19-0567; Rev 0; 5/06

7-Channel Precision Temperature Monitor

General Description

The MAX6689 precision multichannel temperature sensor monitors its own temperature and the temperatures of up to six external diode-connected transistors. All temperature channels have programmable alert thresholds. Channels 1, 4, 5, and 6 also have programmable overtemperature 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 MAX6689 is specified for an operating temperature range of -40°C to +125°C and is available in 20-pin QSOP and TSSOP packages.

Applications

Desktop Computers
Notebook Computers
Workstations
Servers

SMBus is a trademark of Intel Corp.

Pin Configuration appears at end of data sheet.

Features

- **Six Thermal-Diode Inputs**
- **Local Temperature Sensor**
- **1°C Remote Temperature Accuracy (+60°C to +100°C)**
- **Temperature Monitoring Begins at POR for Fail-Safe System Protection**
- **$\overline{\text{ALERT}}$ and $\overline{\text{OVERT}}$ Outputs for Interrupts, Throttling, and Shutdown**
- **$\overline{\text{STBY}}$ Input for Hardware Standby Mode**
- **Small, 20-Pin QSOP and TSSOP Packages**
- **2-Wire SMBus Interface**

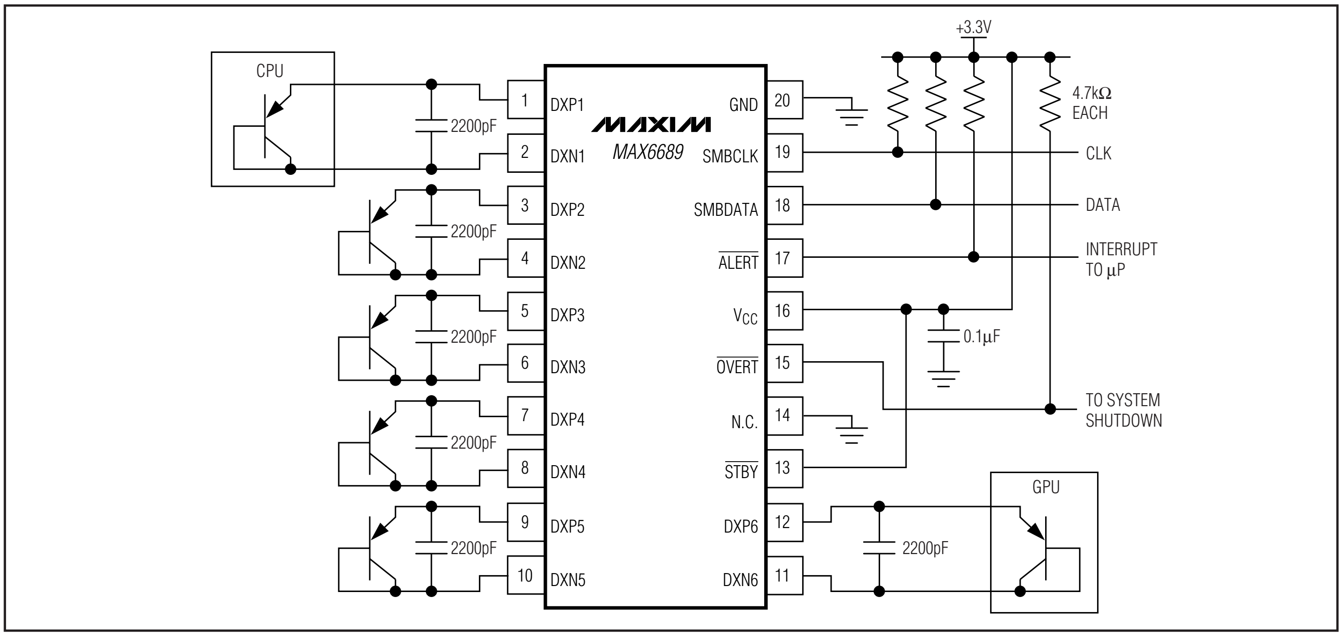
Ordering Information

PART	PIN-PACKAGE	SLAVE ADDRESS	PKG CODE
MAX6689EP34+	20 QSOP	0011 010	E20-1
MAX6689EP38+	20 QSOP	0011 100	E20-1
MAX6689EP9A+	20 QSOP	1001 101	E20-1
MAX6689EP9E+	20 QSOP	1001 111	E20-1
MAX6689UP34+	20 TSSOP	0011 010	U20-2
MAX6689UP38+	20 TSSOP	0011 100	U20-2
MAX6689UP9A+	20 TSSOP	1001 101	U20-2
MAX6689UP9E+	20 TSSOP	1001 111	U20-2

***Note:** All devices are specified over the -40°C to +125°C temperature range.*

+Denotes lead-free package.

Typical Application Circuit



7-Channel Precision Temperature Monitor

ABSOLUTE MAXIMUM RATINGS

V_{CC}, SCK, SDA, $\overline{\text{ALERT}}$, $\overline{\text{OVERT}}$, $\overline{\text{STBY}}$ to GND .....-0.3V to +6V
DXP_ to GND..-0.3V to (V_{CC} + 0.3V)
DXN_ to GND ....-0.3V to +0.8V
SDA, $\overline{\text{ALERT}}$, $\overline{\text{OVERT}}$ Current ....-1mA to +50mA
DXN Current ....±1mA
Continuous Power Dissipation (T_A = +70°C)
  20-Pin QSOP
  (derate 9.1mW/°C above +70°C) 727.3mW
  20-Pin TSSOP
  (derate 11.0mW/°C above +70°C)..............................879.1mW
ESD Protection (all pins, Human Body Model)................±2000V
Operating Temperature Range ....-40°C to +125°C
Junction Temperature...+150°C
Storage Temperature Range ....-60°C to +150°C
Lead Temperature (soldering, 10s) ....+300°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, $V_{\overline{STBY}}$ = V_{CC}, T_A = -40°C to +125°C, unless otherwise noted. Typical values are at V_{CC} = +3.3V and T_A = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Supply Voltage	V_{CC}			3.0		5.5	V
Software Standby Supply Current	I_{SS}	SMBus static			30		µA
Operating Current	I_{CC}	During conversion			500	1000	µA
Temperature Resolution		Channel 1 only			11		Bits
		Other diode channels			8		
Remote Temperature Accuracy		V_{CC} = 3.3V	T_A = T_{RJ} = +60°C to +100°C	-1.0		+1.0	°C
			T_A = T_{RJ} = 0°C to +125°C	-3.0		+3.0	
			DXN_ grounded, T_{RJ} = T_A = 0°C to +85°C			±2.5	
Local Temperature Accuracy		V_{CC} = 3.3V	T_A = +60°C to +100°C	-3.3		+0.7	°C
			T_A = 0°C to +125°C	-5.0		+1.0	
Supply Sensitivity of Temperature Accuracy					±0.2		°C/V
Remote Channel 1 Conversion Time	t_{CONV1}	Resistance cancellation off		95	125	156	ms
		Resistance cancellation on		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	µA
		Low level		8	10	12	
Undervoltage-Lockout Threshold	UVLO	Falling edge of V_{CC} disables ADC		2.30	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
$\overline{\text{ALERT}}$, $\overline{\text{OVERT}}$							
Output Low Voltage	V_{OL}	I_{SINK} = 1mA				0.3	V
		I_{SINK} = 6mA				0.5	
Output Leakage Current						1	µA

