19-2920; Rev 1; 10/08

EVALUATION KIT AVAILABLE

±1°C, SMBus-Compatible Remote/Local Temperature Sensor with Overtemperature Alarm

General Description

The MAX6642 precise, two-channel digital temperature sensor accurately measures the temperature of its own die and a remote PN junction and reports the temperature data over a 2-wire serial interface. The remote PN junction is typically a substrate PNP transistor on the die of a CPU, ASIC, GPU, or FPGA. The remote PN junction can also be a discrete diode-connected small-signal transistor.

The 2-wire serial interface accepts standard system management bus (SMBus™), Write Byte, Read Byte, Send Byte, and Receive Byte commands to read the temperature data and to program the alarm thresholds. To enhance system reliability, the MAX6642 includes an SMBus timeout. The temperature data format is 10 bit with the least significant bit (LSB) corresponding to +0.25°C. The $\overline{ALERT}$ output asserts when the local or remote overtemperature thresholds are violated. A fault queue may be used to prevent the $\overline{ALERT}$ output from setting until two consecutive faults have been detected.

Measurements can be done autonomously or in a single-shot mode.

Remote accuracy is ±1°C maximum error between +60°C and +100°C. The MAX6642 operates from -40°C to +125°C, and measures remote temperatures between 0°C and +150°C. The MAX6642 is available in a 6-pin TDFN package with an exposed pad.

Applications

Desktop Computers
Notebook Computers
Servers
Thin Clients
Test and Measurement
Workstations
Graphic Cards

Selector Guide

PART	MEASURED TEMP RANGE	TOP MARK
MAX6642ATT90-T	0°C to +150°C	AFC
MAX6642ATT92-T	0°C to +150°C	AFD
MAX6642ATT94-T	0°C to +150°C	AFE
MAX6642ATT96-T	0°C to +150°C	AFF
MAX6642ATT98-T	0°C to +150°C	AEW
MAX6642ATT9A-T	0°C to +150°C	AFG
MAX6642ATT9C-T	0°C to +150°C	AFH
MAX6642ATT9E-T	0°C to +150°C	AFI

SMBus is a trademark of Intel Corp.

Features

- **Dual Channel: Measures Remote and Local Temperature**
- **+0.25°C Resolution**
- **High Accuracy ±1°C (max) (Remote) and ±2°C (Local) from +60°C to +100°C**
- **Measures Remote Temperature Up to +150°C**
- **Programmable Overtemperature Alarm Temperature Thresholds**
- **SMBus/I²C-Compatible Interface**
- **Tiny TDFN Package with Exposed Pad**

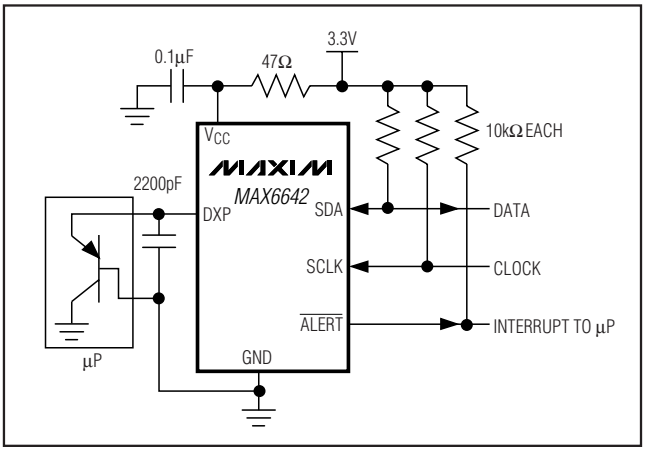
Ordering Information

PART	TEMP RANGE	PIN-PACKAGE
MAX6642ATT90-T	-40°C to +125°C	6 TDFN-EP*
MAX6642ATT92-T	-40°C to +125°C	6 TDFN-EP*
MAX6642ATT94-T	-40°C to +125°C	6 TDFN-EP*
MAX6642ATT96-T	-40°C to +125°C	6 TDFN-EP*
MAX6642ATT98-T	-40°C to +125°C	6 TDFN-EP*
MAX6642ATT9A-T	-40°C to +125°C	6 TDFN-EP*
MAX6642ATT9C-T	-40°C to +125°C	6 TDFN-EP*
MAX6642ATT9E-T	-40°C to +125°C	6 TDFN-EP*

T = Tape and reel.
**EP = Exposed pad.*

Pin Configuration and Functional Diagram appear at end of data sheet.

Typical Operating Circuit



For pricing, delivery, and ordering information, please contact Maxim Direct at 1-888-629-4642, or visit Maxim's website at www.maxim-ic.com.

