



# 7-Channel Precision Remote-Diode, Thermistor, and Local Temperature Monitor

## General Description

The MAX6698 precision multichannel temperature sensor monitors its own temperature, the temperatures of three external diode-connected transistors, and the temperatures of three thermistors. All temperature channels have programmable alert thresholds. Channels 1, 4, 5, and 6 also have programmable over-temperature thresholds. When the measured temperature of a channel exceeds the respective threshold, a status bit is set in one of the status registers. Two open-drain outputs,  $\overline{\text{OVERT}}$  and  $\overline{\text{ALERT}}$ , assert corresponding to these bits in the status register.

The 2-wire serial interface supports the standard system management bus (SMBus™) protocols: write byte, read byte, send byte, and receive byte for reading the temperature data and programming the alarm thresholds.

The MAX6698 is specified for an operating temperature range of  $-40^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$  and is available in 16-pin QSOP and 16-pin TSSOP packages.

## Applications

Desktop Computers      Workstations  
Notebook Computers      Servers

## Features

- ◆ Three Thermal-Diode Inputs and Three Thermistor Inputs
- ◆ Local Temperature Sensor
- ◆  $1^{\circ}\text{C}$  Remote Temperature Accuracy ( $+60^{\circ}\text{C}$  to  $+100^{\circ}\text{C}$ )
- ◆ Temperature Monitoring Begins at POR for Fail-Safe System Protection
- ◆  $\overline{\text{ALERT}}$  and  $\overline{\text{OVERT}}$  Outputs for Interrupts, Throttling, and Shutdown
- ◆ Small 16-Pin QSOP and 16-Pin TSSOP Packages
- ◆ 2-Wire SMBus Interface

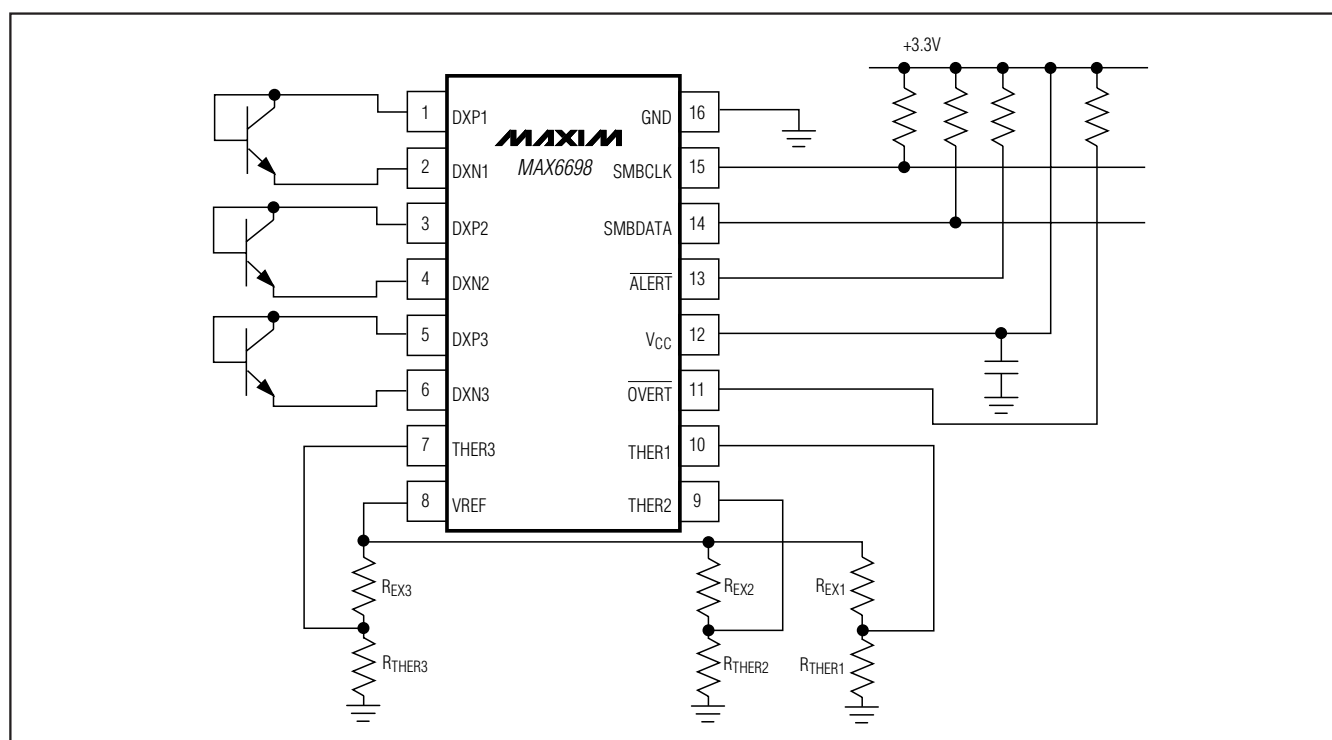
## Ordering Information

| PART         | TEMP RANGE                                      | PIN-PACKAGE | PKG CODE |
|--------------|-------------------------------------------------|-------------|----------|
| MAX6698EE_ _ | $-40^{\circ}\text{C}$ to $+125^{\circ}\text{C}$ | 16 QSOP     | E16-1    |
| MAX6698UE_ _ | $-40^{\circ}\text{C}$ to $+125^{\circ}\text{C}$ | 16 TSSOP    | U16-1    |

\* See the Slave Address section.

Pin Configuration appears at end of data sheet.

## Typical Application Circuit



SMBus is a trademark of Intel Corp.



Maxim Integrated Products 1

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# 7-Channel Precision Remote-Diode, Thermistor, and Local Temperature Monitor

## ABSOLUTE MAXIMUM RATINGS

$V_{CC}$ , SCL, SDA, ALERT, OVERT to GND ..... -0.3V to +6V  
 DXP\_ to GND ..... -0.3V to ( $V_{CC} + 0.3V$ )  
 DXN\_ to GND ..... -0.3V to +0.8V  
 THER\_ to GND ..... -0.3V to +6V  
 VREF to GND ..... -0.3V to +6V  
 SDA, ALERT, OVERT Current ..... -1mA to +50mA  
 DXN Current .....  $\pm 1mA$   
 Continuous Power Dissipation ( $T_A = +70^\circ C$ )

16-Pin QSOP

(derate 8.3mW/ $^\circ C$  above  $+70^\circ C$ ) ..... 666.7mW(E16-1)

16-Pin TSSOP

(derate 9.4mW/ $^\circ C$  above  $+70^\circ C$ ) ..... 754.7mW(U16-1)  
 ESD Protection (all pins, Human Body Model) .....  $\pm 2000V$   
 Operating Temperature Range .....  $-40^\circ C$  to  $+125^\circ C$   
 Junction Temperature .....  $+150^\circ C$   
 Storage Temperature Range .....  $-60^\circ C$  to  $+150^\circ C$   
 Lead Temperature (soldering, 10s) .....  $+300^\circ C$

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

( $V_{CC} = +3.0V$  to  $+5.5V$ ,  $T_A = -40^\circ C$  to  $+125^\circ C$ , unless otherwise noted. Typical values are at  $V_{CC} = +3.3V$  and  $T_A = +25^\circ C$ .) (Note 1)

| PARAMETER                                   | SYMBOL       | CONDITIONS                            | MIN                                                           | TYP       | MAX       | UNITS        |
|---------------------------------------------|--------------|---------------------------------------|---------------------------------------------------------------|-----------|-----------|--------------|
| Supply Voltage                              | $V_{CC}$     |                                       | 3.0                                                           |           | 5.5       | V            |
| Standby Supply Current                      | $I_{SS}$     | SMBus static                          |                                                               | 30        |           | $\mu A$      |
| Operating Current                           | $I_{CC}$     | During conversion                     |                                                               | 500       | 1000      | $\mu A$      |
| Temperature Resolution                      |              | Channel 1 only                        |                                                               | 11        |           | Bits         |
|                                             |              | Other diode channels                  |                                                               | 8         |           |              |
| Remote Temperature Accuracy                 |              | $V_{CC} = 3.3V$                       | $T_A = T_{RJ} = +60^\circ C$ to $+100^\circ C$                | -1.0      | +1.0      | $^\circ C$   |
|                                             |              |                                       | $T_A = T_{RJ} = 0^\circ C$ to $+125^\circ C$                  | -3.0      | +3.0      |              |
|                                             |              |                                       | DXN_ grounded,<br>$T_{RJ} = T_A = 0^\circ C$ to $+85^\circ C$ |           | $\pm 2.5$ |              |
| Local Temperature Accuracy                  |              | $V_{CC} = 3.3V$                       | $T_A = +60^\circ C$ to $+100^\circ C$                         | -2.5      | +2.5      | $^\circ C$   |
|                                             |              |                                       | $T_A = 0^\circ C$ to $+125^\circ C$                           | -3.5      | +3.5      |              |
| Supply Sensitivity of Temperature Accuracy  |              |                                       |                                                               | $\pm 0.2$ |           | $^\circ C/V$ |
| Remote Channel 1 Conversion Time            | $t_{CONV1}$  | Resistance cancellation on            | 95                                                            | 125       | 156       | ms           |
|                                             |              | Resistance cancellation off           | 190                                                           | 250       | 312       |              |
| Remote Channels 2 Through 6 Conversion Time | $t_{CONV\_}$ |                                       | 95                                                            | 125       | 156       | ms           |
| Remote-Diode Source Current                 | $I_{RJ}$     | High level                            | 80                                                            | 100       | 120       | $\mu A$      |
|                                             |              | Low level                             | 8                                                             | 10        | 12        |              |
| Undervoltage-Lockout Threshold              | UVLO         | Falling edge of $V_{CC}$ disables ADC | 2.3                                                           | 2.80      | 2.95      | V            |
| Undervoltage-Lockout Hysteresis             |              |                                       |                                                               | 90        |           | mV           |
| Power-On Reset (POR) Threshold              |              | $V_{CC}$ falling edge                 | 1.2                                                           | 2.0       | 2.5       | V            |
| POR Threshold Hysteresis                    |              |                                       |                                                               | 90        |           | mV           |
| <b>THERMISTOR CONVERSION</b>                |              |                                       |                                                               |           |           |              |
| Voltage-Measurement Accuracy                |              |                                       | -1                                                            |           | +1        | %Full scale  |
| Conversion Time                             |              |                                       |                                                               | 31        |           | ms           |
| Thermistor Reference Voltage                | $V_{REF}$    |                                       |                                                               | 1         |           | V            |

