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ON Semiconductor®

*dB*Cool® Remote Thermal Controller and Voltage Monitor

ADT7466

FEATURES

Monitors two analog voltages or thermistor temperature inputs

One on-chip and up to two remote temperature sensors with series resistance cancellation

Controls and monitors the speed of up to two fans

Automatic fan speed control mode controls system cooling based on measured temperature

Enhanced acoustic mode dramatically reduces user perception of changing fan speeds

Thermal protection feature via $\overline{\text{THERM}}$ output monitors performance impact of Intel® Pentium® 4 processor thermal control circuit via $\overline{\text{PROCHOT}}$ input

3-wire fan speed measurement

Limit comparison of all monitored values

SMBus 1.1 serial interface

APPLICATIONS

Low acoustic noise notebook PCs

GENERAL DESCRIPTION

The ADT7466 *dB*Cool controller is a complete thermal monitor and dual fan controller for noise-sensitive applications requiring active system cooling. It can monitor two analog voltages or the temperature of two thermistors, plus its own supply voltage. It can monitor the temperature of up to two remote sensor diodes, plus its own internal temperature. It can measure and control the speed of up to two fans so that they operate at the lowest possible speed for minimum acoustic noise. The automatic fan speed control loop optimizes fan speed for a given temperature. The effectiveness of the system's thermal solution can be monitored using the $\overline{\text{PROCHOT}}$ input to time and monitor the $\overline{\text{PROCHOT}}$ output of the processor.

FUNCTIONAL BLOCK DIAGRAM

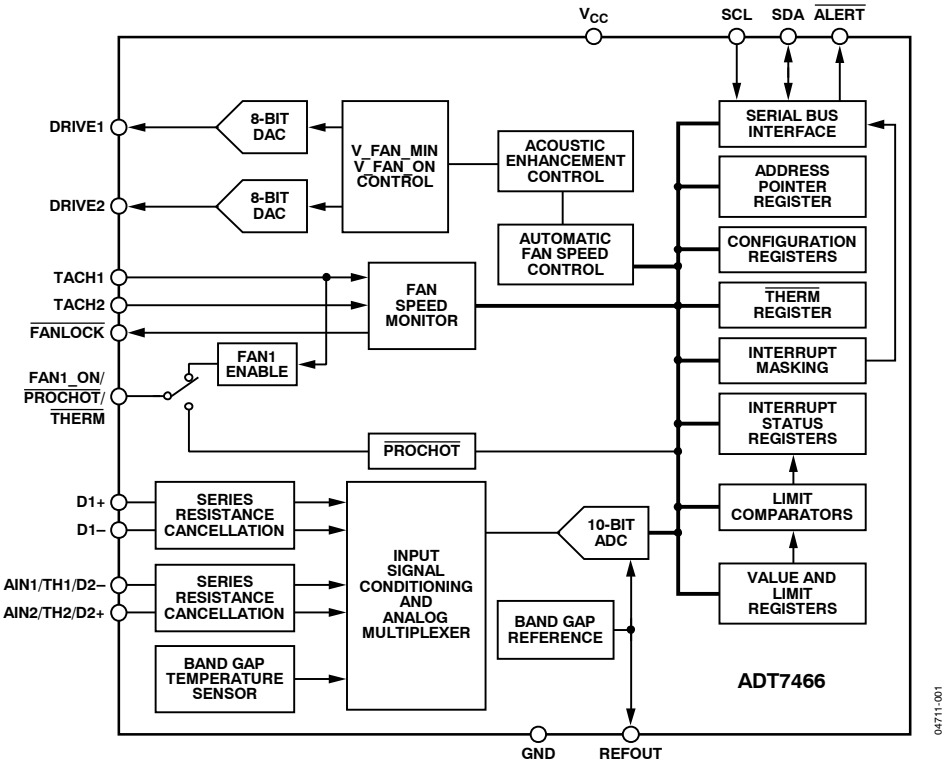

Figure 1.

Protected by U.S. Patent Numbers 6,188,189; 6,169,442; 6,097,239; 5,982,221; 5,867,012.

January 2008 – Rev. 2

Publication Order Number:
ADT7466/D

TABLE OF CONTENTS

REVISION HISTORY

01/08—Rev 2: Correction to ON Semiconductor Logo

12/07—Rev 1: Conversion to ON Semiconductor

06/05—Revision 0: Initial Version

SPECIFICATIONS

$T_A = T_{MIN}$ to T_{MAX}, $V_{CC} = V_{MIN}$ to V_{MAX}, unless otherwise noted.[1]

Table 1.

Parameter	Min	Typ	Max	Unit	Test Conditions/Comments
POWER SUPPLY					
Supply Voltage	3.0	3.3	5.5	V	
Supply Current, I_{CC}		1.4	3	mA	Interface inactive, ADC active
		30	70	µA	Standby mode, digital inputs low
TEMPERATURE-TO-DIGITAL CONVERTER					
Local Sensor Accuracy			±1	°C	20°C ≤ T_A ≤ 60°C; V_{CC} = 3.3 V
			±3	°C	−40°C ≤ T_A ≤ +125°C; V_{CC} = 3.3 V
Resolution		0.25		°C	
Remote Diode Sensor Accuracy			±1	°C	20°C ≤ T_A ≤ 60°C; −40°C ≤ T_D ≤ +125°C; V_{CC} = 3.3 V
			±3	°C	−40°C ≤T_A ≤ +105°C; −40°C ≤ T_D ≤ +125°C; V_{CC} = 3.3 V
			±5	°C	−40°C ≤ T_A ≤ +125°C; −40°C ≤ T_D ≤ +125°C
Resolution		0.25		°C	
Remote Sensor Source Current		192		µA	High level
		72		µA	Mid level
		12		µA	Low level
Series Resistance Cancellation	0		2	kΩ	Maximum resistance in series with thermal diode that can be cancelled out
THERMISTOR-TO-DIGITAL CONVERTER					
Temperature Range	30		100	°C	Range over which specified accuracy is achieved. Wider range can be used with less accuracy.
Resolution		0.25		°C	
Accuracy		±2		°C	Using specified thermistor and application circuit over specified temperature range
ANALOG-TO-DIGITAL CONVERTER					
Input Voltage Range	0		V_{REF}	V	V_{REF} = 2.25V
Total Unadjusted Error (TUE)		±1	±2.5	%	
Differential Nonlinearity (DNL)			±1	LSB	
Power Supply Sensitivity		±1		%/V	
Conversion Time (A_{IN} Input)		8.30	8.65	ms	Averaging enabled
Conversion Time (Local Temperature)		8.63	8.99	ms	Averaging enabled
Conversion Time (Remote Temperature)		35.22	36.69	ms	Averaging enabled
Conversion Time (V_{CC})		7.93	8.26	ms	Averaging enabled
Total Monitoring Cycle Time		68.38	71.24	ms	Averaging enabled, Pin 11 and Pin 12 configured for AIN/TH monitoring (see Table 15)
Total Monitoring Cycle Time		87	90.63	ms	Averaging enabled, Pin 11 and Pin 12 configured for REM2 monitoring (see Table 15)
FAN RPM-TO-DIGITAL CONVERTER					
Accuracy			±4	%	
Full-Scale Count			65,535		
Nominal Input RPM		109		RPM	Fan count = 0xBFFF
		329		RPM	Fan count = 0x3FFF
		5000		RPM	Fan count = 0x0438
		10000		RPM	Fan count = 0x021C
Internal Clock Frequency	78.64	81.92	85.12	kHz	

Parameter	Min	Typ	Max	Unit	Test Conditions/Comments
DRIVE OUTPUTS (DRIVE1, DRIVE2)					
Output Voltage Range		0–2.2		V	Digital input = 0x00 to 0xFF
Output Source Current		2		mA	
Output Sink Current		0.5		mA	
DAC Resolution	8			Bits	
Monotonicity	8			Bits	
Differential Nonlinearity			±1	LSB	
Integral Nonlinearity		±1		LSB	
Total Unadjusted Error			±5	%	I_L = 2 mA
REFERENCE VOLTAGE OUTPUT (REFOUT)					
Output Voltage	2.226	2.25	2.288	V	
Output Source Current			10	mA	
Output Sink Current			0.6	mA	
OPEN-DRAIN SERIAL DATA BUS OUTPUT (SDA)					
Output Low Voltage (V_{OL})			0.4	V	I_{OUT} = −4.0 mA, V_{CC} = 3.3 V
High Level Output Current (I_{OH})		0.1	1	µA	V_{OUT} = V_{CC}
DIGITAL INPUTS (SCL, SDA, TACH INPUTS, PROCHOT)					
Input High Voltage (V_{IH})	2.0			V	
Input Low Voltage (V_{IL})			0.8	V	
Hysteresis		0.5		V	
DIGITAL INPUT CURRENT (TACH INPUTS, PROCHOT)					
Input High Current (I_{IH})	−1			µA	V_{IN} = V_{CC}
Input Low Current (I_{IL})			1	µA	V_{IN} = 0
Input Capacitance ($_{IN}$)		20		pF	
OPEN-DRAIN DIGITAL OUTPUTS (ALERT, FANLOCK, FAN1_ON/THERM)					
Output Low Voltage (V_{OL})			0.4	V	I_{OUT} = −4.0 mA, V_{CC} = 3.3 V
High Level Output Current (I_{OH})		0.1	1	µA	V_{OUT} =V_{CC}
SERIAL BUS TIMING [2]					
Clock Frequency (f_{SCLK})			400	kHz	See Figure 2
Glitch Immunity (t_{SW})			50	ns	See Figure 2
Bus Free Time (t_{BUF})	1.3			µs	See Figure 2
Start Setup Time ($t_{SU;STA}$)	0.6			µs	See Figure 2
Start Hold Time ($t_{HD;STA}$)	0.6			µs	See Figure 2
SCL Low Time (t_{LOW})	1.3			µs	See Figure 2
SCL High Time (t_{HIGH})	0.6			µs	See Figure 2
SCL, SDA Rise Time (t_r)			1000	ns	See Figure 2
SCL, SDA Fall Time (t_f)			300	ns	See Figure 2
Data Setup Time ($t_{SU;DAT}$)	100			ns	See Figure 2
Detect Clock Low Timeout ($t_{TIMEOUT}$)		25	64	Ms	Can be optionally disabled

[1] All voltages are measured with respect to GND, unless otherwise specified. Typical values are at T_A = 25°C and represent the most likely parametric norm. Logic inputs accept input high voltages up to 5 V even when the device is operating at supply voltages below 5 V. Timing specifications are tested at logic levels of V_{IL} = 0.8 V for a falling edge and at V_{IH} = 2.0 V for a rising edge.

