±1°C Temperature Monitor with Series Resistance Cancellation

ADT7461*

FEATURES

On-chip and remote temperature sensor
0.25°C resolution/1°C accuracy on remote channel
1°C resolution/3°C accuracy on local channel
Automatically cancels up to 3 kΩ (typ) of resistance in series with remote diode to allow noise filtering
Extended, switchable temperature measurement range 0°C to +127°C (default) or –55°C to +150°C
Pin and register compatible with ADM1032
2-wire SMBus serial interface with SMBus alert support
Programmable over/under temperature limits
Offset registers for system calibration
Up to 2 overtemperature fail-safe $\overline{\text{THERM}}$ outputs
Small 8-lead SOIC or MSOP package
170 µA operating current, 5.5 µA standby current

APPLICATIONS

Desktop and notebook computers
Industrial controllers
Smart batteries
Automotive
Enbedded systems
Burn-in applications
Instrumentation

PRODUCT DESCRIPTION

The ADT7461 is a dual-channel digital thermometer and under/over temperature alarm, intended for use in PCs and thermal management systems. It is pin and register compatible with the ADM1032. The ADT7461 has three additional features: series resistance cancellation, where up to 3 kΩ (typical) of resistance in series with the temperature monitoring diode may be automatically cancelled from the temperature result, allowing noise filtering; configurable $\overline{\text{ALERT}}$ output; and an extended, switchable temperature measurement range.

The ADT7461 can measure the temperature of a remote thermal diode accurate to ±1°C, and the ambient temperature accurate to ±3°C. The temperature measurement range defaults to 0°C to +127°C, compatible with ADM1032, but can be switched to a wider measurement range, from –55°C to +150°C. The ADT7461 communicates over a 2-wire serial interface compatible with system management bus (SMBus) standards. An $\overline{\text{ALERT}}$ output signals when the on-chip or remote temperature is out of range. The $\overline{\text{THERM}}$ output is a comparator output that allows on/off control of a cooling fan. The $\overline{\text{ALERT}}$ output can be reconfigured as a second $\overline{\text{THERM}}$ output if required.

*Protected by U.S. Patents 5,195,827; 5,867,012; 5,982,221; 6,097,239; 6,133,753; 6,169,442; other patents pending.

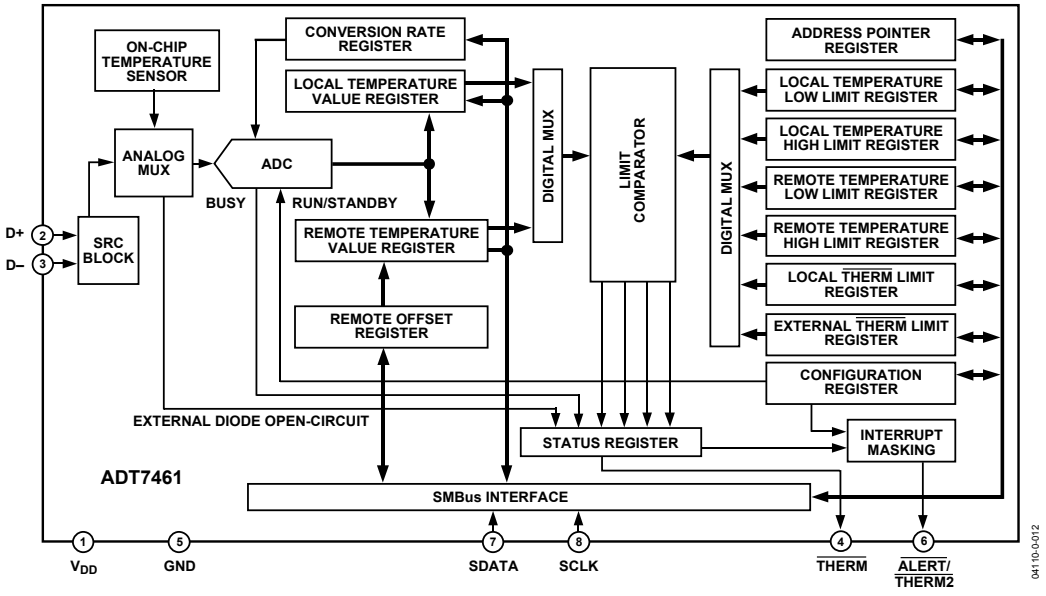


Figure 1. Functional Block Diagram

Rev. 0

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REVISION HISTORY

Revision 0: Initial Version

ADT7461–SPECIFICATIONS

Table 1. ADT7461 Specifications at T_A = −40°C to +120°C , V_{DD} = 3 V to 5.5 V, unless otherwise noted.

Parameter	Min	Typ	Max	Unit	Test Conditions
POWER SUPPLY					
Supply Voltage, V_{DD}	3.0	3.30	5.5	V	
Average Operating Supply Current, I_{DD}		170	215	µA	0.0625 Conversions/Sec Rate[1]
		5.5	10	µA	Standby Mode , −40°C ≤ T_A ≤ +85°C
		5.5	20	µA	Standby Mode, +85°C ≤ T_A ≤ +120°C
Undervoltage Lockout Threshold	2.2	2.55	2.8	V	V_{DD} Input, Disables ADC, Rising Edge
Power-On-Reset Threshold	1		2.5	V	
TEMPERATURE-TO-DIGITAL CONVERTER					
Local Sensor Accuracy		±1	±3	°C	−40°C ≤ T_A ≤ +100°C, 3 V ≤ V_{DD} ≤ 3.6 V
Resolution		1		°C	
Remote Diode Sensor Accuracy			±1	°C	+60°C ≤ T_A ≤ +100°C, −55°C ≤ T_D[2] ≤ +150°C, 3 V ≤ V_{DD} ≤ 3.6 V
			±3	°C	−40°C ≤ T_A ≤ +120°C, −55°C ≤ T_D[2] ≤ +150°C, 3 V ≤ V_{DD} ≤ 5.5 V
Resolution		0.25		°C	
Remote Sensor Source Current		96		µA	High Level[3]
		36		µA	Middle Level[3]
		6		µA	Low Level[3]
Conversion Time	32.13		114.6	ms	From Stop Bit to Conversion Complete (Both Channels) One-Shot Mode with Averaging Switched On
	3.2		12.56	ms	One-Shot Mode with Averaging Off (i.e., Conversion Rate = 16, 32, or 64 Conversions per Second)
Maximum Series Resistance Cancelled		3		kΩ	Resistance Split Evenly on Both the D+ and D– Inputs
OPEN-DRAIN DIGITAL OUTPUTS ($\overline{THERM}$, $\overline{ALERT}$/$\overline{THERM2}$)					
Output Low Voltage, V_{OL}			0.4	V	I_{OUT} = −6.0 mA[3]
High Level Output Leakage Current, I_{OH}		0.1	1	µA	V_{OUT} = V_{DD} [3]
$\overline{ALERT}$ Output Low Sink Current	1			mA	$\overline{ALERT}$ forced to 0.4 V
SMBus INTERFACE[3, 4]					
Logic Input High Voltage, V_{IH}	2.1			V	3 V ≤ V_{DD} ≤ 3.6 V
SCLK, SDATA					
Logic Input Low Voltage, V_{IL}			0.8	V	3 V ≤ V_{DD} ≤ 3.6 V
SCLK, SDATA					
Hysteresis		500		mV	
SMBus Output Low Sink Current	6			mA	SDATA Forced to 0.6 V
Logic Input Current, I_{IH}, I_{IL}	−1		+1	µA	
SMBus Input Capacitance, SCLK, SDATA		5		pF	
SMBus Clock Frequency			400	kHz	
SMBus Timeout[5]		25	64	ms	User Programmable.
SCLK Falling Edge to SDATA Valid Time			1	µs	Master Clocking in Data

[1] See Table 8 for information on other conversion rates.
[2] Guaranteed by characterization but not production tested.
[3] Guaranteed by design but not production tested.
[4] See SMBus Timing Specifications section for more information.
[5] Disabled by default. Details on how to enable it are in the SMBus section of this data sheet.

SMBus TIMING SPECIFICATIONS

Table 2. SMBus Timing Specifications[1]

Parameter	Limit at T_{MIN}, T_{MAX}	Unit	Description
f_{SCLK}	400	kHz max	
t_{LOW}	4.7	µs min	Clock Low Period, between 10% Points.
t_{HIGH}	4	µs min	Clock High Period, between 90% Points.
t_R	1	µs max	Clock/Data Rise Time.
t_F	300	ns max	Clock/Data Fall Time.
$t_{SU;STA}$	4.7	µs min	Start Condition Setup Time.
$t_{HD;STA}$[2]	4	µs min	Start Condition Hold Time.
$t_{SU;DAT}$[3]	250	ns min	Data Setup Time.
$t_{HD;DAT}$	300	µs min	Data Hold Time.
$t_{SU;STO}$[4]	4	µs min	Stop Condition Setup Time.
t_{BUF}	4.7	µs min	Bus Free Time between Stop and Start Conditions.

[1] Guaranteed by design but not production tested.
[2] Time from 10% of SDATA to 90% of SCLK.
[3] Time for 10% or 90% of SDATA to 10% of SCLK.
[4] Time for 90% of SCLK to 10% of SDATA.