±1°C, SMBus-Compatible Remote/Local Temperature Sensor with Overtemperature Alarm

ABSOLUTE MAXIMUM RATINGS

All Voltages Referenced to GND
V_{CC} .....-0.3V to +6V
DXP.....-0.3V to (V_{CC} + 0.3V)
SCLK, SDA, $\overline{ALERT}$ .....-0.3V to +6V
SDA, $\overline{ALERT}$ Current .....-1mA to +50mA
Continuous Power Dissipation (T_A = +70°C)
6-Pin TDFN (derate 24.4mW/°C above +70°C) 1951mW
ESD Protection (all pins, Human Body Model) .....±2000V
Junction Temperature.....+150°C
Operating Temperature Range .....-40°C to +125°C
Storage Temperature Range .....-65°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, T_A = -40°C to +125°C, unless otherwise specified. 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
Temperature Resolution					0.25		°C
					10		Bits
Remote Temperature Error		V_{CC} = 3.3V	T_{RJ} = +60°C to +100°C, T_A = +25°C to +85°C	-1.0		+1.0	°C
			T_{RJ} = 0°C to +125°C	-3.0		+3.0	
			T_{RJ} = +125°C to +150°C	-3.5		+3.5	
Local Temperature Error		V_{CC} = 3.3V	T_A = +60°C to +100°C	-2.0		+2.0	°C
			T_A = 0°C to +125°C	-3.0		+3.0	
Supply Sensitivity of Temperature Error					±0.2		°C/V
Undervoltage Lockout Threshold	UVLO	Falling edge of V_{CC} disables ADC		2.4	2.7	2.95	V
Undervoltage Lockout Hysteresis					90		mV
Power-On-Reset (POR) Threshold		V_{CC} falling edge		1.5	2.0	2.4	V
POR Threshold Hysteresis					90		mV
Standby Supply Current		SMBus static			3	10	µA
Operating Current		During conversion			0.5	1.0	mA
Average Operating Current					260		µA
Conversion Time	t_{CONV}	From stop bit to conversion completion		106	125	143	ms
Conversion Rate	f_{CONV}				8		Hz
Remote-Diode Source Current	I_{RJ}	High level		80	100	120	µA
		Low level		8	10	12	
$\overline{ALERT}$							
Output-Low Sink Current		V_{OL} = 0.4V		1			mA
		V_{OL} = 0.6V		4			
Output-High Leakage Current		V_{OH} = V_{CC}				1	µA

ELECTRICAL CHARACTERISTICS (continued)

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

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
SMBus-COMPATIBLE INTERFACE (SCLK and SDA)						
Logic Input Low Voltage	V_{IL}				0.8	V
Logic Input High Voltage	V_{IH}	V_{CC} = 3.0V	2.2			V
Input Leakage Current	I_{LEAK}	V_{IN} = GND or 5.5V	-1		+1	µA
Output Low Sink Current	I_{OL}	V_{OL} = 0.6V	6			mA
Input Capacitance	C_{IN}			5		pF
SMBus TIMING (Note 2)						
Serial Clock Frequency	f_{SCLK}	(Note 3)			100	kHz
Bus Free Time Between STOP and START Condition	t_{BUF}		4.7			µs
START Condition Setup Time			4.7			µs
Repeat START Condition Setup Time	$t_{SU:STA}$	90% to 90%	50			ns
START Condition Hold Time	$t_{HD:STA}$	10% of SDA to 90% of SCLK	4			µs
STOP Condition Setup Time	$t_{SU:STO}$	90% of SCLK to 90% of SDA	4			µs
Clock Low Period	t_{LOW}	10% to 10%	4.7			µs
Clock High Period	t_{HIGH}	90% to 90%	4			µs
Data Setup Time	$t_{HD:DAT}$	(Note 4)	250			µs
Receive SCLK/SDA Rise Time	t_R				1	µs
Receive SCLK/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	20	28	40	ms

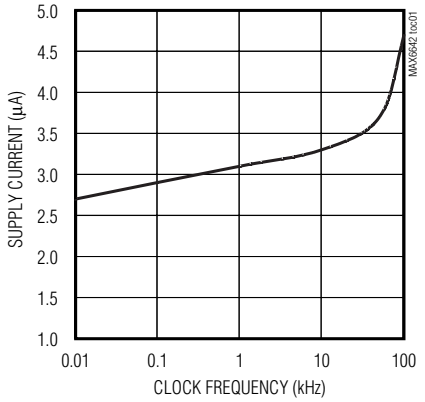
Note 1: All parameters tested at T_A = +25°C. Specifications over temperature are guaranteed by design.
Note 2: Timing specifications guaranteed by design.
Note 3: The serial interface resets when SCLK is low for more than $t_{TIMEOUT}$.
Note 4: A transition must internally provide at least a hold time to bridge the undefined region (300ns max) of SCLK's falling edge.

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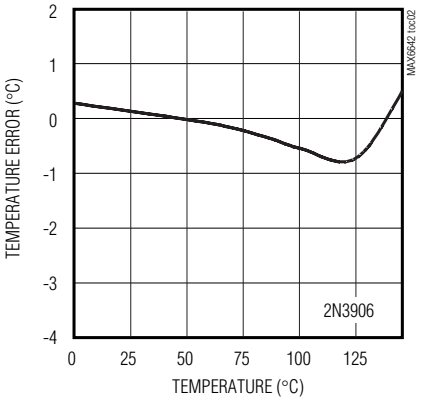
Typical Operating Characteristics

