±0.5°C Accurate, 16-Bit Digital SPI Temperature Sensor

Preliminary Technical Data

ADT7310

FEATURES

- 16-bit temperature-to-digital converter
- Temperature accuracy ±0.5°C from 0°C to 70°C
- SPI-compatible interface
- Operating temperature from−55°C to +175°C
- Operating voltage from 2.7 V to 5.5 V
- Critical overtemperature indicator
- Programmable overtemperature/undertemperature interrupt
- Shutdown mode for low power consumption
- Power consumption: 1 mW typically at 3.3 V
- 8-lead narrow SOIC RoHS-compliant package

APPLICATIONS

- Medical equipment
- Isolated sensors
- Environmental control systems
- Computer thermal monitoring
- Thermal protection
- Industrial process control
- Power system monitors
- Hand-held applications

FUNCTIONAL BLOCK DIAGRAM

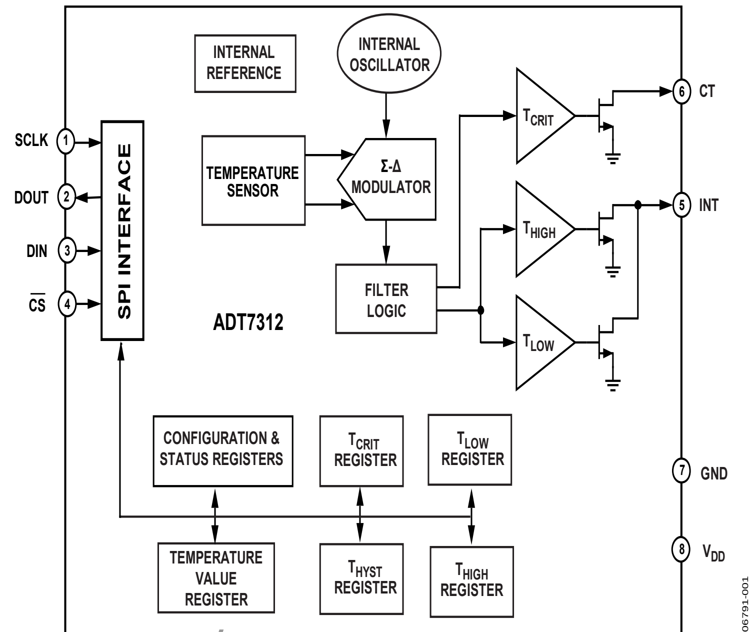

Figure 1.

GENERAL DECSRIPTION

The ADT7310 is a high accuracy digital temperature sensor in a standard narrow SOIC package. It contains a band gap temperature sensor and a 13-bit ADC to monitor and digitize the temperature to a resolution of 0.0625°C. The resolution can be changed to 16 bits by setting a bit in the configuration register, giving a 0.0078°C resolution. The default resolution is 13 bits.

The ADT7410 is guaranteed to operate at supply voltages from 2.7 V to 5.5 V. Operating at 3.3 V, the average supply current is typically 250 µA. The ADT7410 offers a shutdown mode that powers down the device and gives a shutdown current of typically 0.8 µA. The ADT7410 is rated for operation over the −55°C to +150°C temperature range.

The CT pin is an open-drain output that becomes active when the temperature exceeds a programmable critical temperature limit. The default critical temperature limit is 80°C. The INT pin is also an open-drain output that becomes active when the temperature exceeds a programmable limit. The INT pin can operate in either comparator or interrupt mode.

PRODUCT HIGHLIGHTS

An on-chip temperature sensor allows an accurate measurement of the ambient temperature. The measurable temperature range is −55°C to +150°C.

Supply voltage is 2.7 V to 5.5 V.

Available in an 8-lead narrow SOIC packag

Temperature accuracy is ±0.5°C max from 0°C to 70°C.

Default temperature resolution is 0.0625°C.

First conversion on power-up is a fast conversion to ensure fast CT and INT pin activation in overtemperature situations.

Programmable temperature interrupt limits.

Shutdown mode reduces the current consumption to 0.8 µA typical.

One Technology Way, P.O. Box 9106, Norwood, MA 02062-9106, U.S.A.
Tel: 781.329.4700 www.analog.com
Fax: 781.461.3113

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REVISION HISTORY

11/07—Revision PrA: Preliminary Version A

SPECIFICATIONS

T_A = −55°C to +150°C; V_{CC} = 2.7 V to 5.5 V; unless otherwise noted

Table 1.

