Low-Cost, +2.7V to +5.5V, Micropower Temperature Switches in SOT23

ABSOLUTE MAXIMUM RATINGS

Supply Voltage (V_{CC}) Range.....-0.3V to +7V
$\overline{TOVER}$ (MAX6501).....-0.3V to +7V
$\overline{TOVER}$ (MAX6502).....-0.3V to (V_{CC} + 0.3V)
$\overline{TUNDER}$ (MAX6503).....-0.3V to +7V
TUNDER (MAX6504).....-0.3V to (V_{CC} + 0.3V)
All Other Pins.....-0.3V to (V_{CC} + 0.3V)
Input Current (all pins).....20mA
Output Current (all pins).....20mA
Continuous Power Dissipation (T_A = +70°C)
SOT23 (derate 3.1mW/°C above +70°C).....247mW
Operating Temperature Range.....-55°C to +135°C
Storage Temperature Range.....-65°C to +165°C
Lead Temperature (soldering, 10s).....+300°C
Soldering Temperature (reflow).....+260°C

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} = +2.7V to +5.5V, R_{PULLUP} = 100kΩ (MAX6501/MAX6503 only), T_A = T_{MIN} to T_{MAX}, unless otherwise noted. Typical values are at T_A = +25°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	µA
Temperature Threshold Accuracy (Note 2)	ΔT_{TH}	-45°C to -25°C	-6	±0.5	+6	°C
		-15°C to +15°C	-4	±0.5	+4	
		+35°C to +65°C	-4	±0.5	+4	
		+75°C to +125°C	-6	±0.5	+6	
Temperature Threshold Hysteresis	T_{HYST}	HYST = GND		2		°C
		HYST = V_{CC}		10		
HYST Input Threshold (Note 3)	V_{IH}		0.8 x V_{CC}			V
	V_{IL}				0.2 x V_{CC}	
Output Voltage High	V_{OH}	I_{SOURCE} = 500µA, V_{CC} > 2.7V (MAX6502/MAX6504 only)	0.8 x V_{CC}			V
		I_{SOURCE} = 800µA, V_{CC} > 4.5V (MAX6502/MAX6504 only)	V_{CC} - 1.5			
Output Voltage Low	V_{OL}	I_{SINK} = 1.2mA, V_{CC} > 2.7V			0.3	V
		I_{SINK} = 3.2mA, V_{CC} > 4.5V			0.4	
Open-Drain Output Leakage Current		V_{CC} = 2.7V, $V_{\overline{TUNDER}}$ = 5.5V (MAX6503), $V_{\overline{TOVER}}$ = 5.5V (MAX6501)		10		nA

Note 1: 100% production tested at T_A = +25°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°C to +125°C in +10°C increments *(see Selector Guide).*
Note 3: Guaranteed by design.

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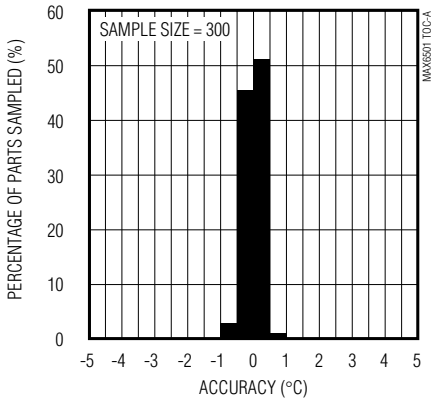
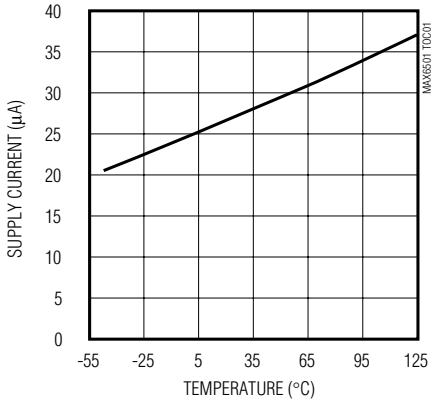
Typical Operating Characteristics

(V_{CC} = +5V, R_{PULLUP} = 100kΩ (MAX6501/MAX6503), T_A = +25°C, unless otherwise noted.)