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

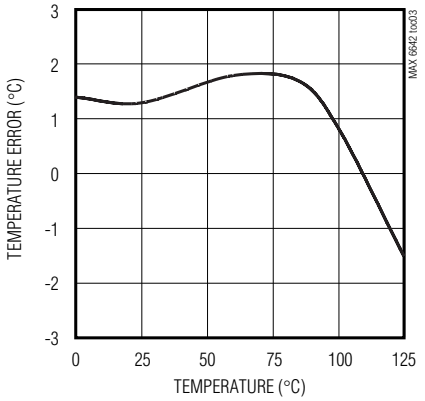
STANDBY SUPPLY CURRENT vs. CLOCK FREQUENCY



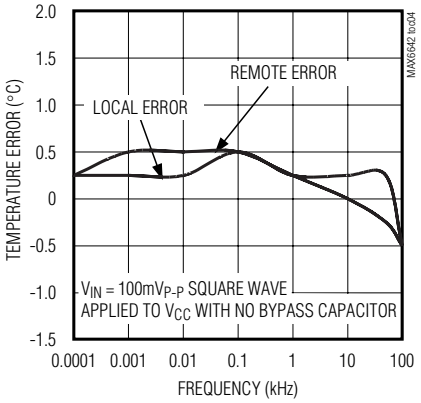
REMOTE TEMPERATURE ERROR vs. REMOTE-DIODE TEMPERATURE



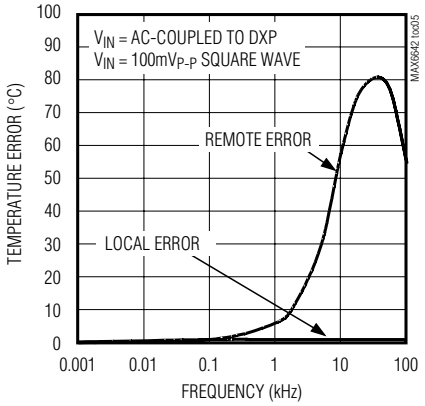
LOCAL TEMPERATURE ERROR vs. DIE TEMPERATURE



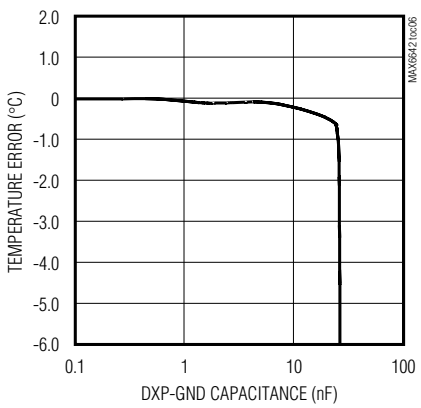
TEMPERATURE ERROR vs. POWER-SUPPLY NOISE FREQUENCY



TEMPERATURE ERROR vs. DXP NOISE FREQUENCY



TEMPERATURE ERROR vs. DXP-GND CAPACITANCE



Pin Description

PIN	NAME	FUNCTION
1	V_{CC}	Supply Voltage Input, +3V to +5.5V. Bypass V_{CC} to GND with a 0.1µF capacitor. A 47Ω series resistor is recommended but not required for additional noise filtering.
2	GND	Ground
3	DXP	Combined Remote-Diode Current Source and ADC Input for Remote-Diode Channel. Place a 2200pF capacitor between DXP and GND for noise filtering.
4	SCLK	SMBus Serial-Clock Input. May be pulled up to +5.5V regardless of V_{CC}.
5	SDA	SMBus Serial-Data Input/Output, Open Drain. May be pulled up to +5.5V regardless of V_{CC}.
6	$\overline{ALERT}$	SMBus Alert (Interrupt) Output, Open Drain. $\overline{ALERT}$ asserts when temperature exceeds user-set limits. See the *$\overline{ALERT}$ Interrupts* section.
—	EP	Exposed Pad. Internally connected to GND. Connect to a PCB ground pad for optimal performance. Not intended as an electrical connection point.

Detailed Description

The MAX6642 is a temperature sensor for local and remote temperature-monitoring applications. Communication with the MAX6642 occurs through the SMBus-compatible serial interface and dedicated alert pins. $\overline{ALERT}$ asserts if the measured local or remote temperature is greater than the software-programmed $\overline{ALERT}$ limit.

The MAX6642 converts temperatures to digital data either at a programmed rate of eight conversions per second or in single conversions. Temperature data is represented by 8 data bits (at addresses 00h and 01h), with the LSB equal to +1°C and the MSB equal to +128°C. Two additional bits of remote temperature data are available in the "extended" register at address 10h and 11h (Table 2) providing resolution of +0.25°C.

ADC and Multiplexer

The averaging ADC integrates over a 60ms period (each channel, typ), with excellent noise rejection.

The multiplexer automatically steers bias currents through the remote and local diodes. The ADC and associated circuitry measure each diode's forward voltage and compute the temperature based on this voltage. Both channels are automatically converted once the conversion process has started, either in free-running or single-shot mode. If one of the two channels is not used, the device still performs both measurements, and the user can ignore the results of the unused channel. If the remote-diode channel is unused, connect DXP to GND rather than leaving DXP open.

The conversion time per channel (remote and internal) is 125ms. If both channels are being used, then each channel is converted four times per second. If the external conversion-only option is selected, then the remote temperature is measured eight times per second. The results of the previous conversion are always available, even if the ADC is busy.