Parameter	Min	Typ	Max	Unit	Test Conditions/Comments
TEMPERATURE SENSOR AND ADC					
Accuracy			±0.5	°C	T_A = 0°C to +70°C
			±0.5	°C	T_A = -20°C to +100°C, V_{DD} = 3.3 V
			±1.5	°C	T_A = −40°C to +125°C
			±2	°C	T_A = −55°C to +150°C
ADC Resolution		13		Bits	Twos complement temperature value of sign bit plus 12 ADC bits (power-up default resolution)
		16		Bits	Twos complement temperature value of sign bit plus 15 ADC bits (D7 = 1 in the configuration register)
Temperature Resolution					
13 Bits		0.0625		°C	
16 Bits		0.0078125		°C	
Temperature Conversion Time		240		ms	Continuous conversion mode and one-shot conversion mode
Fast Temperature Conversion Time		6	10	ms	First conversion on power-up only
Fast One-Shot Conversion Time		60		ms	Fast one-shot conversion mode
Fast Temperature Conversion Accuracy		±TBD	±TBD	°C	T_A = 0°C to +70°C
		±TBD	±TBD	°C	T_A = −40°C to +125°C
		±TBD	±TBD	°C	T_A = −55°C to +150°C
Long-Term Drift		0.08		°C	Drift over 10 years, if part is operated at 55°C
Temperature Hysteresis		0.02		°C	Temperature cycle = 25°C to 125°C, and back to 25°C
Repeatability		0.01	?	°C	T_A = +25°C
DC PSRR		TBD		°C/V	T_A = +25°C
DIGITAL OUTPUTS (OPEN DRAIN)					
High Output Leakage Current, I_{OH}		0.1	5	µA	CT and INT pins pulled up to 5.5 V
Output High Current, I_{OH}			1	mA	V_{OH} = 5 V
Output Low Voltage, V_{OL}			0.4	V	I_{OL} = 2 mA
Output High Voltage, V_{OH}	0.7 × V_{DD}			V	
Output Capacitance, C_{OUT}	3		10		
R_{ON} Resistance (Low Output)		15		Ω	Supply and temperature dependent
DIGITAL INPUTS					
Input Current			±1	µA	V_{IN} = 0 V to V_{DD}
Input Low Voltage, V_{IL}			0.8	V	
Input High Voltage, V_{IH}	2.5			V	
Pin Capacitance		10		pF	
DIGITAL OUTPUT (DOUT)					
Output High Voltage, V_{OH}	V_{OH} − 0.3			V	I_{SOURCE} = I_{SINK} = 200 µA
Output Low Voltage, V_{OL}			0.4	V	I_{OL} = 200 µA
Output Capacitance, C_{OUT}			50	pF	
POWER REQUIREMENTS					
Supply Voltage	2.7		5.5	V	
Supply Current at 3.3 V		TBD	TBD	µA	Peak current while converting ,SPI interface inactive
Supply Current at 5.0 V		TBD	350	µA	Peak current while converting ,SPI interface inactive
Shutdown Mode at 3.3 V		TBD	TBD	µA	Supply current in shutdown mode
Shutdown Mode at 5.0 V		TBD	1	µA	Supply current in shutdown mode

Parameter	Min	Typ	Max	Unit	Test Conditions/Comments
Power Dissipation		TBD		µW	V_{DD} = 3.3 V, normal mode at 25°C
1 Sample Per Second		150		µW	Power dissipated for V_{DD} = 3.3 V at 25°C
1 Sample Per Second		315		µW	Power dissipated for V_{DD} = 5.0 V at 25°C

SPI TIMING SPECIFICATIONS

All input signals are specified with t_R (rise time) = t_F (fall time) = 5 ns (10% to 90% of V_{DD}) and timed from a voltage level of 1.6 V. T_A = −55°C to +150°C, V_{DD} = +2.7 V to +5.5 V, unless otherwise noted.

Table 2.

Parameter[1, 2]	Limit at T_{MIN}, T_{MAX} (B Version)	Unit	Conditions/Comments
t_1	0	ns min	$\overline{CS}$ falling edge to SCLK active edge setup time[4]
t_2	100	ns min	SCLK high pulse width
t_3	100	ns min	SCLK low pulse width
t_4	30	ns min	Data valid to SCLK edge setup time
t_5	25	ns min	Data valid to SCLK edge hold time
t_6[3]	0	ns min	SCLK active edge to data valid delay[4]
	60	ns max	V_{DD} = 4.5 V to 5.5 V
	80	ns max	V_{DD} = 2.7 V to 3.6 V
t_7[5]	10	ns min	Bus relinquish time after $\overline{CS}$ inactive edge
	80	ns max	
t_8	0	ns min	$\overline{CS}$ rising edge to SCLK edge hold time
t_9	0	ns min	$\overline{CS}$ falling edge to DOUT active time
	60	ns max	V_{DD} = 4.5 V to 5.5 V
	80	ns max	V_{DD} = 2.7 V to 3.6 V
t_{10}	10	ns min	SCLK inactive edge to DOUT high

[1] Sample tested during initial release to ensure compliance. All input signals are specified with t_R = t_F = 5 ns (10% to 90% of V_{DD}) and timed from a voltage level of 1.6 V.
[2] See Figure 2.
[3] These numbers are measured with the load circuit shown in Figure 4 and defined as the time required for the output to cross the V_{OL} or V_{OH} limits.
[4] SCLK active edge is falling edge of SCLK.
[5] These numbers are derived from the measured time taken by the data output to change 0.5 V when loaded with the circuit shown in Figure 4. The measured number is then extrapolated back to remove the effects of charging or discharging the 50 pF capacitor. This means that the times quoted in the timing characteristics are the true bus relinquish times of the part and, as such, are independent of external bus loading capacitances.