ELECTRICAL CHARACTERISTICS (continued)

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

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
SMBus INTERFACE (SCL, SDA), $\overline{STBY}$						
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			
Input Leakage Current			-1		+1	µA
Output Low Voltage	V_{OL}	I_{SINK} = 6mA			0.3	V
Input Capacitance	C_{IN}			5		pF
SMBus-COMPATIBLE TIMING (Figures 3 and 4) (Note 2)						
Serial-Clock Frequency	f_{SCL}	(Note 3)			400	kHz
Bus Free Time Between STOP and START Condition	t_{BUF}	f_{SCL} = 100kHz	4.7			µs
		f_{SCL} = 400kHz	1.6			
START Condition Setup Time		f_{SCL} = 100kHz	4.7			µs
		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			µs
		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			µs
STOP Condition Setup Time	$t_{SU:STO}$	90% of SCL to 90% of SDA, f_{SCL} = 100kHz	4			µs
		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			µs
		10% to 10%, f_{SCL} = 400kHz	1.3			
Clock-High Period	t_{HIGH}	90% to 90%	0.6			µs
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	µs
		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 = +85°C. Specifications over temperature are guaranteed by design.

Note 2: Timing specifications are guaranteed by design.

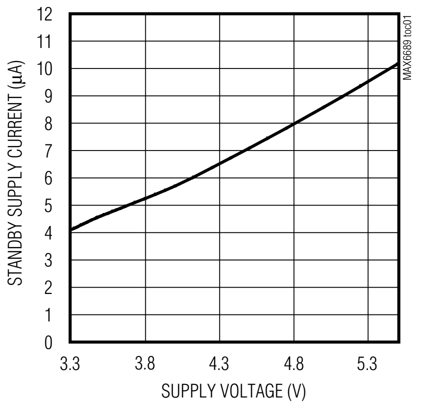
Note 3: The serial interface resets when SCL is low for more than $t_{TIMEOUT}$.

