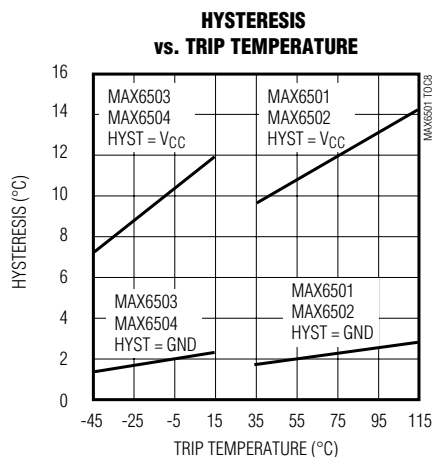
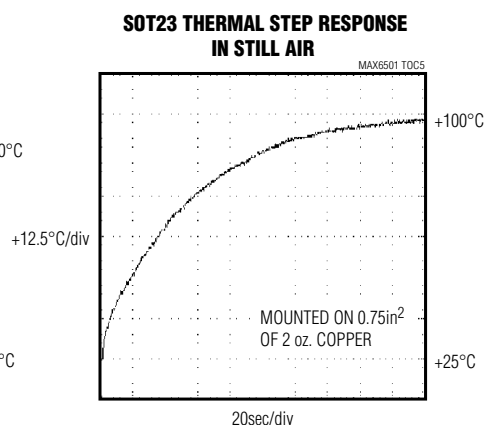
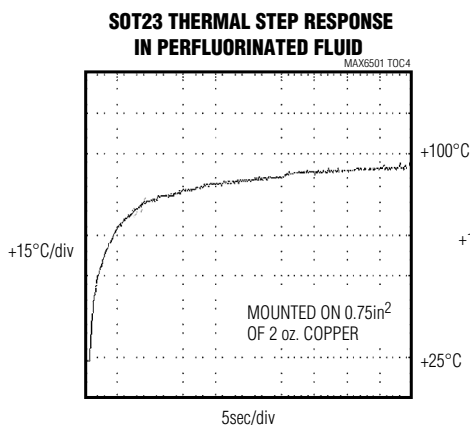
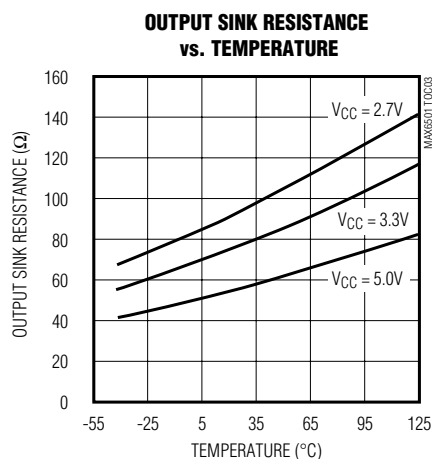
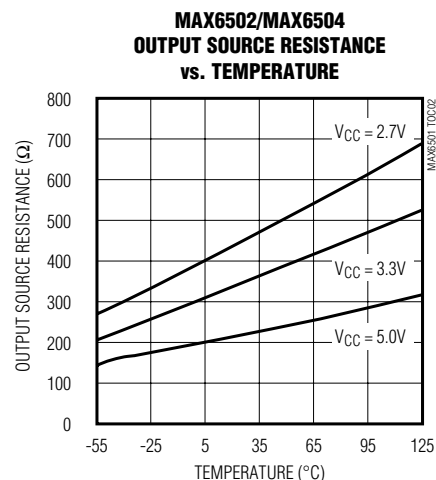
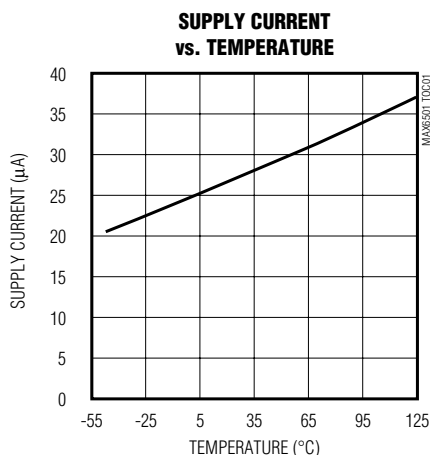
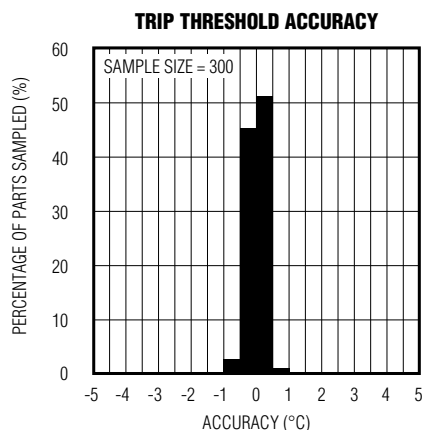
**Note 3:** Guaranteed by design.