# 7-Channel Precision Remote-Diode, Thermistor, and Local Temperature Monitor

## ELECTRICAL CHARACTERISTICS (continued)

( $V_{CC} = +3.0V$  to  $+5.5V$ ,  $T_A = -40^{\circ}C$  to  $+125^{\circ}C$ , unless otherwise noted. Typical values are at  $V_{CC} = +3.3V$  and  $T_A = +25^{\circ}C$ .) (Note 1)

| PARAMETER                                                 | SYMBOL        | CONDITIONS                                   | MIN | TYP | MAX | UNITS   |
|-----------------------------------------------------------|---------------|----------------------------------------------|-----|-----|-----|---------|
| Reference-Load Regulation                                 |               | $0mA < I_{REF} < 2mA$                        |     |     | 0.4 | %       |
| Reference-Supply Rejection                                |               |                                              |     |     | 0.5 | %/V     |
| <b>ALERT, OVERT</b>                                       |               |                                              |     |     |     |         |
| Output Low Voltage                                        | $V_{OL}$      | $I_{SINK} = 1mA$                             |     |     | 0.3 | V       |
|                                                           |               | $I_{SINK} = 6mA$                             |     |     | 0.5 |         |
| Output Leakage Current                                    |               |                                              |     |     | 1   | $\mu A$ |
| <b>SMBus INTERFACE (SCL, SDA)</b>                         |               |                                              |     |     |     |         |
| Logic-Input Low Voltage                                   | $V_{IL}$      |                                              |     |     | 0.8 | V       |
| Logic-Input High Voltage                                  | $V_{IH}$      | $V_{CC} = 3.0V$                              | 2.2 |     |     | V       |
|                                                           |               | $V_{CC} = 5.0V$                              | 2.4 |     |     | V       |
| Input Leakage Current                                     |               |                                              | -1  |     | +1  | $\mu A$ |
| Output Low Voltage                                        | $V_{OL}$      | $I_{SINK} = 6mA$                             |     |     | 0.3 | V       |
| Input Capacitance                                         | $C_{IN}$      |                                              |     | 5   |     | pF      |
| <b>SMBus-COMPATIBLE TIMING (Figures 3 and 4) (Note 2)</b> |               |                                              |     |     |     |         |
| Serial Clock Frequency                                    | $f_{SCL}$     | (Note 3)                                     |     |     | 400 | kHz     |
| Bus Free Time Between STOP and START Condition            | $t_{BUF}$     | $f_{SCL} = 100kHz$                           | 4.7 |     |     | $\mu s$ |
|                                                           |               | $f_{SCL} = 400kHz$                           | 1.6 |     |     |         |
| START Condition Setup Time                                |               | $f_{SCL} = 100kHz$                           | 4.7 |     |     | $\mu s$ |
|                                                           |               | $f_{SCL} = 400kHz$                           | 0.6 |     |     |         |
| Repeat START Condition Setup Time                         | $t_{SU:STA}$  | 90% of SCL to 90% of SDA, $f_{SCL} = 100kHz$ | 0.6 |     |     | $\mu s$ |
|                                                           |               | 90% of SCL to 90% of SDA, $f_{SCL} = 400kHz$ | 0.6 |     |     |         |
| START Condition Hold Time                                 | $t_{HD:STA}$  | 10% of SDA to 90% of SCL                     | 0.6 |     |     | $\mu s$ |
| STOP Condition Setup Time                                 | $t_{SU:STO}$  | 90% of SCL to 90% of SDA, $f_{SCL} = 100kHz$ | 4   |     |     | $\mu s$ |
|                                                           |               | 90% of SCL to 90% of SDA, $f_{SCL} = 400kHz$ | 0.6 |     |     |         |
| Clock Low Period                                          | $t_{LOW}$     | 10% to 10%, $f_{SCL} = 100kHz$               | 1.3 |     |     | $\mu s$ |
|                                                           |               | 10% to 10%, $f_{SCL} = 400kHz$               | 1.3 |     |     |         |
| Clock High Period                                         | $t_{HIGH}$    | 90% to 90%                                   | 0.6 |     |     | $\mu s$ |
| Data Hold Time                                            | $t_{HD:DAT}$  | $f_{SCL} = 100kHz$                           | 300 |     |     | ns      |
|                                                           |               | $f_{SCL} = 400kHz$ (Note 4)                  |     |     | 900 |         |
| Data Setup Time                                           | $t_{SU:DAT}$  | $f_{SCL} = 100kHz$                           | 250 |     |     | ns      |
|                                                           |               | $f_{SCL} = 400kHz$                           | 100 |     |     |         |
| Receive SCL/SDA Rise Time                                 | $t_R$         | $f_{SCL} = 100kHz$                           |     |     | 1   | $\mu s$ |
|                                                           |               | $f_{SCL} = 400kHz$                           |     |     | 0.3 |         |
| Receive SCL/SDA Fall Time                                 | $t_F$         |                                              |     |     | 300 | ns      |
| Pulse Width of Spike Suppressed                           | $t_{SP}$      |                                              | 0   |     | 50  | ns      |
| SMBus Timeout                                             | $t_{TIMEOUT}$ | SDA low period for interface reset           | 25  | 37  | 45  | ms      |

**Note 1:** All parameters are tested at  $T_A = +25^{\circ}C$ . Specifications over temperature are guaranteed by design.

**Note 2:** Timing specifications are guaranteed by design.

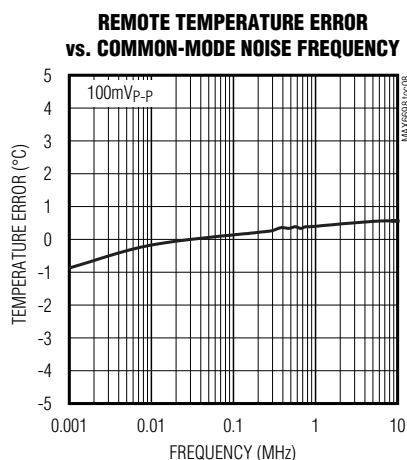
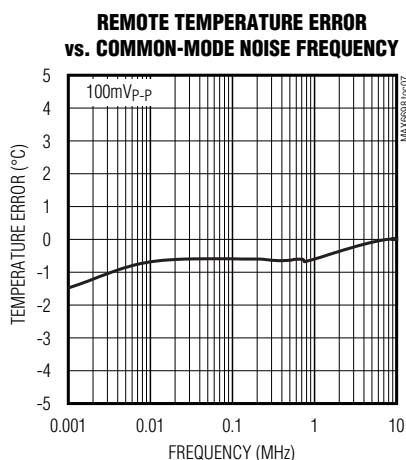
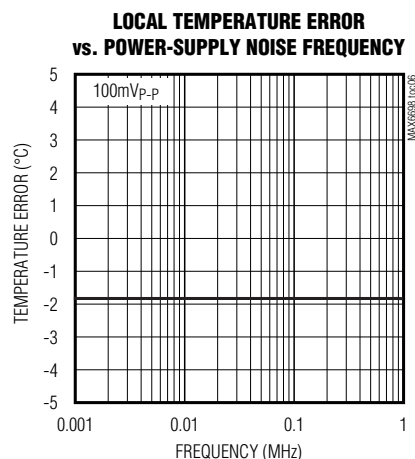
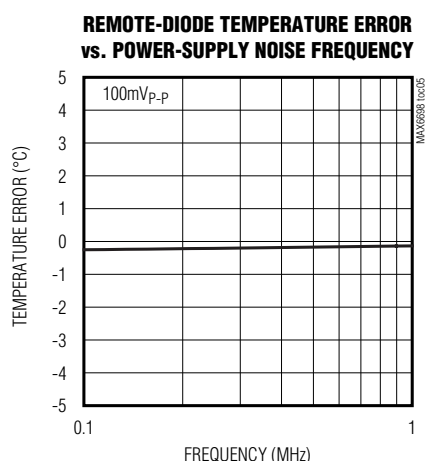
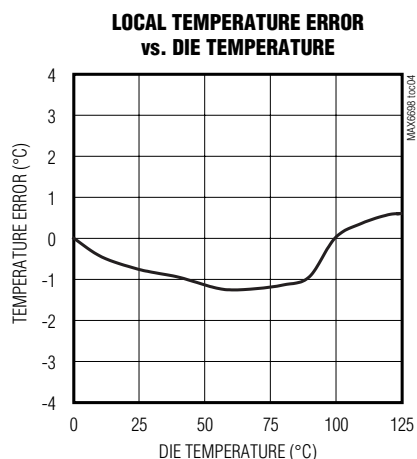
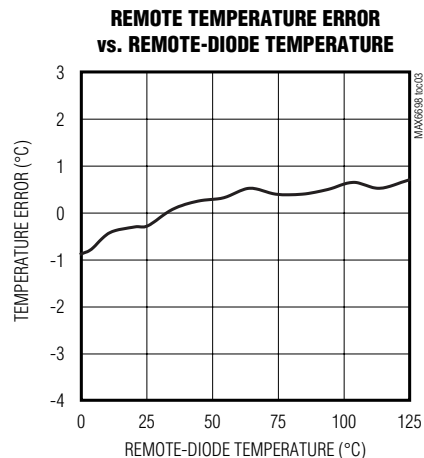
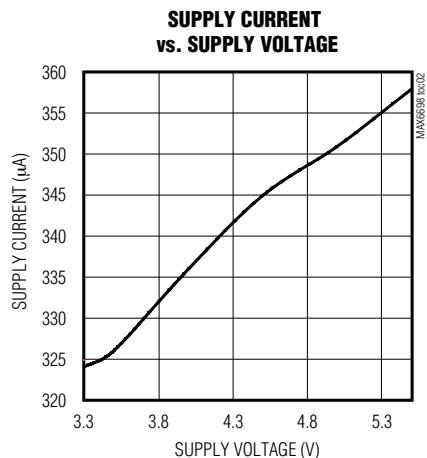
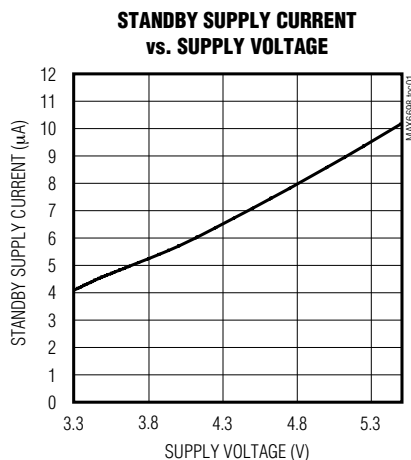
**Note 3:** The serial interface resets when SCL is low for more than  $t_{TIMEOUT}$ .

**Note 4:** A transition must internally provide at least a hold time to bridge the undefined region (300ns max) of SCL's falling edge.

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## Typical Operating Characteristics

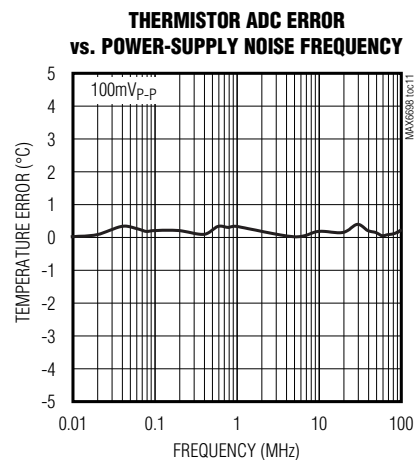
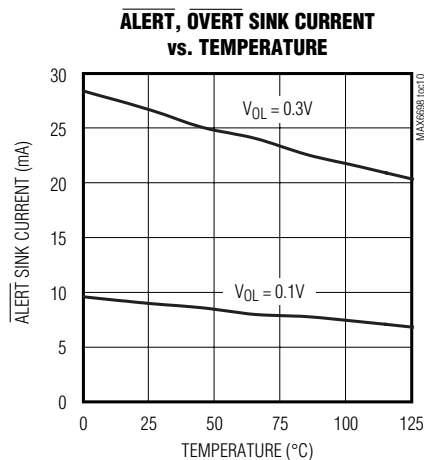
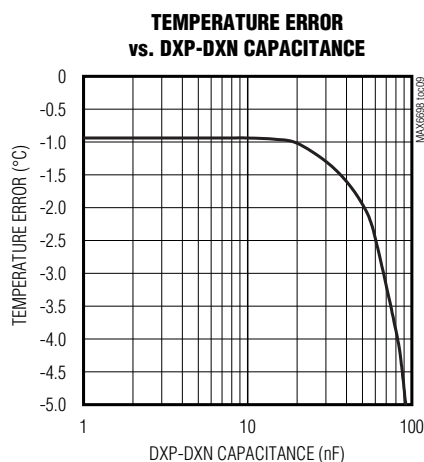
( $V_{CC} = 3.3V$ ,  $T_A = +25^{\circ}C$ , unless otherwise noted.)



# 7-Channel Precision Remote-Diode, Thermistor, and Local Temperature Monitor

## Typical Operating Characteristics (continued)

( $V_{CC} = 3.3V$ ,  $T_A = +25^{\circ}C$ , unless otherwise noted.)