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

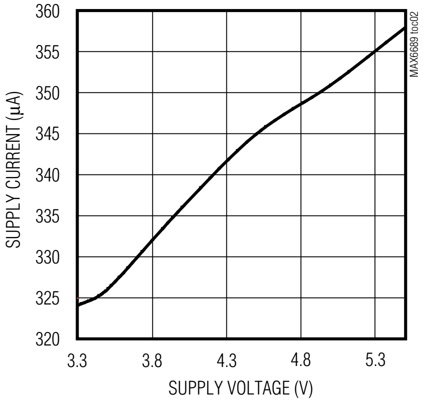
Typical Operating Characteristics

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

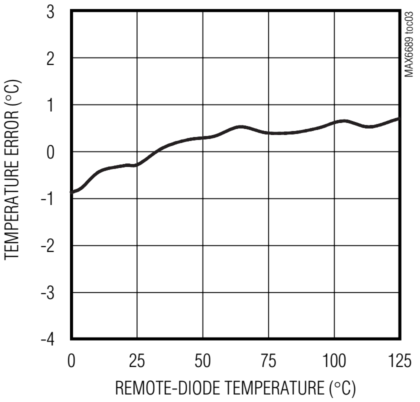
SOFTWARE STANDBY SUPPLY CURRENT vs. SUPPLY VOLTAGE



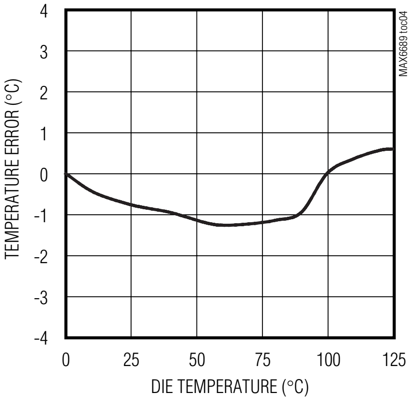
SUPPLY CURRENT vs. SUPPLY VOLTAGE



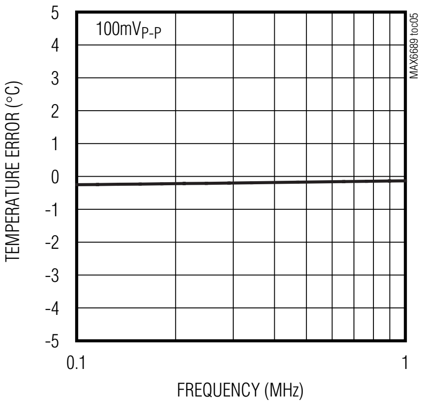
REMOTE TEMPERATURE ERROR vs. REMOTE-DIODE TEMPERATURE



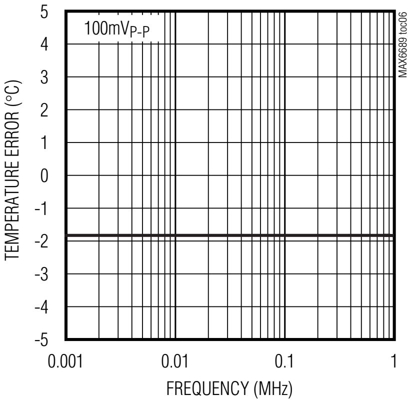
LOCAL TEMPERATURE ERROR vs. DIE TEMPERATURE



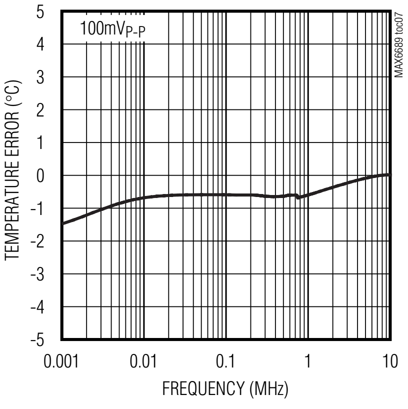
REMOTE-DIODE TEMPERATURE ERROR vs. POWER-SUPPLY NOISE FREQUENCY



LOCAL TEMPERATURE ERROR vs. POWER-SUPPLY NOISE FREQUENCY

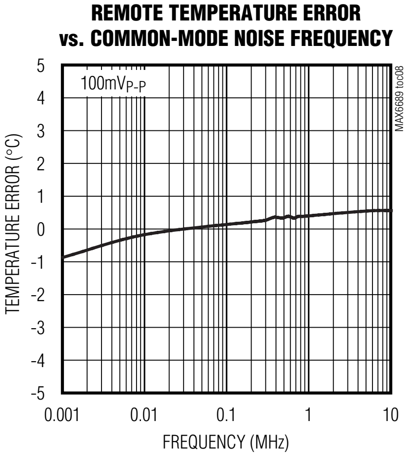


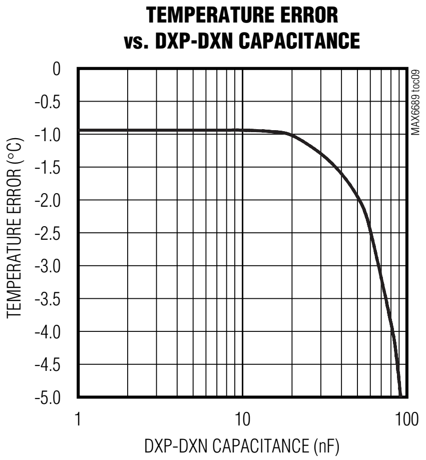
REMOTE TEMPERATURE ERROR vs. COMMON-MODE NOISE FREQUENCY



Typical Operating Characteristics (continued)

(V_{CC} = 3.3V, $V_{\overline{STBY}}$ = V_{CC}, T_A = +25°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 DXN1 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 DXN2 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 DXN3 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	DXP4	Combined Current Source and A/D Positive Input for Channel 4 Remote Diode. Connect to the anode of a remote-diode-connected temperature-sensing transistor. Leave floating or connect to DXN4 if no remote diode is used. Place a 2200pF capacitor between DXP4 and DXN4 for noise filtering.
8	DXN4	Cathode Input for Channel 4 Remote Diode. Connect the cathode of the channel 1 remote-diode-connected transistor to DXN4.

Pin Description (continued)

PIN	NAME	FUNCTION
9	DXP5	Combined Current Source and A/D Positive Input for Channel 5 Remote Diode. Connect to the anode of a remote-diode-connected temperature-sensing transistor. Leave floating or connect to DXN5 if no remote diode is used. Place a 2200pF capacitor between DXP5 and DXN5 for noise filtering.
10	DXN5	Cathode Input for Channel 5 Remote Diode. Connect the cathode of the channel 1 remote-diode-connected transistor to DXN5.
11	DXN6	Cathode Input for Channel 6 Remote Diode. Connect the cathode of the channel 1 remote-diode-connected transistor to DXN6.
12	DXP6	Combined Current Source and A/D Positive Input for Channel 6 Remote Diode. Connect to the anode of a remote-diode-connected temperature-sensing transistor. Leave floating or connect to DXN6 if no remote diode is used. Place a 2200pF capacitor between DXP6 and DXN6 for noise filtering.
13	$\overline{\text{STBY}}$	Active-Low Standby Input. Drive $\overline{\text{STBY}}$ logic-low to place the MAX6689 in standby mode, or logic-high for operate mode. Temperature and threshold data are retained in standby mode.
14	N.C.	No Connection. Must be connected to ground.
15	$\overline{\text{OVERT}}$	Overtemperature Active-Low, Open-Drain Output. $\overline{\text{OVERT}}$ asserts low when the temperature of channels 1, 4, 5, and 6 exceeds the programmed threshold limit.
16	V_{CC}	Supply Voltage Input. Bypass to GND with a 0.1µF capacitor.
17	$\overline{\text{ALERT}}$	SMBus Alert (Interrupt), Active-Low, Open-Drain Output. $\overline{\text{ALERT}}$ asserts low when the temperature of any channel exceeds the programmed $\overline{\text{ALERT}}$ threshold.
18	SMBDATA	SMBus Serial-Data Input/Output. Connect to a pullup resistor.
19	SMBCLK	SMBus Serial-Clock Input. Connect to a pullup resistor.
20	GND	Ground

Detailed Description

The MAX6689 is a precision multichannel temperature monitor that features one local and six remote temperature-sensing channels with 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 MAX6689 is achieved through the SMBus serial interface and a dedicated alert pin. The alarm outputs, $\overline{\text{OVERT}}$ and $\overline{\text{ALERT}}$, assert if the software-programmed temperature thresholds are exceeded. $\overline{\text{ALERT}}$ typically serves as an interrupt, while $\overline{\text{OVERT}}$ can be connected to a fan, system shutdown, or other thermal-management circuitry.

ADC Conversion Sequence

In the default conversion mode, the MAX6689 starts the conversion sequence by measuring the temperature on channel 1, followed by 2, 3, local channel, 4, 5, and 6. The conversion 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 MAX6689 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 channel 1, channel 2, channel 1, channel 3, 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

Enter software standby mode by setting the STOP bit to 1 in the configuration 1 register. Enter hardware standby by pulling $\overline{\text{STBY}}$ low. Software standby mode disables the ADC and reduces the supply current to approximately 30µA. Hardware standby mode halts the ADC clock, but the supply current is approximately 350µA. During either software or hardware 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 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.