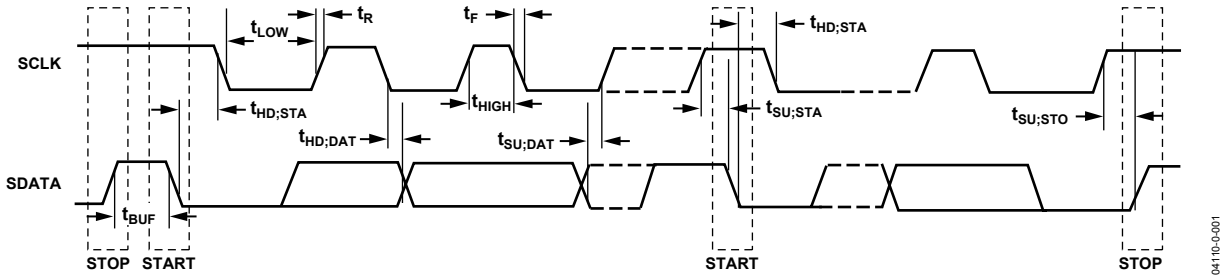


Figure 2. Serial Bus Timing

ABSOLUTE MAXIMUM RATINGS

Table 3. ADT7461 Absolute Maximum Ratings*

Parameter	Rating
Positive Supply Voltage (V_{DD}) to GND	−0.3 V, +5.5 V
D+	−0.3 V to V_{DD} + 0.3 V
D− to GND	−0.3 V to +0.6 V
SCLK, SDATA, $\overline{\text{ALERT}}$	−0.3 V to +5.5 V
$\overline{\text{THERM}}$	−0.3 V to V_{DD} + 0.3 V
Input Current, SDATA, $\overline{\text{THERM}}$	−1 mA, +50 mA
Input Current, D−	±1 mA
ESD Rating, All Pins (Human Body Model)	2000 V
Maximum Junction Temperature (T_J Max)	150°C
Storage Temperature Range	−65°C to +150°C
IR Reflow Peak Temperature	220°C
Lead Temperature (Soldering 10 sec)	300°C

*Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only; 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

8-Lead SOIC Package
θ_{JA} = 121°C/W

8-Lead MSOP Package
θ_{JA} = 142°C/W

PIN CONFIGURATION AND PIN FUNCTION DESCRIPTIONS

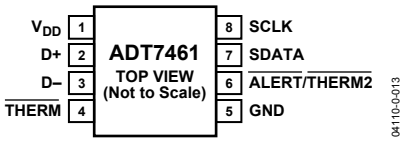


Figure 3. Pin Configuration

Table 4. Pin Function Descriptions

Pin No.	Mnemonic	Description
1	V_{DD}	Positive Supply, 3 V to 5.5 V.
2	D+	Positive Connection to Remote Temperature Sensor.
3	D–	Negative Connection to Remote Temperature Sensor.
4	$\overline{\text{THERM}}$	Open-Drain Output that can be used to turn a fan on/off or throttle a CPU clock in the event of an overtemperature condition. Requires pull-up to V_{DD}.
5	GND	Supply Ground Connection.
6	$\overline{\text{ALERT}}/\overline{\text{THERM2}}$	Open-Drain Logic Output used as interrupt or SMBus alert. This may also be configured as a second $\overline{\text{THERM}}$ output. Requires pull-up resistor.
7	SDATA	Logic Input/Output, SMBus Serial Data. Open-drain output. Requires pull-up resistor.
8	SCLK	Logic Input, SMBus Serial Clock. Requires pull-up resistor.