Low-Power Standby Mode

Standby mode reduces the supply current to less than 10µA by disabling the ADC and timing circuitry. Enter standby mode by setting the $\overline{RUN}$ bit to 1 in the configuration byte register (Table 4). All data is retained in memory, and the SMBus interface is active and listening for SMBus commands. Standby mode is not a shutdown mode. With activity on the SMBus, the device draws more supply current (see the *Typical Operating Characteristics*). In standby mode, the MAX6642 can be forced to perform ADC conversions through the one-shot command, regardless of the $\overline{RUN}$ bit status.

If a standby command is received while a conversion is in progress, the conversion cycle is truncated, and the data from that conversion is not latched into a temperature register. The previous data is not changed and remains available.

Supply-current drain during the 125ms conversion period is 500µA (typ). In standby mode, supply current drops to 3µA (typ).

SMBus Digital Interface

From a software perspective, the MAX6642 appears as a set of byte-wide registers that contain temperature 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 MAX6642 employs four standard SMBus protocols: Write Byte, Read Byte, Send Byte, and Receive Byte. (Figures 1, 2, and 3). The shorter Receive Byte protocol allows quicker transfers, provided that the correct data

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register was previously selected by a Write Byte instruction. Use caution when using the shorter protocols in multimaster systems, as a second master could overwrite the command byte without informing the first master.

Read temperature data from the read internal temperature (00h) and read external temperature (01h) registers. The temperature data format for these registers is 8 bits for each channel, with the LSB representing +1°C (Table 1).

Read the additional bits from the read extended temperature byte register (10h, 11h), which extends the data to 10 bits and the resolution to +0.25°C per LSB (Table 2).

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

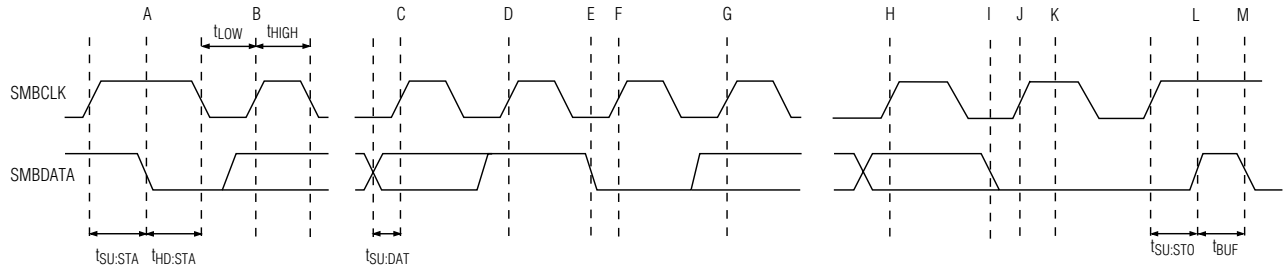
S	ADDRESS	RD	ACK	DATA	///	P
	7 BITS			8 BITS		

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 1. SMBus Protocols



A = START CONDITION
B = MSB OF ADDRESS CLOCKED INTO SLAVE
C = LSB OF ADDRESS CLOCKED INTO SLAVE
D = R/$\overline{W}$ 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 2. SMBus Write Timing Diagram

When a conversion is complete, the main temperature register and the extended temperature register are updated.

Alarm Threshold Registers

Two registers store $\overline{ALERT}$ threshold values—one each for the local and remote channels. If either measured temperature equals or exceeds the corresponding $\overline{ALERT}$ threshold value, the $\overline{ALERT}$ interrupt asserts unless the $\overline{ALERT}$ bit is masked.

The power-on-reset (POR) state of the local $\overline{ALERT}$ T_{HIGH} register is +70°C (0100 0110). The POR state of the remote $\overline{ALERT}$ T_{HIGH} register is +120°C (0111 1000).

Diode Fault Detection

A continuity fault detector at DXP detects an open circuit on DXP, or a DXP short to V_{CC} or GND. If an open or short circuit exists, the external temperature register is loaded with 1111 1111 and status bit 2 (OPEN) of the status byte is set to 1. Immediately after POR, the status register indicates that no fault is present. If a fault is present upon power-up, the fault is not indicated until the end of the first conversion. Diode faults do not set the $\overline{ALERT}$ output.

$\overline{ALERT}$ Interrupts

The $\overline{ALERT}$ interrupt occurs when the internal or external temperature reading exceeds a high temperature limit (user programmed). The $\overline{ALERT}$ interrupt output signal is latched and can be cleared only by reading the status register after the fault condition no longer exists or by successfully responding to the alert response address. If the $\overline{ALERT}$ is cleared by responding to the alert response address and the temperature fault condition still exists, $\overline{ALERT}$ is reasserted after the next temperature-monitoring cycle. To clear $\overline{ALERT}$ while the temperature is above the trip threshold, write a new high limit that is higher than the current temperature. The $\overline{ALERT}$ output is open drain, allowing multiple devices to share a common interrupt line.