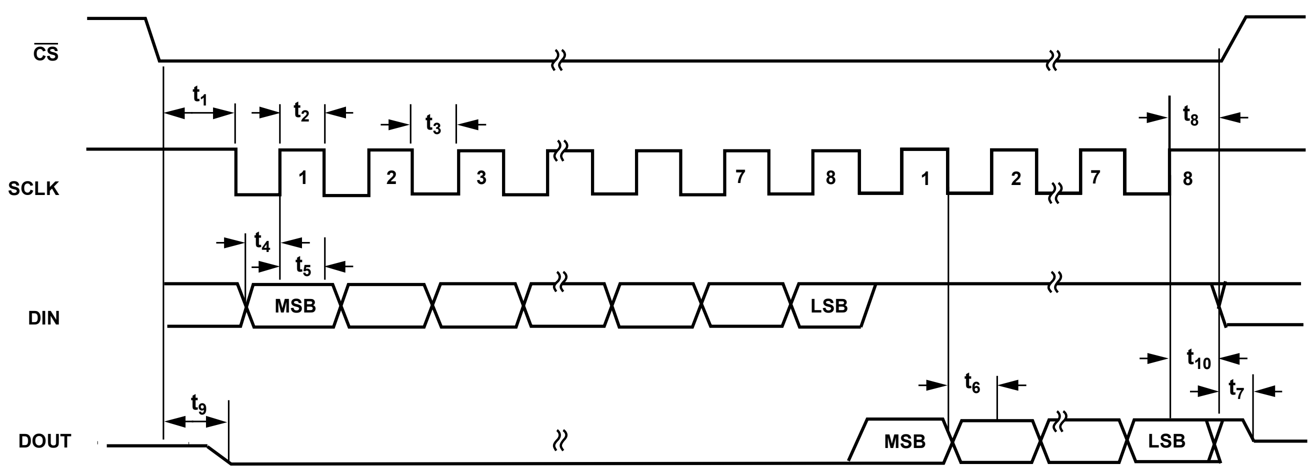


Figure 2. Detailed SPI Timing Diagram

ABSOLUTE MAXIMUM RATINGS

Table 3.

Parameter	Rating
V_{DD} to GND	–0.3 V to +7 V
SDA Input Voltage to GND	–0.3 V to V_{DD} + 0.3 V
SDA Output Voltage to GND	–0.3 V to V_{DD} + 0.3 V
SCL Input Voltage to GND	–0.3 V to V_{DD} + 0.3 V
CT and INT Output Voltage to GND	–0.3 V to V_{DD} + 0.3 V
Operating Temperature Range	–55°C to +150°C
Storage Temperature Range	–65°C to +160°C
Maximum Junction Temperature, T_{JMAX}	150.7°C
8-Lead N-SOIC (R-8)	
Power Dissipation[1]	$W_{MAX} = (T_{JMAX} – T_A{}^2)/\theta_{JA}$
Thermal Impedance[3]	
θ_{JA}, Junction-to-Ambient (Still Air)	157°C/W
θ_{JC}, Junction-to-Case	56°C/W
IR Reflow Soldering	
Peak Temperature (RoHS-Compliant Package)	260°C (+0°C)
Time at Peak Temperature	20 sec to 40 sec
Ramp-Up Rate	3°C/sec maximum
Ramp-Down Rate	–6°C/sec maximum
Time from 25°C to Peak Temperature	8 minutes maximum

[1] Values relate to package being used on a standard 2-layer PCB. This gives a worst-case θ_{JA} and θ_{JC}. Refer to Figure 3 for a plot of maximum power dissipation vs. ambient temperature (T_A).
[2] T_A = ambient temperature.
[3] Junction-to-case resistance is applicable to components featuring a preferential flow direction, for example, components mounted on a heat sink. Junction-to-ambient is more useful for air-cooled, PCB-mounted components.

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.

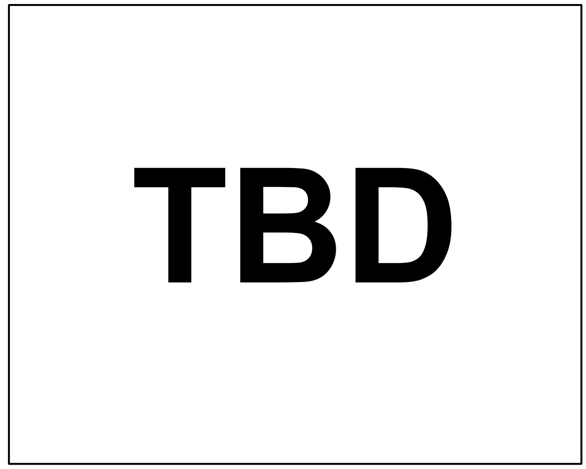


Figure 3. SOIC_N Maximum Power Dissipation vs. Temperature

ESD CAUTION

ESD (electrostatic discharge) sensitive device. Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjected to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.