[2] Guaranteed by design, not production tested.

SERIAL BUS TIMING

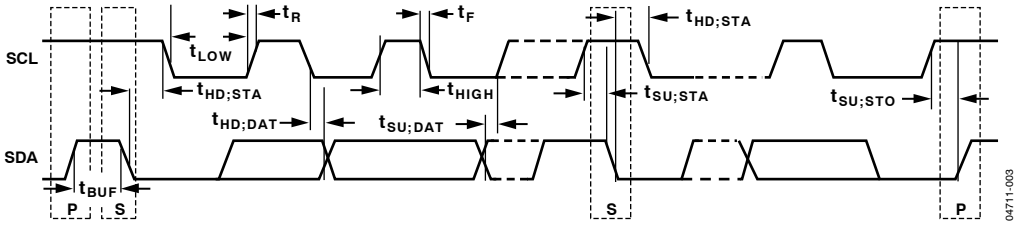

Figure 2. Diagram for Serial Bus Timing

ABSOLUTE MAXIMUM RATINGS

Table 2.

Parameter	Rating
Positive Supply Voltage (V_{CC})	6.5 V
Voltage on Any Other Pin	−0.3 V to 6.5 V
Input Current at Any Pin	±5 mA
Package Input Current	±20 mA
Maximum Junction Temperature (T_J max)	150°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature, Soldering:	
IR Peak Reflow Temperature	220°C
Lead Temperature (10 sec)	300°C
ESD Rating	2000 V

Stresses greater than those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operational section of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

THERMAL CHARACTERISTICS

16-Lead QSOP Package:

θ_{JA} = 105°C/W

θ_{JC} = 39°C/W

ESD CAUTION

ESD (electrostatic discharge) sensitive device. Electrostatic charges as high as 4000 V readily accumulate on the human body and test equipment and can discharge without detection. Although this product features proprietary ESD protection circuitry, permanent damage may occur on devices subjected to high energy electrostatic discharges. Therefore, proper ESD precautions are recommended to avoid performance degradation or loss of functionality.

PIN CONFIGURATION AND FUNCTION DESCRIPTIONS

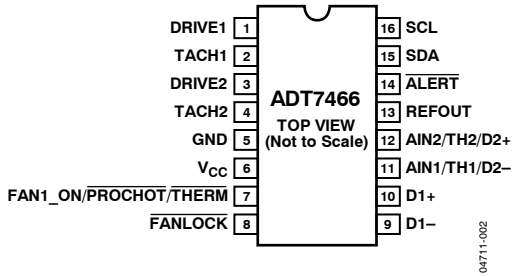

Figure 3. Pin Configuration

Table 3. Pin Function Descriptions

Pin No.	Mnemonic	Type	Description
1	DRIVE1	Analog Output	Output of 8-Bit DAC Controlling Fan 1 Speed.
2	TACH1	Digital Input	Fan Tachometer Input to Measure Speed of Fan 1.
3	DRIVE2	Analog Output	Output of 8-Bit DAC Controlling Fan 2 Speed.
4	TACH2	Digital Input	Fan Tachometer Input to Measure Speed of Fan 2.
5	GND	Ground	Ground Pin for Analog and Digital Circuitry.
6	V_{CC}	Power supply	3.3 V Power Supply. V_{CC} is also monitored through this pin.
7	FAN1_ON/ $\overline{\text{PROCHOT}}$/ $\overline{\text{THERM}}$	Digital I/O	If configured as FAN1_ON, this pin is the open-drain control signal output for the dc-dc converter. Active (high) when DRIVE1 > V_FAN_MIN. If configured as $\overline{\text{PROCHOT}}$, the input can be connected to the $\overline{\text{PROCHOT}}$ output of the Intel Pentium 4 processor to time and monitor $\overline{\text{PROCHOT}}$ assertions. If configured as $\overline{\text{THERM}}$, this pin is the interrupt output to flag critical thermal events.
8	$\overline{\text{FANLOCK}}$	Digital Output	Open-Drain Digital Output. This output is asserted (low) when either of the fans stall or fail to spin up.
9	D1–	Analog Input	Cathode Connection to Thermal Diode 1.
10	D1+	Analog Input	Anode Connection to Thermal Diode 1.
11	AIN1/TH1/D2–	Analog input	0 V to 2.25 V Analog Input. Can be reconfigured as thermistor input or as a cathode connection to Thermal Diode 2. Configured for thermistor connection by default.
12	AIN2(TH2)/D2+	Analog Input	0 V to 2.25 V Analog Input. Can be reconfigured as thermistor input or as an anode connection to Thermal Diode 2. Configured for thermistor connection by default.
13	REFOUT	Analog Output	2.25 V Reference Voltage Output, 20 mA maximum output current.
14	$\overline{\text{ALERT}}$	Digital Output	Open-Drain Digital Output. The SMBus $\overline{\text{ALERT}}$ pin alerts the system to out-of-limit events such as a failed fan, overtemperature, or out-of-limit analog measurement.
15	SDA	Digital I/O	Open-Drain Digital I/O. SMBus bidirectional serial data. Requires SMBus pull-up resistor.
16	SCL	Digital Input	Open-Drain Digital Input. SMBus serial clock input. Requires SMBus pull-up resistor.