# Low-Cost, +2.7V to +5.5V, Micropower Temperature Switches in SOT23 and TO-220

## Typical Operating Characteristics

( $V_{CC} = +5V$ ,  $R_{PULL-UP} = 100k\Omega$  (MAX6501/MAX6503),  $T_A = +25^\circ C$ , unless otherwise noted.)

MAX6501-MAX6504



# Low-Cost, +2.7V to +5.5V, Micropower Temperature Switches in SOT23 and TO-220

## Pin Description

| PIN     |         |         |         | NAME                       | FUNCTION                                                                                                                                                                                                                                                      |
|---------|---------|---------|---------|----------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| MAX6501 | MAX6502 | MAX6503 | MAX6504 |                            |                                                                                                                                                                                                                                                               |
| 1, 2    | 1, 2    | 1, 2    | 1, 2    | GND                        | Ground. Not internally connected. Tie both ground pins together close to the chip. Pin 2 provides the lowest thermal resistance to the die.                                                                                                                   |
| 3       | 3       | 3       | 3       | HYST                       | Hysteresis Input. Connect HYST to GND for +2°C hysteresis, or connect to V <sub>CC</sub> for +10°C hysteresis.                                                                                                                                                |
| 4       | 4       | 4       | 4       | V <sub>CC</sub>            | Supply Input (+2.7V to +5.5V)                                                                                                                                                                                                                                 |
| 5       | —       | —       | —       | $\overline{\text{TOVER}}$  | Open-Drain, Active-Low Output. $\overline{\text{TOVER}}$ goes low when the die temperature exceeds the factory-programmed temperature threshold. Connect to a 100k $\Omega$ pull-up resistor. May be pulled up to a voltage higher than V <sub>CC</sub> .     |
| —       | 5       | —       | —       | TOVER                      | Push-Pull Active-High Output. TOVER goes high when the die temperature exceeds the factory-programmed temperature threshold.                                                                                                                                  |
| —       | —       | 5       | —       | $\overline{\text{TUNDER}}$ | Open-Drain, Active-Low Output. $\overline{\text{TUNDER}}$ goes low when the die temperature goes below the factory-programmed temperature threshold. Connect to a 100k $\Omega$ pull-up resistor. May be pulled up to a voltage higher than V <sub>CC</sub> . |
| —       | —       | —       | 5       | TUNDER                     | Push-Pull Active-High Output. TUNDER goes high when the die temperature falls below the factory-programmed temperature threshold.                                                                                                                             |

## General Description

The MAX6501–MAX6504 fully integrated temperature switches incorporate two temperature-dependent references and a comparator. One reference exhibits a positive temperature coefficient and the other a negative temperature coefficient (Figure 1). The temperature at which the two reference voltages are equal determines the temperature trip point. Pin-selectable +2°C or +10°C hysteresis keeps the output from oscillating when the die temperature approaches the threshold temperature. The MAX6501/MAX6503 have an active-low, open-drain output structure that can only sink current. The MAX6502/MAX6504 have an active-high, push-pull output structure that can sink or source current. The internal power-on reset circuit guarantees the output is at T<sub>TH</sub> = +25°C state at start-up for 50 $\mu$ s.