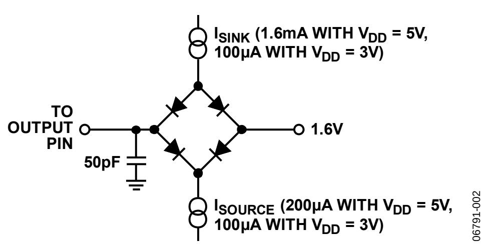


Figure 4. Load Circuit for Timing Characterization

PIN CONFIGURATION AND FUNCTION DESCRIPTIONS

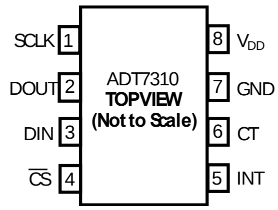


Figure 5. Pin Configuration

Table 4. Pin Function Descriptions

Pin No.	Mnemonic	Description
1	SCLK	Serial Clock Input. The serial clock is used to clock in and clock out data to and from any register of the ADT7310.
2	DOUT	SPI Serial Data Output. Data from the registers output from the part on DOUT pin . Data is clocked out on the SCLK falling edge and is valid on the SCLK rising edge.
3	DIN	Serial Data Input. Serial data to be loaded to the part's control registers is provided on this input. Data is clocked into the registers on the rising edge of SCLK.
4	$\overline{CS}$	Chip Select Input. Logic Input. The device is selected when this input is low. The SCLK input is disabled when this pin is high.
5	INT	Over temperature and Under temperature Indicator. Power-up default setting is as an active low comparator interrupt. Open-drain configuration. Needs a pull-up resistor.
6	CT	Critical Over temperature Indicator. Power-up default polarity is active low. Open-drain configuration. Needs a pull-up resistor.
7	GND	Analog and Digital Ground.
8	V_{DD}	Positive Supply Voltage, 2.7 V to 5.5 V. The supply should be decoupled to ground.

TYPICAL PERFORMANCE CHARACTERISTICS

TBD

Figure 6. Temperature Accuracy of 40 ADT7310 Devices @ 3.3 V

TBD

Figure 7. Temperature Accuracy of 40 ADT7310 Devices @ 5 V

TBD

Figure 8. Operating Supply Current vs. Temperature

TBD

Figure 9. Operating Supply Current vs. Supply Voltage at 30°C

TBD

Figure 10. Shutdown Current vs. Supply Voltage at 30°C

TBD

Figure 11. Temperature Accuracy vs. Supply Ripple Frequency (PSRR)

THEORY OF OPERATION

CIRCUIT INFORMATION

The ADT7310 is a 16-bit digital temperature sensor with the 16th bit acting as the sign bit. An on-board temperature sensor generates a voltage precisely proportional to absolute temperature, which is compared to an internal voltage reference and input to a precision digital modulator. Overall accuracy for the ADT7310 is ±1°C from +130°C to +150°C. The serial interface is SPI compatible and the open-drain outputs of the ADT7310 INT and CT pins are capable of sinking 2 mA.

The on-board temperature sensor has excellent accuracy and linearity over the entire rated temperature range without needing correction or calibration by the user.

The sensor output is digitized by a Σ-Δ analog-to-digital converter. This type of converter utilizes time-domain oversampling and a high accuracy comparator to deliver 16 bits of effective accuracy in an extremely compact circuit.

The measured temperature value is compared with a critical temperature limit stored in the 16-bit T_{CRIT} read/write register, a high temperature limit stored in the 16-bit T_{HIGH} read/write register and a low temperature limit stored in the 16-bit T_{LOW} read/write register. If the measured value exceeds these limits, the INT pin is activated, and if it exceeds the T_{CRIT} limit, the CT pin is activated. The INT pin and the CT pin are programmable for polarity via the configuration register while the INT pin is also programmable for mode operation via the configuration register.

Configuration register functions consist of

Switching between normal operation and full power-down.
Switching between comparator and interrupt event modes on the INT pin.
Setting the CT and INT pins active polarity.
Setting the number of faults that activate the CT and INT pins.

- Enabling the standard one-shot and fast one-shot mode.

CONVERTER DETAILS

The Σ-Δ modulator consists of an input sampler, a summing network, an integrator, a comparator, and a 1-bit DAC. This architecture creates a negative feedback loop and minimizes the integrator output by changing the duty cycle of the comparator output in response to input voltage changes. The comparator samples the output of the integrator at a much higher rate than the input sampling frequency. This oversampling spreads the quantization noise over a much wider band than that of the input signal, improving overall noise performance and increasing accuracy.

The modulated output of the comparator is encoded using a circuit technique that results in SPI temperature data.

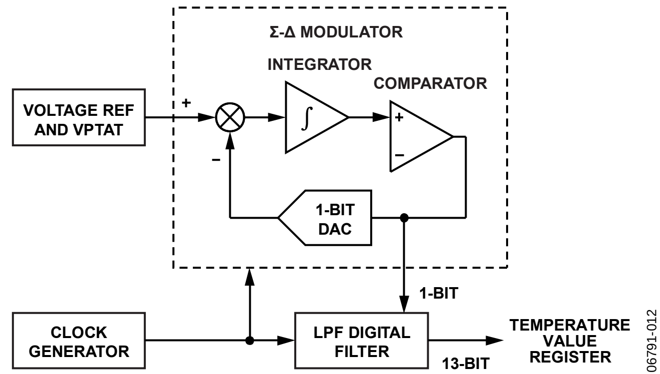


Figure 12. Σ-Δ Modulator

TEMPERATURE MEASUREMENT

In normal mode, the ADT7310 runs an automatic conversion sequence. During this automatic conversion sequence, a conversion takes 240 ms to complete and the ADT7310 is continuously converting. This means that as soon as one temperature conversion is completed another temperature conversion begins. Each temperature conversion result is stored in the temperature value register and is available through the SPI interface.