## Pin Description

| PIN | NAME  | FUNCTION                                                                                                                                                                                                                                                                                          |
|-----|-------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1   | DXP1  | Combined Current Source and A/D Positive Input for Channel 1 Remote Diode. Connect to the anode of a remote-diode-connected temperature-sensing transistor. Leave floating or connect to $V_{CC}$ if no remote diode is used. Place a 2200pF capacitor between DXP1 and DXN1 for noise filtering. |
| 2   | DXN1  | Cathode Input for Channel 1 Remote Diode. Connect the cathode of the channel 1 remote-diode-connected transistor to DXN1.                                                                                                                                                                         |
| 3   | DXP2  | Combined Current Source and A/D Positive Input for Channel 2 Remote Diode. Connect to the anode of a remote-diode-connected temperature-sensing transistor. Leave floating or connect to $V_{CC}$ if no remote diode is used. Place a 2200pF capacitor between DXP2 and DXN2 for noise filtering. |
| 4   | DXN2  | Cathode Input for Channel 2 Remote Diode. Connect the cathode of the channel 2 remote-diode-connected transistor to DXN2.                                                                                                                                                                         |
| 5   | DXP3  | Combined Current Source and A/D Positive Input for Channel 3 Remote Diode. Connect to the anode of a remote-diode-connected temperature-sensing transistor. Leave floating or connect to $V_{CC}$ if no remote diode is used. Place a 2200pF capacitor between DXP3 and DXN3 for noise filtering. |
| 6   | DXN3  | Cathode Input for Channel 3 Remote Diode. Connect the cathode of the channel 1 remote-diode-connected transistor to DXN3.                                                                                                                                                                         |
| 7   | THER3 | Thermistor Voltage Sense Input 3. Connect thermistor 3 between THER3 and ground and an external resistor $R_{EXT3}$ between THER3 and VREF.                                                                                                                                                       |
| 8   | VREF  | Thermistor Reference Voltage (1V Nominal). VREF is automatically enabled for a thermistor conversion, and is disabled for diode measurements.                                                                                                                                                     |

# 7-Channel Precision Remote-Diode, Thermistor, and Local Temperature Monitor

## Pin Description (continued)

| PIN | NAME               | FUNCTION                                                                                                                                                                  |
|-----|--------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 9   | THER2              | Thermistor Voltage Sense Input 2. Connect thermistor 2 between THER2 and ground and an external resistor $R_{EXT3}$ between THER2 and VREF.                               |
| 10  | THER1              | Thermistor Voltage Sense Input 1. Connect thermistor 1 between THER1 and ground and an external resistor $R_{EXT3}$ between THER1 and VREF.                               |
| 11  | $\overline{OVERT}$ | Overtemperature Active-Low, Open-Drain Output. $\overline{OVERT}$ asserts low when the temperature of channels 1, 4, 5, and 6 exceed the programmed threshold limit.      |
| 12  | VCC                | Supply Voltage Input. Bypass to GND with a 0.1 $\mu$ F capacitor.                                                                                                         |
| 13  | $\overline{ALERT}$ | SMBus Alert (Interrupt), Active-Low, Open-Drain Output. $\overline{ALERT}$ asserts low when the temperature of channels 1, 4, 5, and 6 exceed programmed threshold limit. |
| 14  | SMBDATA            | SMBus Serial-Data Input/Output. Connect to a pullup resistor.                                                                                                             |
| 15  | SMBCLK             | SMBus Serial-Clock Input. Connect to a pullup resistor.                                                                                                                   |
| 16  | GND                | Ground                                                                                                                                                                    |

## Detailed Description

The MAX6698 is a precision multichannel temperature monitor that features one local, three remote thermal diode temperature-sensing channels, and three thermistor voltage-sensing channels. All channels have a programmable alert threshold for each temperature channel and a programmable overtemperature threshold for channels 1, 4, 5, and 6 (see Figure 1). Communication with the MAX6698 is achieved through the SMBus serial interface and a dedicated alert ( $\overline{ALERT}$ ) pin. The alarm outputs,  $\overline{OVERT}$  and  $\overline{ALERT}$ , assert if the software-programmed temperature thresholds are exceeded.  $\overline{ALERT}$  typically serves as an interrupt, while  $\overline{OVERT}$  can be connected to a fan, system shutdown, or other thermal-management circuitry.

Note that thermistor “temperature data” is really the voltage across the fixed resistor,  $R_{EXT}$ , in series with the thermistor. This voltage is directly related to temperature, but the data is expressed in percentage of the reference voltage not in  $^{\circ}\text{C}$ .

### ADC Conversion Sequence

In the default conversion mode, the MAX6698 starts the conversion sequence by measuring the temperature on the channel 1 remote diode, followed by the channel 2, remote diode, channel 3 remote diode, and the local channel. Then it measures thermistor channel 1, thermistor channel 2, and thermistor channel 3. The con-

version result for each active channel is stored in the corresponding temperature data register.

In some systems, one of the remote thermal diodes may be monitoring a location that experiences temperature changes that occur much more rapidly than in the other channels. If faster temperature changes must be monitored in one of the temperature channels, the MAX6698 allows channel 1 to be monitored at a faster rate than the other channels. In this mode (set by writing a 1 to bit 4 of the configuration 1 register), measurements of channel 1 alternate with measurements of the other channels. The sequence becomes remote-diode channel 1, remote-diode channel 2, remote-diode channel 1, remote-diode channel 3, remote-diode channel 1, etc. Note that the time required to measure all seven channels is considerably greater in this mode than in the default mode.

### Low-Power Standby Mode

Standby mode reduces the supply current to less than 15 $\mu\text{A}$  by disabling the internal ADC. Enter standby by setting the STOP bit to 1 in the configuration 1 register. During standby, data is retained in memory, and the SMBus interface is active and listening for SMBus commands. The timeout is enabled if a start condition is recognized on the SMBus. Activity on the SMBus causes the supply current to increase. If a standby command is received while a conversion is in progress, the conversion cycle is interrupted, and the temperature registers are not updated. The previous data is not changed and remains available.

# 7-Channel Precision Remote-Diode, Thermistor, and Local Temperature Monitor

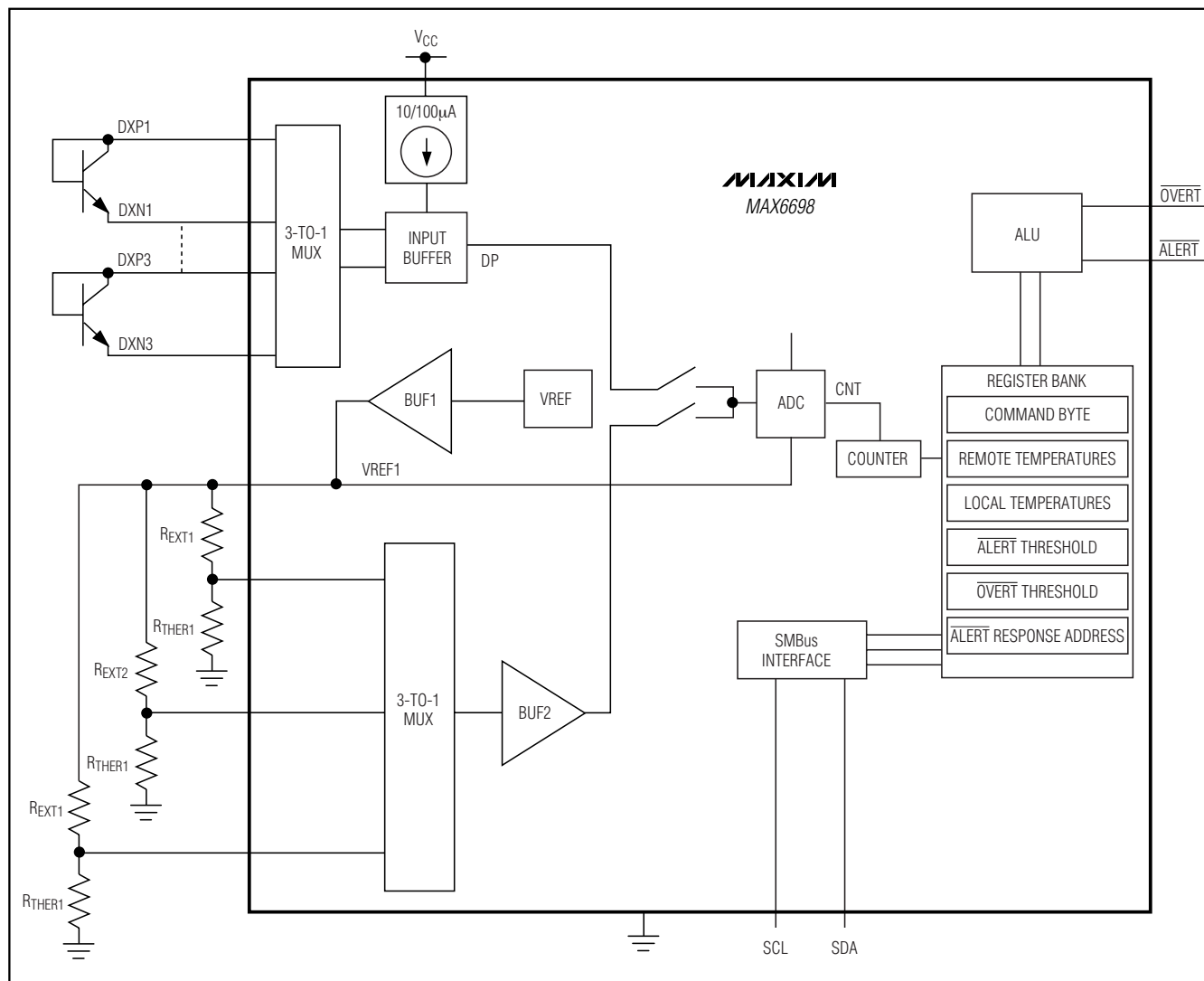


Figure 1. Internal Block Diagram

## SMBus Digital Interface

From a software perspective, the MAX6698 appears as a series of 8-bit registers that contain temperature measurement data, alarm threshold values, and control bits. A standard SMBus-compatible 2-wire serial interface is used to read temperature data and write control bits and alarm threshold data. The same SMBus slave address also provides access to all functions.

The MAX6698 employs four standard SMBus protocols: write byte, read byte, send byte, and receive byte (Figure 2). The shorter receive byte protocol allows quicker transfers, provided that the correct data regis-

ter was previously selected by a read byte instruction. Use caution with the shorter protocols in multimaster systems, since a second master could overwrite the command byte without informing the first master. Figure 3 is the SMBus write timing diagram and Figure 4 is the SMBus read timing diagram.

The remote diode 1 measurement channel provides 11 bits of data (1 LSB = 0.125°C). All other temperature-measurement channels provide 8 bits of temperature data (1 LSB = 1°C). The 8 most significant bits (MSBs) can be read from the local temperature, remote temperature, and thermistor registers. The remaining 3 bits