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

TEMP (°C)	DIGITAL OUTPUT
130.00	1 000 0010
127.00	0 111 1111
126.00	0 111 1110
25	0 001 1001
0.00	0 000 0000
<0.00	0 000 0000
Diode fault (short or open)	1 111 1111

Table 2. Extended Resolution Temperature Register (Low Byte) Data Format

FRACTIONAL TEMP (°C)	DIGITAL OUTPUT
0.000	00XX XXXX
0.250	01XX XXXX
0.500	10XX XXXX
0.750	11XX XXXX

Alert Response Address

The SMBus alert response interrupt pointer provides quick fault identification for simple slave devices like temperature sensors. Upon receiving an $\overline{ALERT}$ interrupt signal, the host master can broadcast a Receive Byte transmission to the alert response slave address

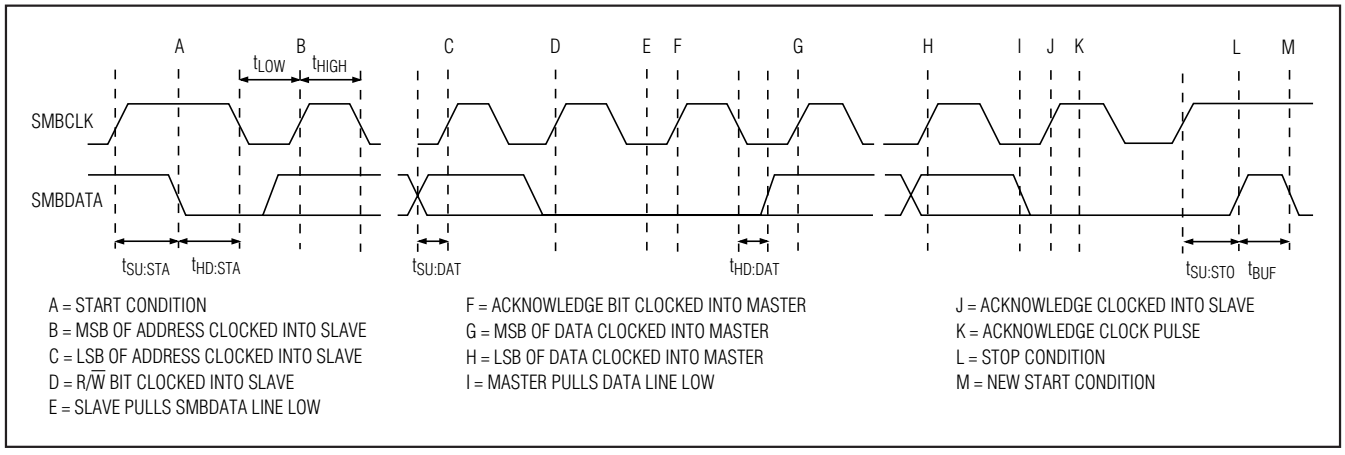


Figure 3. SMBus Read Timing Diagram

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Table 3. Command-Byte Assignments

ADDRESS	POR STATE	FUNCTION
00h	00h (0000 0000)	Read local temperature
01h	00h (0000 0000)	Read remote temperature
02h	N/A	Read status byte
03h	10h (0001 0000)	Read configuration byte
05h	46h (0100 0110) +70°C	Read local high limit
07h	78h (0111 1000) +120°C	Read remote high limit
09h	N/A	Write configuration byte
0Bh	N/A	Write local high limit
0Dh	N/A	Write remote high limit
0Fh	N/A	Single shot
10h	0000 0000	Read remote extended temperature
11h	0000 0000	Read internal extended temperature
FEh	4Dh (0100 1101)	Read manufacturer ID

(0001 100). Following such a broadcast, 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 I²C 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 acknowledge and continues to hold the $\overline{ALERT}$ line low until cleared. (The conditions for clearing an $\overline{ALERT}$ vary depending on the type of slave device.) Successful completion of the alert response protocol clears the interrupt latch. If the condition still exists, the device reasserts the $\overline{ALERT}$ interrupt at the end of the next conversion.

Command Byte Functions

The 8-bit command byte register (Table 3) is the master index that points to the various other registers within the MAX6642. The register's POR state is 0000 0000, so a Receive Byte transmission (a protocol that lacks the

Table 4. Configuration-Byte Bit Assignments

BIT	NAME	POR STATE	FUNCTION
7 (MSB)	MASK1	0	A 1 masks off (disables) the $\overline{ALERT}$ interrupts.
6	STOP/RUN	0	A 1 puts the MAX6642 into standby mode.
5	External only	0	A 1 disables local temperature measurements so that only remote temperature is measured. The measurement rate becomes 8Hz.
4	Fault queue	1	0: $\overline{ALERT}$ is set by a single fault. 1: Two consecutive faults are required to set $\overline{ALERT}$.
3 to 0	—	0000	Reserved.

Table 5. Status-Byte Bit Assignments

BIT	NAME	POR STATE	FUNCTION
7 (MSB)	BUSY	0	A 1 indicates the MAX6642 is busy converting.
6	LHIGH	0	A 1 indicates an internal high-temperature fault. Clear LHIGH with a POR or by reading the status byte.
5	—	0	Reserved.
4	RHIGH	0	A 1 indicates an external high-temperature fault. Clear RHIGH with a POR or by reading the status byte.
3	—	0	Reserved.
2	OPEN	0	A 1 indicates a diode open condition. Clear OPEN with a POR or by reading the status byte when the condition no longer exists.
1 to 0	—	0	Reserved.

command byte) that occurs immediately after POR returns the current local temperature data.