TYPICAL PERFORMANCE CHARACTERISTICS

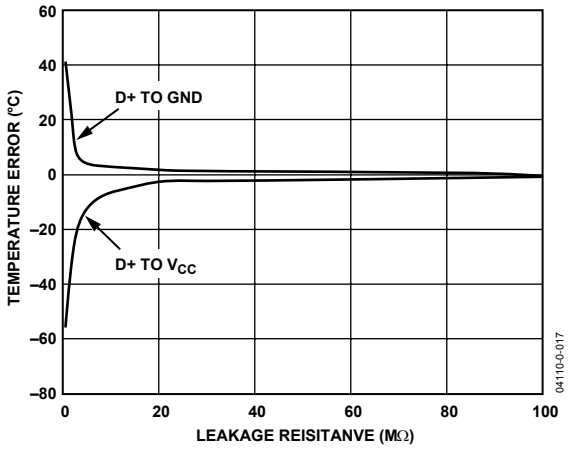


Figure 4. Temperature Error vs. Leakage Resistance

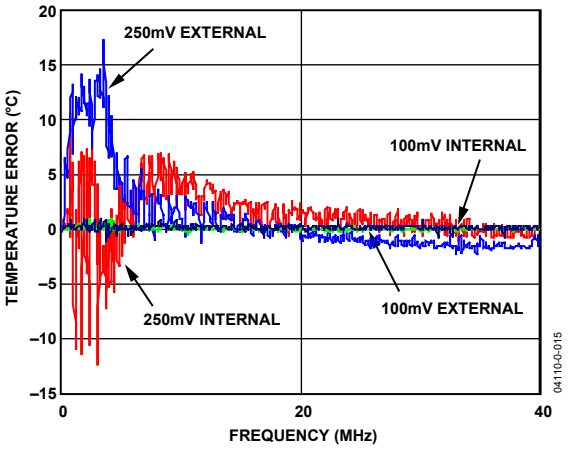


Figure 7. Temperature Error vs. Power Supply Noise Frequency

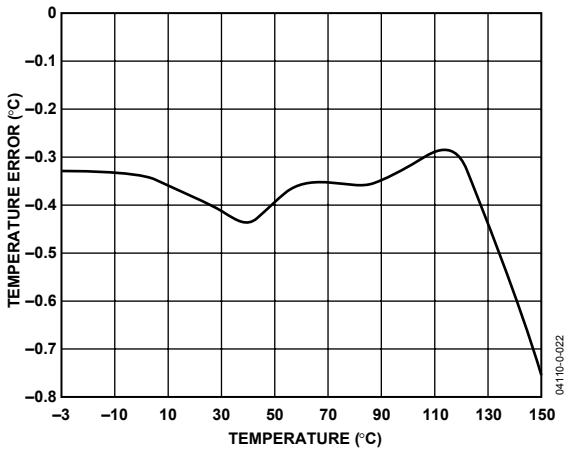


Figure 5. Temperature Error vs. Actual Temperature Using 2N3906

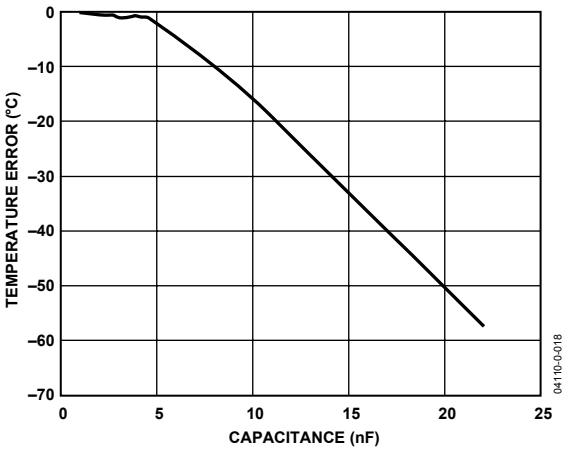


Figure 8. Temperature Error vs. Capacitance between D+ and D–

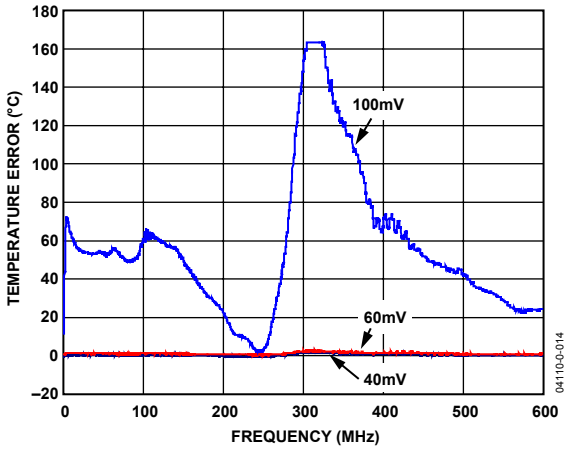


Figure 6. Temperature Error vs. Differential Mode Noise Frequency

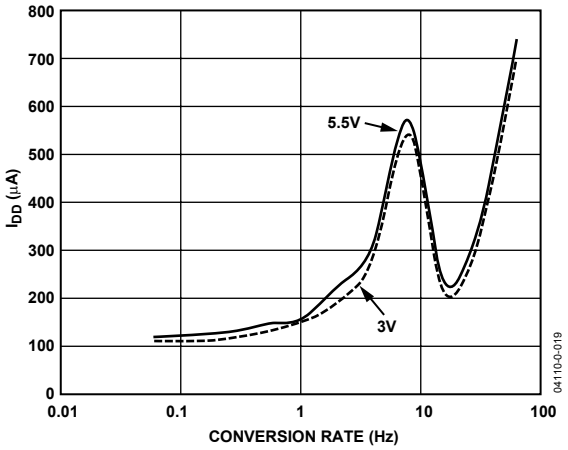


Figure 9. Operating Supply Current vs. Conversion Rate

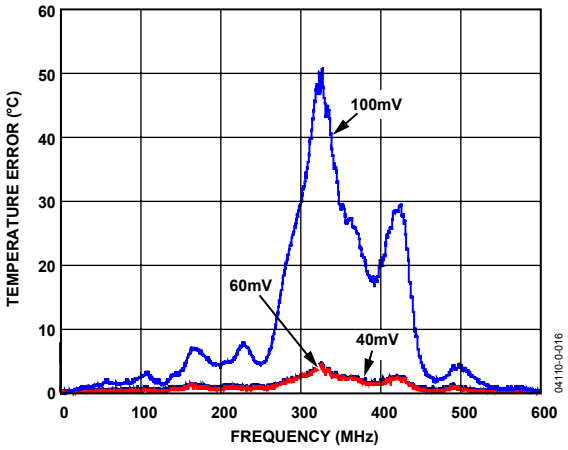


Figure 10. Temperature Error vs. Common-Mode Noise Frequency

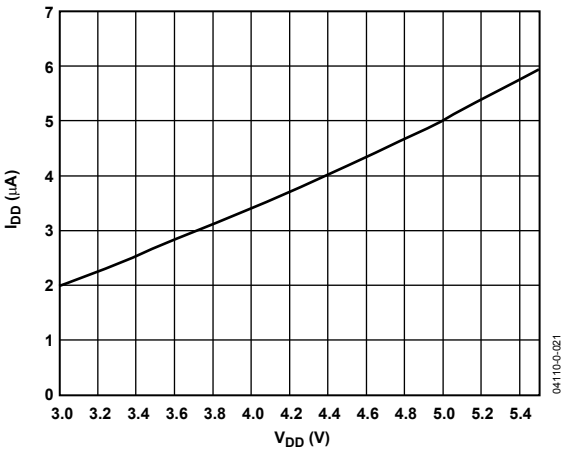


Figure 12. Standby Current vs. Supply Voltage

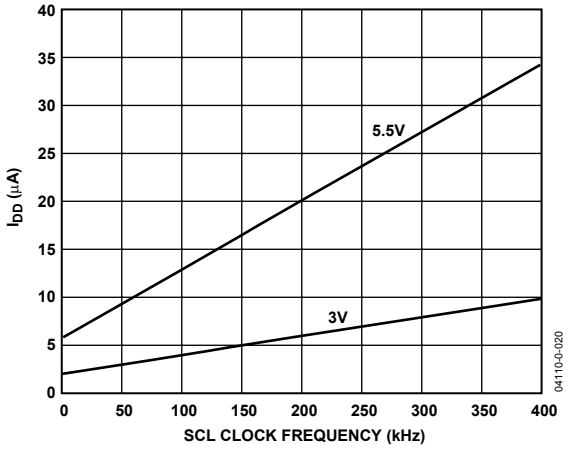


Figure 11. Standby Supply Current vs. Clock Frequency

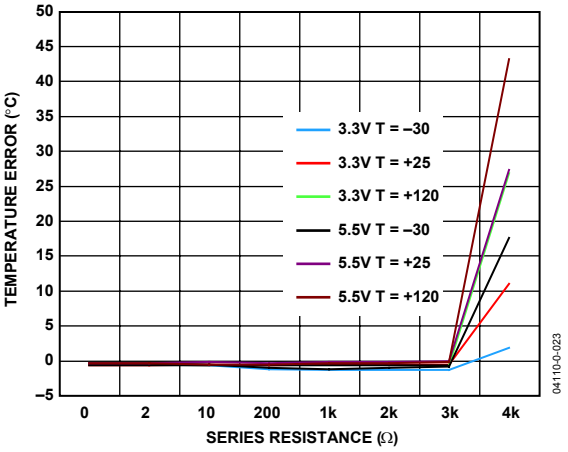


Figure 13. Temperature Error vs. Series Resistance

FUNCTIONAL DESCRIPTION

The ADT7461 is a local and remote temperature sensor and over/under temperature alarm, with the added ability to automatically cancel the effect of 3 kΩ (typical) of resistance in series with the temperature monitoring diode. When the ADT7461 is operating normally, the on-board ADC operates in a free-running mode. The analog input multiplexer alternately selects either the on-chip temperature sensor to measure its local temperature or the remote temperature sensor. The ADC digitizes these signals and the results are stored in the local and remote temperature value registers.

The local and remote measurement results are compared with the corresponding high, low, and $\overline{\text{THERM}}$ temperature limits, stored in eight on-chip registers. Out-of-limit comparisons generate flags that are stored in the status register. A result that exceeds the high temperature limit, the low temperature limit, or an external diode fault will cause the $\overline{\text{ALERT}}$ output to assert low. Exceeding $\overline{\text{THERM}}$ temperature limits causes the $\overline{\text{THERM}}$ output to assert low. The $\overline{\text{ALERT}}$ output can be reprogrammed as a second $\overline{\text{THERM}}$ output.

The limit registers can be programmed, and the device controlled and configured, via the serial SMBus. The contents of any register can also be read back via the SMBus.

Control and configuration functions consist of: switching the device between normal operation and standby mode, selecting the temperature measurement scale, masking or enabling the $\overline{\text{ALERT}}$ output, switching Pin 6 between $\overline{\text{ALERT}}$ and $\overline{\text{THERM2}}$, and selecting the conversion rate.

SERIES RESISTANCE CANCELLATION

Parasitic resistance, seen in series with the remote diode, to the D+ and D− inputs to the ADT7461, is caused by a variety of factors, including PCB track resistance and track length. This series resistance appears as a temperature offset in the remote sensor's temperature measurement. This error typically causes a 0.5°C offset per ohm of parasitic resistance in series with the remote diode.

The ADT7461 automatically cancels out the effect of this series resistance on the temperature reading, giving a more accurate result, without the need for user characterization of this resistance. The ADT7461 is designed to automatically cancel typically up to 3 kΩ of resistance. By using an advanced temperature measurement method, this is transparent to the user. This feature allows resistances to be added to the sensor path to produce a filter, allowing the part to be used in noisy environments. See the section on Noise Filtering for more details.

TEMPERATURE MEASUREMENT METHOD

A simple method of measuring temperature is to exploit the negative temperature coefficient of a diode, 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 ADT7461 is to measure the change in V_{BE} when the device is operated at three different currents. Previous devices have used only two operating currents, but it is the use of a third current that allows automatic cancellation of resistances in series with the external temperature sensor.

Figure 14 shows the input signal conditioning used to measure the output of an external temperature sensor. This figure shows the external sensor as a substrate transistor, but it could equally be a discrete transistor. If a discrete transistor is used, the collector will not be grounded and should be linked to the base. 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. C1 may optionally be added as a noise filter (recommended maximum value 1000 pF). However, a better option in noisy environments is to add a filter, as described in the section on Noise Filtering. See the section on Layout Considerations for more information on C1.

To measure ΔV_{BE}, the operating current through the sensor is switched among three related currents. Shown in Figure 14, N1 × I and N2 × I are 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 may then be calculated using the two ΔV_{BE} measurements. This method can also be shown to cancel the effect of any 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. At rates of 16, 32, and 64 conversions/second, no digital averaging takes place.

Signal conditioning and measurement of the internal temperature sensor is performed in the same manner.

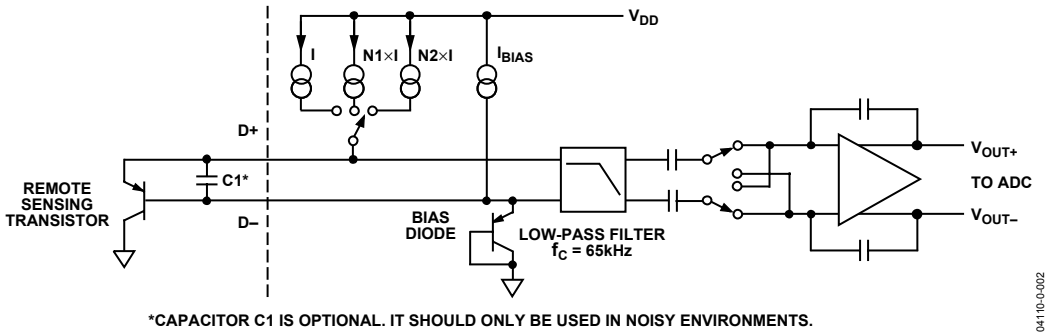


Figure 14. Input Signal Conditioning

TEMPERATURE MEASUREMENT RESULTS

The results of the local and remote temperature measurements are stored in the local and remote temperature value registers and are compared with limits programmed into the local and remote high and low limit registers.

The local temperature value is in Register 0×00 and has a resolution of 1°C. The external temperature value is stored in two registers, with the upper byte in Register 0×01 and the lower byte in Register 0×10. Only the two MSBs in the external temperature low byte are used. This gives the external temperature measurement a resolution of 0.25°C. Table 5 shows the data format for the external temperature low byte.