# 7-Channel Precision Remote-Diode, Thermistor, and Local Temperature Monitor

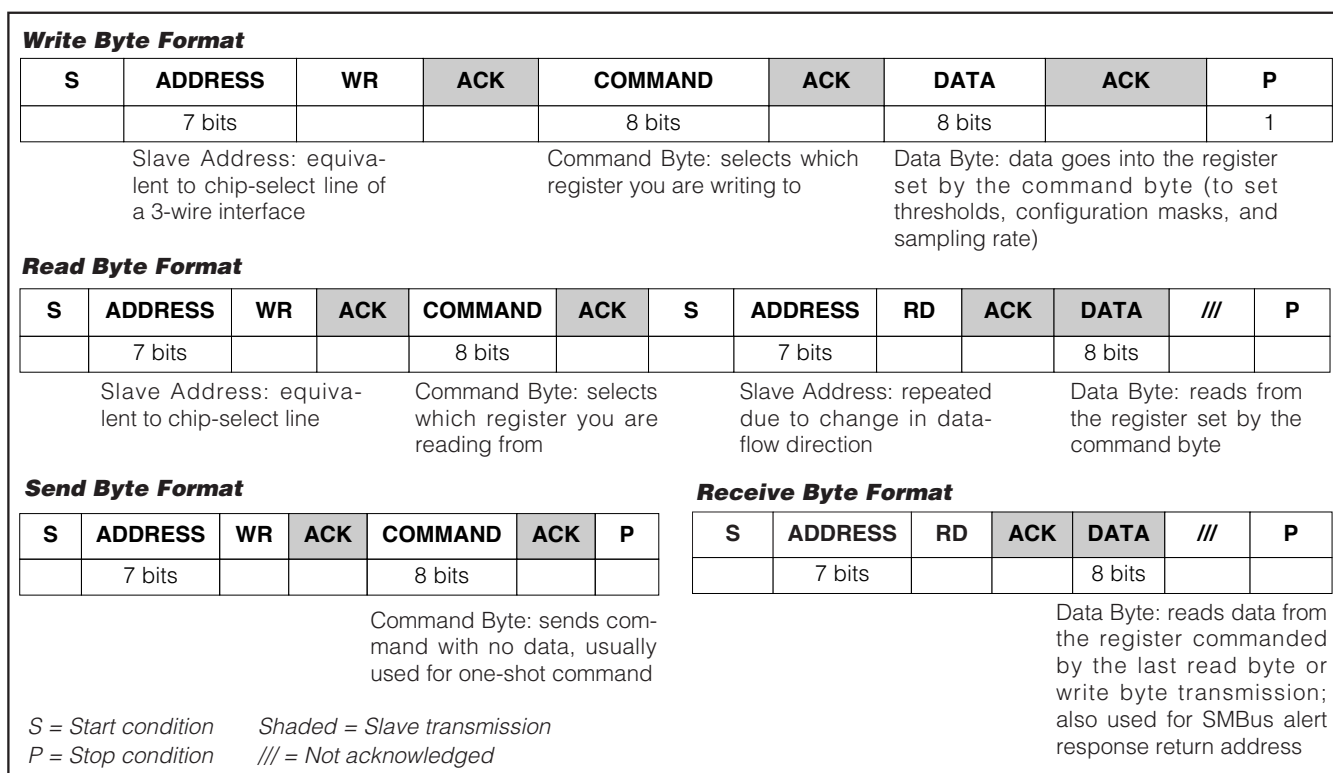


Figure 2. SMBus Protocols

for remote diode 1 can be read from the extended temperature register. If extended resolution is desired, the extended resolution register should be read first. This prevents the most significant bits from being overwritten by new conversion results until they have been read. If the most significant bits have not been read within an SMBus timeout period (nominally 25ms), normal updating continues. Table 1 shows thermistor voltage data format. Table 2 shows the main temperature register (high byte) data format. Table 3 shows the extended resolution temperature register (low byte) data format.

## Diode Fault Detection

If a channel's input DXP<sub>-</sub> and DXN<sub>-</sub> are left open, the MAX6698 detects a diode fault. An open diode fault does not cause either ALERT or OVERT to assert. A bit in the status register for the corresponding channel is set to 1 and the temperature data for the channel is stored as all 1s (FFh). It takes approximately 4ms for the MAX6698 to detect a diode fault. Once a diode fault is detected, the MAX6698 goes to the next channel in the conversion sequence. Depending on operating conditions, a shorted diode may or may not cause ALERT or OVERT to assert, so if a channel will not be used, disconnect its DXP and DXN inputs.

Table 1. Thermistor Voltage Data Format

| V <sub>REXT</sub> | DIGITAL OUTPUT |
|-------------------|----------------|
| 1.000             | 1100 1000      |
| 0.500             | 0110 0100      |
| 0.250             | 0011 0010      |
| 0.055             | 0000 1011      |
| 0.050             | 0000 1010      |
| 0.005             | 0000 0001      |
| 0.000             | 0000 0000      |

## Alarm Threshold Registers

There are 11 alarm threshold registers that store over-temperature ALERT and OVERT threshold values. Seven of these registers are dedicated to store one local alert temperature threshold limit, three remote alert temperature threshold limits, and three thermistor voltage threshold limits (see the *ALERT Interrupt Mode* section). The remaining four registers are dedicated to remote-diode channel 1, and three thermistor channels 1, 2, and 3 to store overtemperature threshold limits (see the *OVERT Overtemperature Alarm* section). Access to these registers is provided through the SMBus interface.



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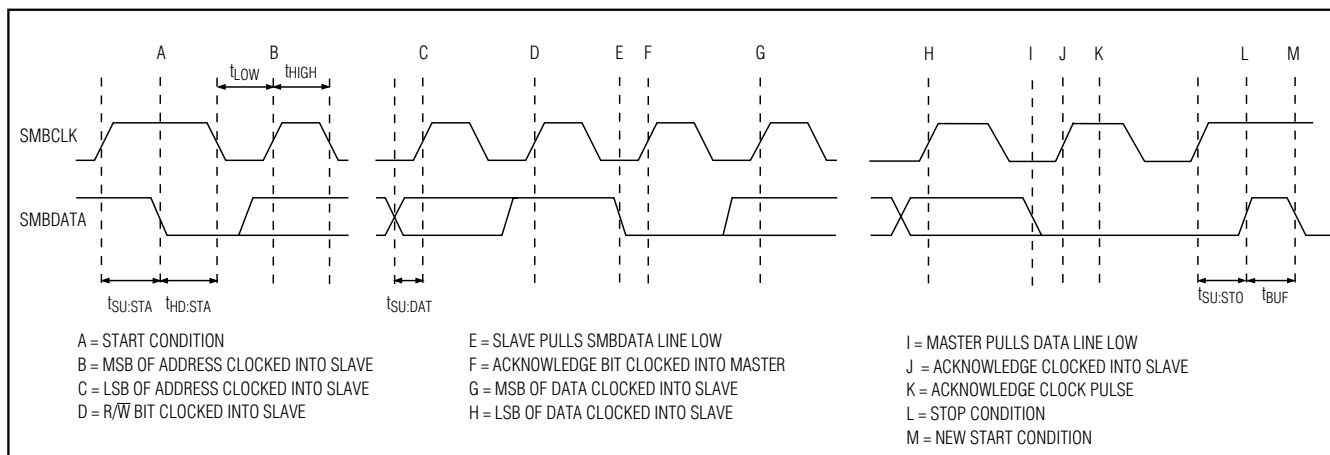


Figure 3. SMBus Write Timing Diagram

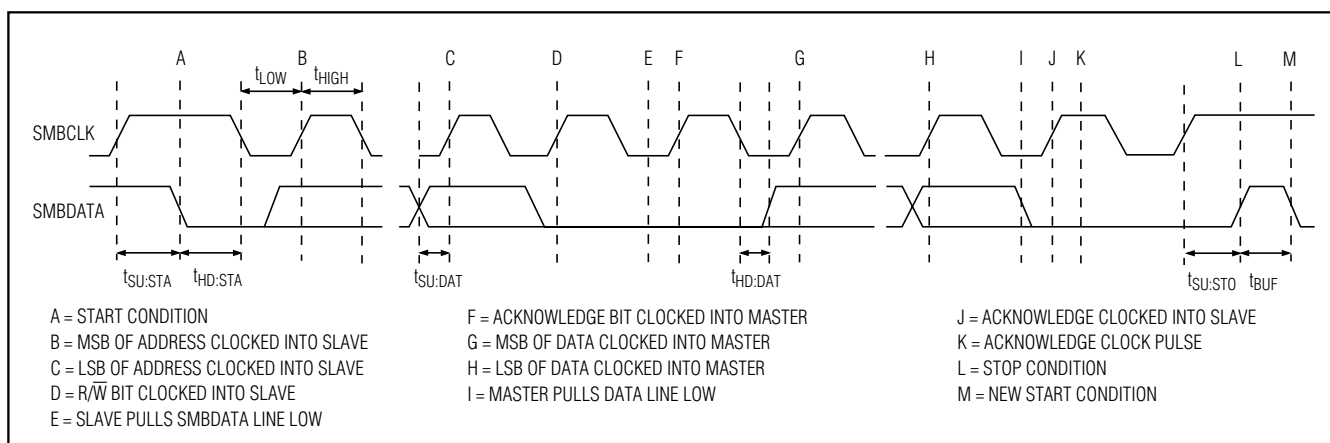


Figure 4. SMBus Read Timing Diagram

**Table 2. Main Temperature Register (High Byte) Data Format**

| TEMP (°C)           | DIGITAL OUTPUT         |
|---------------------|------------------------|
| >127                | 0111 1111              |
| 127                 | 0111 1111              |
| 126                 | 0111 1110              |
| 25                  | 00011001               |
| 0.00                | 0000 0000              |
| <0.00               | 0000 0000              |
| Diode fault (open)  | 1111 1111              |
| Diode fault (short) | 1111 1111 or 1110 1110 |

**Table 3. Extended Resolution Temperature Register (Low Byte) Data Format**

| TEMP (°C) | DIGITAL OUTPUT |
|-----------|----------------|
| 0         | 000X XXXX      |
| +0.125    | 001X XXXX      |
| +0.250    | 010X XXXX      |
| +0.375    | 011X XXXX      |
| +0.500    | 100X XXXX      |
| +0.625    | 101X XXXX      |
| +0.725    | 110X XXXX      |
| +0.875    | 111X XXXX      |

# 7-Channel Precision Remote-Diode, Thermistor, and Local Temperature Monitor

## **ALERT Interrupt Mode**

An ALERT interrupt occurs when the internal or external temperature reading exceeds a high-temperature limit (user programmable). The ALERT interrupt output signal can be cleared by reading the status register(s) associated with the fault(s) or by successfully responding to an alert response address transmission by the master. In both cases, the alert is cleared but is reasserted at the end of the next conversion if the fault condition still exists. The interrupt does not halt automatic conversions. The ALERT output is open drain so that multiple devices can share a common interrupt line. All ALERT interrupts can be masked using the configuration 3 register. The POR state of these registers is shown in Table 4.

## **ALERT Response Address**

The SMBus alert response interrupt pointer provides quick fault identification for simple slave devices that lack the complex logic needed to be a bus master. Upon receiving an interrupt signal, the host master can broadcast a receive byte transmission to the alert response slave address (see the *Slave Addresses* section). Then, any slave device that generated an interrupt attempts to identify itself by putting its own address on the bus.

The alert response can activate several different slave devices simultaneously, similar to the I<sup>2</sup>C General Call. If more than one slave attempts to respond, bus arbitration rules apply, and the device with the lower address code wins. The losing device does not generate an acknowledgment and continues to hold the ALERT line low until cleared. (The conditions for clearing an alert vary depending on the type of slave device.) Successful completion of the alert response protocol clears the output latch. If the condition that caused the alert still exists, the MAX6698 reasserts the ALERT interrupt at the end of the next conversion.

## **OVERT Overtemperature Alarms**

The MAX6698 has four overtemperature registers that store remote alarm threshold data for the OVERT output. OVERT is asserted when a channel's measured temperature (voltage in the case of the thermistor channels) is greater than the value stored in the corresponding threshold register. OVERT remains asserted until the temperature drops below the programmed threshold minus 4°C hysteresis for remote-diode channel 1, or

4 LSB hysteresis for thermistor channels 1, 2, and 3. An overtemperature output can be used to activate a cooling fan, send a warning, initiate clock throttling, or trigger a system shutdown to prevent component damage. See Table 4 for the POR state of the overtemperature threshold registers.

## **Command Byte Functions**

The 8-bit command byte register (Table 4) is the master index that points to the various other registers within the MAX6698. This register's POR state is 0000 0000.

## **Configuration Bytes Functions**

There are three read-write configuration registers (Tables 5, 6, 7) that can be used to control the MAX6698's operation.

### **Configuration 1 Register**

The configuration 1 register (Table 5) has several functions. Bit 7(MSB) is used to put the MAX6698 either in software standby mode (STOP) or continuous conversion mode. Bit 6 resets all registers to their power-on reset conditions and then clears itself. Bit 5 disables the SMBus timeout. Bit 4 enables more frequent conversions on channel 1, as described in the *ADC Conversion Sequence* section. Bit 3 enables resistance cancellation on channel 1. See the *Series Resistance Cancellation* section for more details. The remaining bits of the configuration 1 register are not used. The POR state of this register is 0000 0000 (00h).

### **Configuration 2 Register**

The configuration 2 register functions are described in Table 6. Bits [6:0] are used to mask the ALERT interrupt output. Bit 6 masks the local alert interrupt, bits 5 through 3 mask the remote-diode ALERT interrupts, and bits 2 through 0 mask the thermistor alert interrupts. The power-up state of this register is 0000 0000 (00h).