The MAX6501–MAX6504 are available with factory-preset temperature thresholds from -45°C to +115°C in 10°C increments. Table 1 lists the available temperature threshold ranges. The MAX6501/MAX6503 outputs are intended to interface with a microprocessor ( $\mu$ P) reset input (Figure 2). The MAX6502/MAX6504 outputs are intended for applications such as driving a fan control (Figure 3).

**Table 1. Factory-Programmed Threshold Range**

| PART    | THRESHOLD (T <sub>TH</sub> ) RANGE |
|---------|------------------------------------|
| MAX6501 | +35°C < T <sub>TH</sub> < +115°C   |
| MAX6502 | +35°C < T <sub>TH</sub> < +115°C   |
| MAX6503 | -45°C < T <sub>TH</sub> < +15°C    |
| MAX6504 | -45°C < T <sub>TH</sub> < +15°C    |

## Hysteresis Input

The HYST pin is a CMOS-compatible input that selects hysteresis at either a high level (+10°C for HYST = V<sub>CC</sub>) or a low level (+2°C for HYST = GND). Hysteresis prevents the output from oscillating when the temperature approaches the trip point. The HYST pin should not float. Drive HYST close to ground or V<sub>CC</sub>. Other input voltages cause increased supply current. The actual amount of hysteresis depends on the part's programmed trip threshold. (See the *Typical Operating Characteristics* graphs.)