Table 5. Extended Temperature Resolution (Remote Temperature Low Byte)

Extended Resolution	Remote Temperature Low Byte
0.00°C	0 000 0000
0.25°C	0 100 0000
0.50°C	1 000 0000
0.75°C	1 100 0000

When reading the full external temperature value, both the high and low byte, the two registers should be read in succession. Reading one register does not lock the other, so both should be read before the next conversion finishes. In practice, there is more than enough time to read both registers, as transactions over the SMBus are significantly faster than a conversion time.

TEMPERATURE MEASUREMENT RANGE

The temperature measurement range for both internal and external measurements is, by default, 0°C to +127°C. However, the ADT7461 can be operated using an extended temperature range. It can measure the full temperature range of an external diode, from −55°C to +150°C. The user can switch between these two temperature ranges by setting or clearing Bit 2 in the configuration register. A valid result is available in the next measurement cycle after changing the temperature range.

In extended temperature mode, the upper and lower temperature that can be measured by the ADT7461 is limited by the remote diode selection. The temperature registers themselves can have values from −64°C to +191°C. However, most temperature sensing diodes have a maximum temperature range of −55°C to +150°C.

It should be noted that while both local and remote temperature measurements can be made while the part is in extended temperature mode, the ADT7461 itself should not be exposed to temperatures greater than those specified in the absolute maximum ratings section. Further, the device is only guaranteed to operate as specified at ambient temperatures from −40°C to +120°C.

TEMPERATURE DATA FORMAT

The ADT7461 has two temperature data formats. When the temperature measurement range is from 0°C to +127°C (default), the temperature data format for both internal and external temperature results is binary. When the measurement range is in extended mode, an offset binary data format is used for both internal and external results. Temperature values in the offset binary data format are offset by +64. Examples of temperatures in both data formats are shown in Table 6.

Table 6. Temperature Data Format (Local and Remote Temperature High Byte)

Temperature	Binary	Offset Binary[1]
–55°C	0 000 0000[2]	0 000 1001
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
+150°C	0 111 1111[3]	1 101 0110

[1] Offset binary scale temperature values are offset by +64.
[2] Binary scale temperature measurement returns 0 for all temperatures < 0°C.
[3] Binary scale temperature measurement returns 127 for all temperature > 127°C.

The user may switch between measurement ranges at any time. Switching the range will also switch the data format. The next temperature result following the switching will be reported back to the register in the new format. However, the contents of the limit registers will not change. It is up to the user to ensure that when the data format changes, the limit registers are reprogrammed as necessary. More information on this can be found in the Limit Registers section.

ADT7461 REGISTERS

The ADT7461 contains 22 8-bit registers in total. These registers are used to store the results of remote and local temperature measurements and high and low temperature limits and to configure and control the device. A description of these registers follows, and further details are given in Table 7 through Table 11.

Address Pointer Register

The address pointer register itself does not have, or require, an address, as the first byte of every write operation is automatically written to this register. The data in this first byte always contains the address of another register on the ADT7461, which is stored in the address pointer register. It is to this register address that the second byte of a write operation is written to or to which a subsequent read operation is performed.

The power-on default value of the address pointer register is 0×00, so if a read operation is performed immediately after power-on, without first writing to the address pointer, the value of the local temperature will be returned, since its register address is 0×00.

Temperature Value Registers

The ADT7461 has three registers to store the results of local and remote temperature measurements. These registers can only be written to by the ADC and can be read by the user over the SMBus. The local temperature value register is at Address 0×00.

The external temperature value high byte register is at Address 0×01, with the low byte register at Address 0×10. The power-on default for all three registers is 0×00.

Configuration Register

The configuration register is Address 0×03 at read and Address 0×09 at write. Its power-on default is 0×00. Only four bits of the configuration register are used. Bits 0, 1, 3, and 4 are reserved and should not be written to by the user.

Bit 7 of the configuration register is used to mask the $\overline{\text{ALERT}}$ output. If Bit 7 is 0, the $\overline{\text{ALERT}}$ output is enabled. This is the power-on default. If Bit 7 is set to 1, the $\overline{\text{ALERT}}$ output is disabled. This only applies if Pin 6 is configured as $\overline{\text{ALERT}}$. If Pin 6 is configured as $\overline{\text{THERM2}}$, then the value of Bit 7 has no effect.

If Bit 6 is 0, power-on default, the device is in operating mode with the ADC converting. If Bit 6 is set to 1, the device is in standby mode and the ADC does not convert. The SMBus does, however, remain active in standby mode, so values can be read from or written to the ADT7461 via the SMBus in this mode. The $\overline{\text{ALERT}}$ and $\overline{\text{THERM}}$ outputs are also active in standby mode. Changes made to the registers in standby mode that affect the $\overline{\text{THERM}}$ or $\overline{\text{ALERT}}$ outputs will cause these signals to be updated.

Bit 5 determines the configuration of Pin 6 on the ADT7461. If Bit 5 is 0, (default) then Pin 6 is configured as an $\overline{\text{ALERT}}$ output. If Bit 5 is 1, then Pin 6 is configured as a $\overline{\text{THERM2}}$ output. Bit 7, the $\overline{\text{ALERT}}$ mask bit, is only active when Pin 6 is configured as an $\overline{\text{ALERT}}$ output. If Pin 6 is setup as a $\overline{\text{THERM2}}$ output, then Bit 7 has no effect.

Bit 2 sets the temperature measurement range. If Bit 2 is 0 (default value), the temperature measurement range is set between 0°C to +127°C. Setting Bit 2 to 1 means that the measurement range is set to the extended temperature range.

Table 7. Configuration Register Bit Assignments

Bit	Name	Function	Power-On Default
7	MASK1	0 = $\overline{\text{ALERT}}$ Enabled 1 = $\overline{\text{ALERT}}$ Masked	0
6	RUN/STOP	0 = Run 1 = Standby	0
5	$\overline{\text{ALERT}}/\overline{\text{THERM2}}$	0 = $\overline{\text{ALERT}}$ 1 = $\overline{\text{THERM2}}$	0
4–3	Reserved		0
2	Temperature Range Select	0 = 0°C to 127°C 1 = Extended Range	0
1–0	Reserved		0

Conversion Rate Register

The conversion rate register is Address 0×04 at read and Address 0×0A at write. The lowest four bits of this register are used to program the conversion rate by dividing the internal oscillator clock by 1, 2, 4, 8, 16, 32, 64, 128, 256, 512, or 1024 to give conversion times from 15.5 ms (Code 0×0A) to 16 seconds (Code 0×00). For example, a conversion rate of 8 conversions/second means that beginning at 125 ms intervals the device performs a conversion on the internal and the external temperature channels.

This register can be written to and read back over the SMBus. The higher four bits of this register are unused and must be set to 0. The default value of this register is 0×08, giving a rate of 16 conversions per second. Use of slower conversion times greatly reduces the device power consumption, as shown in Table 8.

Table 8. Conversion Rate Register Codes

Code	Conversion/Second	Average Supply Current µA Typ at V_{DD} = 5.5 V
0×00	0.0625	121.33
0×01	0.125	128.54
0×02	0.25	131.59
0×03	0.5	146.15
0×04	1	169.14
0×05	2	233.12
0×06	4	347.42
0×07	8	638.07
0×08	16	252.44
0×09	32	417.58
0×0A	64	816.87
0×0B to 0×FF	Reserved	

Limit Registers

The ADT7461 has eight limit registers: high, low, and $\overline{\text{THERM}}$ temperature limits for both local and remote temperature measurements. The remote temperature high and low limits span two registers each, to contain an upper and lower byte for each limit. There is also a $\overline{\text{THERM}}$ hysteresis register. All limit registers can be written to and read back over the SMBus. See Table 12 for details of the limit registers' addresses and their power-on default values.

When Pin 6 is configured as an $\overline{\text{ALERT}}$ output, the high limit registers perform a > comparison while the low limit registers perform a ≤ comparison. For example, if the high limit register is programmed with 80°C, then measuring 81°C will result in an out-of-limit condition, setting a flag in the status register. If the low limit register is programmed with 0°C, measuring 0°C or lower will result in an out-of-limit condition.

Exceeding either the local or remote $\overline{\text{THERM}}$ limit asserts $\overline{\text{THERM}}$ low. When Pin 6 is configured as $\overline{\text{THERM2}}$, exceeding either the local or remote high limit asserts $\overline{\text{THERM2}}$ low. A default hysteresis value of 10°C is provided that applies to both $\overline{\text{THERM}}$ channels. This hysteresis value may be reprogrammed to any value after power up (Register Address 0×21).

It is important to remember that the temperature limits data format is the same as the temperature measurement data format. So if the temperature measurement uses default binary, then the temperature limits also use the binary scale. If the temperature measurement scale is switched, however, the temperature limits do not switch automatically. The user must reprogram the limit registers to the desired value in the correct data format. For example, if the remote low limit is set at 10°C and the default binary scale is being used, the limit register value should be 0000 1010b. If the scale is switched to offset binary, the value in the low temperature limit register should be reprogrammed to be 0100 1010b.