On power-up, the first conversion is a fast conversion, taking typically 6 ms. Therefore, the CT and IN pins are activated very quickly after power-up if an overtemperature event is present at power-up.

The conversion clock for the part is generated internally. No external clock is required except when reading from and writing to the serial port.

In continuous conversion mode, the internal clock is reset after every read or write operation. This causes the device to start a temperature conversion after every read or write, the result of which is typically available 240 ms later. Reading from the device before a conversion is complete causes the ADT7310 to finish converting and store the result in a shadow temperature value register. The read operation provides the previous conversion result. As soon as communication to the ADT7310 is complete, the result in the temporary temperature value register is moved into the live temperature value register that can be accessed by the SPI interface.

The measured temperature value is compared with a critical temperature limit, stored in the 16-bit T_{CRIT} read/write register, a high temperature limit, stored in the 16-bit T_{HIGH} read/write register, and a low temperature limit, stored in the 16-bit T_{LOW} read/write register. If the measured value exceeds these limits, the INT pin is activated and if it exceeds the T_{CRIT} limit, the CT pin is activated. This INT pin and the CT pin are programmable for polarity via the configuration register while the INT pin is also programmable for interrupt mode via the configuration register.

ONE-SHOT MODE

Setting Bit 5 = 1 and Bit 6 = 0 of the configuration register enables the one-shot mode. When this mode is enabled, the ADT7310 immediately does a conversion and then goes into shutdown mode. If a one-shot conversion is initiated at a rate of one conversion per second, the current consumption is reduced to typically TBD µA when V_{DD} = 3.3 V and TBD µA when V_{DD} = 5 V.

Wait for a minimum of 240 ms after writing to the one-shot bits before reading back the temperature from the temperature value register. This time ensures that the ADT7310 has time to power up and do a conversion. This is shown in Figure 13.

The one-shot mode is useful when one of the circuit design priorities is to reduce power consumption.

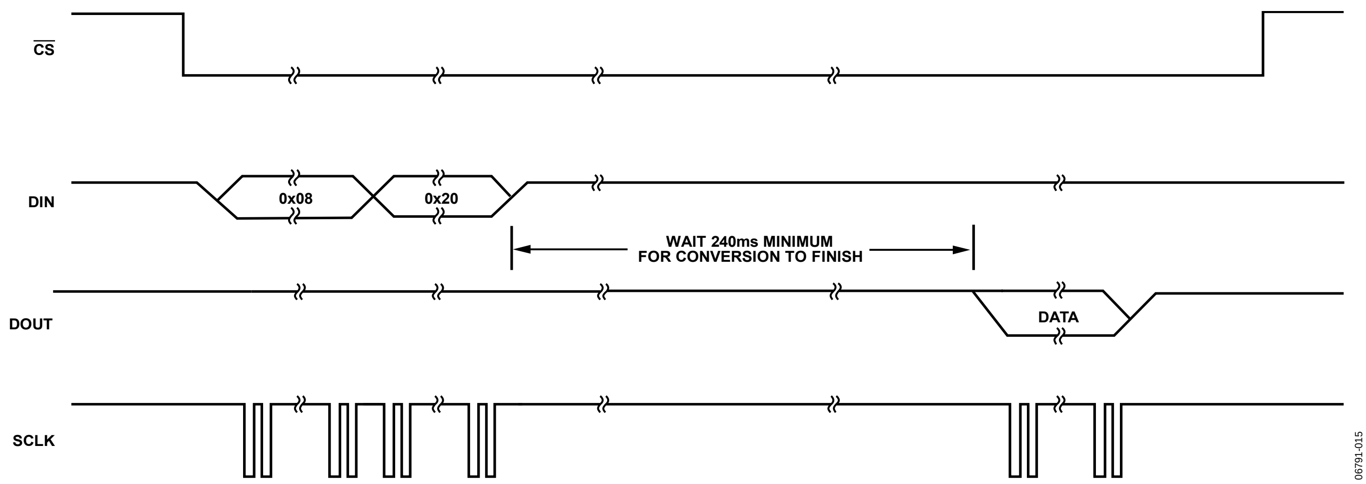


Figure 13. Typical SPI One-Shot Write to Configuration Register Followed by a Read from the Temperature Value Register

Fast One-Shot Mode

A fast one-shot mode reduces the conversion time to 60 ms typically. The temperature accuracy is also reduced but this can be compensated by greatly reduced current consumption. If a fast one-shot conversion is initiated at a rate of one conversion per second, the current consumption is reduced to typically TBD µA when V_{DD} is 3.3 V and TBD µA when V_{DD} is 5 V. A fast one-shot temperature measurement is initiated when the fast one-shot mode in the configuration register is initiated. This is accomplished by writing Bit 5 = 0 and Bit 6 = 1. As soon as Bit D5 and Bit D6 are set up for fast one-shot conversion, the ADT7310 does a temperature conversion, and powers down.

CT & INT Operation in One-Shot Mode

Both the fast and standard one-shot temperature measurements cause the INT and CT pins to go active if the temperature exceeds their corresponding temperature limits. Therefore, it is quite possible that the temperature can exceed the interrupt limits for quite some time before a one-shot conversion is activated. Refer to Figure 14 for more information on one-shot CT pin operation for T_{CRIT} overtemperature events when one of the limits is exceeded.