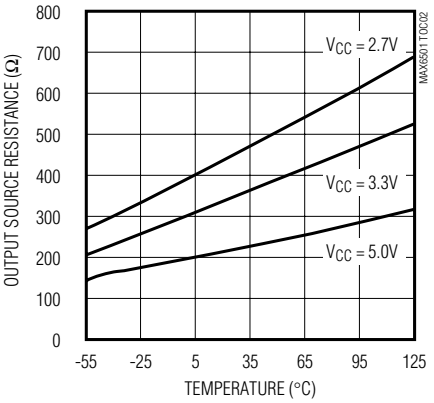
TRIP THRESHOLD ACCURACY



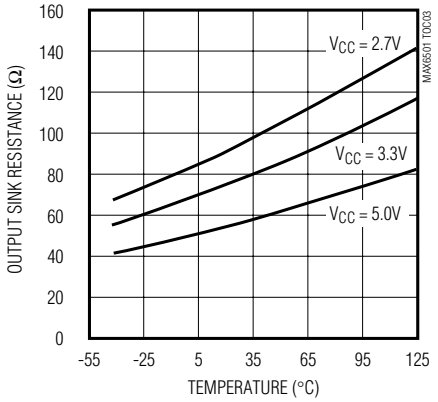
SUPPLY CURRENT vs. TEMPERATURE



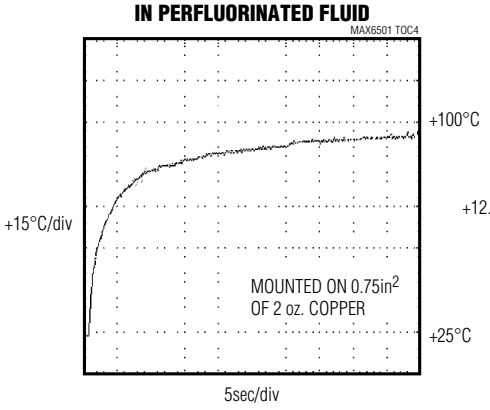
MAX6502/MAX6504 OUTPUT SOURCE RESISTANCE vs. TEMPERATURE



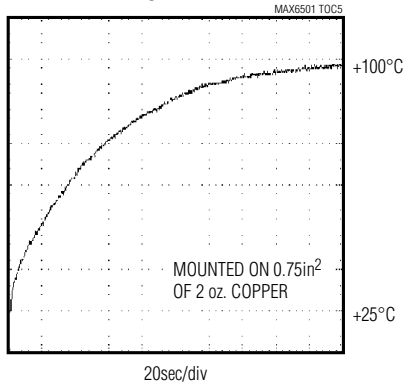
OUTPUT SINK RESISTANCE vs. TEMPERATURE



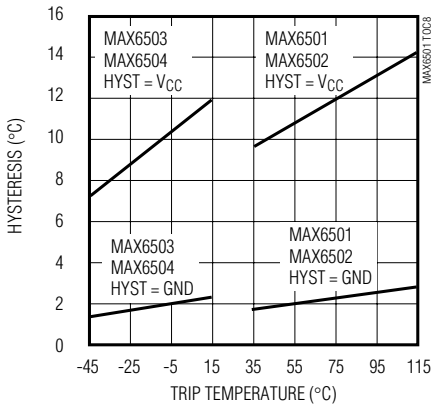
SOT23 THERMAL STEP RESPONSE IN PERFLUORINATED FLUID



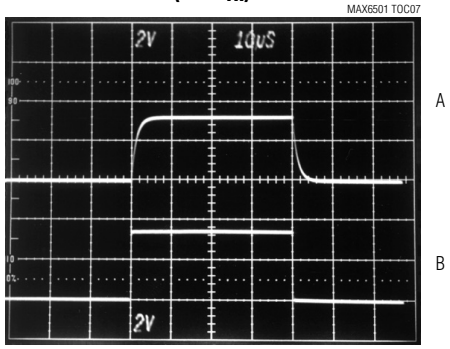
SOT23 THERMAL STEP RESPONSE IN STILL AIR



HYSTERESIS vs. TRIP TEMPERATURE

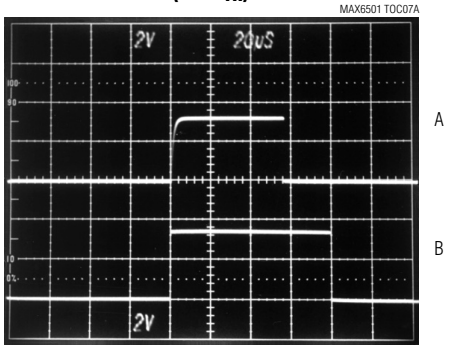


MAX6501 STARTUP AND POWER-DOWN ($T < T_{TH}$)



TRACE A: $\overline{TOVER}$ VOLTAGE, R_{PULLUP} = 100kΩ
TRACE B: V_{CC} PULSE DRIVEN FROM 3.3V CMOS LOGIC OUTPUT

MAX6501 STARTUP DELAY ($T > T_{TH}$)



TRACE A: $\overline{TOVER}$ VOLTAGE, R_{PULLUP} = 100kΩ
TRACE B: V_{CC} PULSE DRIVEN FROM 3.3V CMOS LOGIC OUTPUT

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Pin Description

PIN				NAME	FUNCTION
MAX6501	MAX6502	MAX6503	MAX6504		
1, 2	1, 2	1, 2	1, 2	GND	Ground. Not internally connected. Connect 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_{CC} for 10°C hysteresis.
4	4	4	4	V_{CC}	Supply Input (+2.7V to +5.5V)