TYPICAL PERFORMANCE CHARACTERISTICS

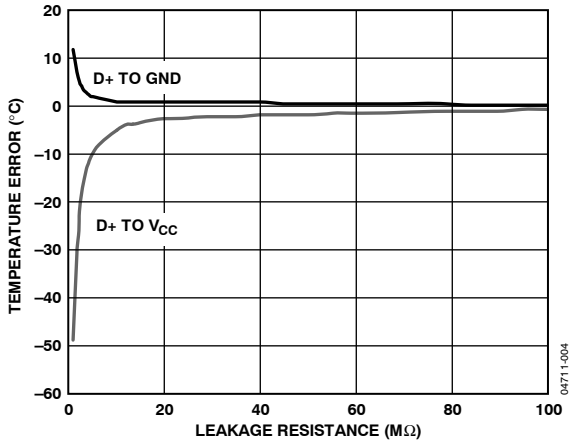

Figure 4. Temperature Error vs. PCB Track Resistance

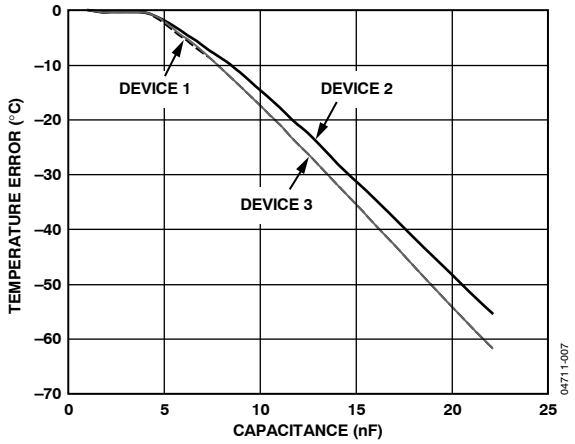

Figure 7. Temperature Error vs. Capacitance Between D+ and D–

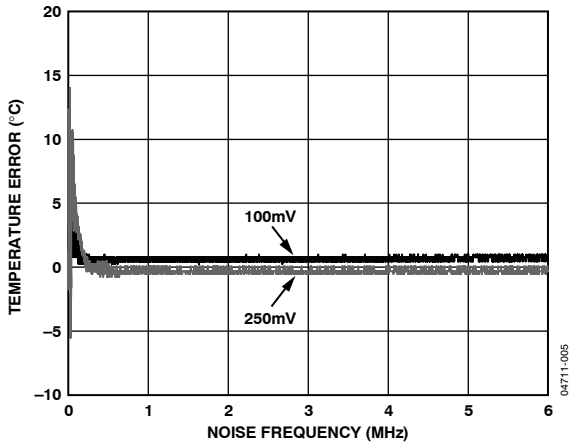

Figure 5. Remote Temperature Error vs. Power Supply Noise Frequency

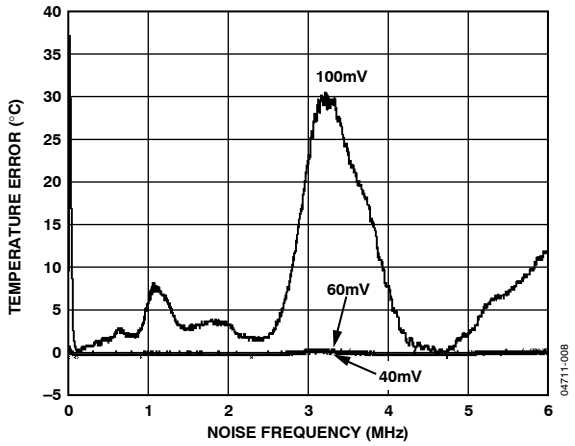

Figure 8. Remote Temperature Error vs. Common-Mode Noise Frequency

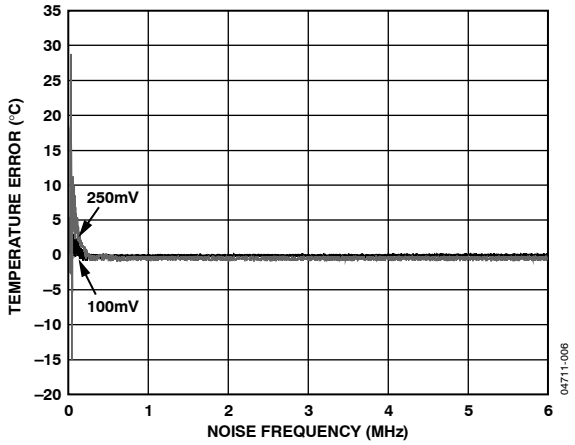

Figure 6. Local Temperature Error vs. Power Supply Noise Frequency

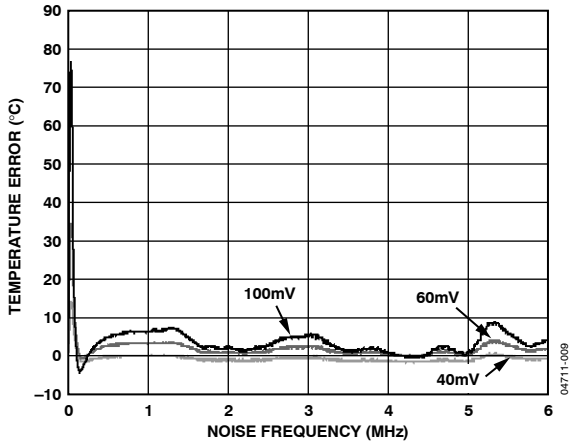

Figure 9. Remote Temperature Error vs. Differential Mode Noise Frequency

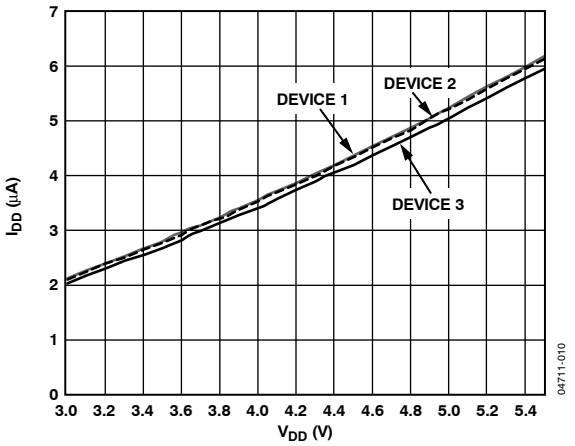

Figure 10. Standby Supply Current vs. Supply Voltage

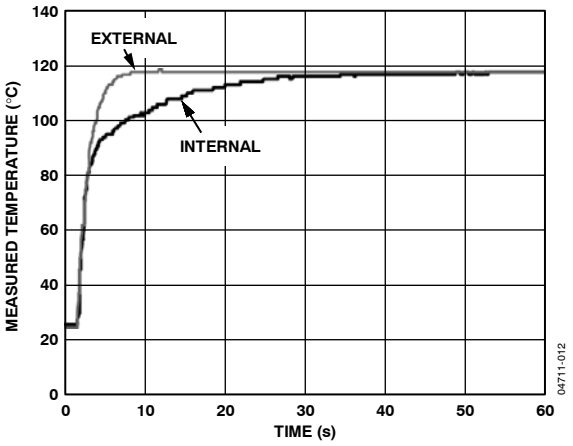

Figure 13. Response to Thermal Shock

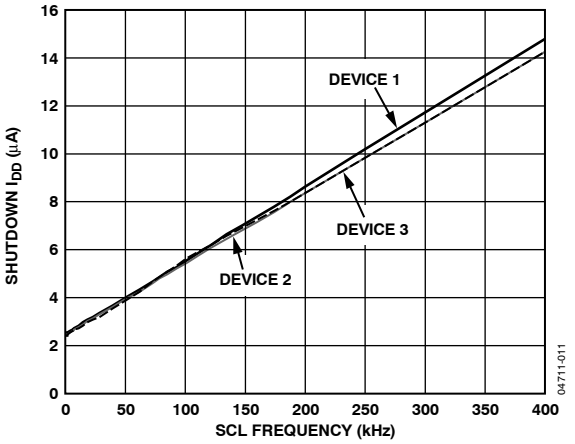

Figure 11. Standby Current vs. Clock Frequency

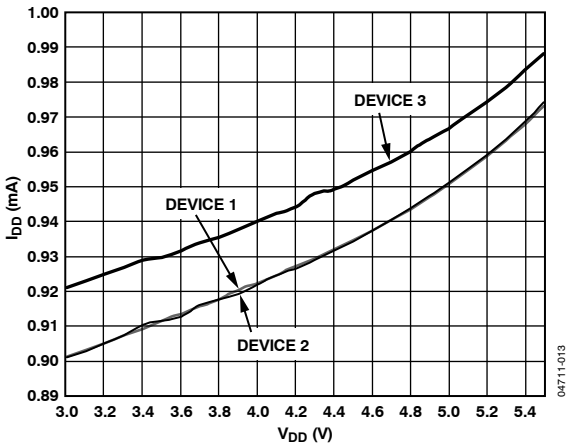

Figure 14. Supply Current vs. Supply Voltage

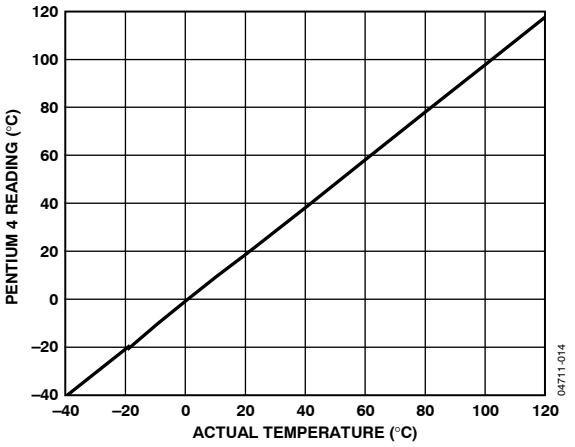

Figure 12. Pentium 4 Temperature Measurement vs. ADT7466 Reading

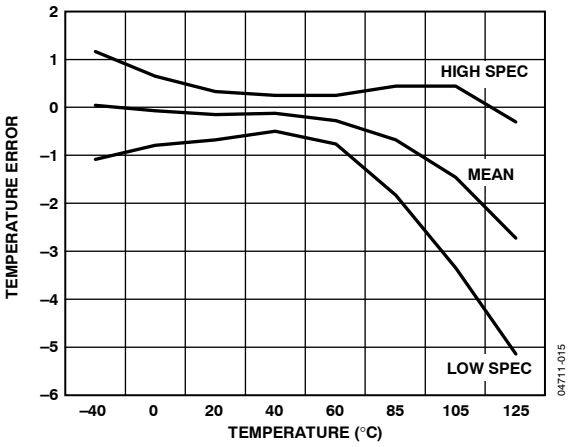

Figure 15. Local Temperature Error

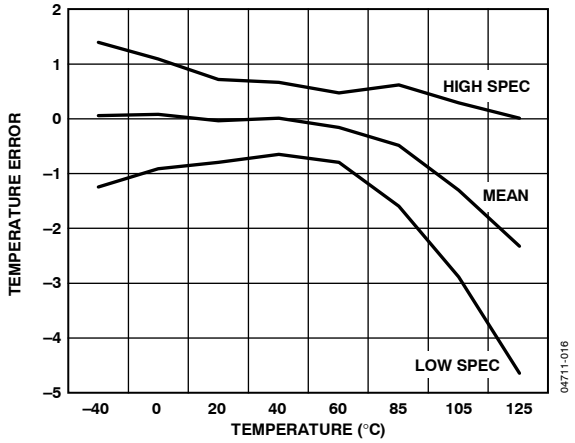

Figure 16. Remote Temperature Error

FUNCTIONAL DESCRIPTION

The ADT7466 is a complete thermal monitor and dual fan controller for any system requiring monitoring and cooling. The device communicates with the system via a serial system management bus (SMBus). The serial data line (SDA, Pin 15) is used for reading and writing addresses and data. The input line, (SCL, Pin 16) is the serial clock. All control and programming functions of the ADT7466 are performed over the serial bus. In addition, an $\overline{\text{ALERT}}$ output is provided to indicate out-of-limit conditions.

MEASUREMENT INPUTS

The device has three measurement inputs, two for voltage and one for temperature. It can also measure its own supply voltage and can measure ambient temperature with its on-chip temperature sensor.

Pin 11 and Pin 12 are analog inputs with an input range of 0 V to 2.25 V. They can easily be scaled for other input ranges by using external attenuators. These pins can also be configured for temperature monitoring by using thermistors or a second remote diode temperature measurement.

The ADT7466 can simultaneously monitor the local temperature, the remote temperature by using a discrete transistor, and two thermistor temperatures.

Remote temperature sensing is provided by the D+ and D– inputs, to which diode connected, remote temperature sensing transistors such as a 2N3904 or CPU thermal diode can be connected.

Temperature sensing using thermistors is carried out by placing the thermistor in series with a resistor. The excitation voltage is provided by the REFOUT pin.

The device also accepts input from an on-chip band gap temperature sensor that monitors system ambient temperature.

Power is supplied to the chip via Pin 6. The system also monitors V_{CC} through this pin. It is normally connected to a 3.3 V supply. It can, however, be connected to a 5 V supply and monitored without going over range.

SEQUENTIAL MEASUREMENT

When the ADT7466 monitoring sequence is started, it sequentially cycles through the measurement of analog inputs and the temperature sensors. Measured values from these inputs are stored in value registers, which can be read out over the serial bus, or can be compared with programmed limits stored in the limit registers. The results of out of limit comparisons are stored in the status registers, which can be read over the serial bus to flag out-of-limit conditions.

FAN SPEED MEASUREMENT AND CONTROL

The ADT7466 has two tachometer inputs for measuring the speed of 3-wire fans, and it has two 8-bit DACs to control the speed of two fans. The temperature measurement and fan speed control can be linked in an automatic control loop, which can operate without CPU intervention to maintain system operating temperature within acceptable limits. The enhanced acoustics feature ensures that fans operate at the minimum possible speed consistent with temperature control, and change speed gradually. This reduces the user's perception of changing fan speed.

INTERNAL REGISTERS OF THE ADT7466

Table 4 provides brief descriptions of the ADT7466's principal internal registers. More detailed information on the function of each register is given in Table 30 to Table 72.

Table 4. Internal Register Summary

Register	Description
Configuration	These registers provide control and configuration of the ADT7466 including alternate pinout functionality.
Address Pointer	This register contains the address that selects one of the other internal registers. When writing to the ADT7466, the first byte of data is always a register address, which is written to the address pointer register.
Status	These registers provide status of each limit comparison and are used to signal out-of-limit conditions on the temperature, voltage, or fan speed channels. Whenever a status bit is set, the $\overline{\text{ALERT}}$ output (Pin 14) goes low.
Interrupt Mask	These registers allow interrupt sources to be masked so that they do not affect the $\overline{\text{ALERT}}$ output.
Value and Limit	The results of analog voltage inputs, temperature, and fan speed measurements are stored in these registers, along with their limit values.
Offset	These registers allow each temperature channel reading to be offset by a twos complement value written to these registers.
$\overline{\text{PROCHOT}}$ Status	This register allows the ADT7466 to monitor and time any $\overline{\text{PROCHOT}}$ events gauging system performance.
T_{MIN}	These registers program the starting temperature for each fan under automatic fan speed control.
T_{RANGE}	These registers program the temperature-to-fan speed control slope in automatic fan speed control mode for each fan drive output.
Enhance Acoustics	This register sets the step size for fan drive changes in AFC mode to minimize acoustic noise.

THEORY OF OPERATION

SERIAL BUS INTERFACE

The serial system management bus (SMBus) is used to control the ADT7466. The ADT7466 is connected to this bus as a slave device under the control of a master controller.