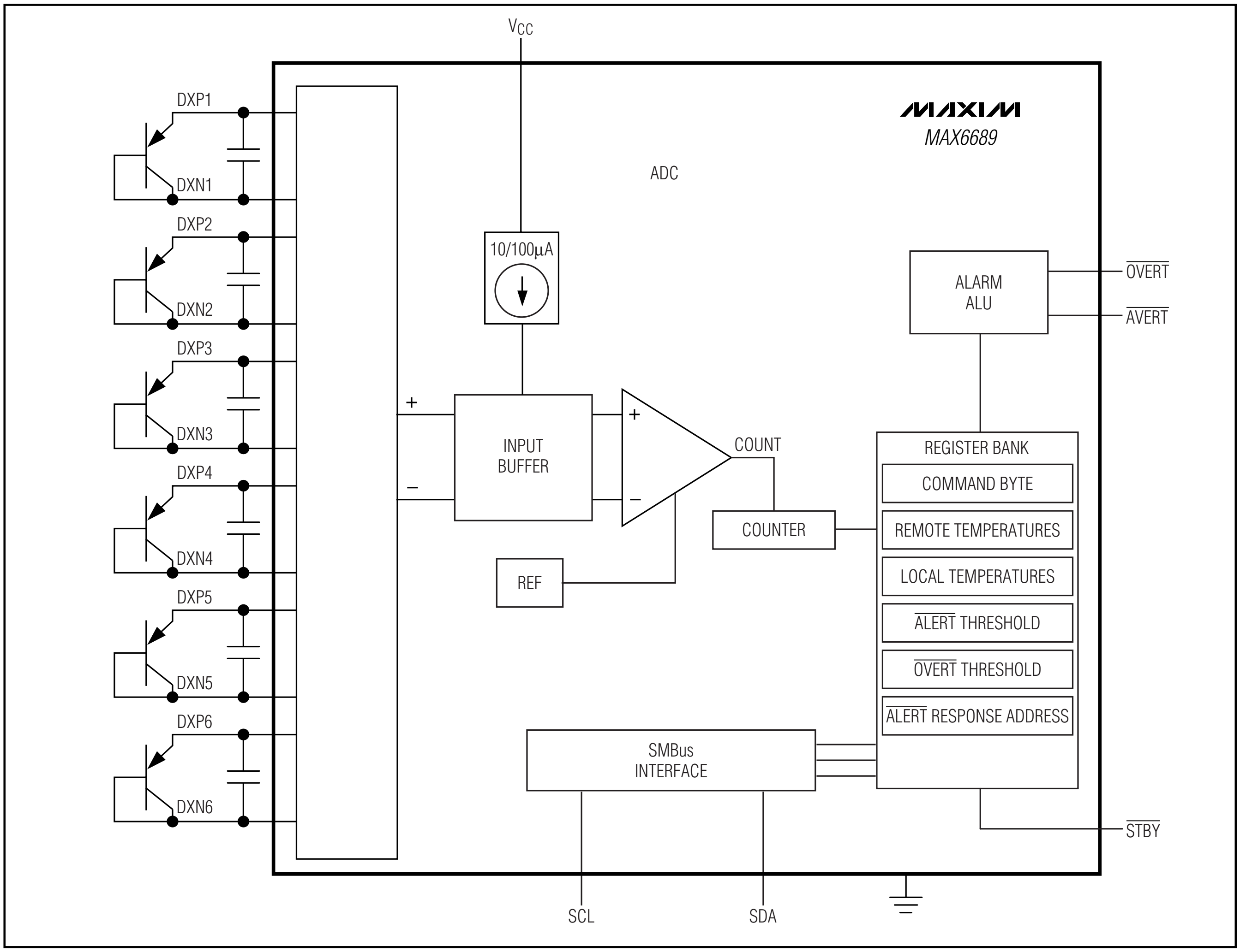


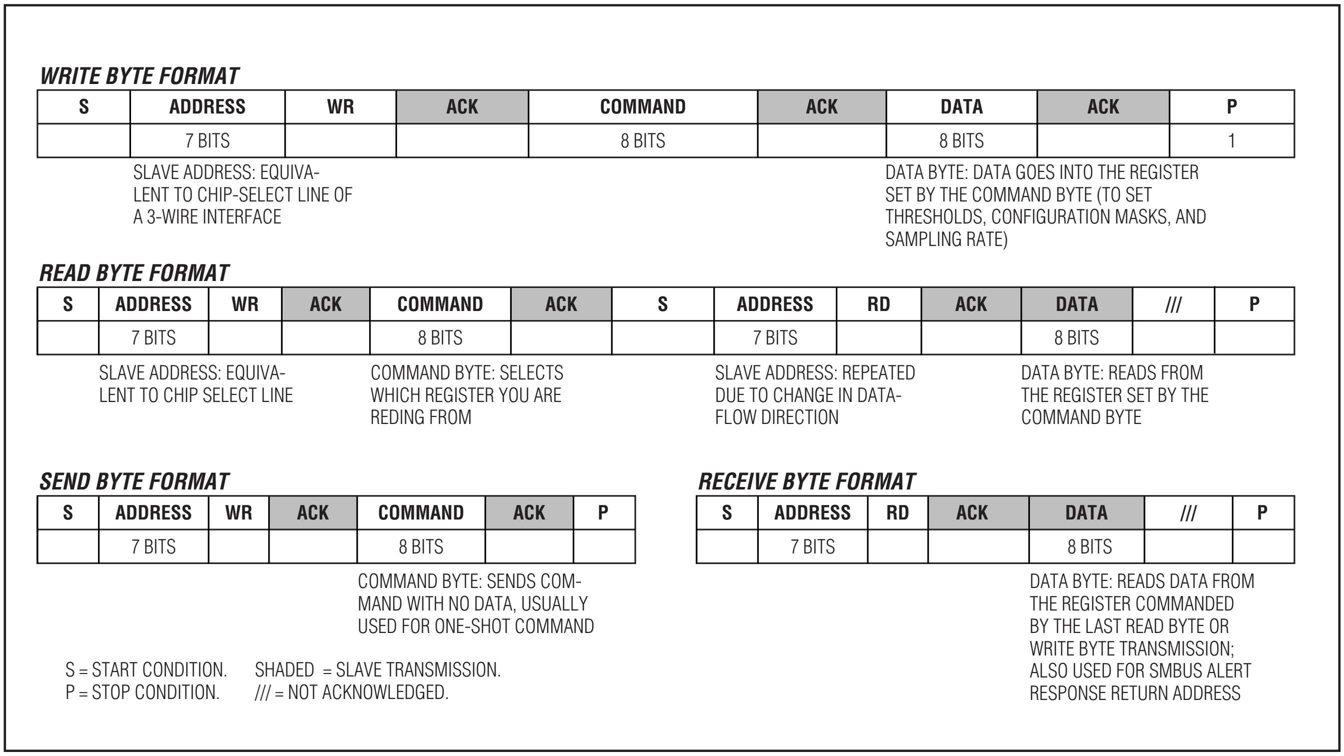
Figure 1. Internal Block Diagram

SMBus Digital Interface

From a software perspective, the MAX6689 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 MAX6689 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 register 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 and remote temperature registers. The remaining 3 bits 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