### **Configuration 3 Register**

Table 7 describes the configuration 3 register. Bits 5, 4, 3, and 0 mask the OVERT interrupt output for thermistor channels 1, 2, and 3 and remote-diode channel 1. The remaining bits, 7, 6, 2, and 1, are reserved. The power-up state of this register is 0000 0000 (00h).

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**Table 4. Command Byte Register Bit Assignment**

| REGISTER                                          | ADDRESS (HEX) | POR STATE (HEX) | READ/ WRITE | DESCRIPTION                                                                       |
|---------------------------------------------------|---------------|-----------------|-------------|-----------------------------------------------------------------------------------|
| Local                                             | 07            | 00              | R           | Read local temperature register                                                   |
| Remote 1                                          | 01            | 00              | R           | Read channel 1 remote temperature register                                        |
| Remote 2                                          | 02            | 00              | R           | Read channel 2 remote temperature register                                        |
| Remote 3                                          | 03            | 00              | R           | Read channel 3 remote temperature register                                        |
| Thermistor 1                                      | 04            | 00              | R           | Read thermistor 1 voltage register                                                |
| Thermistor 2                                      | 05            | 00              | R           | Read thermistor 2 voltage register                                                |
| Thermistor 3                                      | 06            | 00              | R           | Read thermistor 3 voltage register                                                |
| Configuration 1                                   | 41            | 00              | R/W         | Read/write configuration register 1                                               |
| Configuration 2                                   | 42            | 00              | R/W         | Read/write configuration register 2                                               |
| Configuration 3                                   | 43            | 00              | R/W         | Read/write configuration register 3                                               |
| Status 1                                          | 44            | 00              | R           | Read status register 1                                                            |
| Status 2                                          | 45            | 00              | R           | Read status register 2                                                            |
| Status 3                                          | 46            | 00              | R           | Read status register 3                                                            |
| Local $\overline{\text{ALERT}}$ High Limit        | 17            | 5A              | R/W         | Read/write local alert high-temperature threshold limit register                  |
| Remote 1 $\overline{\text{ALERT}}$ High Limit     | 11            | 6E              | R/W         | Read/write channel 1 remote-diode alert high-temperature threshold limit register |
| Remote 2 $\overline{\text{ALERT}}$ High Limit     | 12            | 7F              | R/W         | Read/write channel 2 remote-diode alert high-temperature threshold limit register |
| Remote 3 $\overline{\text{ALERT}}$ High Limit     | 13            | 64              | R/W         | Read/write channel 3 remote-diode alert high-temperature threshold limit register |
| Thermistor 1 $\overline{\text{ALERT}}$ High Limit | 14            | 64              | R/W         | Read/write thermistor 1 voltage alert high-threshold limit register               |
| Thermistor 2 $\overline{\text{ALERT}}$ High Limit | 15            | 64              | R/W         | Read/write thermistor 2 alert high-threshold limit register                       |
| Thermistor 3 $\overline{\text{ALERT}}$ High Limit | 16            | 64              | R/W         | Read/write thermistor 3 alert high-threshold limit register                       |
| Remote 1 $\overline{\text{OVERT}}$ High Limit     | 21            | 6E              | R/W         | Read/write channel 1 remote-diode overtemperature threshold limit register        |
| Thermistor 1 $\overline{\text{OVERT}}$ High Limit | 24            | 7F              | R/W         | Read/ write thermistor 1 overtemperature threshold limit register                 |
| Thermistor 2 $\overline{\text{OVERT}}$ High Limit | 25            | 5A              | R/W         | Read/write thermistor 2 overtemperature threshold limit register                  |
| Thermistor 3 $\overline{\text{OVERT}}$ High Limit | 26            | 5A              | R/W         | Read/write thermistor3 overtemperature threshold limit register                   |
| Remote 1 Extended Temperature                     | 09            | 00              | R           | Read channel 1 remote-diode extended temperature register                         |
| Manufacturer ID                                   | 0A            | 4D              | R           | Read manufacturer ID                                                              |
| Device ID and Revision                            | 0E            | 00              | —           | —                                                                                 |

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**Table 5. Configuration 1 Register**

| BIT    | NAME                    | POR STATE | FUNCTION                                                                                                                |
|--------|-------------------------|-----------|-------------------------------------------------------------------------------------------------------------------------|
| 7(MSB) | STOP                    | 0         | Standby Mode Control Bit. If STOP is set to logic 1, the MAX6698 stops converting and enters standby mode.              |
| 6      | POR                     | 0         | Reset Bit. Set to logic 1 to put the device into its power-on state. This bit is self-clearing.                         |
| 5      | TIMEOUT                 | 0         | Timeout Enable Bit. Set to logic 0 to enable SMBus timeout.                                                             |
| 4      | Fast remote 1           | 0         | Channel 1 Fast Conversion Bit. Set to logic 1 to enable fast conversion of channel 1.                                   |
| 3      | Resistance cancellation | 0         | Resistance Cancellation Bit. When set to logic 1, the MAX6698 cancels series resistance in the channel 1 thermal diode. |
| 2      | Reserved                | 0         | —                                                                                                                       |
| 1      | Reserved                | 0         | —                                                                                                                       |
| 0      | Reserved                | 0         | —                                                                                                                       |

**Table 6. Configuration 2 Register**

| BIT    | NAME                     | POR STATE | FUNCTION                                                                                               |
|--------|--------------------------|-----------|--------------------------------------------------------------------------------------------------------|
| 7(MSB) | Reserved                 | 0         | —                                                                                                      |
| 6      | Mask Local ALERT         | 0         | Local Alert Mask. Set to logic 1 to mask local channel $\overline{\text{ALERT}}$ .                     |
| 5      | Mask Thermistor 3ALERT   | 0         | Thermistor 3 Alert Mask. Set to logic 1 to mask thermistor 3 $\overline{\text{ALERT}}$ .               |
| 4      | Mask Thermistor 2ALERT   | 0         | Thermistor 2 Alert Mask. Set to logic 1 to mask thermistor 2 $\overline{\text{ALERT}}$ .               |
| 3      | Mask Thermistor 1ALERT   | 0         | Thermistor 1 Alert Mask. Set to logic 1 to mask thermistor 1 $\overline{\text{ALERT}}$ .               |
| 2      | Mask Remote-Diode 3ALERT | 0         | Remote-Diode 3 Alert Interrupt Mask. Set to logic 1 to mask remote diode 3 $\overline{\text{ALERT}}$ . |
| 1      | Mask Remote-Diode 2ALERT | 0         | Remote-Diode 2 Alert Interrupt Mask. Set to logic 1 to mask remote diode 2 $\overline{\text{ALERT}}$ . |
| 0      | Mask Remote-Diode 2ALERT | 0         | Remote-Diode 1 Alert Interrupt Mask. Set to logic 1 to mask remote diode 1 $\overline{\text{ALERT}}$ . |

## Status Registers Functions

Status registers 1, 2, and 3 (Tables 8, 9, 10) indicate which (if any) temperature thresholds have been exceeded and if there is an open-circuit or short-circuit fault detected with the external sense junctions. Status register 1 indicates if the measured temperature has exceeded the threshold limit set in the ALERT registers for the local or remote-sensing diodes. Status register 2 indicates if the measured temperature has exceeded the threshold limit set in the  $\overline{\text{OVERT}}$  registers. Status register 3 indicates if there is a diode fault (open or short) in any of the remote-sensing channels.

Bits in the alert status register clear by a successful read, but set again after the next conversion unless the fault is corrected, either by a drop in the measured temperature or an increase in the threshold temperature.

The  $\overline{\text{ALERT}}$  interrupt output follows the status flag bit. Once the  $\overline{\text{ALERT}}$  output is asserted, it can be deasserted by either reading status register 1 or by successfully responding to an alert response address. In both cases, the alert is cleared even if the fault condition exists, but the  $\overline{\text{ALERT}}$  output reasserts at the end of the next conversion. Reading the status 2 register does not clear the  $\overline{\text{OVERT}}$  interrupt output. To eliminate the fault condition,

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**Table 7. Configuration 3 Register**

| BIT    | NAME                                        | POR STATE | FUNCTION                                                                                                                |
|--------|---------------------------------------------|-----------|-------------------------------------------------------------------------------------------------------------------------|
| 7(MSB) | Reserved                                    | 0         | —                                                                                                                       |
| 6      | Reserved                                    | 0         | —                                                                                                                       |
| 5      | Mask Thermistor 3 $\overline{\text{OVERT}}$ | 0         | Thermistor 3 $\overline{\text{OVERT}}$ Mask Bit. Set to logic 1 to mask thermistor 3 $\overline{\text{OVERT}}$ .        |
| 4      | Mask Thermistor 2 $\overline{\text{OVERT}}$ | 0         | Thermistor 2 $\overline{\text{OVERT}}$ Mask Bit. Set to logic 1 to mask thermistor 2 $\overline{\text{OVERT}}$ .        |
| 3      | Mask Thermistor 1 $\overline{\text{OVERT}}$ | 0         | Thermistor 1 $\overline{\text{OVERT}}$ Mask Bit. Set to logic 1 to mask thermistor 1 $\overline{\text{OVERT}}$ .        |
| 2      | Reserved                                    | 0         | —                                                                                                                       |
| 1      | Reserved                                    | 0         | —                                                                                                                       |
| 0      | Mask $\overline{\text{OVERT}}$ 1            | 0         | Channel 1 Remote-Diode $\overline{\text{OVERT}}$ Mask Bit. Set to logic 1 to mask channel 1 $\overline{\text{OVERT}}$ . |

either the measured value must drop below the threshold minus the hysteresis value (4°C or 4 LSBs), or the trip threshold must be set at least 4°C (or 4 LSBs) above the current value.

## Applications Information

### Remote-Diode Selection

The MAX6698 directly measures the die temperature of CPUs and other ICs that have on-chip temperature-sensing diodes (see the *Typical Application Circuit*) or it can measure the temperature of a discrete diode-connected transistor.

### Effect of Ideality Factor

The accuracy of the remote temperature measurements depends on the ideality factor ( $n$ ) of the remote “diode” (actually a transistor). The MAX6698 is optimized for  $n = 1.008$ . A thermal diode on the substrate of an IC is normally a pnp with the base and emitter brought out the collector (diode connection) grounded. DXP\_ must be connected to the anode (emitter) and DXN\_ must be connected to the cathode (base) of this pnp. If a sense transistor with an ideality factor other than 1.008 is used, the output data is different from the data obtained with the optimum ideality factor. Fortunately, the difference is predictable. Assume a remote-diode sensor designed for a nominal ideality factor  $n_{\text{NOMINAL}}$  is used to measure the temperature of a diode with a

different ideality factor  $n_1$ . The measured temperature  $T_M$  can be corrected using:

$$T_M = T_{\text{ACTUAL}} \left( \frac{n_1}{n_{\text{NOMINAL}}} \right)$$

where temperature is measured in Kelvin and  $n_{\text{NOMINAL}}$  for the MAX6698 is 1.008. As an example, assume you want to use the MAX6698 with a CPU that has an ideality factor of 1.002. If the diode has no series resistance, the measured data is related to the real temperature as follows:

$$T_{\text{ACTUAL}} = T_M \times \left( \frac{n_{\text{NOMINAL}}}{n_1} \right) = T_M \times \left( \frac{1.008}{1.002} \right) = T_M(1.00599)$$

For a real temperature of +85°C (358.15K), the measured temperature is +82.87°C (356.02K), an error of -2.13°C.