Single-Shot

The single-shot command immediately forces a new conversion cycle to begin. If the single-shot command is received while the MAX6642 is in standby mode ($\overline{RUN}$ bit = 1), a new conversion begins, after which the device returns to standby mode. If a single-shot conversion is in progress when a single-shot command is received, the command is ignored. If a single-shot command is received in autonomous mode ($\overline{RUN}$ bit = 0), the command is ignored.

Configuration Byte Functions

The configuration byte register (Table 4) is a read-write register with several functions. Bit 7 is used to mask (disable) interrupts. Bit 6 puts the MAX6642 into standby mode (STOP) or autonomous (RUN) mode. Bit 5 disables local temperature conversions for faster (8Hz) remote temperature monitoring. Bit 4 prevents setting the $\overline{ALERT}$ output until two consecutive measurements result in fault conditions.

Status Byte Functions

The status byte register (Table 5) indicates which (if any) temperature thresholds have been exceeded. This byte also indicates whether the ADC is converting and whether there is an open-circuit fault detected on the external sense junction. After POR, the normal state of all flag bits is zero, assuming no alarm conditions are present. The status byte is cleared by any successful read of the status byte after the overtemperature fault condition no longer exists.

Slave Addresses

The MAX6642 has eight fixed addresses available. These are shown in Table 6.

The MAX6642 also responds to the SMBus alert response slave address (see the *Alert Response Address* section).

Table 6. Slave Address

PART NO. SUFFIX	ADDRESS
MAX6642ATT90	1001 000
MAX6642ATT92	1001 001
MAX6642ATT94	1001 010
MAX6642ATT96	1001 011
MAX6642ATT98	1001 100
MAX6642ATT9A	1001 101
MAX6642ATT9C	1001 110
MAX6642ATT9E	1001 111

POR and UVLO

To prevent ambiguous power-supply conditions from corrupting the data in memory and causing erratic behavior, a POR voltage detector monitors V_{CC} and clears the memory if V_{CC} falls below 2.1 (typ). When power is first applied and V_{CC} rises above 2.1 (typ), the logic blocks begin operating, although reads and writes at V_{CC} levels below 3V are not recommended. A second V_{CC} comparator, the ADC undervoltage lockout (UVLO) comparator prevents the ADC from converting until there is sufficient headroom (V_{CC} = +2.7V typ).

Power-Up Defaults

Power-up defaults include:

- $\overline{ALERT}$ output is cleared.
- ADC begins autoconverting at a 4Hz rate.
- Command byte is set to 00h to facilitate quick local Receive Byte queries.
- Local (internal) T_{HIGH} limit set to +70°C.
- Remote (external) T_{HIGH} limit set to +120°C.

Applications Information

Remote-Diode Selection

The MAX6642 can directly measure the die temperature of CPUs and other ICs that have on-board temperature-sensing diodes (see the *Typical Operating Circuit*) or they 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 MAX6642 is optimized for n = 1.008, which is the typical value for the Intel Pentium III. A thermal diode on the substrate of an IC is normally a PNP with its collector grounded. Connect the anode (emitter) to DXP and the cathode to GND of the MAX6642.

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 $n_{NOMINAL}$ 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:

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

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where temperature is measured in Kelvin and $n_{NOMIMAL}$ for the MAX6642 is 1.008.

As an example, assume you want to use the MAX6642 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:

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

For a real temperature of +85°C (358.15K), the measured temperature is +82.91°C (356.02K), an error of -2.13°C.

Effect of Series Resistance

Series resistance in a sense diode contributes additional errors. For nominal diode currents of 10µA and 100µA, the change in the measured voltage due to series resistance is:

$$\Delta V_M = R_S\,(100\mu A - 10\mu A) = 90\mu A \times R_S$$

Since +1°C corresponds to 198.6µV, series resistance contributes a temperature offset of:

$$\frac{90\frac{\mu V}{\Omega}}{198.6\frac{\mu V}{^\circ C}} = 0.453\frac{^\circ C}{\Omega}$$

Assume that the diode being measured has a series resistance of 3Ω. The series resistance contributes an offset of:

$$3\Omega \times 0.453\frac{^\circ C}{\Omega} = +1.36^\circ C$$

The effects of the ideality factor and series resistance are additive. If the diode has an ideality factor of 1.002 and series resistance of 3Ω, the total offset can be calculated by adding error due to series resistance with error due to ideality factor:

$$1.36^\circ C - 2.13^\circ C = -0.77^\circ C$$

for a diode temperature of +85°C.

In this example, the effect of the series resistance and the ideality factor partially cancel each other.

Table 7. Remote-Sensor Transistor Manufacturers

MANUFACTURER	MODEL NO.
Central Semiconductor (USA)	CMPT3906
Rohm Semiconductor (USA)	SST3906
Samsung (Korea)	KST3906-TF
Siemens (Germany)	SMBT3906
Zetex (England)	FMMT3906CT-ND

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

Discrete Remote Diodes

When the remote-sensing diode is a discrete transistor, connect its collector and base together. Table 7 lists examples of discrete transistors that are appropriate for use with the MAX6642.