WRITE BYTE FORMAT

S	ADDRESS	WR	ACK	COMMAND	ACK	DATA	ACK	P
	7 BITS			8 BITS		8 BITS		1

SLAVE ADDRESS: EQUIVALENT TO CHIP-SELECT LINE OF A 3-WIRE INTERFACE

DATA BYTE: DATA GOES INTO THE REGISTER SET BY THE COMMAND BYTE (TO SET THRESHOLDS, CONFIGURATION MASKS, AND SAMPLING RATE)

READ BYTE FORMAT

S	ADDRESS	WR	ACK	COMMAND	ACK	S	ADDRESS	RD	ACK	DATA	///	P
	7 BITS			8 BITS			7 BITS			8 BITS		

SLAVE ADDRESS: EQUIVALENT TO CHIP SELECT LINE

COMMAND BYTE: SELECTS WHICH REGISTER YOU ARE REDING FROM

SLAVE ADDRESS: REPEATED DUE TO CHANGE IN DATA-FLOW DIRECTION

DATA BYTE: READS FROM THE REGISTER SET BY THE COMMAND BYTE

SEND BYTE FORMAT

S	ADDRESS	WR	ACK	COMMAND	ACK	P
	7 BITS			8 BITS		

COMMAND BYTE: SENDS COMMAND WITH NO DATA, USUALLY USED FOR ONE-SHOT COMMAND

RECEIVE BYTE FORMAT

S	ADDRESS	RD	ACK	DATA	///	P
	7 BITS			8 BITS		

DATA BYTE: READS DATA FROM THE REGISTER COMMANDED BY THE LAST READ BYTE OR WRITE BYTE TRANSMISSION; ALSO USED FOR SMBUS ALERT RESPONSE RETURN ADDRESS

S = START CONDITION.
P = STOP CONDITION.

SHADED = SLAVE TRANSMISSION.
/// = NOT ACKNOWLEDGED.

Figure 2. SMBus Protocols

Table 1. Main Temperature Register (High-Byte) Data Format

TEMP (°C)	DIGITAL OUTPUT
> +127	0111 1111
+127	0111 1111
+126	0111 1110
+25	0001 1001
0	0000 0000
< 0	0000 0000
Diode fault (short or open)	1111 1111

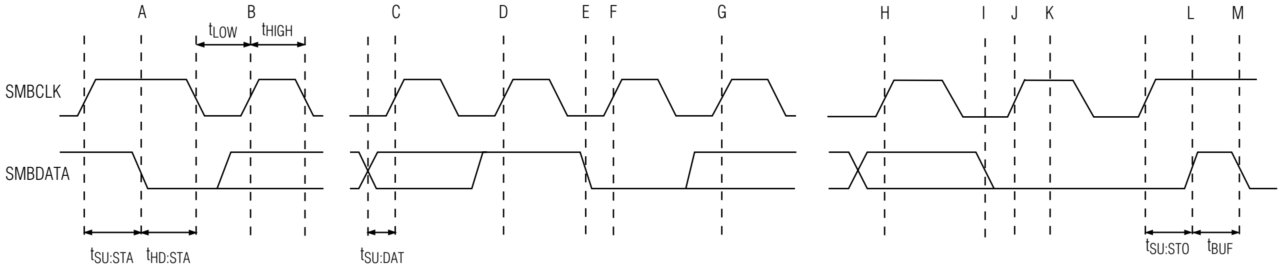
conversion results until they have been read. If the most significant bits have not been read within an SMBus timeout period (nominally 37ms), normal updating continues. Table 1 shows the main temperature register (high-byte) data format, and Table 2 shows the extended resolution register (low-byte) data format.

Table 2. 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

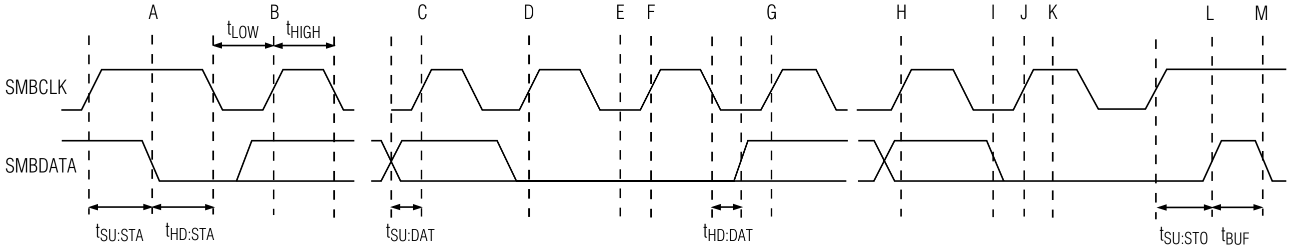
Diode Fault Detection

If a channel's input DXP_ and DXN_ are left open or shorted together, the MAX6689 detects a diode fault. A diode fault, whether a short or an open circuit, does not cause either $\overline{\text{ALERT}}$ or $\overline{\text{OVERT}}$ 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. It takes approximately 4ms for the MAX6689 to detect a diode fault. Once a diode fault is detected, the MAX6689 jumps onto the next channel in the conversion sequence.



A = START CONDITION.
B = MSB OF ADDRESS CLOCKED INTO SLAVE.
C = LSB OF ADDRESS CLOCKED INTO SLAVE.
D = R/$\overline{\text{W}}$ BIT CLOCKED INTO SLAVE.
E = SLAVE PULLS SMBDATA LINE LOW.
F = ACKNOWLEDGE BIT CLOCKED INTO MASTER.
G = MSB OF DATA CLOCKED INTO SLAVE.
H = LSB OF DATA CLOCKED INTO SLAVE.
I = MASTER PULLS DATA LINE LOW.
J = ACKNOWLEDGE CLOCKED INTO SLAVE.
K = ACKNOWLEDGE CLOCK PULSE.
L = STOP CONDITION.
M = NEW START CONDITION.