# Low-Cost, +2.7V to +5.5V, Micropower Temperature Switches in SOT23 and TO-220

MAX6501-MAX6504

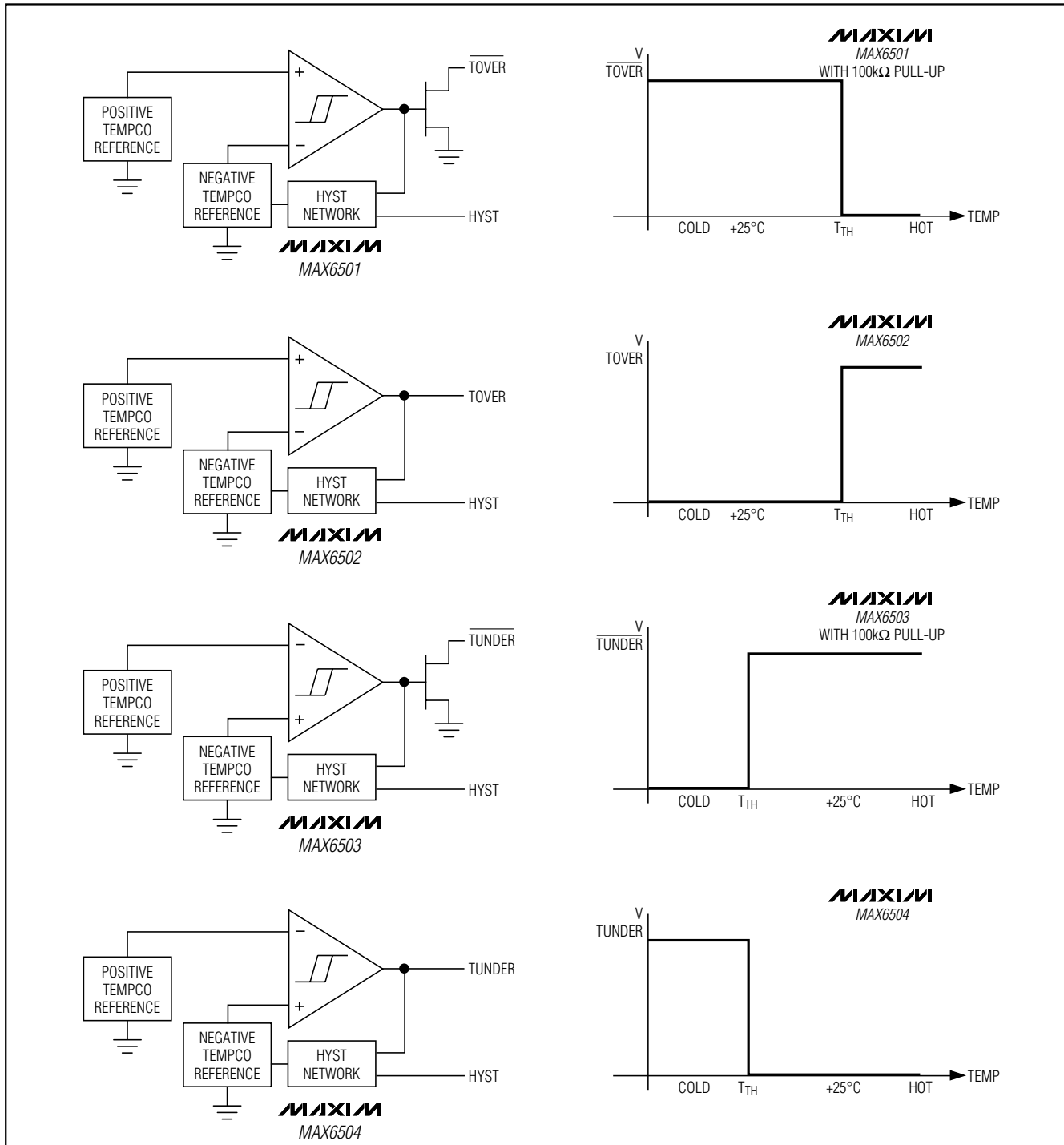


Figure 1. Block and Functional Diagrams

## Low-Cost, +2.7V to +5.5V, Micropower Temperature Switches in SOT23 and TO-220

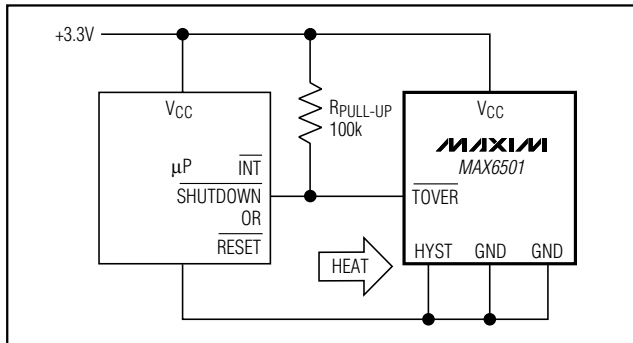


Figure 2. Microprocessor Alarm/Reset

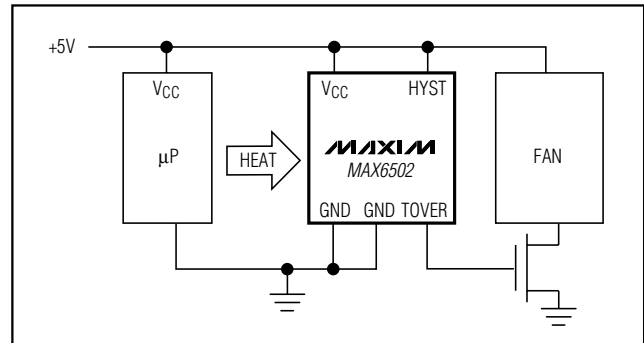


Figure 3. Overtemperature Fan Control

### Applications Information

#### Thermal Considerations

The MAX6501-MAX6504 supply current is typically 30μA. When used to drive high-impedance loads, the devices dissipate negligible power. Therefore, the die temperature is essentially the same as the package temperature. The key to accurate temperature monitoring is good thermal contact between the MAX6501-MAX6504 package and the device being monitored. In some applications, the SOT23-5 package may be small enough to fit underneath a socketed μP, allowing the device to monitor the μP's temperature directly. The TO-220 package can monitor the temperature of a heat sink directly, and presents the lower thermal resistance of the two packages. Use the monitor's output to reset the μP, assert an interrupt, or trigger an external alarm.