5	—	—	—	$\overline{TOVER}$	Open-Drain, Active-Low Output. $\overline{TOVER}$ goes low when the die temperature exceeds the factory-programmed temperature threshold. Connect to a 100kΩ pullup resistor. May be pulled up to a voltage higher than V_{CC}.
—	5	—	—	TOVER	Push-Pull Active-High Output. TOVER goes high when the die temperature exceeds the factory-programmed temperature threshold.
—	—	5	—	$\overline{TUNDER}$	Open-Drain, Active-Low Output. $\overline{TUNDER}$ goes low when the die temperature goes below the factory-programmed temperature threshold. Connect to a 100kΩ pullup resistor. May be pulled up to a voltage higher than V_{CC}.
—	—	—	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_{TH} = +25°C state at startup for 50µs.

The MAX6501–MAX6504 are available with factory-preset temperature thresholds from -45°C to +125°C in 10°C increments. Table 1 lists the available temperature threshold ranges. The MAX6501/MAX6503 outputs are intended to interface with a microprocessor (µP) 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_{TH}) RANGE
MAX6501	+35°C < T_{TH} < +125°C
MAX6502	+35°C < T_{TH} < +125°C
MAX6503	-45°C < T_{TH} < +15°C
MAX6504	-45°C < T_{TH} < +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_{CC}) 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 be left unconnected. Drive HYST close to ground or V_{CC}. 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*).