### Series Resistance Cancellation

Some thermal diodes on high-power ICs can have excessive series resistance, which can cause temperature measurement errors with conventional remote temperature sensors. Channel 1 of the MAX6698 has a series resistance cancellation feature (enabled by bit 3 of the configuration 1 register) that eliminates the effect of diode series resistance. Set bit 3 to 1 if the series resistance is large enough to affect the accuracy of

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**Table 8. Status 1 Register**

| BIT    | NAME                 | POR STATE | FUNCTION                                                                                                                                                                                                    |
|--------|----------------------|-----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 7(MSB) | Reserved             | 0         | —                                                                                                                                                                                                           |
| 6      | Local ALERT          | 0         | Local Channel High-Alert Bit. This bit is set to logic 1 when the local temperature exceeds the temperature threshold limit in the local ALERT high-limit register.                                         |
| 5      | Thermistor 3 ALERT   | 0         | Thermistor 3 Alert Bit. This bit is set to logic 1 when the thermistor 3 voltage exceeds the threshold limit in the thermistor 3 ALERT high-limit register.                                                 |
| 4      | Thermistor 2 ALERT   | 0         | Thermistor 2 Alert Bit. This bit is set to logic 1 when the thermistor 2 voltage exceeds the threshold limit in the thermistor 2 ALERT high-limit register.                                                 |
| 3      | Thermistor 1 ALERT   | 0         | Thermistor 1 Alert Bit. This bit is set to logic 1 when the thermistor 1 voltage exceeds the threshold limit in the thermistor 1 ALERT high-limit register.                                                 |
| 2      | Remote-Diode 3 ALERT | 0         | Channel 3 Remote-Diode High-Alert Bit. This bit is set to logic 1 when the channel 3 remote-diode temperature exceeds the programmed temperature threshold limit in the remote 3 ALERT high-limit register. |
| 1      | Remote-Diode 2 ALERT | 0         | Channel 2 Remote-Diode High-Alert Bit. This bit is set to logic 1 when the channel 2 remote-diode temperature exceeds the temperature threshold limit in the remote 2 ALERT high-limit register.            |
| 0      | Remote-Diode 1 ALERT | 0         | Channel 1 Remote-Diode High-Alert Bit. This bit is set to logic 1 when the channel 1 remote-diode temperature exceeds the temperature threshold limit in the remote 1 ALERT high-limit register.            |

channel 1. The series resistance cancellation function increases the conversion time for channel 1 by 125ms. This feature cancels the bulk resistance of the sensor and any other resistance in series (wire, contact resistance, etc.). The cancellation range is from 0 to 100Ω.

## Discrete Remote Diodes

When the remote-sensing diode is a discrete transistor, its collector and base must be connected together. Table 11 lists examples of discrete transistors that are appropriate for use with the MAX6698. The transistor must be a small-signal type with a relatively high forward voltage; otherwise, the A/D input voltage range can be violated. The forward voltage at the highest expected temperature must be greater than 0.25V at 10μA, and at the lowest expected temperature, the forward voltage must be less than 0.95V at 100μA. Large power transistors must not be used. Also, ensure that the base resistance is less than 10Ω. Tight specifications for forward current gain ( $50 < \beta < 150$ , for example) indicate that the manufacturer has good process controls and that the devices have consistent  $V_{BE}$  characteristics. Manufacturers of discrete transistors do not normally specify or guarantee ideality factor. This is normally not a problem since good-quality discrete transistors tend to have ideality factors that fall within a relatively narrow range. We have observed varia-

tions in remote temperature readings of less than  $\pm 2^{\circ}\text{C}$  with a variety of discrete transistors. Still, it is good design practice to verify good consistency of temperature readings with several discrete transistors from any manufacturer under consideration.

## Unused Diode Channels

If one or more of the remote diode channels is not needed, the DXP and DXN inputs for that channel should either be unconnected, or the DXP input should be connected to VCC. The status register indicates a diode "fault" for this channel and the channel is ignored during the temperature-measurement sequence. It is also good practice to mask any unused channels immediately upon power-up by setting the appropriate bits in the Configuration 2 and Configuration 3 registers. This will prevent unused channels from causing ALERT# or OVERT# to assert.

## Thermistor Measurements

The MAX6698 can use three external thermistors to measure temperature. A thermistor's resistance varies as a function of temperature. A negative temperature coefficient (NTC) thermistor can be connected between the thermistor input and ground, with a series resistor, REXT\_, connected from the thermistor input to VREF.

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**Table 9. Status 2 Register**

| BIT    | NAME               | POR STATE | FUNCTION                                                                                                                                                                                                     |
|--------|--------------------|-----------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 7(MSB) | Reserved           | 0         | —                                                                                                                                                                                                            |
| 6      | Reserved           | 0         | —                                                                                                                                                                                                            |
| 5      | Thermistor 3 OVERT | 0         | Thermistor 3 Overtemperature Status Bit. This bit is set to logic 1 when the thermistor 3 voltage exceeds the threshold limit in the thermistor 3 OVERT high-limit register.                                 |
| 4      | Thermistor 2 OVERT | 0         | Thermistor 2 Overtemperature Status Bit. This bit is set to logic 1 when the thermistor 2 voltage exceeds the threshold limit in the thermistor 2 OVERT high-limit register.                                 |
| 3      | Thermistor 1 OVERT | 0         | Thermistor 1 Overtemperature Status Bit. This bit is set to logic 1 when the thermistor 1 voltage exceeds the threshold limit in the thermistor 1 OVERT high-limit register.                                 |
| 2      | Reserved           | 0         | —                                                                                                                                                                                                            |
| 1      | Reserved           | 0         | —                                                                                                                                                                                                            |
| 0      | Remote 1 OVERT     | 0         | Channel 1 Remote-Diode Overtemperature Status Bit. This bit is set to logic 1 when the channel 1 remote-diode temperature exceeds the temperature threshold limit in the remote 1 OVERT high-limit register. |

**Table 10. Status 3 Register**

| BIT    | NAME          | POR STATE | FUNCTION                                                                                                                                  |
|--------|---------------|-----------|-------------------------------------------------------------------------------------------------------------------------------------------|
| 7(MSB) | Reserved      | 0         | —                                                                                                                                         |
| 6      | Reserved      | 0         | —                                                                                                                                         |
| 5      | Reserved      | 0         | —                                                                                                                                         |
| 4      | Reserved      | 0         | —                                                                                                                                         |
| 3      | Diode fault 3 | 0         | Channel 3 Remote-Diode Fault Bit. This bit is set to 1 when DXP3 and DXN3 are open circuit or when DXP3 is connected to V <sub>CC</sub> . |
| 2      | Diode fault 2 | 0         | Channel 2 Remote-Diode Fault Bit. This bit is set to 1 when DXP2 and DXN2 are open circuit or when DXP2 is connected to V <sub>CC</sub> . |
| 1      | Diode fault 1 | 0         | Channel 1 Remote-Diode Fault Bit. This bit is set to 1 when DXP1 and DXN1 are open circuit or when DXP1 is connected to V <sub>CC</sub> . |
| 0      | Reserved      | 0         | —                                                                                                                                         |

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**Table 11. Remote-Sensors Transistor Manufacturers**

| MANUFACTURER                | MODEL NO.     |
|-----------------------------|---------------|
| Central Semiconductor (USA) | CMPT3904      |
| Rohm Semiconductor (USA)    | SST3904       |
| Samsung (Korea)             | KST3904-TF    |
| Siemens (Germany)           | SMBT3904      |
| Zetex (England)             | FMMT3904CT-ND |

**Note:** Discrete transistors must be diode connected (base shorted to collector).

## Slave Addresses

Table 12 lists the MAX6698 slave addresses.

**Table 12. Slave Address**

| PART        | SMBus SLAVE ID | PIN-PACKAGE |
|-------------|----------------|-------------|
| MAX6698EE34 | 0011 010       | 16 QSOP     |
| MAX6698EE38 | 0011 100       | 16 QSOP     |
| MAX6698EE99 | 1001 100       | 16 QSOP     |
| MAX6698EE9C | 1001 110       | 16 QSOP     |
| MAX6698UE34 | 0011 010       | 16 TSSOP    |
| MAX6698UE38 | 0011 100       | 16 TSSOP    |
| MAX6698UE99 | 1001 100       | 16 TSSOP    |
| MAX6698UE9C | 1001 110       | 16 TSSOP    |

VREF supplies a reference voltage (1V nominal) to bias the thermistor/REXT\_ voltage-divider. The voltage across REXT is measured by the MAX6698's ADC, resulting in a voltage that is directly proportional to temperature. The data in the thermistor registers gives the voltage across REXT as a fraction of the reference voltage (1LSB = 0.5% of VREF).

Because thermistors have nonlinear temperature-resistance functions, and because different thermistors have different functions, it is important to understand the relationship between temperature, REXT, and the voltage across REXT for a given thermistor. Table 13 shows temperature vs. the thermistor channel data for a Betatherm 10k3A1 thermistor and REXT=1600Ω.

## Thermal Mass and Self-Heating

When sensing local temperature, the MAX6698 measures the temperature of the printed-circuit board (PCB) to which it is soldered. The leads provide a good thermal path between the PCB traces and the die. As

with all IC temperature sensors, thermal conductivity between the die and the ambient air is poor by comparison, making air temperature measurements impractical. Because the thermal mass of the PCB is far greater than that of the MAX6698, the device follows temperature changes on the PCB with little or no perceivable delay. When measuring the temperature of a CPU or other IC with an on-chip sense junction, thermal mass has virtually no effect; the measured temperature of the junction tracks the actual temperature within a conversion cycle.

When measuring temperature with discrete remote transistors, the best thermal response times are obtained with transistors in small packages (i.e., SOT23 or SC70). Take care to account for thermal gradients between the heat source and the sensor, and ensure that stray air currents across the sensor package do not interfere with measurement accuracy. Self-heating does not significantly affect measurement accuracy. Remote-sensor self-heating due to the diode current source is negligible.

## ADC Noise Filtering

The integrating ADC has good noise rejection for low-frequency signals such as power-supply hum. In environments with significant high-frequency EMI, connect an external 2200pF capacitor between DXP\_ and DXN\_. Larger capacitor values can be used for added filtering, but do not exceed 3300pF because it can introduce errors due to the rise time of the switched current source. High-frequency noise reduction is needed for high-accuracy remote measurements. Noise can be reduced with careful PCB layout as discussed in the *PCB Layout* section.

## PCB Layout

**Follow these guidelines to reduce the measurement error when measuring remote temperature:**

- 1) Place the MAX6698 as close as is practical to the remote diode. In noisy environments, such as a computer motherboard, this distance can be 4in to 8in (typ). This length can be increased if the worst noise sources are avoided. Noise sources include CRTs, clock generators, memory buses, and PCI buses.
- 2) Do not route the DXP-DXN lines next to the deflection coils of a CRT. Also, do not route the traces across fast digital signals, which can easily introduce +30°C error, even with good filtering.



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- 3) Route the DXP and DXN traces in parallel and in close proximity to each other. Each parallel pair of traces should go to a remote diode. Route these traces away from any higher voltage traces, such as +12VDC. Leakage currents from PCB contamination must be dealt with carefully since a  $20\text{M}\Omega$  leakage path from DXP to ground causes about  $+1^\circ\text{C}$  error. If high-voltage traces are unavoidable, connect guard traces to GND on either side of the DXP-DXN traces (Figure 5).
- 4) Route through as few vias and crossunders as possible to minimize copper/solder thermocouple effects.
- 5) Use wide traces when practical.
- 6) When the power supply is noisy, add a resistor (up to  $47\Omega$ ) in series with  $V_{CC}$ .