Accurate temperature monitoring depends on the thermal resistance between the device being monitored and the MAX6501-MAX6504 die. Heat flows in and out of plastic packages, primarily through the leads. Pin 2 of the SOT23-5 package provides the lowest thermal resistance to the die. Short, wide copper traces leading to the temperature monitor ensure that heat transfers quickly and reliably.

The rise in die temperature due to self-heating is given by the following formula:

$$\Delta T_J = P_{DISSIPATION} \times \theta_{JA}$$

where  $P_{DISSIPATION}$  is the power dissipated by the MAX6501-MAX6504, and  $\theta_{JA}$  is the package's thermal resistance.

The typical thermal resistance is 140°C/W for the SOT23-5 package and 75°C/W for the TO-220 package. To limit the effects of self-heating, minimize the output currents. For example, if the MAX6501 or MAX6503 sink 1mA, the output voltage is guaranteed to be less than 0.3V. Therefore, an additional 0.3mW of

power is dissipated within the IC. This corresponds to a 0.042°C shift in the die temperature in the SOT23-5.

#### Temperature-Window Alarm

The MAX6501-MAX6504 temperature switch outputs assert when the die temperature is outside the factory-programmed range. Combining the outputs of two devices creates an over/undertemperature alarm. The MAX6501/MAX6503 and the MAX6502/MAX6504 are designed to form two complementary pairs, each containing one cold trip-point output and one hot trip-point output. The assertion of either output alerts the system to an out-of-range temperature. The MAX6502/MAX6504 push/pull output stages can be ORed to produce a thermal out-of-range alarm. More favorably, a MAX6501/MAX6503 can be directly wire-ORed with a single external resistor to accomplish the same task (Figure 4).

The temperature window alarms shown in Figure 4 can be used to accurately determine when a device's temperature falls out of the -5°C to +75°C range. The thermal-overrange signal can be used to assert a thermal shutdown, power-up, recalibration, or other temperature-dependent function.

#### Low-Cost, Fail-Safe Temperature Monitor

In high-performance/high-reliability applications, multiple temperature monitoring is important. The high-level integration and low cost of the MAX6501-MAX6504 facilitate the use of multiple temperature monitors to increase system reliability. Figure 5's application uses two MAX6502s with different temperature thresholds to ensure that fault conditions that can overheat the monitored device cause no permanent damage. The first temperature monitor activates the fan when the die temperature exceeds +45°C. The second MAX6502 triggers a system shutdown if the die temperature reaches +75°C. The second temperature monitor's output asserts when a wide variety of destructive fault conditions occur, including latchups, short circuits, and cooling-system failures.