The ADT7466 has an SMBus timeout feature. When this is enabled, the SMBus times out after typically 25 ms of no activity. However, this feature is enabled by default. Bit 5 of Configuration Register 1 (0x00) should be set to 1 to disable this feature.

The ADT7466 supports optional packet error checking (PEC). It is triggered by supplying the extra clock pulses for the PEC byte. The PEC byte is calculated using CRC-8. The frame check sequence (FCS) conforms to CRC-8 by the polynomial

$$C(x) = x8 + x2 + x1 + 1$$

Consult the SMBus Specifications Rev. 1.1 for more information (www.smbus.org).

The ADT7466 has a 7-bit serial bus address, which is fixed at 1001100.

The serial bus protocol operates as follows:

The master initiates data transfer by establishing a start condition, defined as a high-to-low transition on the serial data line SDA while the serial clock line SCL remains high. This indicates that an address/data stream follows. All slave peripherals connected to the serial bus respond to the start condition, and shift in the next 8 bits, consisting of a 7-bit address (MSB first) and a R/$\overline{W}$ bit, which determines the direction of the data transfer, that is, whether data is written to or read from the slave device.

The address of the ADT7466 is set at 1001100. Since the address must always be followed by a write bit (0) or a read bit (1), and data is generally handled in 8-bit bytes, it may be more convenient to think that the ADT7466 has an 8-bit write address of 10011000 (0x98) and an 8-bit read address of 10011001 (0x99). The peripheral whose address corresponds to the transmitted address responds by pulling the data line low during the low period before the 9th clock pulse, known as the acknowledge bit. All other devices on the bus now remain idle while the selected device waits for data to be read from or written to it. If the R/$\overline{W}$ bit is 0, the master writes to the slave device. If the R/$\overline{W}$ bit is 1, the master reads from the slave device.

Data is sent over the serial bus in sequences of 9 clock pulses, 8 bits of data followed by an acknowledge bit from the slave device. Transitions on the data line must occur during the low period of the clock signal and remain stable during the high period, because a low-to-high transition when the clock is high may be interpreted as a stop signal. The number of data bytes that can be transmitted over the serial bus in a single read or write operation is limited only by what the master and slave devices can handle.

When all data bytes have been read or written, stop conditions are established. In write mode, the master pulls the data line high during the 10th clock pulse to assert a stop condition. In read mode, the master device overrides the acknowledge bit by pulling the data line high during the low period before the ninth clock pulse. This is known as No Acknowledge. The master takes the data line low during the low period before the 10th clock pulse, and then high during the 10th clock pulse to assert a stop condition.

Any number of bytes of data can be transferred over the serial bus in one operation, but it is not possible to mix read and write in one operation, because the type of operation is determined at the beginning and subsequently cannot be changed without starting a new operation.

ADT7466 write operations contain either one or two bytes, and read operations contain one byte, and perform the following functions.

To write data to one of the device data registers or read data from it, the address pointer register must be set so that the correct data register is addressed, and data can be written to that register or read from it. The first byte of a write operation always contains an address that is stored in the address pointer register. If data is to be written to the device, the write operation contains a second data byte that is written to the register selected by the address pointer register. This is shown in Figure 17. The device address is sent over the bus followed by R/$\overline{W}$ set to 0. This is followed by two data bytes. The first data byte is the address of the internal data register to be written to, which is stored in the address pointer register. The second data byte is the data to be written to the internal data register.

When reading data from a register, there are two possibilities.

If the ADT7466 address pointer register value is unknown or not the desired value, it is necessary to first set it to the correct value before data can be read from the desired data register. This is done by performing a write to the ADT7466 as before, but only the data byte containing the register address is sent since data is not to be written to the register. This is shown in Figure 18.

A read operation is then performed consisting of the serial bus address, R/$\overline{W}$ bit set to 1, followed by the data byte read from the data register. This is shown in Figure 19.

If the address pointer register is known to already be at the desired address, data can be read from the corresponding data register without first writing to the address pointer register, so the procedure in Figure 18 can be omitted.

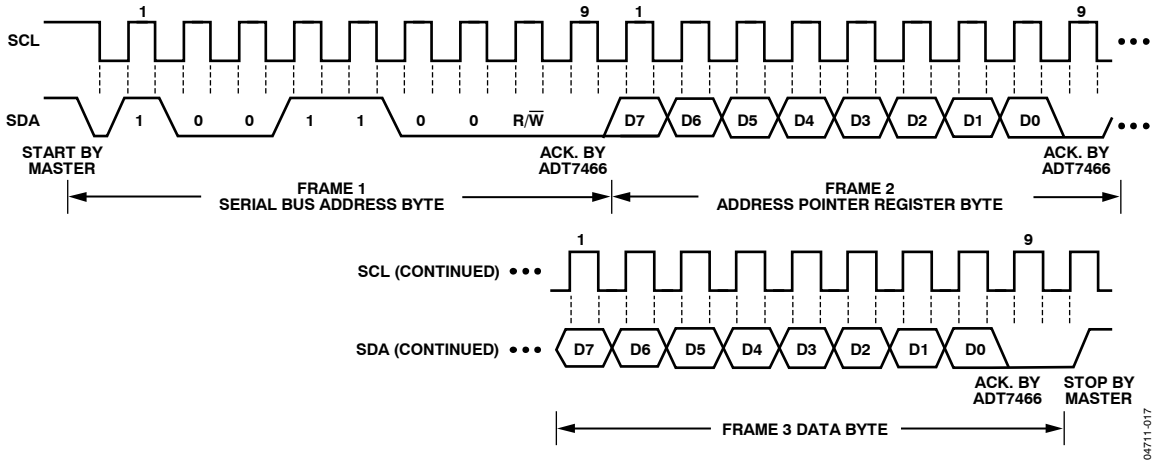

Figure 17. Writing a Register Address to the Address Pointer Register, then Writing Data to the Selected Register

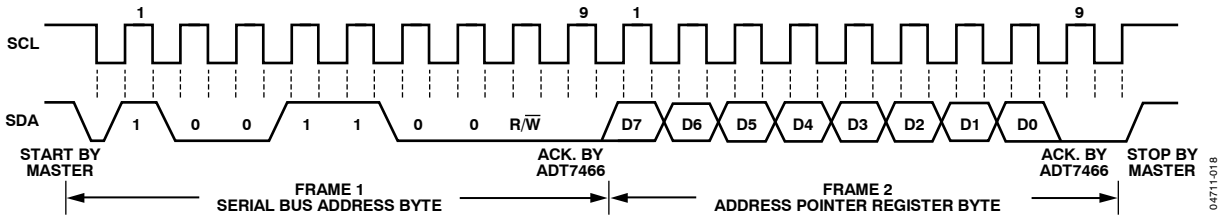

Figure 18. Writing to the Address Pointer Register Only

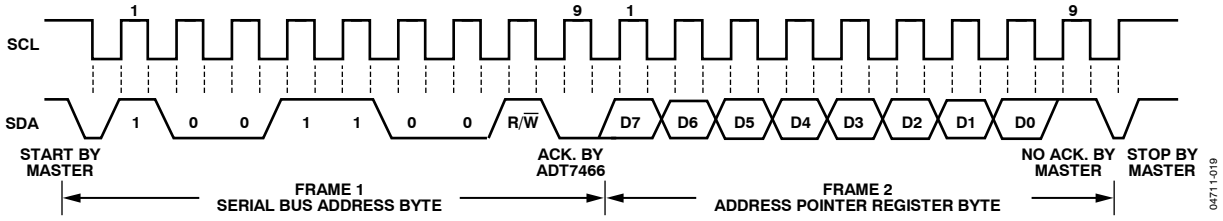

Figure 19. Reading Data from a Previously Selected Register

Although it is possible to *read* a data byte from a data register without first writing to the address pointer register if the address pointer register is already at the correct value, it is not possible to *write* data to a register without writing to the address pointer register, because the first data byte of a write is always written to the address pointer register.

In addition to supporting the send byte and receive byte protocols, the ADT7466 also supports the read byte protocol (see the SMBus Specifications Rev. 1.1 for more information).

If it is required to perform several read or write operations in succession, the master can send a repeat start condition instead of a stop condition to begin a new operation.

WRITE AND READ OPERATIONS

The SMBus specification defines several protocols for different types of write and read operations. The protocols used in the ADT7466 are discussed in the following sections. The following abbreviations are used in the diagrams:

S—Start
P—Stop
R—Read
W—Write
A—Acknowledge
$\overline{A}$—No Acknowledge

Write Operations

The ADT7466 uses the send byte and write byte protocols.

Send Byte

In this operation, the master device sends a single command byte to a slave device, as follows:

1. The master device asserts a start condition on SDA.
2. The master sends the 7-bit slave address followed by the write bit (low).
3. The addressed slave device asserts ACK on SDA.
4. The master sends a register address.
5. The slave asserts ACK on SDA.
6. The master asserts a stop condition on SDA and the transaction ends.

For the ADT7466, the send byte protocol is used to write a register address to RAM for a subsequent single-byte read from the same address. This is shown in Figure 20.

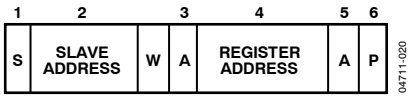

Figure 20. Setting a Register Address for Subsequent Read

If it is required to read data from the register immediately after setting up the address, the master can assert a repeat start condition immediately after the final ACK and carry out a single-byte read without asserting an intermediate stop condition.

Write Byte

In this operation, the master device sends a command byte and one data byte to the slave device, as follows:

1. The master device asserts a start condition on SDA.
2. The master sends the 7-bit slave address followed by the write bit (low).
3. The addressed slave device asserts ACK on SDA.
4. The master sends a register address.
5. The slave asserts ACK on SDA.
6. The master sends a data byte.
7. The slave asserts ACK on SDA.
8. The master asserts a stop condition on SDA to end the transaction.

This is shown in Figure 21.

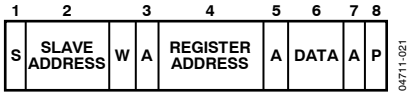

Figure 21. Single-Byte Write to a Register

Read Operations

The ADT7466 uses the following SMBus read protocols.

Receive Byte

This is useful when repeatedly reading a single register. The register address needs to have been set up previously.

In this operation, the master device receives a single byte from a slave device, as follows:

1. The master device asserts a start condition on SDA.
2. The master sends the 7-bit slave address followed by the read bit (high).
3. The addressed slave device asserts ACK on SDA.
4. The master receives a data byte.
5. The master asserts NO ACK on SDA.
6. The master asserts a stop condition on SDA and the transaction ends.