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.

ADC Noise Filtering

The integrating ADC used has good noise rejection for low-frequency signals such as 60Hz/120Hz power-supply hum. In noisy environments, high-frequency noise reduction is needed for high-accuracy remote measurements. The noise can be reduced with careful PCB layout and proper external noise filtering.

High-frequency EMI is best filtered at DXP with an external 2200pF capacitor. Larger capacitor values can be used for added filtering, but do not exceed 3300pF because excessive capacitance can introduce errors

due to the rise time of the switched current source. Nearly all noise sources tested cause the temperature conversion results to be higher than the actual temperature, typically by +1°C to +10°C, depending on the frequency and amplitude (see the *Typical Operating Characteristics*).

PCB Layout

Follow these guidelines to reduce the measurement error of the temperature sensors:

1) Connect the thermal-sense diode to the MAX6642 using two traces—one between DXP and the anode, the other between the MAX6642's GND and the cathode. Do not connect the cathode to GND at the sense diode.
2) Place the MAX6642 as close as is practical to the remote thermal 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 ISA/PCI buses.
3) Do not route the thermal diode lines next to the deflection coils of a CRT. Also, do not route the traces across fast digital signals, which can easily introduce a 30°C error, even with good filtering.
4) Route the thermal diode traces in parallel and in close proximity to each other, away from any higher voltage traces, such as +12VDC. Leakage currents from PCB 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 trace (Figure 4).
5) Route through as few vias and crossunders as possible to minimize copper/solder thermocouple effects.
6) When introducing a thermocouple, make sure that both the thermal diode paths have matching thermocouples. A copper-solder thermocouple exhibits 3µV/°C, and it takes about 200µV of voltage error at DXP to cause a +1°C measurement error. Adding a few thermocouples causes a negligible error.
7) Use wide traces. Narrow traces are more inductive and tend to pick up radiated noise. The 10-mil widths and spacing recommended in Figure 4 are not absolutely necessary, as they offer only a minor improvement in leakage and noise over narrow traces. Use wider traces when practical.
8) Add a 47Ω resistor in series with V_{CC} for best noise filtering (see the *Typical Operating Circuit*).
9) Copper cannot be used as an EMI shield; only ferrous materials such as steel work well. Placing a copper ground plane between the DXP-DXN traces and traces carrying high-frequency noise signals does not help reduce EMI.

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 GND and the shield to GND. Leave the shield unconnected at the remote diode.

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.

Thermal Mass and Self-Heating

When sensing local temperature, this device is intended to measure the temperature of the PCB to which it is soldered. The leads provide a good thermal path between the PCB traces and the die. 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 MAX6642, the device follows temperature changes on the PCB with little or no perceivable delay.

When measuring 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

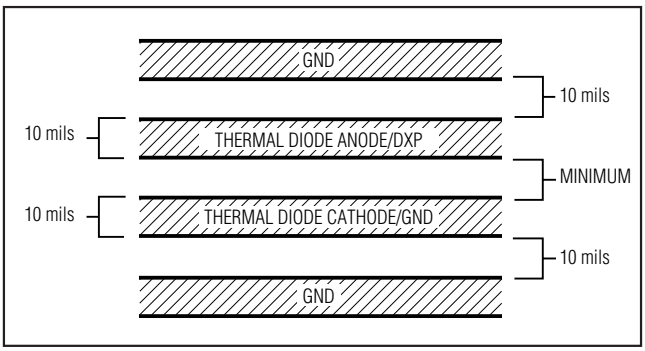


Figure 4. Recommended DXP PC Traces

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tracks the actual temperature within a conversion cycle. When measuring temperature with discrete remote sensors, smaller packages, such as SOT23s, yield the best thermal response times. 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. For the local diode, the worst-case error occurs when autoconverting at the fastest rate and simultaneously sinking maximum current at the $\overline{ALERT}$ output. For example, with V_{CC} = +5.0V, at an 8Hz conversion rate and with $\overline{ALERT}$ sinking 1mA, the typical power dissipation is:

$$5.0V \times 450\mu A + 0.4V \times 1mA = 2.65mW$$

$\varnothing_{J-A}$ for the 6-pin TDFN package is about +41°C/W, so assuming no copper PCB heat sinking, the resulting temperature rise is:

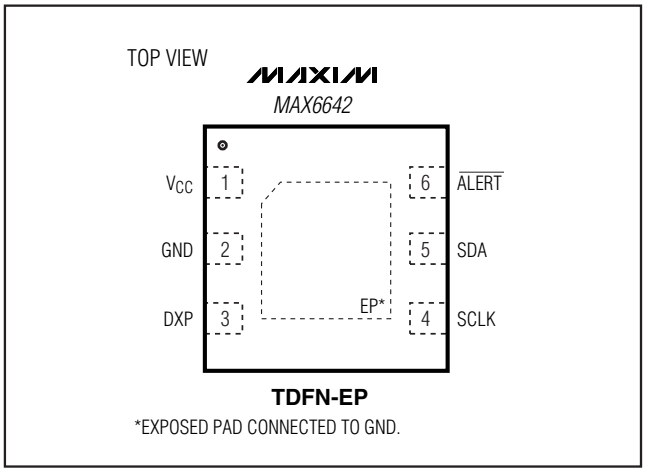
$$\Delta T = 2.65mW \times 41°C/W = +0.11°C$$

Even under nearly worst-case conditions, it is difficult to introduce a significant self-heating error.