# Low-Cost, +2.7V to +5.5V, Micropower Temperature Switches in SOT23 and TO-220

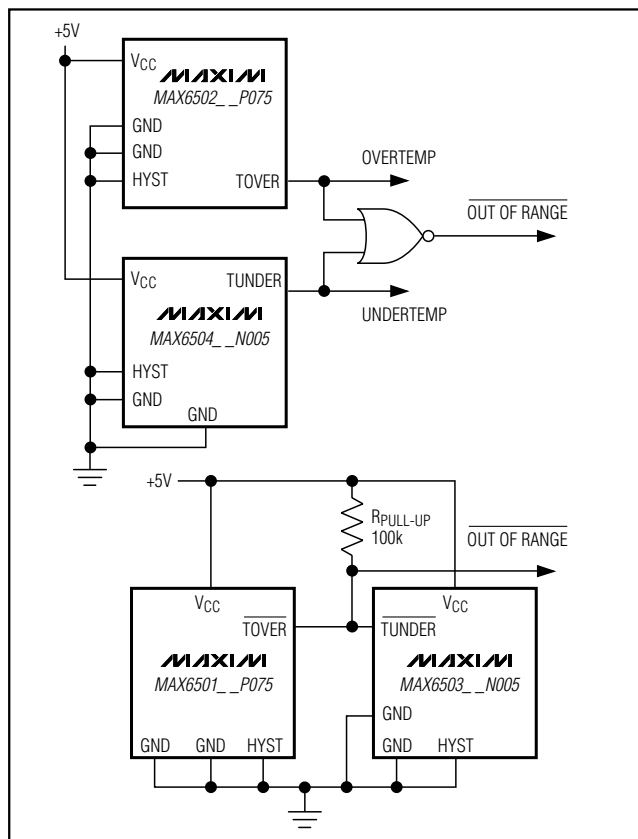


Figure 4. Temperature-Window Alarms

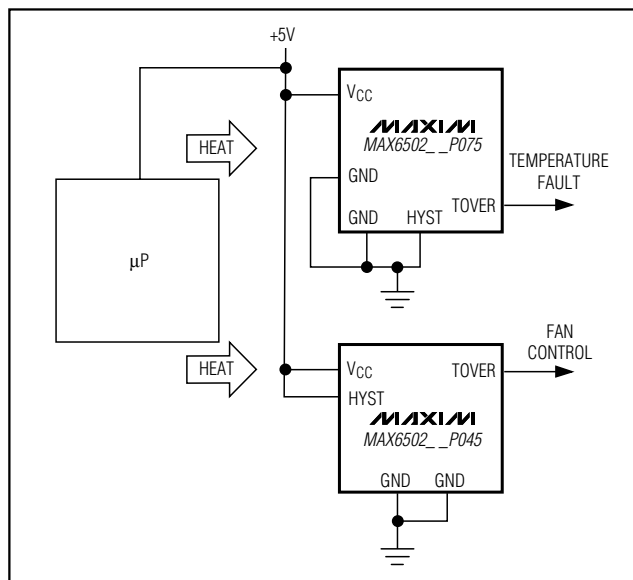


Figure 5. Low-Power, High-Reliability, Fail-Safe Temperature Monitor

MAX6501-MAX6504

Table 2. Device Marking Codes for SOT23-5 Package

| DEVICE        | CODE | MINIMUM ORDER |
|---------------|------|---------------|
| MAX6501UKP035 | ABZF | 10k           |
| MAX6501UKP045 | ABZR | 2.5k          |
| MAX6501UKP055 | ACFW | 2.5k          |
| MAX6501UKP065 | ABZS | 2.5k          |
| MAX6501UKP075 | ACFV | 2.5k          |
| MAX6501UKP085 | ACDP | 2.5k          |
| MAX6501UKP095 | ABZT | 2.5k          |
| MAX6501UKP105 | ACFU | 10k           |
| MAX6501UKP115 | ACAG | 2.5k          |
| MAX6502UKP035 | ABZG | 10k           |
| MAX6502UKP045 | ABZU | 2.5k          |
| MAX6502UKP055 | ACGC | 2.5k          |
| MAX6502UKP065 | ABZV | 2.5k          |
| MAX6502UKP075 | ACGB | 2.5k          |
| MAX6502UKP085 | ACGA | 2.5k          |
| MAX6502UKP095 | ABZW | 2.5k          |