Figure 3. SMBus Write-Timing Diagram



A = START CONDITION.
B = MSB OF ADDRESS CLOCKED INTO SLAVE.
C = LSB OF ADDRESS CLOCKED INTO SLAVE.
D = R/$\overline{\text{W}}$ BIT CLOCKED INTO SLAVE.
E = SLAVE PULLS SMBDATA LINE LOW.
F = ACKNOWLEDGE BIT CLOCKED INTO MASTER.
G = MSB OF DATA CLOCKED INTO MASTER.
H = LSB OF DATA CLOCKED INTO MASTER.
I = MASTER PULLS DATA LINE LOW.
J = ACKNOWLEDGE CLOCKED INTO SLAVE.
K = ACKNOWLEDGE CLOCK PULSE.
L = STOP CONDITION.
M = NEW START CONDITION.

Figure 4. SMBus Read-Timing Diagram

Alarm Threshold Registers

There are 11 alarm threshold registers that store overtemperature $\overline{\text{ALERT}}$ and $\overline{\text{OVERT}}$ threshold values. Seven of these registers are dedicated to store one local alert temperature threshold limit and six remote alert temperature threshold limits (see the *$\overline{\text{ALERT}}$ Interrupt Mode* section). The remaining four registers are dedicated to remote channels 1, 4, 5, and 6 to store overtemperature threshold limits (see the *$\overline{\text{OVERT}}$ Overtemperature Alarms* section). Access to these registers is provided through the SMBus interface.

$\overline{\text{ALERT}}$ Interrupt Mode

An $\overline{\text{ALERT}}$ interrupt occurs when the internal or external temperature reading exceeds a high-temperature limit (user programmable). The $\overline{\text{ALERT}}$ output clears if the temperature goes below the high-temperature limit threshold. The $\overline{\text{ALERT}}$ interrupt output signal can also 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 $\overline{\text{ALERT}}$ output is open drain so that multiple devices can share a common interrupt line. All $\overline{\text{ALERT}}$ interrupts can be masked using the configuration 3 register. The POR state of these registers is shown in Table 1.

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^{2}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 MAX6689 reasserts the ALERT interrupt at the end of the next conversion.

OVERT Overtemperature Alarms

The MAX6689 has four overtemperature registers that store remote alarm threshold data for the OVERT output. OVERT is asserted when a channel's measured temperature 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. 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 3 for the POR state of the overtemperature threshold registers.

Command Byte Functions

The 8-bit command byte register (Table 3) is the master index that points to the various other registers within the MAX6689. This register's POR state is 0000 0000.

Configuration Byte Functions

There are three read-write configuration registers (Tables 4, 5, and 6) that can be used to control the MAX6689's operation.

Configuration 1 Register

The configuration 1 register (Table 4) has several functions. Bit 7 (MSB) is used to put the MAX6689 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 5. Bits [6:0] are used to mask the ALERT interrupt output. Bit 6 masks the local alert interrupt and bits 5 through bit 0 mask the remote alert interrupts. The power-up state of this register is 0000 0000 (00h).

Configuration 3 Register

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

Status Register Functions

Status registers 1, 2, and 3 (Tables 7, 8, and 9) 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 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 ALERT interrupt output follows the status flag bit. Once the ALERT output is asserted, it can be deasserted by either reading status register 1 or by successfully responding to an alert response address.

**Purchase of I^{2}C components from Maxim Integrated Products, Inc., or one of its sublicensed Associated Companies, conveys a license under the Philips I^{2}C Patent Rights to use these components in an I^{2}C system, provided that the system conforms to the I^{2}C Standard Specification as defined by Philips.*

Table 3. 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
Remote 4	04	00	R	Read channel 4 remote temperature register
Remote 5	05	00	R	Read channel 5 remote temperature register
Remote 6	06	00	R	Read channel 6 remote temperature 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
Status1	44	00	R	Read status register 1
Status2	45	00	R	Read status register 2
Status3	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
Remote 4 $\overline{\text{ALERT}}$ High Limit	14	64	R/W	Read/write channel 4 remote-diode alert high-temperature threshold limit register
Remote 5 $\overline{\text{ALERT}}$ High Limit	15	64	R/W	Read/write channel 5 remote-diode alert high-temperature threshold limit register
Remote 6 $\overline{\text{ALERT}}$ High Limit	16	64	R/W	Read/write channel 6 remote-diode alert high-temperature threshold limit register
Remote 1 $\overline{\text{OVERT}}$ High Limit	21	6E	R/W	Read/write channel 1 remote-diode overtemperature threshold limit register
Remote 4 $\overline{\text{OVERT}}$ High Limit	24	7F	R/W	Read/write channel 4 remote-diode overtemperature threshold limit register
Remote 5 $\overline{\text{OVERT}}$ High Limit	25	5A	R/W	Read/write channel 5 remote-diode overtemperature threshold limit register
Remote 6 $\overline{\text{OVERT}}$ High Limit	26	5A	R/W	Read/write channel 6 remote-diode 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

Table 4. Configuration 1 Register

BIT	NAME	POR STATE	FUNCTION
7 (MSB)	STOP	0	Standby-Mode Control Bit. If STOP is set to logic 1, the MAX6689 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	$\overline{\text{TIMEOUT}}$	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 MAX6689 cancels series resistance in the channel 1 thermal diode.
2	Reserved	0	—
1	Reserved	0	—
0	Reserved	0	—

Table 5. 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 ALERT 6	0	Channel 6 Alert Mask. Set to logic 1 to mask channel 6 $\overline{\text{ALERT}}$.
4	Mask ALERT 5	0	Channel 5 Alert Interrupt Mask. Set to logic 1 to mask channel 5 $\overline{\text{ALERT}}$.
3	Mask ALERT 4	0	Channel 4 Alert Mask. Set to logic 1 to mask channel 4 $\overline{\text{ALERT}}$.
2	Mask ALERT 3	0	Channel 3 Alert Interrupt Mask. Set to logic 1 to mask channel 3 $\overline{\text{ALERT}}$.
1	Mask ALERT 2	0	Channel 2 Alert Mask. Set to logic 1 to mask channel 2 $\overline{\text{ALERT}}$.
0	Mask ALERT 1	0	Channel 1 Alert Mask. Set to logic 1 to mask channel 1 $\overline{\text{ALERT}}$.

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. The bits indicating the fault for the $\overline{\text{OVERT}}$ interrupt output clear only on reading the status 2 register even if the fault conditions still exist. Reading the status 2 register does not clear the $\overline{\text{OVERT}}$ interrupt output. To eliminate the fault condition, either the measured temperature must drop below the temperature threshold minus the hysteresis value (4°C), or the trip temperature must be set at least 4°C above the current temperature.