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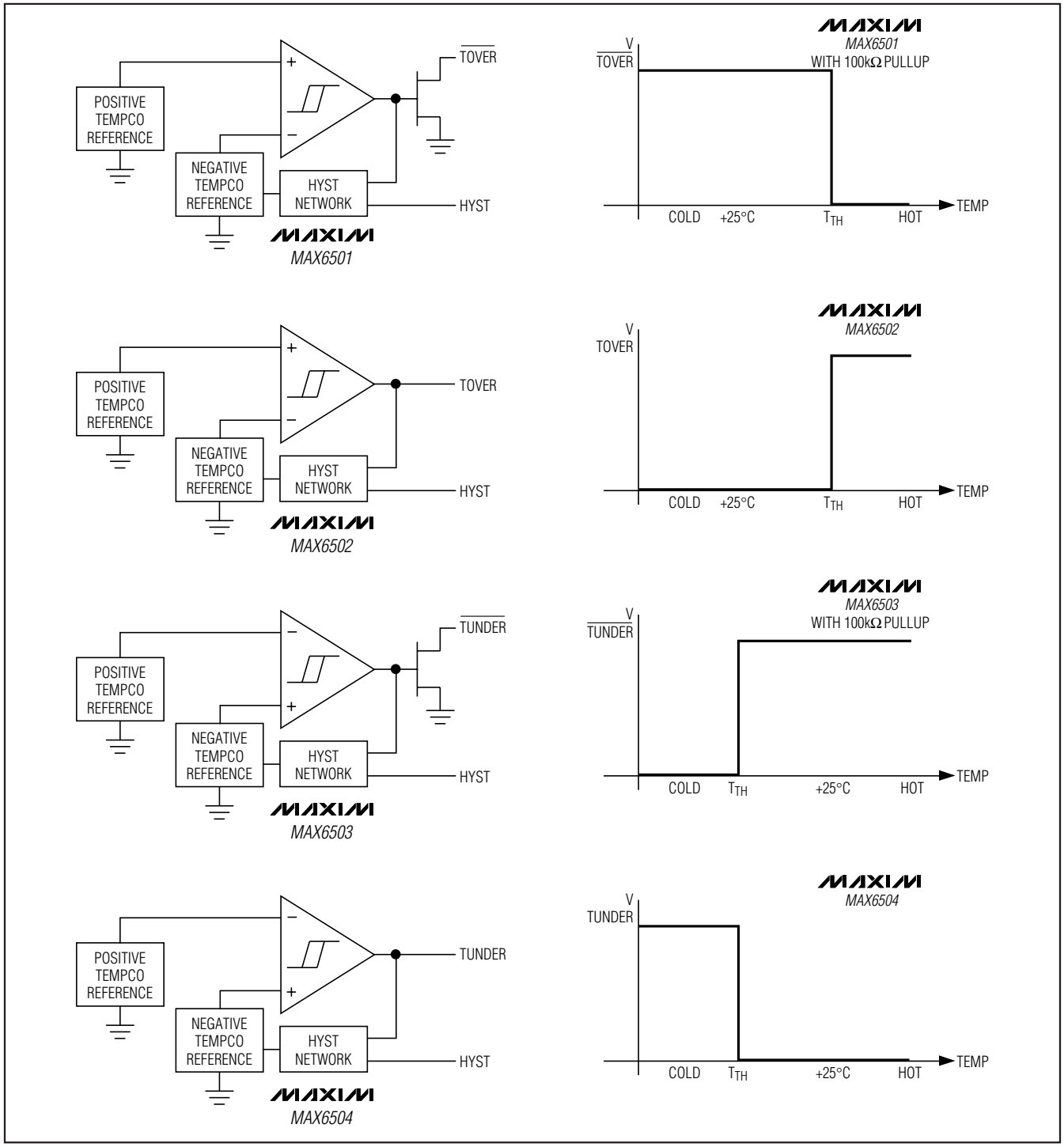

Figure 1. Block and Functional Diagrams

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Low-Cost, +2.7V to +5.5V, Micropower Temperature Switches in SOT23