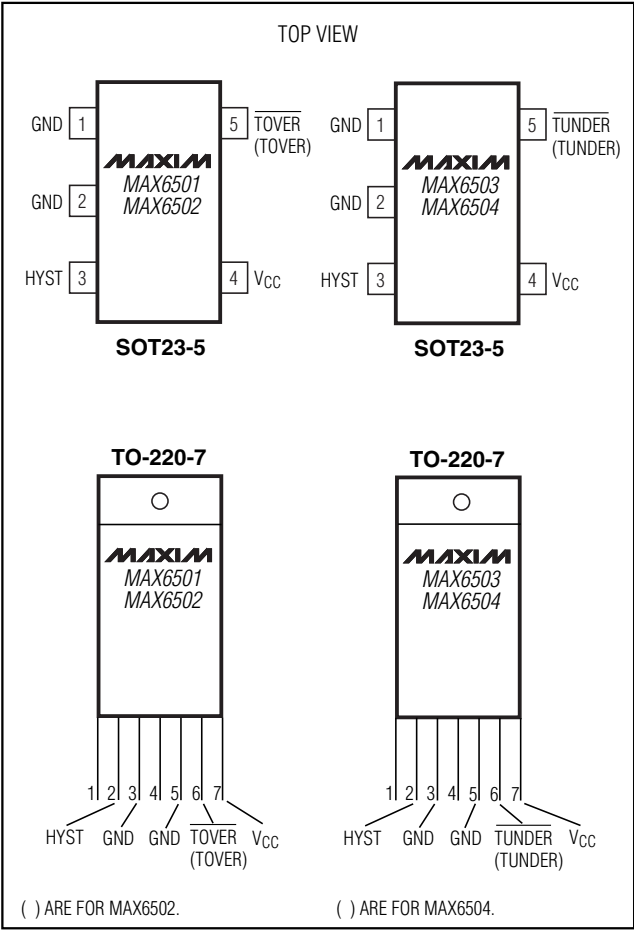
| DEVICE        | CODE | MINIMUM ORDER |
|---------------|------|---------------|
| MAX6502UKP105 | ACFZ | 10k           |
| MAX6502UKP115 | ACFY | 2.5k          |
| MAX6503UKN045 | ADIZ | 10k           |
| MAX6503UKN035 | ACAQ | 10k           |
| MAX6503UKN025 | ACAP | 10k           |
| MAX6503UKN015 | ACFX | 2.5k          |
| MAX6503UKN005 | ACAN | 10k           |
| MAX6503UKP005 | ABZX | 2.5k          |
| MAX6503UKP015 | ACAM | 10k           |
| MAX6504UKN045 | ACAX | 10k           |
| MAX6504UKN035 | ACAW | 10k           |
| MAX6504UKN025 | ACAV | 10k           |
| MAX6504UKN015 | ACGD | 2.5k          |
| MAX6504UKN005 | ACAT | 10k           |
| MAX6504UKP005 | ABZY | 2.5k          |
| MAX6504UKP015 | ADKE | 10k           |

# Low-Cost, +2.7V to +5.5V, Micropower Temperature Switches in SOT23 and TO-220

## Selector Guide

| PART                                 | MAX6501    | MAX6502   | MAX6503    | MAX6504   |
|--------------------------------------|------------|-----------|------------|-----------|
| OUTPUT STAGE                         | Open-Drain | Push-Pull | Open-Drain | Push-Pull |
| TRIP TEMP THRESHOLD                  | Hot        | Hot       | Cold       | Cold      |
| STANDARD TEMPERATURE THRESHOLDS (°C) | -45        |           | ✓          | ✓         |
|                                      | -35        |           | ✓          | ✓         |
|                                      | -25        |           | ✓          | ✓         |
|                                      | -15        |           | ✓          | ✓         |
|                                      | -5         |           | ✓          | ✓         |
|                                      | +5         |           | ✓          | ✓         |
|                                      | +15        |           | ✓          | ✓         |
|                                      | +35        | ✓         |            |           |
|                                      | +45        | ✓         |            |           |
|                                      | +55        | ✓         |            |           |
|                                      | +65        | ✓         |            |           |
|                                      | +75        | ✓         |            |           |
|                                      | +85        | ✓         |            |           |
|                                      | +95        | ✓         |            |           |
|                                      | +105       | ✓         |            |           |
|                                      | +115       | ✓         |            |           |

## Pin Configurations



## Chip Information

TRANSISTOR COUNT: 237  
SUBSTRATE CONNECTED TO GND

Maxim cannot assume responsibility for use of any circuitry other than circuitry entirely embodied in a Maxim product. No circuit patent licenses are implied. Maxim reserves the right to change the circuitry and specifications without notice at any time.

8 Maxim Integrated Products, 120 San Gabriel Drive, Sunnyvale, CA 94086 408-737-7600

© 1999 Maxim Integrated Products Printed USA MAXIM is a registered trademark of Maxim Integrated Products.