Applications Information

Remote-Diode Selection

The MAX6689 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 MAX6689 is optimized for n = 1.012. 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 1.012 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

Table 6. Configuration 3 Register

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

factor $n_{NOMINAL}$ is used to measure the temperature of a diode with a different ideality factor n1. The measured temperature T_M can be corrected using:

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

where temperature is measured in Kelvin and $n_{NOMIMAL}$ for the MAX6689 is 1.012. As an example, assume you want to use the MAX6689 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:

$$T_{ACTUAL} = T_M \times \left(\frac{n_{NOMINAL}}{n_1}\right) = T_M \times \left(\frac{1.012}{1.002}\right) = T_M(1.00998)$$

For a real temperature of +85°C (358.15K), the measured temperature is +81.46°C (354.61K), an error of -3.539°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 MAX6689 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 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 10 lists examples of discrete transistors that are appropriate for use with the MAX6689. 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 100Ω. Tight specifications for forward current gain (50 < ß <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 variations in remote temperature readings of less than ±2°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.

Table 7. 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	Remote 6 ALERT	0	Channel 6 Remote-Diode High-Alert Bit. This bit is set to logic 1 when the channel 6 remote-diode temperature exceeds the temperature threshold limit in the remote 6 ALERT high-limit register.
4	Remote 5 ALERT	0	Channel 5 Remote-Diode High-Alert Bit. This bit is set to logic 1 when the channel 5 remote-diode temperature exceeds the programmed temperature threshold limit in the remote 5 ALERT high-limit register.
3	Remote 4 ALERT	0	Channel 4 Remote-Diode High-Alert Bit. This bit is set to logic 1 when the channel 4 remote-diode temperature exceeds the temperature threshold limit in the remote 4 ALERT high-limit register.
2	Remote 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 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 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.

Unused Diode Channels

If one or more of the remote-diode channels is not needed, short the DXP and DXN pins for that channel together. The status register indicates a diode “fault” for this channel and the channel is ignored during the temperature-measurement sequence.

Thermal Mass and Self-Heating

When sensing local temperature, the MAX6689 measures the temperature of the PC board to which it is soldered. The leads provide a good thermal path between the PC board 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 PC board is far greater than that of the MAX6689, the device follows temperature changes on the PC board 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.

Table 8. Status 2 Register

BIT	NAME	POR STATE	FUNCTION
7 (MSB)	Reserved	0	—
6	Reserved	0	—
5	Remote 6 OVERT	0	Channel 6 Remote-Diode Overtemperature Status Bit. This bit is set to logic 1 when the channel 6 remote-diode temperature exceeds the temperature threshold limit in the remote 6 OVERT high-limit register.
4	Remote 5 OVERT	0	Channel 5 Remote Diode Overtemperature Status Bit. This bit is set to logic 1 when the channel 5 remote-diode temperature exceeds the temperature threshold limit in the remote 5 OVERT high-limit register.
3	Remote 4 OVERT	0	Channel 4 Remote Diode Overtemperature Status Bit. This bit is set to logic 1 when the channel 4 remote-diode temperature exceeds the temperature threshold limit in the remote 4 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 9. Status 3 Register

BIT	NAME	POR STATE	FUNCTION
7 (MSB)	Reserved	0	—
6	Diode fault 6	0	Channel 6 Remote-Diode Fault Bit. This bit is set to 1 when DXP6 and DXN6 are either shorted or open circuit.
5	Diode fault 5	0	Channel 5 Remote-Diode Fault Bit. This bit is set to 1 when DXP5 and DXN5 are either shorted or open circuit.
4	Diode fault 4	0	Channel 4 Remote-Diode Fault Bit. This bit is set to 1 when DXP4 and DXN4 are either shorted or open circuit.
3	Diode fault 3	0	Channel 3 Remote-Diode Fault Bit. This bit is set to 1 when DXP3 and DXN3 are either shorted or open circuit.
2	Diode fault 2	0	Channel 2 Remote-Diode Fault Bit. This bit is set to 1 when DXP2 and DXN2 are either shorted or open circuit.
1	Diode fault 1	0	Channel 1 Remote-Diode Fault Bit. This bit is set to 1 when DXP1 and DXN1 are either shorted or open circuit.
0	Reserved	0	—

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 PC board layout as discussed in the *PC Board Layout* section.

Table 10. Remote-Sensors Transistor Manufacturer

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 Address

Table 11 shows the MAX6689 slave addresses.

Table 11. Slave Address

PART	SMBus SLAVE ID	PIN-PACKAGE
MAX6689EP34	0011 010	20 QSOP
MAX6689EP38	0011 100	20 QSOP
MAX6689EP9A	1001 101	20 QSOP
MAX6689EP9E	1001 111	20 QSOP
MAX6689UP34	0011 010	20 TSSOP
MAX6689UP38	0011 100	20 TSSOP
MAX6689UP9A	1001 101	20 TSSOP
MAX6689UP9E	1001 111	20 TSSOP

PC Board Layout

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

1) Place the MAX6689 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.
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 PC board contamination must be dealt with carefully since a 20MΩ leakage path from DXP to ground causes about +1°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. 5mil to 10mil traces are typical. Be aware of the effect of trace resistance on temperature readings when using long, narrow traces.
6) When the power supply is noisy, add a resistor (up to 47Ω) in series with V_{CC}.

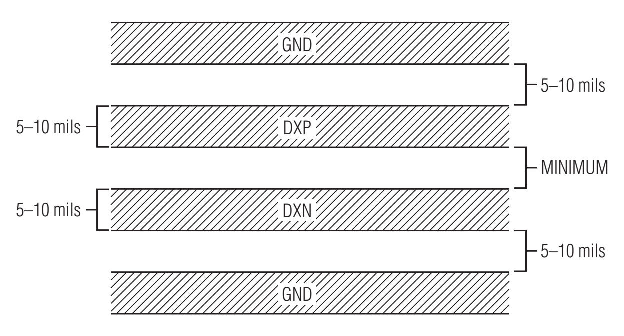
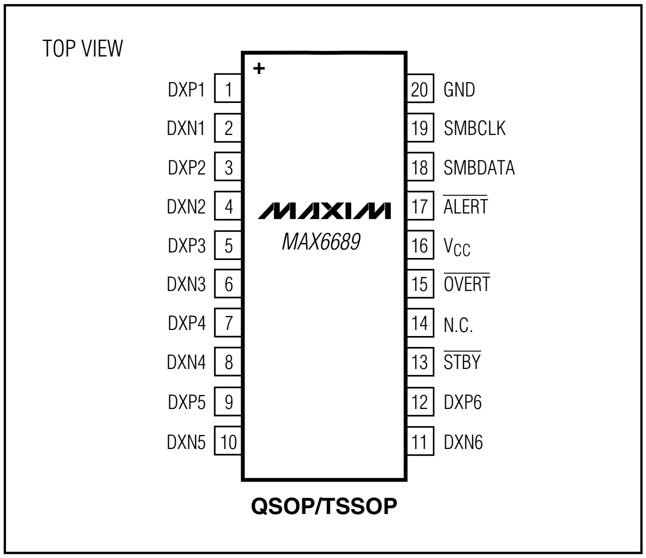


Figure 5. Recommended DXP-DXN PC Board Traces. The two outer guard traces are recommended if high-voltage traces will be near the DXN and DXP traces.