### Twisted-Pair and Shielded Cables

Use a twisted-pair cable to connect the remote sensor for remote-sensor distances longer than 8in or in very noisy environments. Twisted-pair cable lengths can be between 6ft and 12ft before noise introduces excessive errors. For longer distances, the best solution is a shielded twisted pair like that used for audio microphones. For example, Belden #8451 works well for dis-

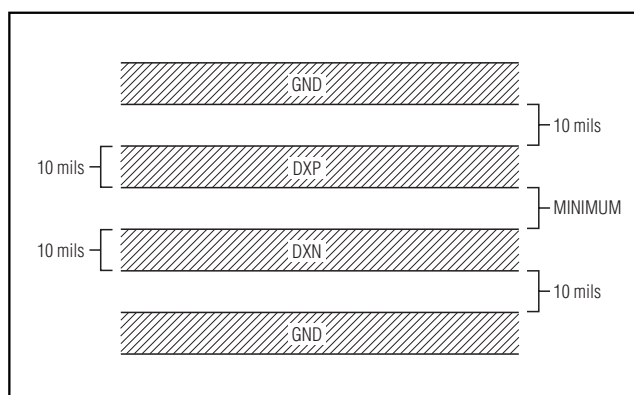


Figure 5. Recommended DXP-DXN PCB Traces

tances up to 100ft in a noisy environment. At the device, connect the twisted pair to DXP and DXN and the shield to GND. Leave the shield unconnected at the remote sensor. For very long cable runs, the cable's parasitic capacitance often provides noise filtering, so the  $2200\text{pF}$  capacitor can often be removed or reduced in value. Cable resistance also affects remote-sensor accuracy. For every  $1\Omega$  of series resistance the error is approximately  $+1/2^\circ\text{C}$ .

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Table 13. Temperature vs. Thermistor Channel Data for a Betatherm 103A1 Thermistor and REXT = 1600Ω

| T (°C) | R <sub>THERM</sub> | V <sub>REXT</sub> | CODE (DECIMAL) | BINARY CODE | HEX CODE |
|--------|--------------------|-------------------|----------------|-------------|----------|
| -20    | 96974              | 0.016231          | 3              | 11000000    | 3        |
| -19    | 91525              | 0.017181          | 3              | 11000000    | 3        |
| -18    | 86415              | 0.018179          | 4              | 10000000    | 4        |
| -17    | 81621              | 0.019226          | 4              | 10000000    | 4        |
| -16    | 77121              | 0.020325          | 4              | 10000000    | 4        |
| -15    | 72895              | 0.021478          | 4              | 10000000    | 4        |
| -14    | 68927              | 0.022686          | 5              | 10100000    | 5        |
| -13    | 65198              | 0.023953          | 5              | 10100000    | 5        |
| -12    | 61693              | 0.025279          | 5              | 10100000    | 5        |
| -11    | 58397              | 0.026668          | 5              | 10100000    | 5        |
| -10    | 55298              | 0.02812           | 6              | 11000000    | 6        |
| -9     | 52380              | 0.029641          | 6              | 11000000    | 6        |
| -8     | 49633              | 0.03123           | 6              | 11000000    | 6        |
| -7     | 47047              | 0.03289           | 7              | 11100000    | 7        |
| -6     | 44610              | 0.034625          | 7              | 11100000    | 7        |
| -5     | 42314.6            | 0.036434          | 7              | 11100000    | 7        |
| -4     | 40149.5            | 0.038324          | 8              | 10000000    | 8        |
| -3     | 38108.5            | 0.040294          | 8              | 10000000    | 8        |
| -2     | 36182.8            | 0.042347          | 8              | 10000000    | 8        |
| -1     | 34366.1            | 0.044486          | 9              | 10010000    | 9        |
| 0      | 32650.8            | 0.046714          | 9              | 10010000    | 9        |
| 1      | 31030.4            | 0.049034          | 10             | 10100000    | A        |
| 2      | 29500.1            | 0.051447          | 10             | 10100000    | A        |
| 3      | 28054.2            | 0.053955          | 11             | 10110000    | B        |
| 4      | 26687.6            | 0.056562          | 11             | 10110000    | B        |
| 5      | 25395.5            | 0.059269          | 12             | 11000000    | C        |
| 6      | 24172.7            | 0.062081          | 12             | 11000000    | C        |
| 7      | 23016              | 0.064998          | 13             | 11010000    | D        |
| 8      | 21921.7            | 0.068022          | 14             | 11100000    | E        |
| 9      | 20885.2            | 0.071158          | 14             | 11100000    | E        |
| 10     | 19903.5            | 0.074406          | 15             | 11110000    | F        |
| 11     | 18973.6            | 0.07777           | 16             | 10000000    | 10       |
| 12     | 18092.6            | 0.081249          | 16             | 10000000    | 10       |
| 13     | 17257.4            | 0.084847          | 17             | 10001000    | 11       |
| 14     | 16465.1            | 0.088569          | 18             | 10010000    | 12       |
| 15     | 15714              | 0.092411          | 18             | 10010000    | 12       |
| 16     | 15001.2            | 0.096379          | 19             | 10011000    | 13       |
| 17     | 14324.6            | 0.100473          | 20             | 10100000    | 14       |
| 18     | 13682.6            | 0.104694          | 21             | 10101000    | 15       |

## 7-Channel Precision Remote-Diode, Thermistor, and Local Temperature Monitor

**Table 13. Temperature vs. Thermistor Channel Data for a Betatherm 103A1 Thermistor and REXT = 1600Ω (continued)**

| T (°C) | R <sub>THERM</sub> | V <sub>REXT</sub> | CODE<br>(DECIMAL) | BINARY CODE | HEX CODE |
|--------|--------------------|-------------------|-------------------|-------------|----------|
| 19     | 13072.8            | 0.109045          | 22                | 10110000    | 16       |
| 20     | 12493.7            | 0.113526          | 23                | 10111000    | 17       |
| 21     | 11943.3            | 0.11814           | 24                | 11000000    | 18       |
| 22     | 11420              | 0.122888          | 25                | 11001000    | 19       |
| 23     | 10922.7            | 0.127768          | 26                | 11010000    | 1A       |
| 24     | 10449.9            | 0.132781          | 27                | 11011000    | 1B       |
| 25     | 10000              | 0.137931          | 28                | 11100000    | 1C       |
| 26     | 9572               | 0.143215          | 29                | 11101000    | 1D       |
| 27     | 9164.7             | 0.148634          | 30                | 11110000    | 1E       |
| 28     | 8777               | 0.154187          | 31                | 11111000    | 1F       |
| 29     | 8407.7             | 0.159877          | 32                | 10000000    | 20       |
| 30     | 8056               | 0.1657            | 33                | 10000100    | 21       |
| 31     | 7720.9             | 0.171657          | 34                | 10001000    | 22       |
| 32     | 7401.7             | 0.177744          | 36                | 10010000    | 24       |
| 33     | 7097.2             | 0.183967          | 37                | 10010100    | 25       |
| 34     | 6807               | 0.190318          | 38                | 10011000    | 26       |
| 35     | 6530.1             | 0.1968            | 39                | 10011100    | 27       |
| 36     | 6266.1             | 0.203404          | 41                | 10100100    | 29       |
| 37     | 6014.2             | 0.210134          | 42                | 10101000    | 2A       |
| 38     | 5773.7             | 0.216987          | 43                | 10101100    | 2B       |
| 39     | 5544.1             | 0.223961          | 45                | 10110100    | 2D       |
| 40     | 5324.9             | 0.23105           | 46                | 10111000    | 2E       |
| 41     | 5115.6             | 0.238251          | 48                | 11000000    | 30       |
| 42     | 4915.5             | 0.245568          | 49                | 11000100    | 31       |
| 43     | 4724.3             | 0.252992          | 51                | 11001100    | 33       |
| 44     | 4541.6             | 0.260518          | 52                | 11010000    | 34       |
| 45     | 4366.9             | 0.268146          | 54                | 11011000    | 36       |
| 46     | 4199.9             | 0.275867          | 55                | 11011100    | 37       |
| 47     | 4040.1             | 0.283683          | 57                | 11100100    | 39       |
| 48     | 3887.2             | 0.291588          | 58                | 11101000    | 3A       |
| 49     | 3741.1             | 0.299564          | 60                | 11110000    | 3C       |
| 50     | 3601               | 0.307633          | 62                | 11111000    | 3E       |
| 51     | 3466.9             | 0.315775          | 63                | 11111100    | 3F       |
| 52     | 3338.6             | 0.323978          | 65                | 10000010    | 41       |
| 53     | 3215.6             | 0.332254          | 66                | 10000100    | 42       |
| 54     | 3097.9             | 0.340578          | 68                | 10001000    | 44       |
| 55     | 2985.1             | 0.348956          | 70                | 10001100    | 46       |
| 56     | 2876.9             | 0.35739           | 71                | 10001110    | 47       |
| 57     | 2773.2             | 0.365865          | 73                | 10010010    | 49       |

# 7-Channel Precision Remote-Diode, Thermistor, and Local Temperature Monitor

Table 13. Temperature vs. Thermistor Channel Data for a Betatherm 103A1 Thermistor and  $R_{EXT} = 1600\Omega$  (continued)

| T (°C) | R <sub>THERM</sub> | V <sub>REXT</sub> | CODE (DECIMAL) | BINARY CODE | HEX CODE |
|--------|--------------------|-------------------|----------------|-------------|----------|
| 58     | 2673.9             | 0.374365          | 75             | 10010110    | 4B       |
| 59     | 2578.5             | 0.382913          | 77             | 10011010    | 4D       |
| 60     | 2487.1             | 0.391476          | 78             | 10011100    | 4E       |
| 61     | 2399.4             | 0.40006           | 80             | 10100000    | 50       |
| 62     | 2315.2             | 0.408664          | 82             | 10100100    | 52       |
| 63     | 2234.7             | 0.417243          | 83             | 10100110    | 53       |
| 64     | 2156.7             | 0.425906          | 85             | 10101010    | 55       |
| 65     | 2082.3             | 0.434511          | 87             | 10101110    | 57       |
| 66     | 2010.8             | 0.443115          | 89             | 10110010    | 59       |
| 67     | 1942.1             | 0.451709          | 90             | 10110100    | 5A       |
| 68     | 1876               | 0.460299          | 92             | 10111000    | 5C       |
| 69     | 1812.6             | 0.468851          | 94             | 10111100    | 5E       |
| 70     | 1751.6             | 0.477384          | 95             | 10111110    | 5F       |
| 71     | 1693               | 0.485879          | 97             | 11000010    | 61       |
| 72     | 1636.63            | 0.494341          | 99             | 11000010    | 63       |
| 73     | 1582.41            | 0.502764          | 101            | 11001010    | 65       |
| 74     | 1530.28            | 0.511136          | 102            | 11001100    | 66       |
| 75     | 1480.12            | 0.51946           | 104            | 11010000    | 68       |
| 76     | 1431.87            | 0.527727          | 106            | 11010100    | 6A       |
| 77     | 1385.37            | 0.535947          | 107            | 11010110    | 6B       |
| 78     | 1340.68            | 0.544092          | 109            | 11011010    | 6D       |
| 79     | 1297.64            | 0.552173          | 110            | 11011100    | 6E       |
| 80     | 1256.17            | 0.560191          | 112            | 11100000    | 70       |
| 81     | 1216.23            | 0.568135          | 114            | 11100100    | 72       |
| 82     | 1177.75            | 0.576006          | 115            | 11100110    | 73       |
| 83     | 1140.71            | 0.58379           | 117            | 11101010    | 75       |
| 84     | 1104.99            | 0.591499          | 118            | 11101100    | 76       |
| 85     | 1070.58            | 0.599121          | 120            | 11110000    | 78       |
| 86     | 1037.4             | 0.606658          | 121            | 11110010    | 79       |
| 87     | 1005.4             | 0.614109          | 123            | 11110110    | 7B       |
| 88     | 974.56             | 0.621465          | 124            | 11111000    | 7C       |
| 89     | 944.81             | 0.628731          | 126            | 11111100    | 7E       |
| 90     | 916.11             | 0.635902          | 127            | 11111110    | 7F       |
| 91     | 888.41             | 0.642981          | 129            | 10000001    | 81       |
| 92     | 861.7              | 0.649957          | 130            | 10000010    | 82       |