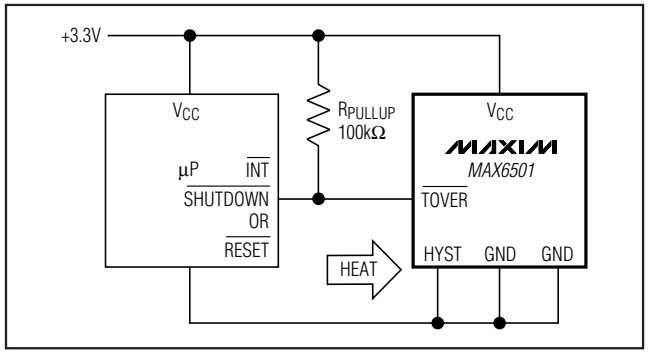

Figure 2. Microprocessor Alarm/Reset

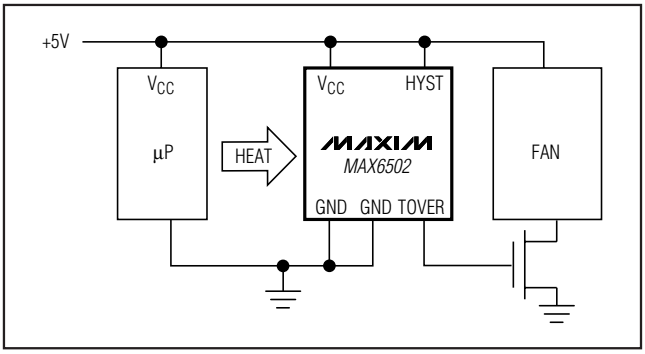

Figure 3. Overtemperature Fan Control

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 package may be small enough to fit underneath a socketed µP, allowing the device to monitor the µP's temperature directly. 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 θ_{JA} is the package's thermal resistance.

The typical thermal resistance is 140°C/W for the SOT23 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.

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.

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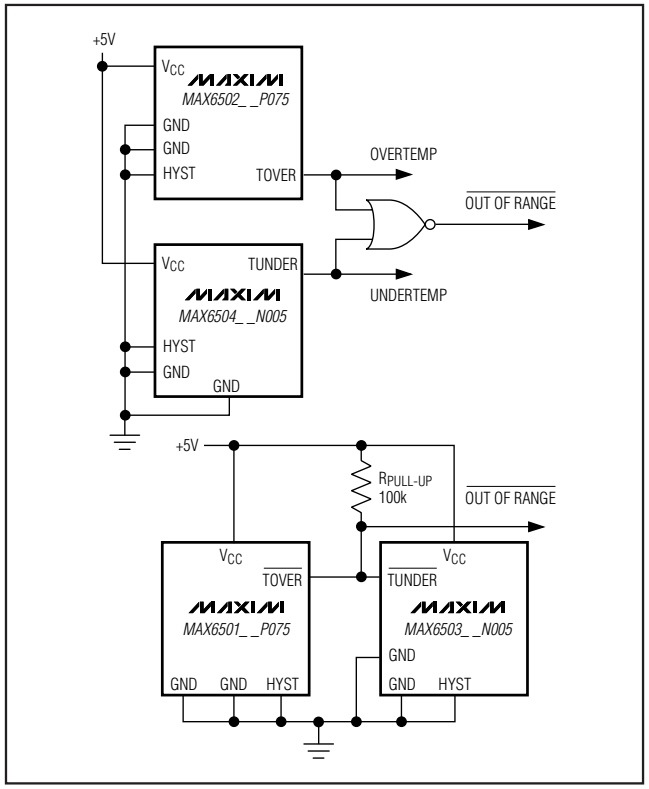