Status Register

The status register is a read-only register, at Address 0×02. It contains status information for the ADT7461.

Bit 7 of the status register indicates that the ADC is busy converting when it is high. The other bits in this register flag the out-of-limit temperature measurements (Bits 6–3 and Bits 1–0) and the remote sensor open circuit (Bit 2).

If Pin 6 is configured as an $\overline{\text{ALERT}}$ output, the following applies. If the local temperature measurement exceeds its limits, Bit 6 (high limit) or Bit 5 (low limit) of the status register asserts to flag this condition. If the remote temperature measurement exceeds its limits, then Bit 4 (high limit) or Bit 3 (low limit) asserts. Bit 2 asserts to flag an open-circuit condition on the remote sensor. These five flags are NOR'd together, so if any of them is high, the $\overline{\text{ALERT}}$ interrupt latch will be set and the $\overline{\text{ALERT}}$ output will go low.

Reading the status register will clear the five flags, Bits 6–2, provided the error conditions that caused the flags to be set have gone away. A flag bit can only be reset if the corresponding value register contains an in-limit measurement or if the sensor is good.

The $\overline{\text{ALERT}}$ interrupt latch is not reset by reading the status register. It will be reset when the $\overline{\text{ALERT}}$ output has been serviced by the master reading the device address, provided the error condition has gone away and the status register flag bits have been reset.

When Flag 1 and/or Flag 0 are set, the $\overline{\text{THERM}}$ output goes low to indicate that the temperature measurements are outside the programmed limits. The $\overline{\text{THERM}}$ output does not need to be reset, unlike the $\overline{\text{ALERT}}$ output. Once the measurements are within the limits, the corresponding status register bits are reset automatically, and the $\overline{\text{THERM}}$ output goes high. The user may add hysteresis by programming Register 0×21. The $\overline{\text{THERM}}$ output will be reset only when the temperature falls to limit value–hysteresis value.

When Pin 6 is configured as $\overline{\text{THERM2}}$, only the high temperature limits are relevant. If Flag 6 and/or Flag 4 are set, the $\overline{\text{THERM2}}$ output goes low to indicate that the temperature measurements are outside the programmed limits. Flag 5 and Flag 3 have no effect on $\overline{\text{THERM2}}$. The behavior of $\overline{\text{THERM2}}$ is otherwise the same as $\overline{\text{THERM}}$.

Table 9. Status Register Bit Assignments

Bit	Name	Function
7	BUSY	1 When ADC Converting
6	LHIGH*	1 When Local High Temperature Limit Tripped
5	LLOW*	1 When Local Low Temperature Limit Tripped
4	RHIGH*	1 When Remote High Temperature Limit Tripped
3	RLOW*	1 When Remote Low Temperature Limit Tripped
2	OPEN*	1 When Remote Sensor Open Circuit
1	RTHRM	1 When Remote $\overline{\text{THERM}}$ Limit Tripped
0	LTHRM	1 When Local $\overline{\text{THERM}}$ Limit Tripped

*These flags stay high until the status register is read, or they are reset by POR.

Offset Register

Offset errors may be introduced into the remote temperature measurement by clock noise or by the thermal diode being located away from the hot spot. To achieve the specified accuracy on this channel, these offsets must be removed.

The offset value is stored as a 10-bit, twos complement value in Registers 0×11 (high byte) and 0×12 (low byte, left justified). Only the upper 2 bits of register 0×12 are used. The MSB of Register 0×11 is the sign bit. The minimum offset that can be programmed is −128°C, and the maximum is +127.75°C. The value in the offset register is added or subtracted to the measured value of the remote temperature.

The offset register powers up with a default value of 0°C and will have no effect unless the user writes a different value to it.

Table 10. Sample Offset Register Codes

Offset Value	0×11	0×12
−128°C	1000 0000	00 00 0000
−4°C	1111 1100	00 00 0000
−1°C	1111 1111	00 000000
−0.25°C	1111 1111	10 00 0000
0°C	0000 0000	00 00 0000
+0.25°C	0000 0000	01 00 0000
+1°C	0000 0001	00 00 0000
+4°C	0000 0100	00 00 0000
+127.75°C	0111 1111	11 00 0000

One-Shot Register

The one-shot register is used to initiate a conversion and comparison cycle when the ADT7461 is in standby mode, after which the device returns to standby. Writing to the one-shot register address (0×0F) causes the ADT7461 to perform a conversion and comparison on both the internal and the external temperature channels. This is not a data register as such, and it is the write operation to Address 0×0F that causes the one-shot conversion. The data written to this address is irrelevant and is not stored.

Consecutive $\overline{\text{ALERT}}$ Register

The value written to this register determines how many out-of-limit measurements must occur before an $\overline{\text{ALERT}}$ is generated. The default value is that one out-of-limit measurement generates an $\overline{\text{ALERT}}$. The maximum value that can be chosen is 4. The purpose of this register is to allow the user to perform some filtering of the output. This is particularly useful at the fastest three conversion rates, where no averaging takes place. This register is at Address 0×22.

Table 11. Consecutive $\overline{\text{ALERT}}$ Register Bit

Register Value	Number of Out-of-Limit Measurements Required
y××× 000×	1
y××× 001×	2
y××× 011×	3
y××× 111×	4

× = Don't care bit.
y = SMBus timeout bit. Default = 0. See SMBus section for more information.

Table 12. List of ADT7461 Registers

Read Address (Hex)	Write Address (Hex)	Name	Power-On Default
Not Applicable	Not Applicable	Address Pointer	Undefined
00	Not Applicable	Local Temperature Value	0000 0000 (0×00)
01	Not Applicable	External Temperature Value High Byte	0000 0000 (0×00)
02	Not Applicable	Status	Undefined
03	09	Configuration	0000 0000 (0×00)
04	0A	Conversion Rate	0000 1000 (0×08)
05	0B	Local Temperature High Limit	0101 0101 (0×55) (85°C)
06	0C	Local Temperature Low Limit	0000 0000 (0×00) (0°C)
07	0D	External Temperature High Limit High Byte	0101 0101 (0×55) (85°C)
08	0E	External Temperature Low Limit High Byte	0000 0000 (0×00) (0°C)
Not Applicable	0F	One-Shot	
10	Not Applicable	External Temperature Value Low Byte	0000 0000
11	11	External Temperature Offset High Byte	0000 0000
12	12	External Temperature Offset Low Byte	0000 0000
13	13	External Temperature High Limit Low Byte	0000 0000
14	14	External Temperature Low Limit Low Byte	0000 0000
19	19	External $\overline{\text{THERM}}$ Limit	0110 1100 (0×55) (85°C)
20	20	Local $\overline{\text{THERM}}$ Limit	0101 0101 (0×55) (85°C)
21	21	$\overline{\text{THERM}}$ Hysteresis	0000 1010 (0×0A) (10°C)
22	22	Consecutive $\overline{\text{ALERT}}$	0000 0001 (0×01)
FE	Not Applicable	Manufacturer ID	0100 0001 (0×41)
FF	Not Applicable	Die Revision Code	0101 0001 (0×51)

*Writing to address 0F causes the ADT7461 to perform a single measurement. It is not a data register as such and it does not matter what data is written to it.

SERIAL BUS INTERFACE

Control of the ADT7461 is carried out via the serial bus. The ADT7461 is connected to this bus as a slave device, under the control of a master device.

The ADT7461 has an SMBus timeout feature. When this is enabled, the SMBus will timeout after typically 25 ms of no activity. However, this feature is not enabled by default. Bit 7 of the consecutive alert register (Address = 0×22) should be set to enable it.

The ADT7461 supports packet error checking (PEC) and its use is optional. It is triggered by supplying the extra clock for the PEC byte. The PEC byte is calculated using CRC-8. The frame check sequence (FCS) conforms to CRC-8 by the polynomial

$$C(x) = x^8 + x^2 + x^1 + 1$$

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

ADDRESSING THE DEVICE

In general, every SMBus device has a 7-bit device address, except for some devices that have extended, 10-bit addresses. When the master device sends a device address over the bus, the slave device with that address will respond. The ADT7461 is available with one device address, 0×4C (1001 100b).

The serial bus protocol operates as follows:

1. The master initiates data transfer by establishing a START condition, defined as a high-to-low transition on the serial data line SDATA, while the serial clock line SCLK remains high. This indicates that an address/data stream will follow. All slave peripherals connected to the serial bus respond to the START condition and shift in the next eight bits, consisting of a 7-bit address (MSB first) plus an R/$\overline{\text{W}}$ bit, which determines the direction of the data transfer, i.e., whether data will be written to or read from the slave device. The peripheral whose address corresponds to the transmitted address responds by pulling the data line low during the low period before the ninth 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/$\overline{\text{W}}$ bit is a 0, the master will write to the slave device. If the R/$\overline{\text{W}}$ bit is a 1, the master will read from the slave device.

2. Data is sent over the serial bus in a sequence of nine clock pulses, eight 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, since 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.

3. When all data bytes have been read or written, stop conditions are established. In write mode, the master will pull the data line high during the tenth clock pulse to assert a STOP condition. In read mode, the master device will override 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 will then take the data line low during the low period before the tenth clock pulse, then high during the tenth clock pulse to assert a STOP condition.