For the ADT7466, the receive byte protocol is used to read a single byte of data from a register whose address was set previously by a send byte or write byte operation.

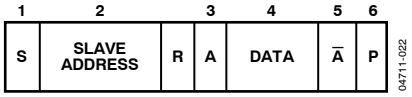

Figure 22. Single-Byte Read from a Register

ALERT RESPONSE ADDRESS (ARA)

ARA is a feature of SMBus devices that allows an interrupting device to identify itself to the host when multiple devices exist on the same bus. The $\overline{\text{ALERT}}$ output can be used as an interrupt output, or it can be used as an $\overline{\text{ALERT}}$. One or more outputs can be connected to a common $\overline{\text{ALERT}}$ line connected to the master. If a device's $\overline{\text{ALERT}}$ line goes low, the following occurs:

1. $\overline{\text{ALERT}}$ is pulled low.
2. The master initiates a read operation and sends the alert response address (ARA = 0001 100). This is a general call address, which must not be used as a specific device address.
3. The device whose $\overline{\text{ALERT}}$ output is low responds to the alert response address, and the master reads its device address. The address of the device is now known, and it can be interrogated in the usual way.
4. If more than one device's $\overline{\text{ALERT}}$ output is low, the one with the lowest device address has priority, in accordance with normal SMBus arbitration.
5. Once the ADT7466 responds to the alert response address, the master must read the status registers, the $\overline{\text{ALERT}}$ is cleared only if the error condition no longer exists.

SMBus TIMEOUT

The ADT7466 includes an SMBus timeout feature. If there is no SMBus activity for 25 ms, the ADT7466 assumes that the bus is locked, and it releases the bus. This prevents the device from locking or holding the SMBus expecting data. Some SMBus controllers cannot handle the SMBus timeout feature, so they are disabled.

Table 5. Configuration Register 1—Register 0x00

Bit Address and Value	Description
<5> TODIS = 0	SMBus timeout enabled (default)
<5> TODIS = 1	SMBus timeout disabled

VOLTAGE MEASUREMENT

The ADT7466 has two external voltage measurement channels. Pin 11 and Pin 12 are analog inputs with a range of 0 V to 2.25 V. It can also measure its own supply voltage, V_{CC}. The V_{CC} supply voltage measurement is carried out through the V_{CC} pin (Pin 6). Setting Bit 6 of Configuration Register 1 (0x00) allows a 5 V supply to power the ADT7466 and be measured without overranging the V_{CC} measurement channel.

A/D Converter

All analog inputs are multiplexed into the on-chip, successive approximation, analog-to-digital converter. This has a resolution of 10 bits. The basic input range is 0 V to 2.25 V, but the V_{CC} input has built in attenuators to allow measurement of 3.3 V or 5 V. To allow for the tolerance of the supply voltage, the ADC produces an output of 3/4 full scale (decimal 768 or 0x300) for the nominal supply voltage, and so has adequate headroom to cope with overvoltages.

Table 9 shows the input ranges of the analog inputs and the output codes of the ADC.

Table 6. Voltage Measurement Registers

Register	Description	Default
0x0A	AIN1 reading	0x00
0x0B	AIN2 reading	0x00
0x0C	V_{CC} reading	0x00

Associated with each voltage measurement channel are high and low limit registers. Exceeding the programmed high or low limit causes the appropriate status bit to be set. Exceeding either limit can also generate $\overline{\text{ALERT}}$ interrupts.

Table 7. Voltage Measurement Limit Registers

Register	Description	Default
0x14	AIN1 low limit	0x00
0x15	AIN1 high limit	0xFF
0x16	AIN2 low limit	0x00
0x17	AIN2 high limit	0xFF
0x18	V_{CC} low limit	0x00
0x19	V_{CC} high limit	0xFF

When the ADC is running, it samples and converts a voltage input in 1 ms, and averages 16 conversions to reduce noise. Therefore a measurement on each input takes nominally 16 ms.

Turn Off Averaging

For each voltage measurement read from a value register, 16 readings have actually been made internally and the results averaged, before being placed into the value register. There can be an instance where faster conversions are required. Setting Bit 4 of Configuration Register 2 (0x01) turns averaging off. This effectively gives a reading 16 times faster (1 ms), but as a result the reading can be noisier.

Single-Channel ADC Conversions

Setting Bit 3 of Configuration Register 4 (0x03) places the ADT7466 into single-channel ADC conversion mode. In this mode, the ADT7466 can be made to read a single voltage channel only. If the internal ADT7466 clock is used, the selected input is read every 1 ms. The appropriate ADC channel is selected by writing to Bits 2:0 of Configuration Register 4 (0x03).

Table 8. Single-Channel ADC Conversions

Bits 2:0, Reg. 0x03	Channel Selected
000	AIN1
001	AIN2
010	V_{CC}

REFERENCE VOLTAGE OUTPUT

The ADT7466 has a reference voltage of 2.25 V, which is available on Pin 13 of the device. It can be used for scaling and offsetting the analog inputs to give different voltage ranges. It can also be used as an excitation voltage for a thermistor when the analog inputs are configured as thermistor inputs. See the Temperature Measurement section for more details.

CONFIGURATION OF PIN 11 AND PIN 12

Pin 11 and Pin 12 can be used for analog inputs, thermistor inputs, or connecting a second remote thermal diode. The ADT7466 is configured for thermistor connection by default. The device is configured for the different modes by setting the appropriate bits in the configuration registers. Bits 6:7 of Configuration Register 3 (0x02) configure the device for either analog inputs or thermistor inputs. Bit 7 of Configuration Register 2 (0x01) configures Pin 11 and Pin 12 for the connection of a second thermal diode. Bits 2:3 of Interrupt Status Register 2 (0x11) indicate either an open or short circuit on Thermal Diode 1 and Diode 2 inputs. Bits 4:5 of Interrupt Status Register 2 (0x11) indicate either an open or short circuit on TH1 and TH2 inputs. It is advisable to mask interrupts on diode open/short alerts when in thermistor monitoring mode and to mask interrupts on thermistor open/short alerts when in REM2 mode.

Table 9. A-to-D Output Code vs. V_{IN}

V_{CC} 3.3 V	V_{CC} 5 V	A_{IN}	Decimal	Binary
<0.0172	<0.026	<0.0088	0	00000000
0.017–0.034	0.026–0.052	0.0088–0.0176	1	00000001
0.034–0.052	0.052–0.078	0.0176–0.0264	2	00000010
0.052–0.069	0.078–0.104	0.0264–0.0352	3	00000011
1.110–1.127	**1.667–1.693**	**0.563–0.572**	**64 (¼ scale)**	**01000000**
2.220–2.237	**3.333–3.359**	**1.126–1.135**	**128 (½ scale)**	**10000000**
3.3–3.347	**5–5.026**	**1.689–1.698**	**192 (¾ scale)**	**11000000**
4.371–4.388	6.563–6.589	2.218–2.226	252	11111100
4.388–4.405	6.589–6.615	2.226–2.235	253	11111101
4.405–4.423	6.615–6.641	2.235–2.244	254	11111110
>4.423	>6.634	>2.244	255	11111111

Table 10. Mode Configuration Summary

Mode	Configuration Register Settings	Limits	Alerts[1]	Description
Thermistor Mode				Default mode. Mask interrupts on diode NC. (Set Bits 2:3 of Reg. 0x13.)
TH1	Register 0x02 Bit 7 = 1	Low: Reg 0x14 High: Reg 0x15	OOL: Reg. 0x10, Bit 6 NC: Reg. 0x11, Bit 4	
TH2	Register 0x02 Bit 6 = 1	Low: Reg 0x16 High: Reg 0x17	OOL: Reg. 0x10, Bit 5 NC: Reg. 0x11, Bit 5	
AIN Mode				Ensure that AFC is not on. (Clear Bits 0:1 of AFC Configuration Register 1, 0x05.)
AIN1	Register 0x 02 Bit 7 = 0	Low: Reg 0x14 High: Reg 0x15	OOL: Reg. 0x10, Bit 6	
AIN2	Register 0x02 Bit 6 = 0	Low: Reg 0x16 High: Reg 0x17	OOL: Reg. 0x10, Bit 5	
Remote 2 Diode Mode	Register 0x01 Bit 7 = 1	Low: Reg 0x14 High: Reg 0x15	OOL: Reg. 0x10, Bit 6 NC: Reg. 0x11, Bit 3	Mask interrupts on thermistor NC. (Set Bits 4:5 of Reg. 0x13) and AIN2 (Bit 5 of Reg. 0x12.)

[1] OOL = Out of limit. NC = No connection.

TEMPERATURE MEASUREMENT

The ADT7466 has two dedicated temperature measurement channels, one for measuring the temperature of an on-chip band gap temperature sensor, and one for measuring the temperature of a remote diode, usually located in the CPU. In addition, the analog input channels, AIN1 and AIN2, can be reconfigured to measure the temperature of a second diode by setting Bit 7 of Configuration Register 2 (0x01), or to measure temperature using thermistors by setting Bit 6 and/or Bit 7 of Configuration Register 3 (0x02).

SERIES RESISTANCE CANCELLATION

Parasitic resistance, seen in series with the remote diode between the D+ and D− inputs to the ADT7466, is caused by a variety of factors including PCB track resistance and track length. This series resistance appears as a temperature offset in the sensor's temperature measurement. This error typically causes a 1°C offset per ohm of parasitic resistance in series with the remote diode. The ADT7466 automatically cancels the effect of this series resistance on the temperature reading, giving a more accurate result without the need for user characterization of the resistance. The ADT7466 is designed to automatically cancel typically 2 kΩ of resistance. This is done transparently to the user, using an advanced temperature measurement method described in the following section.

TEMPERATURE MEASUREMENT METHOD

A simple method of measuring temperature is to exploit the negative temperature coefficient of a diode, by measuring the base emitter voltage (V_{BE}) of a transistor operated at constant current. Unfortunately, this technique requires calibration to null out the effect of the absolute value of V_{BE}, which varies from device to device.

The technique used in the ADT7466 measures the change in V_{BE} when the device is operated at three different currents. Previous devices used only two operating currents, but it is the third current that allows series resistance cancellation.

Figure 24 shows the input signal conditioning used to measure the output of a remote temperature sensor. This figure shows the remote sensor as a substrate transistor, provided for temperature monitoring on some microprocessors, but it could also be a discrete transistor. If a discrete transistor is used, the collector is not grounded, and should be linked to the base. To prevent ground noise from interfering with the measurement, the more negative terminal of the sensor is not referenced to ground but is biased above ground by an internal diode at the D− input. If the sensor is operating in an extremely noisy environment, C1 may optionally be added as a noise filter. Its value should never exceed 1000 pF. See the Layout Considerations section for more information on C1.