Note that in interrupt mode, a read from any register resets the INT pin after it is activated by a write to the standard or fast one-shot bits. In the comparator mode, once the temperature drops below the T_{HIGH} – T_{HYST} value or goes above the T_{LOW} + T_{HYST} value, a write to the standard or fast one-shot bits resets the INT pin, depending on which one-shot bit caused the interrupt.

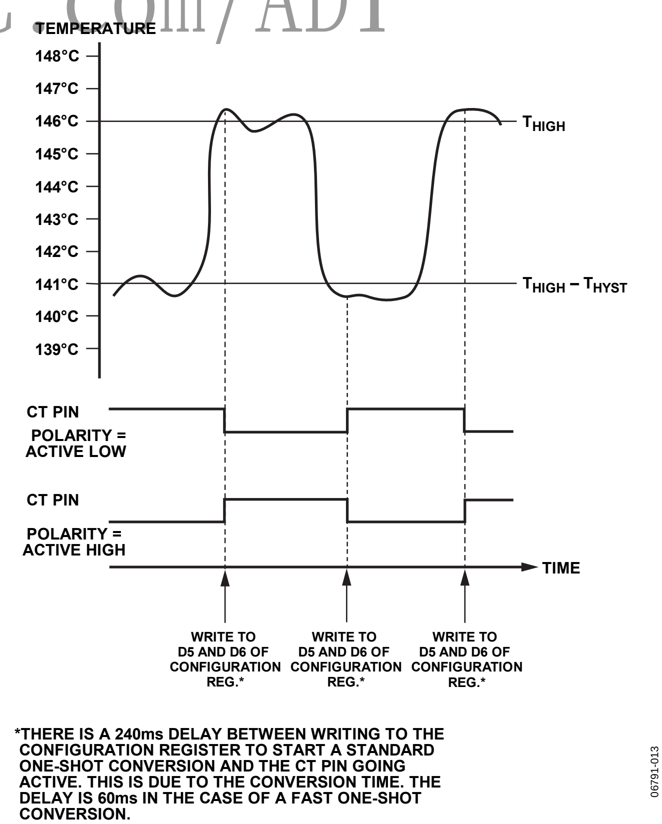


Figure 14. One-Shot CT Pin

CONTINUOUS READ MODE

When the command byte = 01010100 (0x54), the contents of the temperature value register can be read out without requiring repeated writes to the communications register. Simply sending 16 SCLK clocks to the ADT7310 clocks the contents of the temperature value register onto the DOUT pin.

To exit the continuous read mode, the command byte 01010000 (0x50) must be written to the ADT7310.

While in continuous read mode, the part monitors activity on the DIN line so that it can receive the instruction to exit the continuous read mode. Additionally, a reset occurs if 32 consecutive 1s are seen on the DIN pin. Therefore, DIN should be held low in continuous read mode until an instruction is to be written to the device.

In continuous read mode, the temperature value register cannot be read when a conversion is taking place. If an attempt is made to read the temperature value register while a conversion is taking place, then all 0's are read. This is because the continuous read mode blocks read access to temperature value register during a conversion.

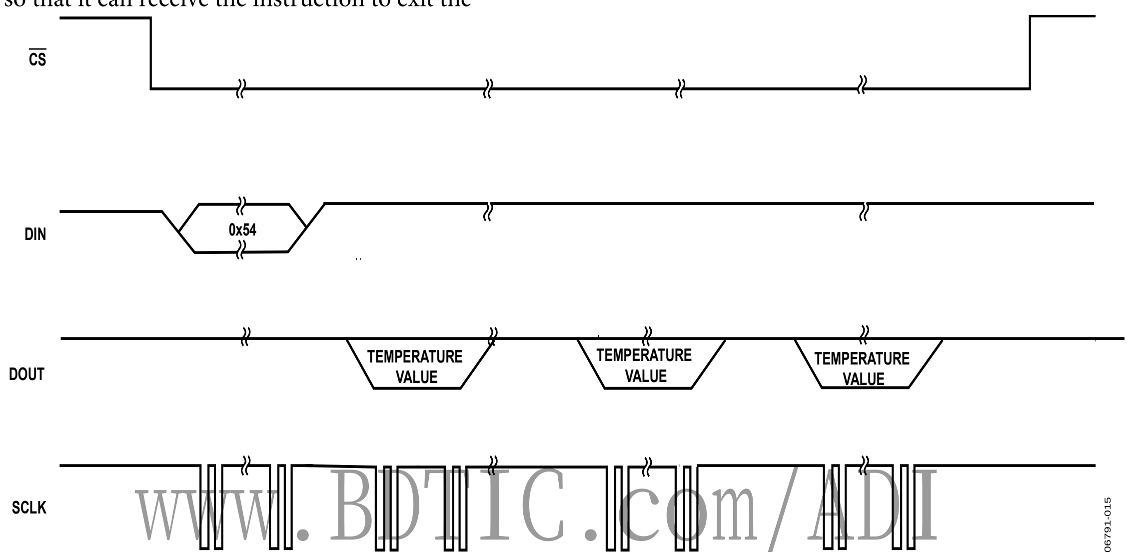


Figure 15. Continuous Read Mode

SHUTDOWN

The ADT7310 can be placed in shutdown mode via the configuration register, in which case the entire IC is shut down and no further conversions are initiated until the ADT7310 is taken out of shutdown mode. The ADT7310 can be taken out of shutdown mode by writing 00 to Bit 5 and Bit 6 in the configuration register. The ADT7310 typically takes TBD ms to come out of shutdown mode. The conversion result from the last conversion prior to shutdown can still be read from the ADT7310 even when it is in shutdown mode. When the part is taken out of shutdown mode, the internal clock is started and a conversion is initiated.