Any number of bytes of data may 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 cannot subsequently be changed without starting a new operation. In the case of the ADT7461, write operations contain either one or two bytes, while read operations contain one byte.

To write data to one of the device data registers or to read data from it, the address pointer register must be set so that the correct data register is addressed. The first byte of a write operation always contains a valid 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 illustrated in Figure 15. 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.

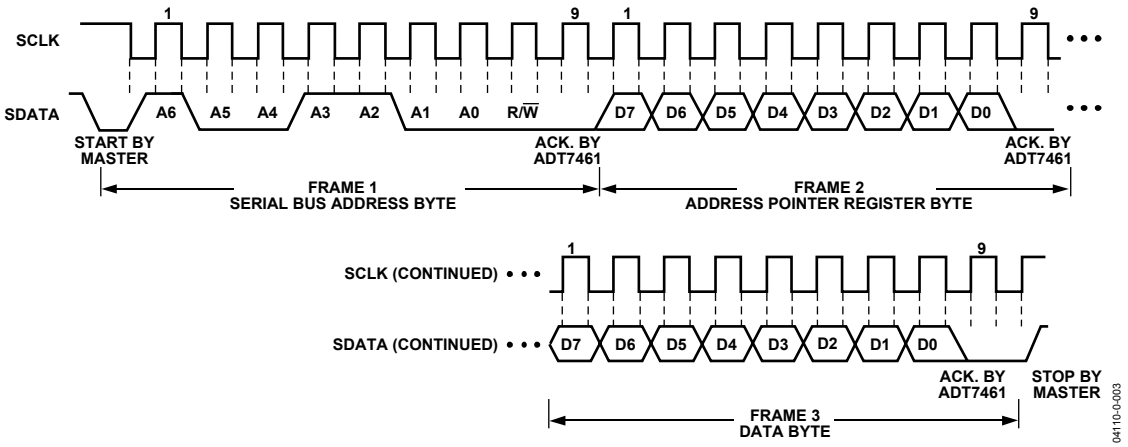


Figure 15. Writing a Register Address to the Address Pointer Register, then Writing Data to the Selected Register

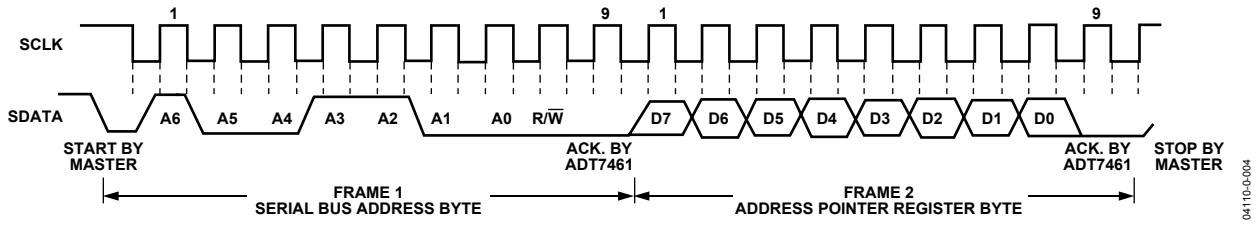


Figure 16. Writing to the Address Pointer Register Only

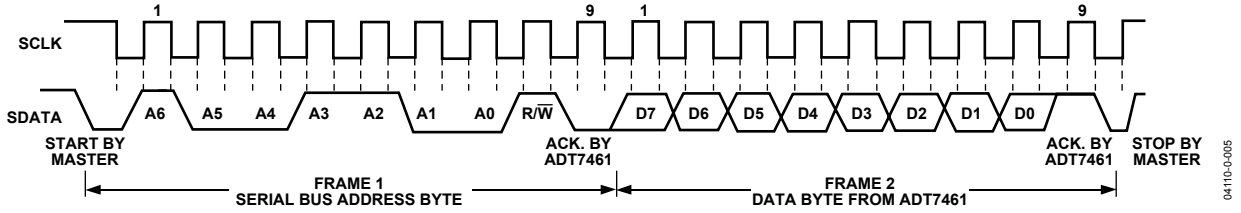


Figure 17. Reading from a Previously Selected Register

When reading data from a register there are two possibilities:

- If the ADT7461's address pointer register value is unknown or not the desired value, it is first necessary to 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 ADT7461 as before, but only the data byte containing the register read address is sent, as data is not to be written to the register. This is shown in Figure 16.

  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 17.

- If the address pointer register is known to be already at the desired address, data can be read from the corresponding data register without first writing to the address pointer register and the bus transaction shown in Figure 16 can be omitted.

Notes

1. 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.

2. Do not forget that some of the ADT7461 registers have different addresses for read and write operations. The write address of a register must be written to the address pointer if data is to be written to that register, but it may not be possible to read data from that address. The read address of a register must be written to the address pointer before data can be read from that register.

$\overline{\text{ALERT}}$ OUTPUT

This is applicable when Pin 6 is configured as an $\overline{\text{ALERT}}$ output. The $\overline{\text{ALERT}}$ output goes low whenever an out-of-limit measurement is detected, or if the remote temperature sensor is open circuit. It is an open-drain output and requires a pull-up to V_{DD}. Several $\overline{\text{ALERT}}$ outputs can be wire-ORed together, so that the common line will go low if one or more of the $\overline{\text{ALERT}}$ outputs goes low.

The $\overline{\text{ALERT}}$ output can be used as an interrupt signal to a processor, or it may be used as an $\overline{\text{SMBALERT}}$. Slave devices on the SMBus cannot normally signal to the bus master that they want to talk, but the $\overline{\text{SMBALERT}}$ function allows them to do so.

One or more $\overline{\text{ALERT}}$ outputs can be connected to a common $\overline{\text{SMBALERT}}$ line connected to the master. When the $\overline{\text{SMBALERT}}$ line is pulled low by one of the devices, the following procedure occurs as illustrated in Figure 18.

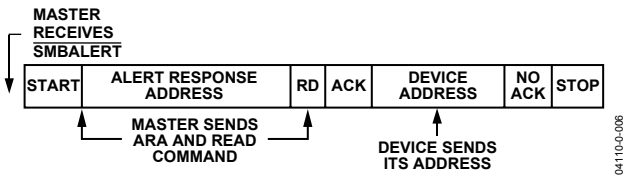


Figure 18. Use of SMBALERT

1. $\overline{\text{SMBALERT}}$ is pulled low.

2. Master initiates a read operation and sends the alert response address (ARA = 0001 100). This is a general call address that 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. As the device address is seven bits, an LSB of 1 is added. 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 will have priority, in accordance with normal SMBus arbitration.

5. Once the ADT7461 has responded to the alert response address, it will reset its $\overline{\text{ALERT}}$ output, provided that the error condition that caused the $\overline{\text{ALERT}}$ no longer exists. If the $\overline{\text{SMBALERT}}$ line remains low, the master will send the ARA again, and so on until all devices whose $\overline{\text{ALERT}}$ outputs were low have responded.

LOW POWER STANDBY MODE

The ADT7461 can be put into low power standby mode by setting Bit 6 of the configuration register. When Bit 6 is low, the ADT7461 operates normally. When Bit 6 is high, the ADC is inhibited, and any conversion in progress is terminated without writing the result to the corresponding value register.

The SMBus is still enabled. Power consumption in the standby mode is reduced to less than 10 µA if there is no SMBus activity or 100 µA if there are clock and data signals on the bus.

When the device is in standby mode, it is still possible to initiate a one-shot conversion of both channels by writing to the one-shot register (Address 0×0F), after which the device will return to standby. It does not matter what is written to the one-shot register, all data written to it is ignored. It is also possible to write new values to the limit register while in standby mode. If the values stored in the temperature value registers are now outside the new limits, an $\overline{\text{ALERT}}$ is generated, even though the ADT7461 is still in standby.

SENSOR FAULT DETECTION

The ADT7461 has sensor fault detection circuitry internally at its D+ input. This circuit can detect situations where an external remote diode is not connected, or is incorrectly connected, to

the ADT7461. A simple voltage comparator trips if the voltage at D+ exceeds V_{DD} −1 V (typical), signifying an open circuit between D+ and D−. The output of this comparator is checked when a conversion is initiated. Bit 2 of the status register (OPEN flag) is set if a fault is detected. If the $\overline{\text{ALERT}}$ pin is enabled, setting this flag will cause $\overline{\text{ALERT}}$ to assert low.

If the user does not wish to use an external sensor with the ADT7461, then in order to prevent the OPEN flag being set continuously, the user should tie the D+ and D− inputs of the ADT7461 together.

Most temperature sensing diodes have an operating temperature range of −55°C to +150°C. Above 150°C, they lose their semiconductor characteristics and approximate conductors instead. This results in a diode short, setting the OPEN flag. The external diode in this case will no longer give an accurate temperature measurement. A read of the temperature result register will give the last good temperature measurement. The user should be aware that, while the diode fault is triggered, the temperature measurement on the external channel may not be accurate.