To measure ΔV_{BE}, the operating current through the sensor is switched between three related currents. Figure 24 shows N1 × I and N2 × I as different multiples of the current I. The currents through the temperature diode are switched between I and N1 × I, giving ΔV_{BE1}, and then between I and N2 × I, giving ΔV_{BE2}. The temperature can then be calculated using the two ΔV_{BE} measurements. This method can also cancel the effect of series resistance on the temperature measurement. The resulting ΔV_{BE} waveforms are passed through a 65 kHz low-pass filter to remove noise, and then to a chopper-stabilized amplifier. This amplifies and rectifies the waveform to produce a dc voltage proportional to ΔV_{BE}. The ADC digitizes this voltage, and a temperature measurement is produced. To reduce the effects of noise, digital filtering is performed by averaging the results of 16 measurement cycles for low conversion rates. Signal conditioning and measurement of the internal temperature sensor is performed in the same manner.

USING DISCRETE TRANSISTORS

If a discrete transistor is used, the collector is not grounded and should be linked to the base. If an NPN transistor is used, the emitter is connected to the D− input and the base to the D+ input. If a PNP transistor is used, the base is connected to the D− input and the emitter to the D+ input. Figure 23 shows how to connect the ADT7466 to an NPN or PNP transistor for temperature measurement. To prevent ground noise interfering with the measurement, the more negative terminal of the sensor is not referenced to ground, but is biased above ground by an internal diode at the D− input.

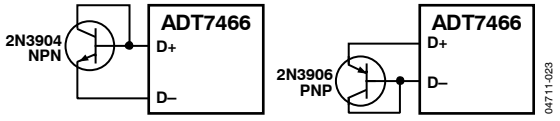

Figure 23. Connections for NPN and PNP Transistors

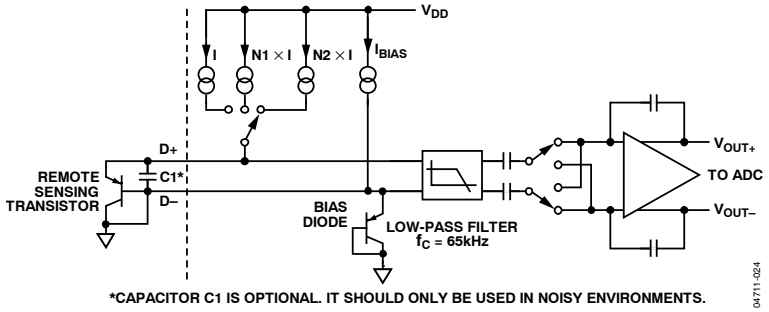

Figure 24. Signal Conditioning for Remote Diode Temperature Sensors

Temperature Data Format

The temperature data stored in the temperature data registers consists of a high byte with an LSB size equal to 1°C. If higher resolution is required, two additional bits are stored in the extended temperature registers, giving a resolution of 0.25°C. The temperature measurement range for both local and remote measurements is, by default, 0°C to 127°C (binary), so the ADC output code equals the temperature in degrees Celsius, and half the range of the ADC is not actually used.

The ADT7466 can also be operated by using an extended temperature range from −64°C to +191°C. In this case, the whole range of the ADC is used, but the ADC code is offset by +64°C, so it does not correspond directly to the temperature. (0°C = 0100000) .

The user can switch between these two temperature ranges by setting or clearing Bit 7 in Configuration Register 1. The measurement range should be switched only once after power-up, and the user should wait for two monitoring cycles (approximately 68 ms) before expecting a valid result. Both ranges have different data formats, as shown in Table 11.

Table 11. Temperature Data Format

Temperature	Binary[1]	Offset Binary[2]
−64°C	0 000 0000	0 000 0000
0°C	0 000 0000	0 100 0000
1°C	0 000 0001	0 100 0001
10°C	0 000 1010	0 100 1010
25°C	0 001 1001	0 101 1001
50°C	0 011 0010	0 111 0010
75°C	0 100 1011	1 000 1011
100°C	0 110 0100	1 010 0100
125°C	0 111 1101	1 011 1101
127°C	0 111 1111	1 011 1111
191°C	0 111 1111	1 111 1111

[1] Binary scale temperature measurement returns 0 for all temperatures ≤0°C.
[2] Offset binary scale temperature values are offset by +64.

While the temperature measurement range can be set to −64°C to +191°C for both local and remote temperature monitoring, the ADT7466 itself should not be exposed to temperatures greater than those specified in the Absolute Maximum Ratings table. Furthermore, the device is guaranteed to only operate at ambient temperatures from −40°C to +125°C. In practice, the device itself should not be exposed to extreme temperatures, and may need to be shielded in extreme environments to comply with these requirements. Only the remote temperature monitoring diode should be exposed to temperatures above +120°C and below −40°C. Care should be taken in choosing a remote temperature diode to ensure that it can function over the required temperature range.

Nulling Out Temperature Errors

The ADT7466 automatically nulls out temperature measurement errors due to series resistance, but systematic errors in the temperature measurement can arise from a number of sources, and the ADT7466 can reduce these errors. As CPUs run faster, it is more difficult to avoid high frequency clocks when routing the D+, D− tracks around a system board. Even when recommended layout guidelines are followed, there may still be temperature errors attributed to noise being coupled onto the D+/D− lines. High frequency noise generally has the effect of giving temperature measurements that are too high by a constant amount. The ADT7466 has temperature offset registers at addresses 0x26 and 0x27 for the remote and local temperature channels. A one time calibration of the system can determine the offset caused by system board noise and null it out using the offset registers. The offset registers automatically add a twos complement 8-bit reading to every temperature measurement. The LSB adds 1°C offset to the temperature reading so the 8-bit register effectively allows temperature offsets of up to ±128°C with a resolution of 1°C. This ensures that the readings in the temperature measurement registers are as accurate as possible.

Table 12. Temperature Offset Registers

Register	Description	Default
0x24	Thermistor 1/Remote 2 offset	0x00 (0°C)
0x25	Thermistor 2 offset	0x00 (0°C)
0x26	Remote1 temperature offset	0x00 (0°C)
0x27	Local temperature offset	0x00 (0°C)

Table 13. Temperature Measurement Registers

Register	Description	Default
0x0D	Remote temperature	0x00
0x0E	Local temperature	0x00
0x08	Extended Resolution 1 Bits 1:0 remote temperature LSBs	0x00
0x09	Extended Resolution 2 Bits 1:0 local temperature LSBs	0x00

Associated with each temperature measurement channel are high and low limit registers. Exceeding the programmed high or low limit causes the appropriate status bit to be set. Exceeding either limit can also generate $\overline{\text{ALERT}}$ interrupts.

Table 14. Temperature Measurement Limit Registers

Register	Description	Default
0x1A	Remote1 temperature low limit	0x00
0x1B	Remote1 temperature high limit	0x7F
0x1C	Local temperature low limit	0x00
0x1D	Local temperature high limit	0x7F
0x14	Thermistor 1/Remote 2 low limit	0x00
0x15	Thermistor 1/Remote 2 high limit	0xFF
0x16	Thermistor 2 low limit	0x00
0x17	Thermistor 2 high limit	0xFF

All temperature limits must be programmed in the same format as the temperature measurement. If this is offset binary, add 64 (0x40 or 01000000) to the actual temperature limit in degrees Celsius.

Layout Considerations

Digital boards can be electrically noisy environments. Take the following precautions to protect the analog inputs from noise, particularly when measuring the very small voltages from a remote diode sensor.

Place the ADT7466 as close as possible to the remote sensing diode. Provided that the worst noise sources, such as clock generators, data/address buses and CRTs, are avoided, this distance can be 4 inches to 8 inches.

If the distance to the remote sensor is more than 8 inches, the use of twisted-pair cable is recommended. This works from about 6 feet to 12 feet.

For very long distances (up to 100 feet), use shielded twisted pair, such as Belden #8451 microphone cable. Connect the twisted pair to D+ and D− and the shield to GND close to the ADT7466. Leave the remote end of the shield unconnected to avoid ground loops.

Because the measurement technique uses switched current sources, excessive cable and/or filter capacitance can affect the measurement. When using long cables, the filter capacitor could be reduced or removed.

Route the D+ and D− tracks close together, in parallel, with grounded guard tracks on each side. Provide a ground plane under the tracks if possible.

Use wide tracks to minimize inductance and reduce noise pickup. A 5 mil track minimum width and spacing is recommended.

Figure 25. Arrangement of Signal Tracks

Try to minimize the number of copper/solder joints, which can cause thermocouple effects. Where copper/solder joints are used, make sure that they are in both the D+ and D− paths and are at the same temperature.

Thermocouple effects should not be a major problem because 1°C corresponds to about 240 μV, and thermocouple voltages are about 3 μV/°C of temperature difference. Unless there are two thermocouples with a big temperature differential between them, thermocouple voltages should be much less than 200 mV.

Place a 0.1 μF bypass capacitor close to the ADT7466.

TEMPERATURE MEASUREMENT USING THERMISTORS

The analog input channels, AIN1 and AIN2, can be used to measure temperature by using negative temperature coefficient (NTC) thermistors. NTC thermistors have a nonlinear transfer function of the form

$$R_{t2} = R_{t1} \times e\left(\frac{B}{t_2} - \frac{B}{t_1}\right)$$

where:
R_{t2} is the resistance at temperature *t2*.
R_{t1} is the resistance at temperature *t1* (usually 25°C).
e = 2.71828.
B is the B constant of the thermistor (typically between 3000 and 5000).

A thermistor can be made to give a voltage output that is fairly linear over a limited range by making it part of a potential divider as shown in Figure 26.

A potential divider, with a thermistor as the upper part connected to REFOUT, produces an output voltage that varies nonlinearly in proportion to the inverse of the resistance. By suitable choice of thermistor and fixed resistor, this can be made to approximately cancel the nonlinearity of the thermistor resistance vs. temperature curve, thus giving a fairly linear output voltage with temperature over a limited range. This circuit uses REFOUT as the excitation voltage for both the thermistor and for the ADC, so any variation in REFOUT is cancelled, and the measurement is purely ratiometric.