Chip Information

PROCESS: BiCMOS

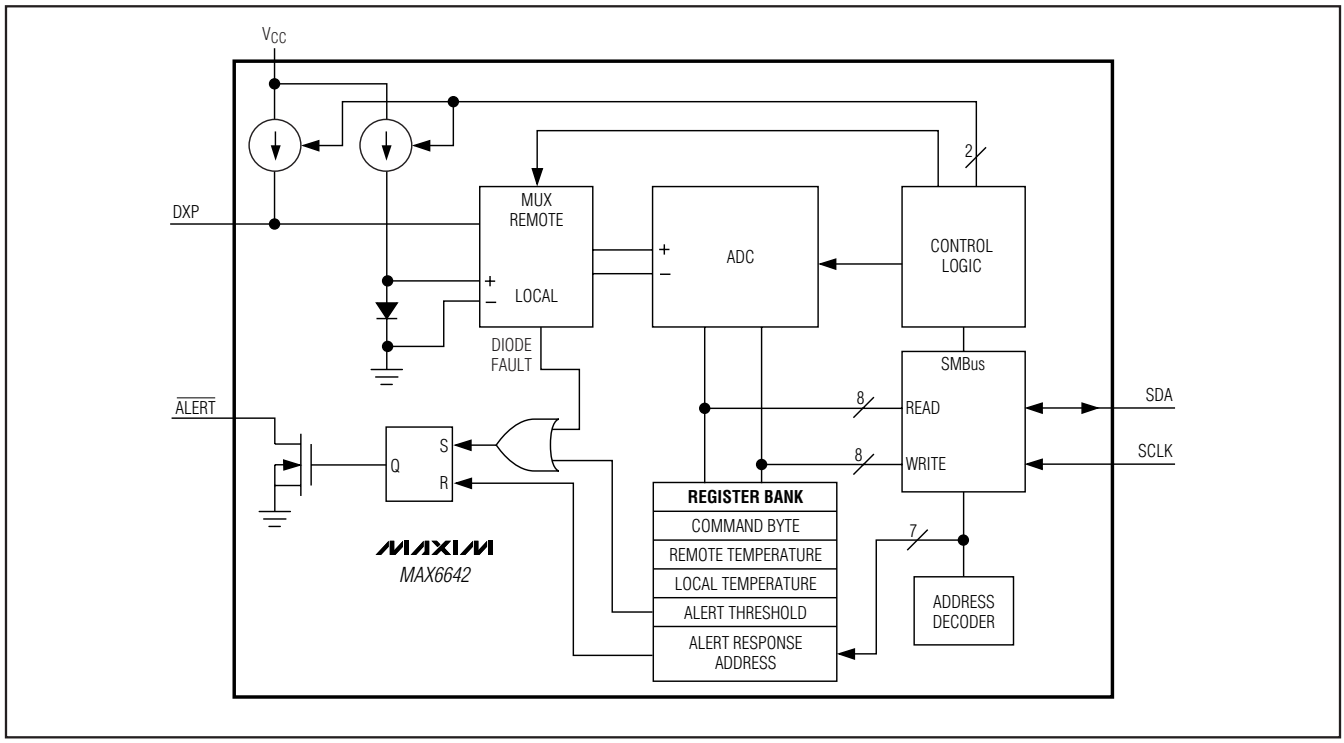
Pin Configuration



TDFN-EP

*EXPOSED PAD CONNECTED TO GND.

Functional Diagram



Package Information

For the latest package outline information and land patterns, go to **www.maxim-ic.com/packages**.

PACKAGE TYPE	PACKAGE CODE	DOCUMENT NO.
6 TDFN-EP	T663-2	**21-0137**

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Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
0	8/03	Initial release	—
1	10/08	Add missing EP description to *Ordering Information* and *Pin Description*, remove the transistor count on page 12, and correct some minor style issues.	1, 5, 9, 10, 12

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Analog Devices:

5B47-J-01-NI AD2701SD MAX17606AZT+T HMC-APH462-SX LTC4368IMS-2#PBF ADP2166ACPZ-1.0-R7 MAX1483CUA+T MAX192AEAP+ MAX323CSA-T MAX994ESD+ 5962-9073001HYC LTC3246IMSE#PBF MAX4204EUA+ MAX4888CETI+ MAX296CPA+ MAX3094ECPE+ 5962-8982401PA(AD586SQ/883B) AD2700SD ADIS16000AMLZ MAX11158EUB+ MAX1291BEEI-T 6B21 LT3799EMSE-1#PBF MAX1148BEUP+ MAX3488CPA+ MAX5182BEEI+ ADUM4121ARIZ-RL MAX15158ZATJ+ MAX3245ECUI+ MAX6778XK+T