THE ADT7461 INTERRUPT SYSTEM

The ADT7461 has two interrupt outputs, $\overline{\text{ALERT}}$ and $\overline{\text{THERM}}$. Both have different functions and behavior. $\overline{\text{ALERT}}$ is maskable and responds to violations of software-programmed temperature limits or an open-circuit fault on the external diode. $\overline{\text{THERM}}$ is intended as a fail-safe interrupt output that cannot be masked.

If the external or local temperature exceeds the programmed high temperature limits, or equals or exceeds the low temperature limits, the $\overline{\text{ALERT}}$ output is asserted low. An open-circuit fault on the external diode also causes $\overline{\text{ALERT}}$ to assert. $\overline{\text{ALERT}}$ is reset when serviced by a master reading its device address, provided the error condition has gone away, and the status register has been reset.

The $\overline{\text{THERM}}$ output asserts low if the external or local temperature exceeds the programmed $\overline{\text{THERM}}$ limits. The $\overline{\text{THERM}}$ temperature limits should normally be equal to or greater than the high temperature limits. $\overline{\text{THERM}}$ is reset automatically when the temperature falls back within the $\overline{\text{THERM}}$ limit. The external $\overline{\text{THERM}}$ limit is set by default to 85°C, as is the local $\overline{\text{THERM}}$ limit. A hysteresis value can be programmed, in which case, $\overline{\text{THERM}}$ will reset when the temperature falls to the limit value minus the hysteresis value. This applies to both local and remote measurement channels. The power-on hysteresis default value is 10°C, but this may be reprogrammed to any value after power-up.

The hysteresis loop on the $\overline{\text{THERM}}$ outputs is useful when $\overline{\text{THERM}}$ is used for on/off control of a fan. The user's system can be set up so that when $\overline{\text{THERM}}$ asserts a fan can be switched on to cool the system. When $\overline{\text{THERM}}$ goes high again, the fan can be switched off. Programming a hysteresis value protects from fan jitter, where the temperature hovers around the $\overline{\text{THERM}}$ limit, and the fan is constantly being switched.

Table 13. $\overline{\text{THERM}}$ Hysteresis

$\overline{\text{THERM}}$ Hysteresis	Binary Representation
0°C	0 000 0000
1°C	0 000 0001
10°C	0 000 1010

Figure 19 shows how the $\overline{\text{THERM}}$ and $\overline{\text{ALERT}}$ outputs operate. A user may wish to use the $\overline{\text{ALERT}}$ output as a $\overline{\text{SMBALERT}}$ to signal to the host via the SMBus that the temperature has risen. The user could use the $\overline{\text{THERM}}$ output to turn on a fan to cool the system, if the temperature continues to increase. This method would ensure that there is a fail-safe mechanism to cool the system, without the need for host intervention.

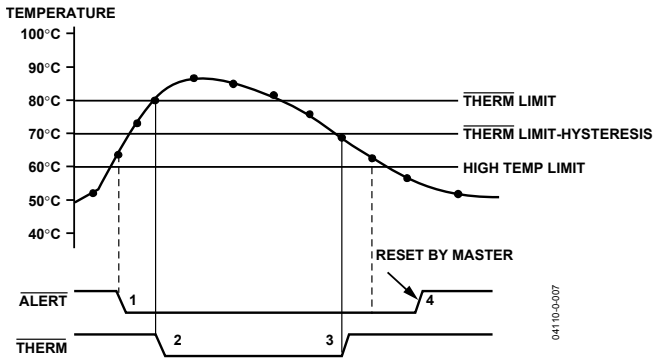


Figure 19. Operation of the $\overline{\text{ALERT}}$ and $\overline{\text{THERM}}$ Interrupts

1. If the measured temperature exceeds the high temperature limit, the $\overline{\text{ALERT}}$ output will assert low.
2. If the temperature continues to increase and exceeds the $\overline{\text{THERM}}$ limit, the $\overline{\text{THERM}}$ output asserts low. This can be used to throttle the CPU clock or switch on a fan.
3. The $\overline{\text{THERM}}$ output deasserts (goes high) when the temperature falls to $\overline{\text{THERM}}$ limit minus hysteresis. In Figure 19, the default hysteresis value of 10°C is shown.
4. The $\overline{\text{ALERT}}$ output deasserts only when the temperature has fallen below the high temperature limit, and the master has read the device address and cleared the status register.

Pin 6 on the ADT7461 can be configured as either an $\overline{\text{ALERT}}$ output or as an additional $\overline{\text{THERM}}$ output. $\overline{\text{THERM2}}$ will assert low when the temperature exceeds the programmed local and/or remote high temperature limits. It is reset in the same manner as $\overline{\text{THERM}}$, and it is not maskable. The programmed hysteresis value applies to $\overline{\text{THERM2}}$ also.

Figure 20 shows how $\overline{\text{THERM}}$ and $\overline{\text{THERM2}}$ might operate together to implement two methods of cooling the system. In this example, the $\overline{\text{THERM2}}$ limits are set lower than the $\overline{\text{THERM}}$ limits. The $\overline{\text{THERM2}}$ output could be used to turn on a fan. If the temperature continues to rise and exceeds the $\overline{\text{THERM}}$ limits, the $\overline{\text{THERM}}$ output could provide additional cooling by throttling the CPU.

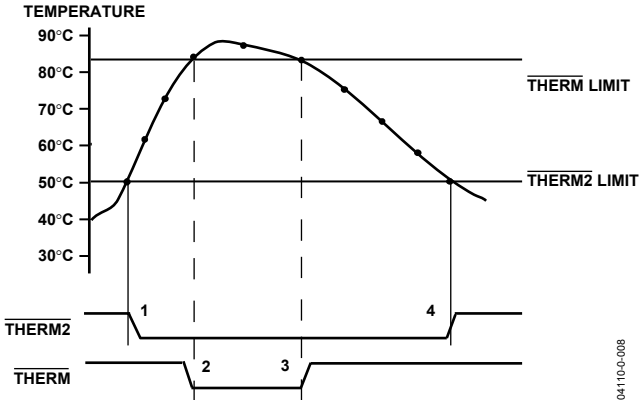


Figure 20. Operation of the $\overline{\text{THERM}}$ and $\overline{\text{THERM2}}$ Interrupts

1. When the $\overline{\text{THERM2}}$ limit is exceeded, the $\overline{\text{THERM2}}$ signal asserts low.
2. If the temperature continues to increase and exceeds the $\overline{\text{THERM}}$ limit, the $\overline{\text{THERM}}$ output asserts low.
3. The $\overline{\text{THERM}}$ output deasserts (goes high) when the temperature falls to $\overline{\text{THERM}}$ limit minus hysteresis. In Figure 20, there is no hysteresis value shown.
4. As the system cools further, and the temperature falls below the $\overline{\text{THERM2}}$ limit, the $\overline{\text{THERM2}}$ signal resets. Again, no hysteresis value is shown for $\overline{\text{THERM2}}$.

The temperature measurement could be either the local or the external temperature measurement.

APPLICATION INFORMATION

Noise Filtering

For temperature sensors operating in noisy environments, previous practice was to place a capacitor across the D+ and D– pins to help combat the effects of noise. However, large capacitances affect the accuracy of the temperature measurement, leading to a recommended maximum capacitor value of 1000 pF. While this capacitor will reduce the noise, it will not eliminate it, making it difficult to use the sensor in a very noisy environment.

The ADT7461 has a major advantage over other devices when it comes to eliminating the effects of noise on the external sensor. The series resistance cancellation feature allows a filter to be constructed between the external temperature sensor and the part. The effect of any filter resistance seen in series with the remote sensor is automatically cancelled from the temperature result.

The construction of a filter allows the ADT7461 and the remote temperature sensor to operate in noisy environments. Figure 21 shows a low-pass R-C-R filter, with the following values: R = 100 Ω and C = 1 nF. This filtering reduces both common-mode noise and differential noise.

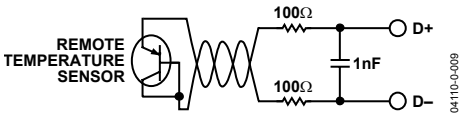


Figure 21. Filter Between Remote Sensor and ADT7461

FACTORS AFFECTING DIODE ACCURACY

Remote Sensing Diode

The ADT7461 is designed to work with substrate transistors built into processors or with discrete transistors. Substrate transistors will generally be PNP types with the collector connected to the substrate. Discrete types can be either PNP or NPN transistor connected as a diode (base shorted to collector). If an NPN transistor is used, the collector and base are connected to D+ and the emitter to D–. If a PNP transistor is used, the collector and base are connected to D– and the emitter to D+.

To reduce the error due to variations in both substrate and discrete transistors, a number of factors should be taken into consideration:

- The ideality factor, n_f, of the transistor is a measure of the deviation of the thermal diode from ideal behavior. The ADT7461 is trimmed for an n_f value of 1.008. The following equation may be used to calculate the error introduced at a temperature T (°C), when using a transistor whose n_f does not equal 1.008. Consult the processor data sheet for the n_f values.

$$\Delta T = \left(n_f - 1.008\right)/1.008 \times \left(273.15\ Kelvin + T\right)$$

  To factor this in, the user can write the ΔT value to the offset register. It will then be automatically added to or subtracted from the temperature measurement by the ADT7461.