FAULT QUEUE

Bit D0 and Bit D1 of the configuration register is used to set up a fault queue. Up to four faults is provided to prevent false tripping of the INT and CT pins when the ADT7310 is used in a noisy temperature environment. The number of faults set in the queue must occur consecutively to set the INT and CT outputs. For example, if the number of faults set in the queue is four, then four consecutive temperature conversions must occur with each result exceeding a temperature limit in any of the limit registers before the INT and CT pins are activated. If two consecutive temperature conversions exceed a temperature limit and the third conversion does not, the fault count is reset back to zero.

TEMPERATURE DATA FORMAT

One LSB of the ADC corresponds to 0.0625°C. The ADC can theoretically measure a temperature range of −256°C to +255°C, but the ADT7310 is guaranteed to measure a low value temperature limit of −55°C to a high value temperature limit of +175°C. The temperature measurement result is stored in the 16-bit temperature value register. It is compared with the high temperature limits stored in the T_{CRIT} setpoint register and the T_{HIGH} setpoint register. The temperature measurement result is also compared with the low temperature limit stored in the T_{LOW} setpoint register.

Temperature data in the temperature value register, the T_{CRIT} setpoint register, the T_{HIGH} setpoint register, and the T_{LOW} setpoint register is represented by a 13-bit twos complement word. The MSB is the temperature sign bit. The three LSBs of the temperature value, bits [2:0], on power-up default, are not part of the temperature conversion result and are flag bits for T_{CRIT}, T_{HIGH} and T_{LOW}. Table 5 shows the 13-bit temperature data format without Bit 0 to Bit 2.

The number of bits in the temperature data word can be extended to 16 bits twos complement by setting bit 7 = 1 in the configuration register. When using a 16-bit temperature data value, the temperature value bits[2:0] are not used as flag bits and are now the LSB bits of the temperature value. The power-on default setting is to have a 13-bit temperature data value.

Designers that use a 9-bit temperature data format can still use the ADT7310 by ignoring the last four LSBs of the 13-bit temperature value. These four LSBs are Bit D3 to Bit D6 in Table 5.

Table 5. 13-Bit Temperature Data Format

Temperature	Digital Output (Binary) D15 to D3	Digital Output (Hex)
−55°C	1 1100 1001 0000	0x1C90
−50°C	1 1100 1110 0000	0x1CE0
−25°C	1 1110 0111 0000	0x1E70
−0.0625°C	1 1111 1111 1111	0x1FFF
0°C	0 0000 0000 0000	0x000
+0.0625°C	0 0000 0000 0001	0x001
+10°C	0 0000 1010 0000	0x0A0
+25°C	0 0001 1001 0000	0x190
+50°C	0 0011 0010 0000	0x320
+75°C	0 0100 1011 0000	0x4B0
+100°C	0 0110 0100 0000	0x640
+125°C	0 0111 1101 0000	0x7D0
+150°C	0 1001 0110 0000	0x960
+175°C	0 1010 1111 0000	0xAF0

Temperature Conversion Formulas

16-Bit Temperature Data Format

Positive Temperature = ADC Code(d)/128
Negative Temperature = (ADC Code(d)[1] − 65536)/128
Negative Temperature = (ADC Code(d)[2] − 32768)/128

13-Bit Temperature Data Format

Positive Temperature = ADC Code(d)/16
Negative Temperature = (ADC Code(d)[3] − 8192)/16
Negative Temperature = (ADC Code(d)[2] − 4096)/16

10-Bit Temperature Data Format

Positive Temperature = ADC Code(d)/2
Negative Temperature = (ADC Code(d)[4] − 1024)/2
Negative Temperature = (ADC Code(d)[2] − 512)/2

9-Bit Temperature Data Format

Positive Temperature = ADC Code(d)
Negative Temperature = ADC Code(d)[5] − 512
Negative Temperature = ADC Code(d)[2] − 256

[1] For ADC Code, use all 16 bits of the data byte, including the sign bit.
[2] For ADC Code, MSB is removed from the ADC code.
[3] For ADC Code, use all 13 bits of the data byte, including the sign bit.
[4] For ADC Code, use all 10 bits of the data byte, including the sign bit.
[5] For ADC Code, use all nine bits of the data byte, including the sign bit.

REGISTERS

The ADT7310 contains eight registers:

- Five temperature registers
- One status register
- One ID register
- One configuration register

The status register, configuration register, the T_{HYST} register,
and the ID register are the only registers that are eight bits wide while the rest are 16 bits wide. The temperature value register, the status register, and the ID register are read-only. Both a read and write can be performed on the rest of the registers. On power-up, the serial interface address pointer, (command word bits [C5:C3]), is loaded with 0x00 and points to the status register.