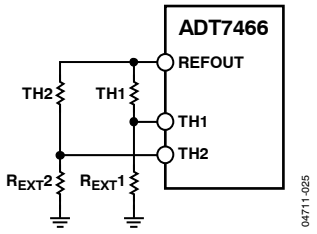

Figure 26. Temperature Measurement Using Thermistor

Thermistor Linearization

A linear transfer function can be obtained over a limited temperature range by connecting the thermistor in series with an optimum resistor. Placing a resistor in series with the thermistor as shown in Figure 26 produces an S-shaped error curve as shown in Figure 27. The overall error across the range can be reduced by calculating the external resistor so that the error is 0 at the ends of the range. R_{EXT} is calculated as follows:

$$R_{EXT} = \frac{R_{MID} \times (R_{MIN} + R_{MAX}) - (2 \times R_{MIN} \times R_{MAX})}{(R_{MIN} + R_{MAX} - 2 \times R_{MID})}$$

where:
R_{MIN} is the thermistor value at T_{MIN}.
R_{MAX} is the thermistor value at T_{MAX}.
R_{MID} is the thermistor value at $\frac{T_{MIN} + T_{MAX}}{2}$

Figure 27 shows the linearity error using a 100 kΩ thermistor with a B value of 3500 and a 14400 Ω resistor. Using the specified thermistor and resistor, the error over a temperature range of 30°C to 100°C is less than ±2°C. Other thermistors can be used, but the resistor value is different. A smaller error can be achieved over a narrower temperature range; conversely, a wider temperature range can be used, but the error is greater. In both cases, the optimum resistor value is different.

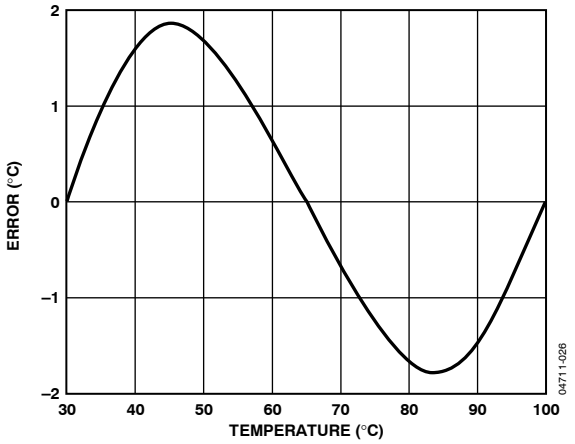

Figure 27. Linearity Error Using Specified Components

Thermistor Normalization

Even when the thermistor is linearized, it does not provide an output to the ADC that gives a direct temperature reading in degrees Celsius. The linearized data is proportional to the voltage applied; however, normalization is needed to use the value as a temperature reading.

To overcome this problem, when an analog input is configured for use with a thermistor, the output of the ADC is scaled and offset so that it produces the same output (for example, 1 LSB = 0.25°C) as from the thermal diode input, when R_{EXT} is chosen to linearize the thermistor over 30°C to 100°C.

Normalization can be chosen for 10 kΩ thermistors by setting Bit 0 of Configuration Register 2 (0x01) or for 100 kΩ thermistors by clearing this bit (default setting).

READING TEMPERATURE FROM THE ADT7466

It is important to note that temperature can be read from the ADT7466 as an 8-bit value (with 1°C resolution) or as a 10-bit value (with 0.25°C resolution). If only 1°C resolution is required, the temperature readings can be read at any time and in no particular order.

If the 10-bit measurement is required, this involves a 2-register read for each measurement. The extended resolution registers (0x08 and 0x09) should be read first. This causes all temperature reading registers to be frozen until all temperature reading registers have been read. This prevents an MSB reading from being updated while its 2 LSBs are being read and vice versa.

Measurement Sequence

The ADT7466 automatically measures each analog and temperature channel in the following round-robin sequence:

1. AIN1/TH1
2. AIN2(TH2)
3. V_{CC}
4. Remote Temperature 1 (D1)
5. Local Temperature

If AIN1 and AIN2 are configured for a second thermal diode, this is measured instead of the AIN1 and AIN 2 measurements, and the result stored in the AIN1 reading register (0x0A).

Analog Monitoring Cycle Time

The analog monitoring cycle begins when a 1 is written to the start bit (Bit 0) of Configuration Register 1 (0x00). The ADC measures each analog input in turn, and, as each measurement is completed, the result is automatically stored in the appropriate value register. This round-robin monitoring cycle continues until disabled by writing a 0 to Bit 0 of Configuration Register 1.

Since the ADC is normally left to free-run in this manner, the time to monitor all the analog inputs is normally not of interest, because the most recently measured value of any input can be read at any time.

For applications where the monitoring cycle time is important, it can easily be calculated from the measurement times of the individual channels. With averaging turned on, each measurement is taken 16 times and the averaged result is placed in the value register. The worst-case monitoring cycle times for averaging turned on and off is described in Table 15.

Fan tach measurements are made in parallel but independently and are not synchronized with the analog measurements.

Table 15. Monitoring Cycle Time

	Monitoring Cycle Time	
Channel	**Avg On**	**Avg Off**
Local temperature	8.99 ms	1.36 ms
Remote 1 temperature	36.69 ms	6.25 ms
Remote 2 temperature	36.69 ms	6.25 ms
AIN1/Thermistor 1	8.65 ms	1.02 ms
AIN2/Thermistor 2	8.65 ms	1.02 ms
V_{CC}	8.26ms	0.61ms
Total[1]	**71.24 ms**	**10.26ms**
Total[2]	**90.63 ms**	**14.47 ms**

[1] Pin 11 and Pin 12 configured for AIN/thermistor monitoring. The total excludes the Remote 2 temperature time.
[2] Pin 11 and Pin 12 configured for second thermal diode monitoring. The total excludes the AIN1/Thermistor 1 and AIN2/Thermistor 2 times.

ADDITIONAL ADC FUNCTIONS

A number of other functions are available on the ADT7466 to offer the systems designer increased flexibility.

Turn Off Averaging

For each temperature measurement read from a value register, 16 readings have actually been made internally and the results averaged before being placed into the value register. The user may want to take a very fast measurement, for example, of CPU temperature. Setting Bit 4 of Configuration Register 2 (0x01) turns averaging off.

Single-Channel ADC Conversions

Setting Bit 3 of Configuration Register 4 (Address 0x03) places the ADT7466 into single-channel ADC conversion mode. In this mode, the ADT7466 can be made to read a single temperature channel only. The selected input is read every 1.4 ms. The appropriate ADC channel is selected by writing to Bits 2:0 of Configuration Register 4 (Address 0x03).

Table 16. ADC Single-Channel Selection

Bits 2:0, Reg. 0x03	Channel Selected
000	AIN1/ Thermistor1
001	AIN2/ Thermistor2
010	V_{CC}
011	Remote 1 temperature
100	Local temperature
101	Remote 2 temperature

LIMIT VALUES

High and low limits are associated with each measurement channel on the ADT7466. These limits can form the basis of system status monitoring; a status bit can be set for any out-of-limit condition and detected by polling the device. Alternatively, $\overline{\text{ALERT}}$ interrupts can be generated to flag out-of-limit conditions for a processor or microcontroller.

Voltage and temperature limits are only 8-bit values and are compared with the 8 MSBs of the voltage and temperature values.

8-Bit Limits

The following tables list the 8-bit limits on the voltage limit and temperature limit registers of the ADT7466.

Table 17. Voltage Limit Registers

Register	Description	Default
0x14	AIN1 low limit	0x00
0x15	AIN1 high limit	0xFF
0x16	AIN2 low limit	0x00
0x17	AIN2 high limit	0xFF
0x18	V_{CC} low limit	0x00
0x19	V_{CC} high limit	0xFF

Table 18. Temperature Limit Registers

Register	Description	Default
0x1A	Remote temperature low limit	0x00
0x1B	Remote temperature high limit	0x7F
0x1C	Local temperature low limit	0x00
0x1D	Local temperature high limit	0x7F
0x1E	$\overline{\text{PROCHOT}}$ limit	0x00
0x1F	AIN1(TH1)/REM2 $\overline{\text{THERM}}$ limit	0x64
0x20	AIN2(TH2) $\overline{\text{THERM}}$ limit	0x64
0x21	Remote $\overline{\text{THERM}}$ limit	0x64
0x22	Local $\overline{\text{THERM}}$ limit	0x64

16-Bit Limits

The fan tach measurements are 16-bit results. The fan tach limits are also 16 bits, consisting of a high byte and low byte. Since fans running under speed or stalled are normally the only conditions of interest, only high limits exist for fan tachs. Since the fan tach period is actually being measured, exceeding the limit indicates a slow or stalled fan.

Table 19. Fan Limit Registers

Register	Description	Default
0x4C	TACH1 minimum low byte	0xFF
0x4D	TACH1 minimum high byte	0xFF
0x4E	TACH2 minimum low byte	0xFF
0x4F	TACH2 minimum high byte	0xFF

Out-of-Limit Comparisons

Once all limits have been programmed, ADT7466 monitoring can be enabled. The ADT7466 measures all parameters in round-robin format and sets the appropriate status bit for out-of-limit conditions. Comparisons are done differently depending on whether the measured value is being compared to a high or low limit.

A *greater than* comparison is performed when comparing with the high limit.

A *less than or equal to* comparison is performed when comparing with the low limit.

Status Registers

The results of limit comparisons are stored in Status Register 1 and Status Register 2. The status register bit for each channel reflects the status of the last measurement and limit comparison on that channel. If a measurement is within limits, the corresponding status register bit is cleared to 0. If the measurement is out-of-limits the corresponding status register bit is set to 1.

The state of the various measurement channels can be polled by reading the status registers over the serial bus. When Bit 7 (OOL) of Status Register 1 (0x10) is 1, an out-of-limit event has been flagged in Status Register 2. Therefore the user need only read Status Register 2 when this bit is set. Alternatively, the $\overline{\text{ALERT}}$ output (Pin 14) can be used as an interrupt, which automatically notifies the system supervisor of an out-of-limit condition. Reading the status registers clears the appropriate status bit as long as the error condition that caused the interrupt has cleared. Status register bits are sticky, meaning that they remain set until read by software. Whenever a status bit is set, indicating an out-of-limit condition, it remains set even if the event that caused it cleared (until read). The only way to clear the status bit is to read the status register when the event clears.

Interrupt status mask registers (0x12, 0x13) allow individual interrupt sources to be masked from causing an $\overline{\text{ALERT}}$. However, if one of these masked interrupt sources goes out-of-limit, its associated status bit is set in the interrupt status registers.