- Some CPU manufacturers specify the high and low current levels of the substrate transistors. The high current level of the ADT7461, I_{HIGH}, is 96 μA and the low level current, I_{LOW}, is 6 μA. If the ADT7461 current levels do not match the current levels specified by the CPU manufacturer, it may become necessary to remove an offset. The CPUs data sheet will advise whether this offset needs to be removed and how to calculate it. This offset may be programmed to the offset register. It is important to note that if more than one offset must be considered, the algebraic sum of these offsets must be programmed to the offset register.

If a discrete transistor is being used with the ADT7461, the best accuracy will be obtained by choosing devices according to the following criteria:

- Base-emitter voltage greater than 0.25 V at 6 μA, at the highest operating temperature.
- Base-emitter voltage less than 0.95 V at 100 μA, at the lowest operating temperature.
- Base resistance less than 100 Ω.
- Small variation in h_{FE} (say 50 to 150) that indicates tight control of V_{BE} characteristics.

Transistors, such as 2N3904, 2N3906, or equivalents in SOT-23 packages, are suitable devices to use.

THERMAL INERTIA AND SELF-HEATING

Accuracy depends on the temperature of the remote sensing diode and/or the internal temperature sensor being at the same temperature as that being measured. A number of factors can affect this. Ideally, the sensor should be in good thermal contact with the part of the system being measured. If it is not, the thermal inertia caused by the sensor's mass will cause a lag in the response of the sensor to a temperature change. In the case of the remote sensor, this should not be a problem, since it will either be a substrate transistor in the processor or can be a small package device, such as SOT-23, placed in close proximity to it.

The on-chip sensor, however, will often be remote from the processor and will only be monitoring the general ambient temperature around the package. The thermal time constant of the SOIC-8 package in still air is about 140 seconds, and if the ambient air temperature quickly changed by 100 degrees, it would take about 12 minutes (5 time constants) for the junction temperature of the ADT7461 to settle within 1 degree of this. In practice, the ADT7461 package will be in electrical, and hence thermal, contact with a PCB and may also be in a forced airflow. How accurately the temperature of the board and/or the forced airflow reflects the temperature to be measured will also affect the accuracy. Self-heating due to the power dissipated in the ADT7461 or the remote sensor causes the chip temperature of the device or remote sensor to rise above ambient. However, the current forced through the remote sensor is so small that self-heating is negligible. In the case of the ADT7461, the worst-case condition occurs when the device is converting at 64 conversions per second while sinking the maximum current of 1 mA at the $\overline{\text{ALERT}}$ and $\overline{\text{THERM}}$ output. In this case, the total power dissipation in the device is about 4.5 mW. The thermal resistance, θ_{JA}, of the SOIC-8 package is about 121°C/W.

LAYOUT CONSIDERATIONS

Digital boards can be electrically noisy environments, and the ADT7461 is measuring very small voltages from the remote sensor, so care must be taken to minimize noise induced at the sensor inputs. The following precautions should be taken:

- Place the ADT7461 as close as possible to the remote sensing diode. Provided that the worst noise sources, i.e., clock generators, data/address buses, and CRTs, are avoided, this distance can be 4 inches to 8 inches.
- Route the D+ and D– tracks close together, in parallel, with grounded guard tracks on each side. To minimize inductance and reduce noise pick-up, a 5 mil track width and spacing is recommended. Provide a ground plane under the tracks if possible.



Figure 22. Typical Arrangement of Signal Tracks

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

  Thermocouple effects should not be a major problem as 1°C corresponds to about 200 mV, and thermocouple voltages are about 3 mV/°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 V_{DD} pin. In extremely noisy environments, an input filter capacitor may be placed across D+ and D– close to the ADT7461. This capacitance can effect the temperature measurement, so care must be taken to ensure that any capacitance seen at D+ and D– is a maximum of 1,000 pF. This maximum value includes the filter capacitance, plus any cable or stray capacitance between the pins and the sensor diode.
- If the distance to the remote sensor is more than 8 inches, the use of twisted pair cable is recommended. This will work up to about 6 feet to 12 feet.

- For really long distances (up to 100 feet), use shielded twisted pair, such as Belden No. 8451 microphone cable. Connect the twisted pair to D+ and D– and the shield to GND close to the ADT7461. Leave the remote end of the shield unconnected to avoid ground loops.

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

APPLICATION CIRCUIT

Figure 23 shows a typical application circuit for the ADT7461, using a discrete sensor transistor connected via a shielded, twisted pair cable. The pull-ups on SCLK, SDATA, and $\overline{\text{ALERT}}$ are required only if they are not already provided elsewhere in the system.

The SCLK and SDATA pins of the ADT7461 can be interfaced directly to the SMBus of an I/O controller, such as the Intel 820 chipset.

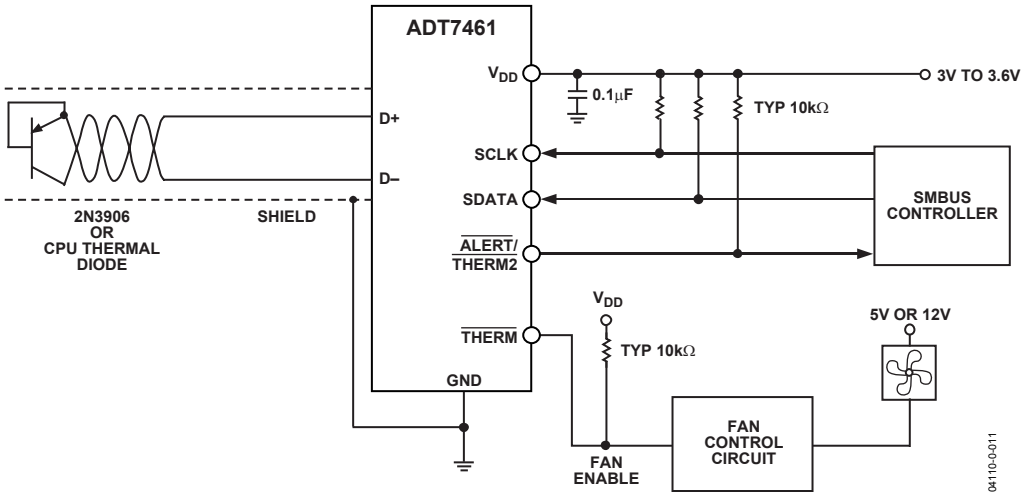


Figure 23. Typical Application Circuit

OUTLINE DIMENSIONS

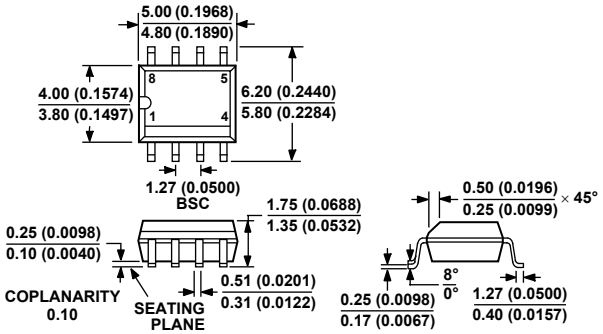


Figure 24. 8-Lead Standard Small Outline Package
[SOIC] (R-8)
Dimensions shown in millimeters and (inches)

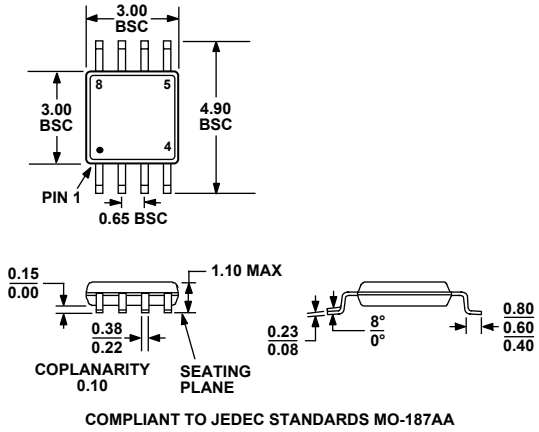


Figure 25. 8-Lead Micro Small Outline Package
[MSOP] (RM-8)
Dimensions shown in millimeters

ORDERING GUIDE

Model	Operating Temperature Range	Package Description	Package Option	Branding Information	SMBus Address
ADT7461AR	−40°C to +125°C	8-Lead SOIC Package	R-8	ADT7461AR	4C
ADT7461AR-REEL	−40°C to +125°C	8-Lead SOIC Package	R-8	ADT7461AR	4C
ADT7461AR-REEL7	−40°C to +125°C	8-Lead SOIC Package	R-8	ADT7461AR	4C
ADT7461ARM	−40°C to +125°C	8-Lead MSOP Package	RM-8	T1B	4C
ADT7461ARM-REEL	−40°C to +125°C	8-Lead MSOP Package	RM-8	T1B	4C
ADT7461ARM-REEL7	−40°C to +125°C	8-Lead MSOP Package	RM-8	T1B	4C
EVAL-ADT7461EB		ADT7461 Evaluation Board			

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