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 distances 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 2200pF capacitor can often be removed or reduced in value. Cable resistance also affects remote-sensor accuracy. For every 1Ω of series resistance the error is approximately +1/2°C.

Pin Configuration



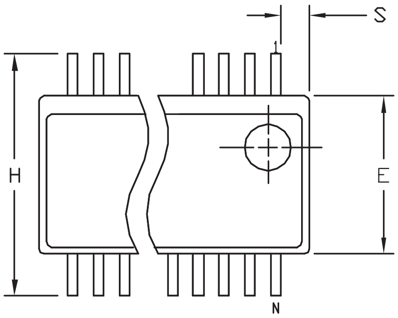
Chip Information

PROCESS: BiCMOS

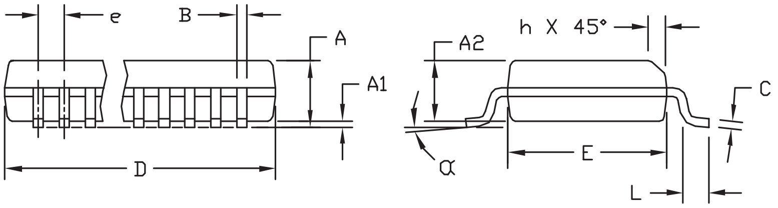
Package Information

(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**.)

QSOP.EPS



	INCHES		MILLIMETERS	
DIM	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			
	MIN.	MAX.	MIN.	MAX.	N	
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.

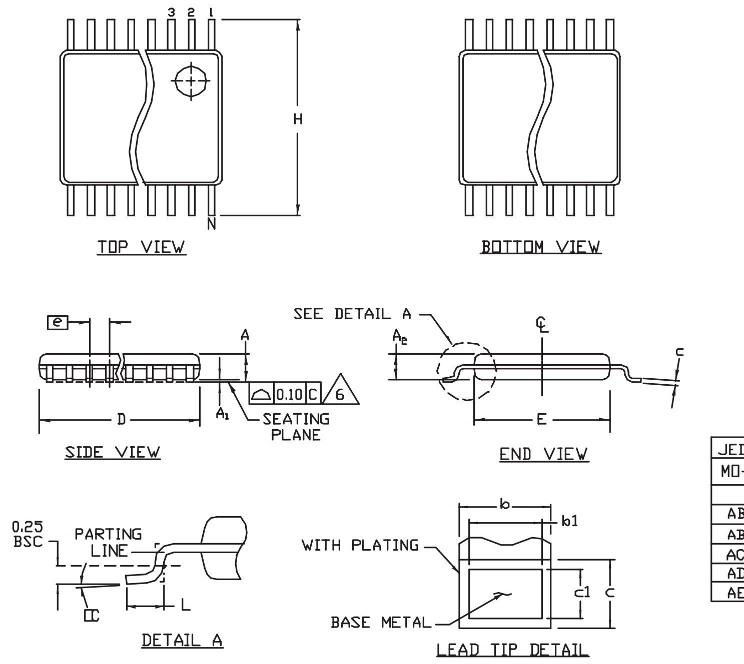
DALLAS SEMICONDUCTOR MAXIM
PROPRIETARY INFORMATION
TITLE:
PACKAGE OUTLINE, QSOP .150", .025" LEAD PITCH

APPROVAL	DOCUMENT CONTROL NO.	REV.	
	21-0055	F	1/1

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**.)

TSSOP4.40mm.EPS



SYMBOL	COMMON DIMENSIONS			
	MILLIMETERS		INCHES	
	MIN.	MAX.	MIN.	MAX.
A	——	1.10		.043
A_1	0.05	0.15	.002	.006
A_2	0.85	0.95	.033	.037
b	0.19	0.30	.007	.012
b_1	0.19	0.25	.007	.010
c	0.09	0.20	.004	.008
c_1	0.09	0.14	.004	.006
D	SEE VARIATIONS		SEE VARIATIONS	
E	4.30	4.50	.169	.177
e	0.65 BSC		.026 BSC	
H	6.25	6.55	.246	.258
L	0.50	0.70	.020	.028
N	SEE VARIATIONS		SEE VARIATIONS	
α	0°	8°	0°	8°

JEDEC			VARIATIONS			
MO-153	N		MILLIMETERS		INCHES	
			MIN.	MAX.	MIN.	MAX.
AB-1	14	D	4.90	5.10	.193	.201
AB	16	D	4.90	5.10	.193	.201
AC	20	D	6.40	6.60	.252	.260
AD	24	D	7.70	7.90	.303	.311
AE	28	D	9.60	9.80	.378	.386

NOTES:
1. DIMENSIONS D AND E DO NOT INCLUDE FLASH
2. MOLD FLASH OR PROTRUSIONS NOT TO EXCEED 0.15mm PER SIDE
3. CONTROLLING DIMENSION: MILLIMETER
4. MEETS JEDEC OUTLINE MO-153. SEE JEDEC VARIATIONS TABLE
5. "N" REFERS TO NUMBER OF LEADS
6. THE LEAD TIPS MUST LIE WITHIN A SPECIFIED ZONE. THIS TOLERANCE ZONE IS DEFINED BY TWO PARALLEL PLANES. ONE PLANE IS THE SEATING PLANE, DATUM [-C-]; THE OTHER PLANE IS AT THE SPECIFIED DISTANCE FROM [-C-] IN THE DIRECTION INDICATED

-DRAWING NOT TO SCALE-

DALLAS SEMICONDUCTOR MAXIM

TITLE: PACKAGE OUTLINE, TSSOP 4.40mm BODY

APPROVAL	DOCUMENT CONTROL NO.	REV.	
	21-0066	G	1/1