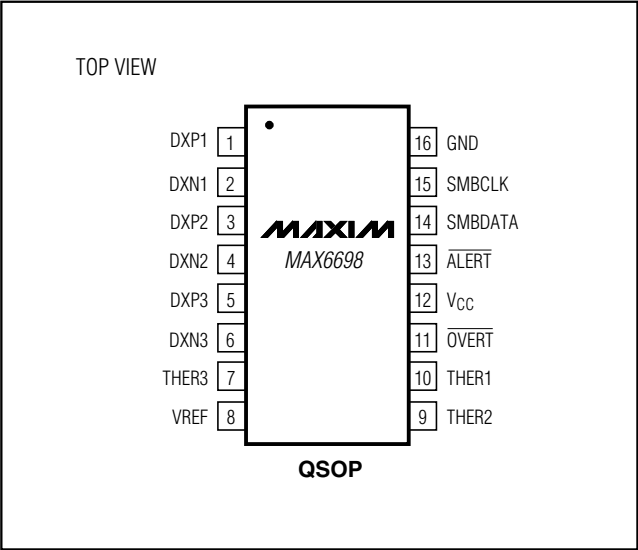
## 7-Channel Precision Remote-Diode, Thermistor, and Local Temperature Monitor

**Table 13. Temperature vs. Thermistor Channel Data for a Betatherm 103A1 Thermistor and REXT = 1600Ω (continued)**

| T (°C) | R <sub>THERM</sub> | V <sub>REXT</sub> | CODE<br>(DECIMAL) | BINARY CODE | HEX CODE |
|--------|--------------------|-------------------|-------------------|-------------|----------|
| 93     | 835.93             | 0.656833          | 131               | 10000011    | 83       |
| 94     | 811.03             | 0.663617          | 133               | 10000101    | 85       |
| 95     | 786.99             | 0.6703            | 134               | 10000110    | 86       |
| 96     | 763.79             | 0.676879          | 135               | 10000111    | 87       |
| 97     | 741.38             | 0.683358          | 137               | 10001001    | 89       |
| 98     | 719.74             | 0.689732          | 138               | 10001010    | 8A       |
| 99     | 698.82             | 0.696009          | 139               | 10001011    | 8B       |
| 100    | 678.63             | 0.702176          | 140               | 10001100    | 8C       |
| 101    | 659.1              | 0.708247          | 142               | 10001110    | 8E       |
| 102    | 640.23             | 0.714212          | 143               | 10001111    | 8F       |
| 103    | 622                | 0.720072          | 144               | 10010000    | 90       |
| 104    | 604.36             | 0.725834          | 145               | 10010001    | 91       |
| 105    | 587.31             | 0.731492          | 146               | 10010010    | 92       |
| 106    | 570.82             | 0.737049          | 147               | 10010011    | 93       |
| 107    | 554.86             | 0.742508          | 149               | 10010101    | 95       |
| 108    | 539.44             | 0.747859          | 150               | 10010110    | 96       |
| 109    | 524.51             | 0.753115          | 151               | 10010111    | 97       |
| 110    | 510.06             | 0.758272          | 152               | 10011000    | 98       |
| 111    | 496.08             | 0.76333           | 153               | 10011001    | 99       |
| 112    | 482.55             | 0.768289          | 154               | 10011010    | 9A       |
| 113    | 469.45             | 0.773152          | 155               | 10011011    | 9B       |
| 114    | 456.76             | 0.777923          | 156               | 10011100    | 9C       |
| 115    | 444.48             | 0.782595          | 157               | 10011101    | 9D       |
| 116    | 432.58             | 0.787177          | 157               | 10011101    | 9D       |
| 117    | 421.06             | 0.791664          | 158               | 10011110    | 9E       |
| 118    | 409.9              | 0.79606           | 159               | 10011111    | 9F       |
| 119    | 399.08             | 0.800368          | 160               | 10100000    | A0       |
| 120    | 388.59             | 0.80459           | 161               | 10100001    | A1       |
| 121    | 378.44             | 0.808718          | 162               | 10100010    | A2       |
| 122    | 368.59             | 0.812764          | 163               | 10100011    | A3       |
| 123    | 359.05             | 0.816722          | 163               | 10100011    | A3       |
| 124    | 349.79             | 0.820601          | 164               | 10100100    | A4       |
| 125    | 340.82             | 0.824394          | 165               | 10100101    | A5       |
| 126    | 332                | 0.828157          | 166               | 10100110    | A6       |
| 127    | 323.5              | 0.831817          | 166               | 10100110    | A6       |

# 7-Channel Precision Remote-Diode, Thermistor, and Local Temperature Monitor

## Pin Configuration



## Chip Information

PROCESS: BiCMOS

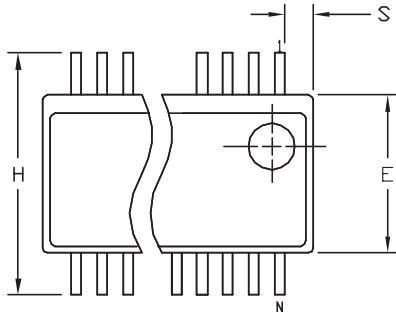
# 7-Channel Precision Remote-Diode, Thermistor, and Local Temperature Monitor

## Package Information

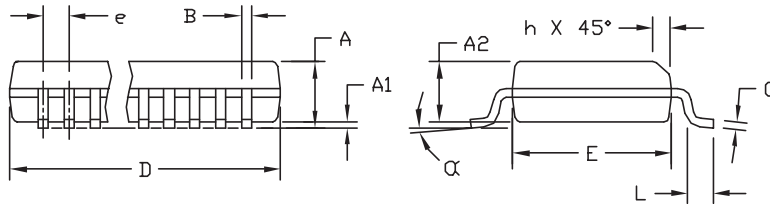
(The package drawing(s) in this data sheet may not reflect the most current specifications. For the latest package outline information, go to [www.maxim-ic.com/packages](http://www.maxim-ic.com/packages).)

MAX6698

QSOP-EPS



| DIM | INCHES         |       | MILLIMETERS |       |
|-----|----------------|-------|-------------|-------|
|     | MIN            | MAX   | MIN         | MAX   |
| A   | .053           | .069  | 1.35        | 1.75  |
| A1  | .004           | .010  | .102        | .254  |
| A2  | .049           | .065  | 1.245       | 1.651 |
| B   | .008           | .012  | 0.20        | 0.30  |
| C   | .0075          | .0098 | 0.191       | 0.249 |
| D   | SEE VARIATIONS |       |             |       |
| E   | .150           | .157  | 3.81        | 3.99  |
| e   | .025 BSC       |       | 0.635 BSC   |       |
| H   | .230           | .244  | 5.84        | 6.20  |
| h   | .010           | .016  | 0.25        | 0.41  |
| L   | .016           | .035  | 0.41        | 0.89  |
| N   | SEE VARIATIONS |       |             |       |
| α   | 0°             | 8°    | 0°          | 8°    |



### VARIATIONS:

|   | INCHES |       | MILLIMETERS |       | N     |
|---|--------|-------|-------------|-------|-------|
|   | MIN.   | MAX.  | MIN.        | MAX.  |       |
| D | .189   | .196  | 4.80        | 4.98  | 16 AB |
| S | .0020  | .0070 | 0.05        | 0.18  |       |
| D | .337   | .344  | 8.56        | 8.74  | 20 AD |
| S | .0500  | .0550 | 1.270       | 1.397 |       |
| D | .337   | .344  | 8.56        | 8.74  | 24 AE |
| S | .0250  | .0300 | 0.635       | 0.762 |       |
| D | .386   | .393  | 9.80        | 9.98  | 28 AF |
| S | .0250  | .0300 | 0.635       | 0.762 |       |

### NOTES:

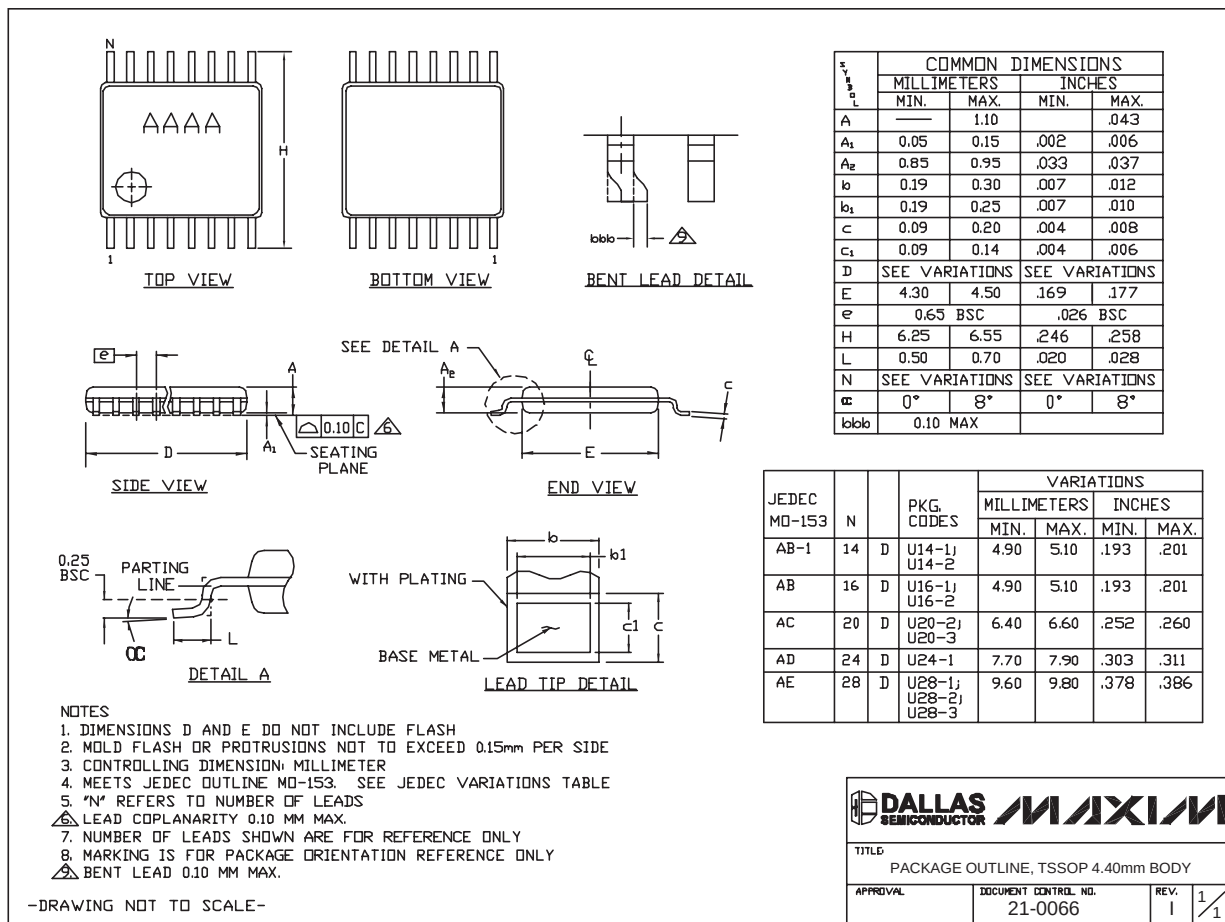
- 1). D & E DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS.
- 2). MOLD FLASH OR PROTRUSIONS NOT TO EXCEED .006" PER SIDE.
- 3). CONTROLLING DIMENSIONS: INCHES.
- 4). MEETS JEDEC MO137.

|                                                                        |                                                |                              |
|------------------------------------------------------------------------|------------------------------------------------|------------------------------|
|                                                                        |                                                |                              |
| <small>PROPRIETARY INFORMATION</small>                                 |                                                |                              |
| <small>TITLE:</small><br>PACKAGE OUTLINE, QSOP .150", .025" LEAD PITCH |                                                |                              |
| <small>APPROVAL:</small>                                               | <small>DOCUMENT CONTROL NO.</small><br>21-0055 | <small>REV:</small><br>F 1/1 |

# 7-Channel Precision Remote-Diode, Thermistor, and Local Temperature Monitor

## Package Information (continued)

(The package drawing(s) in this data sheet may not reflect the most current specifications. For the latest package outline information, go to [www.maxim-ic.com/packages](http://www.maxim-ic.com/packages).)



TSSOP4.40mm.EPS

## Revision History

Pages changed at Rev 2: 1, 2, 24

Pages changed at Rev 3: 1, 5, 8, 9, 10, 14–17, 24

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