Figure 4. Temperature-Window Alarms

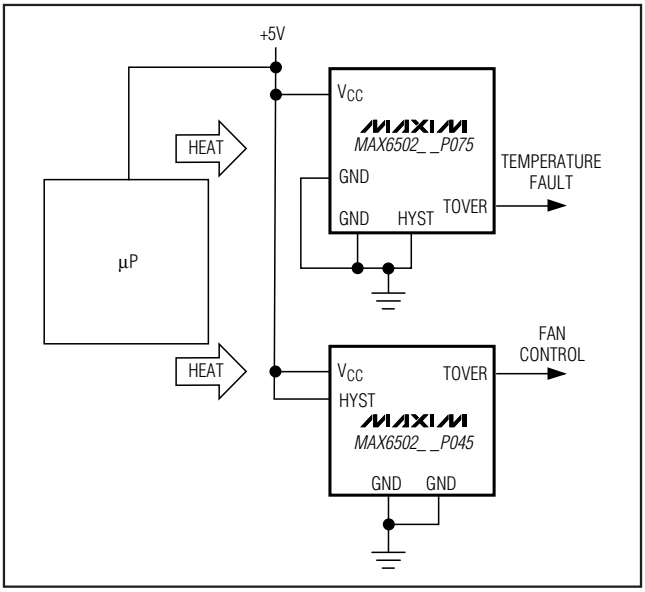

Figure 5. Low-Power, High-Reliability, Fail-Safe Temperature Monitor

Table 2. Device Marking Codes

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
MAX6501UKP125	ADQK	25k
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
MAX6502UKP125	ADUD	25k
MAX6503UKN045	ADIZ	10k
MAX6503UKN035	ADVS	10k
MAX6503UKN025	ADVR	10k
MAX6503UKN015	ACFX	2.5k
MAX6503UKN005	ADNZ	10k
MAX6503UKP005	ABZX	2.5k
MAX6503UKP015	ADPN	10k
MAX6504UKN045	ACAX	10k
MAX6504UKN035	ADVU	10k
MAX6504UKN025	ADVT	10k
MAX6504UKN015	ACGD	2.5k
MAX6504UKN005	ADVX	10k
MAX6504UKP005	ABZY	2.5k
MAX6504UKP015	ADKE	10k

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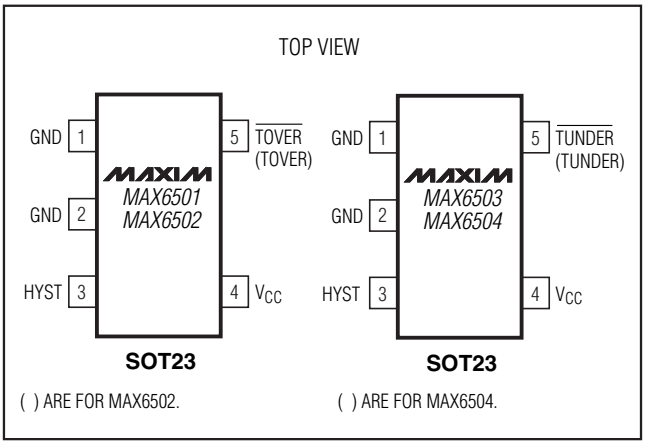
Selector Guide

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	✓	✓		
	+125	✓	✓		

Pin Configurations



( ) ARE FOR MAX6502.

( ) ARE FOR MAX6504.

Chip Information

SUBSTRATE CONNECTED TO GND

Package Information

For the latest package outline information and land patterns (footprints), go to **www.maxim-ic.com/packages**. Note that a "+", "#", or "-" in the package code indicates RoHS status only. Package drawings may show a different suffix character, but the drawing pertains to the package regardless of RoHS status.

PACKAGE TYPE	PACKAGE CODE	OUTLINE NO.	LAND PATTERN NO.
5 SOT23	U5+2	21-0057	90-0174

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Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
5	10/06	In Table 2 updated the device marking codes for MAX6503UKN035, MAX6503UKN025, MAX6503UKN005, MAX6503UKP015, MAX6504UKN035, MAX6504UKN025, and MAX6504UKN005	7
6	2/11	Removed the TO-220 package from entire data sheet; changed all leaded parts to lead(Pb)-free parts in the *Ordering Information* table; in the *Absolute Maximum Ratings* section changed the continuous power dissipation numbers (7.1mW/°C to 3.1mW/°C and 571mW to 247mW) and added the soldering temperature; added the *Package Information* table	All

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