Table 20. Interrupt Status Register 1 (Reg. 0x10)

Bit No.	Name	Description
7	OOL	1 indicates that a bit in Status Register 2 is set and that Status Register 2 should be read.
6	AIN1	1 indicates that AIN1 is out of limit.
5	AIN2	1 indicates that AIN2 is out of limit.
4	VCC	1 indicates that V_{CC} is out of limit.
3	REM	1 indicates that the remote temperature measurement is out of limit.
2	LOC	1 indicates that the local temperature measurement is out of limit.
1	FAN1	1 indicates that the Tach 1 count is above limit (fan speed below limit).
0	FAN2	1 indicates that the Tach 2 count is above limit (fan speed below limit).

Table 21. Interrupt Status Register 2 (Reg. 0x11)

Bit No.	Name	Description
5	THRM2	1 indicates that TH1 is open-circuit.
4	THRM1	1 indicates that TH2 is open-circuit.
3	D2	1 indicates that Remote Temperature Sensing Diode 2 is open-circuit or short-circuit.
2	D1	1 indicates that Remote Temperature Sensing Diode 1 is open-circuit or short-circuit.
1	PHOT	1 indicates that the $\overline{\text{PROCHOT}}$ limit has been exceeded.
0	OVT	1 indicates that a $\overline{\text{THERM}}$ overtemperature limit has been exceeded.

ALERT INTERRUPT BEHAVIOR

The ADT7466 can be polled for status, or an $\overline{\text{ALERT}}$ interrupt can be generated for out-of-limit conditions. It is important to note how the $\overline{\text{ALERT}}$ output and status bits behave when writing interrupt handler software.

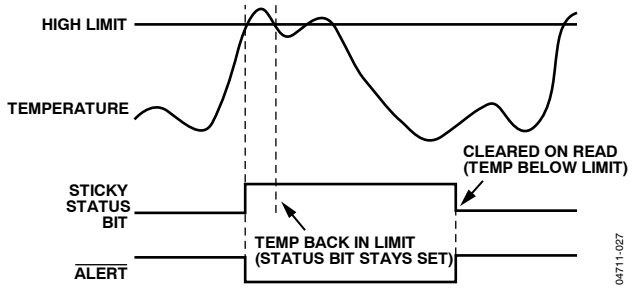

Figure 28. $\overline{\text{ALERT}}$ and Status Bit Behavior

Figure 28 shows how the $\overline{\text{ALERT}}$ output and sticky status bits behave. Once a limit is exceeded, the corresponding status bit is

set to 1. The status bit remains set until the error condition subsides and the status register is read. This ensures that an out-of-limit event cannot be missed if software is polling the device periodically. The $\overline{\text{ALERT}}$ output remains low while a reading is out-of-limit, until the status register is read. This has implications on how software handles the interrupt.

Handling Alert Interrupts

To prevent the system from being tied up servicing interrupts, it is recommended to handle the $\overline{\text{ALERT}}$ interrupt as follows:

1. Detect the $\overline{\text{ALERT}}$ assertion.
2. Enter the interrupt handler.
3. Read the status registers to identify the interrupt source.
4. Mask the interrupt source by setting the appropriate mask bit in the interrupt mask registers (0x12, 0x13).
5. Take the appropriate action for a given interrupt source.
6. Exit the interrupt handler.
7. Periodically poll the status registers. If the interrupt status bit has cleared, reset the corresponding interrupt mask bit to 0. This causes the $\overline{\text{ALERT}}$ output and status bits to behave as shown in Figure 29.

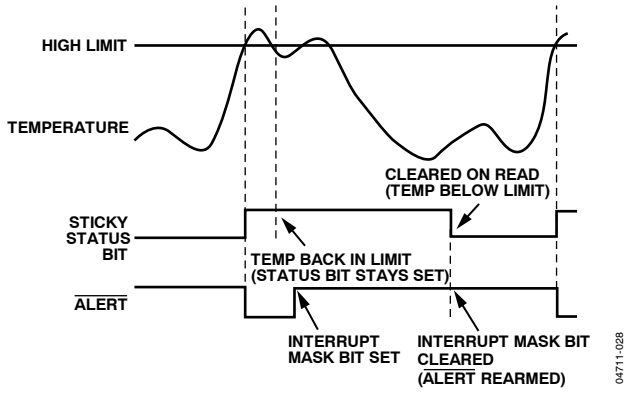

Figure 29. How Masking the Interrupt Source Affects $\overline{\text{ALERT}}$ Output

Masking Interrupt Sources

Interrupt Mask Registers 1 and 2 are located at Addresses 0x12 and 0x13. These registers allow individual interrupt sources to be masked to prevent $\overline{\text{ALERT}}$ interrupts. Masking an interrupt source prevents only the $\overline{\text{ALERT}}$ output from being asserted; the appropriate status bit is set as normal.

Table 22. Interrupt Mask Register 1 (Reg. 0x12)

Bit No.	Name	Description
7	OOL	1 masks $\overline{\text{ALERT}}$ for any alert condition flagged in Status Register 2.
6	AIN1(TH1)/ REM2	1 masks $\overline{\text{ALERT}}$ for AIN1(TH1)/REM2.
5	AIN2(TH2)	1 masks $\overline{\text{ALERT}}$ for AIN2(TH2).
4	VCC	1 masks $\overline{\text{ALERT}}$ for Vcc.
3	REM1	1 masks $\overline{\text{ALERT}}$ for remote temperature.
2	LOC	1 masks $\overline{\text{ALERT}}$ for local temperature.
1	FAN1	1 masks $\overline{\text{ALERT}}$ for Fan 1.
0	FAN2	1 masks $\overline{\text{ALERT}}$ for Fan 2.

Table 23. Interrupt Mask Register 2 (Reg. 0x13)

Bit No.	Name	Description
5	THRM2	1 masks $\overline{\text{ALERT}}$ for TH1 open- or short-circuit errors.
4	THRM1	1 masks TH2 open- or short-circuit errors.
3	D1	1 masks $\overline{\text{ALERT}}$ for Diode 1 open- or short-circuit errors.
2	D2	1 masks $\overline{\text{ALERT}}$ for Diode 2 open- or short-circuit errors.
1	PHOT	1 masks $\overline{\text{ALERT}}$ for $\overline{\text{PROCHOT}}$.
0	OVT	1 masks $\overline{\text{ALERT}}$ for over temperature (exceeding $\overline{\text{THERM}}$ limits).

Measuring $\overline{\text{PROCHOT}}$ Assertion Time

The ADT7466 has an internal timer to measure $\overline{\text{PROCHOT}}$ assertion time. The timer is started on the assertion of the ADT7466 $\overline{\text{PROCHOT}}$ input, and stopped on the negation of the pin. The timer counts $\overline{\text{PROCHOT}}$ times cumulatively, that is, the timer resumes counting on the next $\overline{\text{PROCHOT}}$ assertion. The $\overline{\text{PROCHOT}}$ timer continues to accumulate $\overline{\text{PROCHOT}}$ assertion times until the timer is read (it is cleared on read) or until it reaches full scale. If the counter reaches full scale, it stops at that reading until it is cleared.

The 8-bit $\overline{\text{PROCHOT}}$ timer register (0x0F) is designed such that Bit 0 is set to 1 on the first $\overline{\text{PROCHOT}}$ assertion. Once the cumulative $\overline{\text{PROCHOT}}$ assertion time exceeds 50 ms, Bit 1 of the $\overline{\text{PROCHOT}}$ timer is set, and Bit 0 becomes the LSB of the timer with a resolution of 22.76 ms.

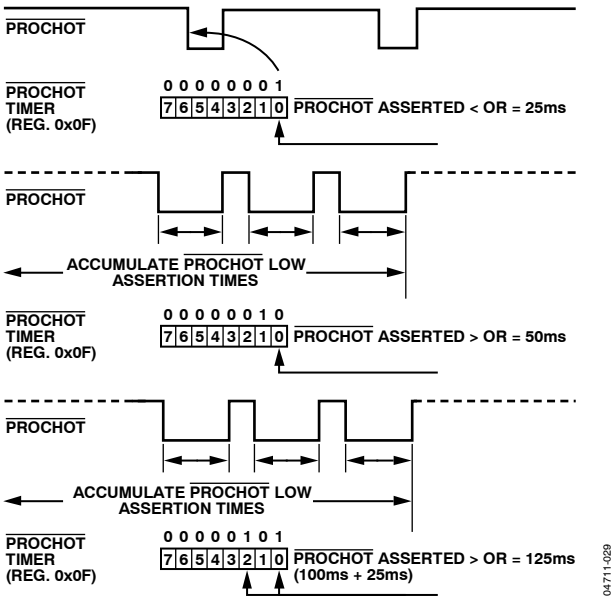

Figure 30. PROCHOT Timer

Figure 30 shows how the PROCHOT timer behaves as the PROCHOT input is asserted and negated. Bit 0 is set on the first PROCHOT assertion that is detected. This bit remains set until the cumulative PROCHOT assertions exceed 50 ms. At this time, Bit 1 of the PROCHOT timer is set, and Bit 0 is cleared. Bit 0 now reflects timer readings with a resolution of 25 ms. When using the PROCHOT timer, be aware of the following.

After a PROCHOT timer read (0x0F):

- The contents of the timer are cleared on read.
- The PHOT bit (Bit 1) of Status Register 2 is cleared automatically.

If the PROCHOT timer is read during a PROCHOT assertion, the following happens:

- The contents of the timer are cleared.
- Bit 0 of the PROCHOT timer is set to 1 (since a PROCHOT assertion is occurring).
- The PROCHOT timer increments from 0.
- If the PROCHOT limit (0x1E) = 0x00, the PHOT bit is set.

Generating ALERT Interrupts from PROCHOT Events

The ADT7466 can generate ALERTs when a programmable PROCHOT limit is exceeded. This allows the systems designer to ignore brief, infrequent PROCHOT assertions, while capturing longer PROCHOT events that could signify a more serious thermal problem within the system. Register 0x1E is the PROCHOT limit register. This 8-bit register allows a limit from 0 seconds (first PROCHOT assertion) to 6.4 seconds to be set before an ALERT is generated. The PROCHOT timer value is compared with the contents of the PROCHOT limit register. If the PROCHOT timer value exceeds the PROCHOT limit value, the PHOT bit (Bit 1) of Status Register 2 is set, and an ALERT is generated. The PHOT bit (Bit 1) of Mask Register 2 (0x13) masks ALERTs if this bit is set to 1, although the PHOT bit of Interrupt Status Register 2 is still set if the PROCHOT limit is exceeded.

Figure 32 is a functional block diagram of the PROCHOT timer limit and associated circuitry. Writing a value of 0x00 to the PROCHOT limit register (0x21) causes ALERT to be generated on the first PROCHOT assertion. A PROCHOT limit value of 0x01 generates an ALERT when cumulative PROCHOT assertions exceed 50 ms.