Table 6. ADT7310 Registers

Address [C5, C4, C3]	Description	Power-On Default
000	Status	0x80
001	Configuration	0x00
010	Temperature value	0x0000
011	ID	0x00
100	T_{CRIT}	0x4980 (+147°C)
101	T_{HYST}	0x05 (5°C)
110	T_{HIGH}	0x2000 (+64°C)
111	T_{LOW}	0X0500 (+10°C)

Status Register

This 8-bit read-only register reflects the status of the over temperature and under temperature interrupts that can cause the CT and INT pins to go active. It also reflects the status of a temperature conversion operation. The interrupt flags in this register are reset by a read operation to the status register and/or when the temperature value returns within the temperature limits, less the hysteresis value. The RDYB bit is reset after a read from the temperature value register. In standard and fast one-shot modes, the RDYB bit is reset after a write to the one-shot bits.

Table 7. Status Register

Address	Data Bit	Default Value	Type	Name	Description
000	[3:0]	000	R	Unused	Reads back 0
	[4]	0	R	T_{LOW}	This bit is set to 1 when the temperature goes below the T_{LOW} temperature limit. The bit is cleared to 0 when the status register is read and/or when the temperature measured goes back above the limit set in T_{LOW} + T_{HYST} registers.
	[5]	0	R	T_{HIGH}	This bit is set to 1 when the temperature goes above the T_{HIGH} temperature limit. The bit is cleared to 0 when the status register is read and/or when the temperature measured goes back below the limit set in T_{HIGH} – T_{HYST} registers
	[6]	0	R	T_{CRIT}	This bit is set to 1when the temperature goes over the T_{CRIT} temperature limit. This bit clears to 0 when the status register is read and/or when the temperature measured goes back below the limit set in T_{CRIT} – T_{HYST} registers.
	[7]	1	R	RDBY	This bit goes low when the temperature conversion result is written into the temperature value register. It is reset to 1 when the temperature value register is read. In standard and fast one-shot modes, this bit is reset after a write to the one-shot bits.

Configuration Register

This 8-bit read/write register stores various configuration modes for the ADT7310. These modes are shutdown, over temperature and under temperature interrupts, one-shot, continuous conversion, interrupt pins polarity, and overtemperature fault queues .

Table 8. Configuration Register

Address	Data Bit	Default Value	Type	Name	Description
001	[1:0]	00	R/$\overline{W}$	Fault queue	These two bits set the number of overtemperature faults that occur before setting the INT and CT pins. This helps to avoid false triggering due to temperature noise. 00 = 1 fault (default) 01 = 2 faults 10 = 3 faults 11= 4 faults
	[2]	0	R/$\overline{W}$	CT pin polarity	This bit selects the output polarity of the CT pin. 0 = active low; 1 = active high.
	[3]	0	R/$\overline{W}$	INT pin polarity	This bit selects the output polarity of the INT pin. 0 = active low; 1 = active high.
	[4]	0	R/$\overline{W}$	INT mode	This bit selects between comparator and interrupt mode. 0 = comparator mode; 1 = interrupt mode
	[6:5]	00	R/$\overline{W}$	Operation mode	These two bits set the operational mode for the ADT7310. 00 = continuous conversion (default). Once one conversion is finished, the ADT7310 starts another 01 = One shot. Conversion time is typically 240 ms 10 = Fast one shot. Conversion time is typically 60 ms. This operational mode reduces the average current consumption even more so than the standard one-shot mode 11= Shutdown. All circuitry except interface circuitry is powered down
	[7]	0	R/$\overline{W}$	Resolution	This bit sets up the resolution of the ADC when converting. 0 = 13-Bit resolution. Sign bit + 12 bits gives a temperature resolution of 0.0625°C 1 = 16-Bit resolution. Sign bit + 15 bits gives a temperature resolution of 0.0078125°C

Temperature Value Register

This 16-bit read-only register stores the temperature measured by the internal temperature sensor. The temperature is stored in twos complement format with the MSB being the temperature sign bit. When reading from this register, the MSBs are clocked out first. Bit D0 to Bit D2 are event alarm flags for T_{CRIT}, T_{HIGH}, and T_{LOW}. When the ADC is configured to convert the temperature to a 15-bit digital value then D0 to D2 are no longer used as flag bits and are instead used as the LSB bits for the extended digital value.

Table 9. Temperature Value Register

Address	Data Bit	Default Value	Type	Name	Description
010	[0]	0	R	T_{LOW} Flag/ LSB0	Flags T_{LOW} event. While temperature value is below T_{LOW}, this bit is set to 1. Flag clears to 0 when If Configuration register[7] = 1, this contains the LSB of the 15 bit temperature value
	[1]	0	R	T_{HIGH} Flag/ LSB1	Flags T_{LOW} event. While temperature value is below T_{LOW}, this bit is set to 1. Flag clears to 0 when If Configuration register[7] = 1, this contains the LSB of the 15 bit temperature value
	[2]	0	R	T_{CRIT} Flag/LSB2	Flags T_{LOW} event. While temperature value is below T_{LOW}, this bit is set to 1. Flag clears to 0 when If Configuration register[7] = 1, this contains the LSB of the 15 bit temperature value
	[14:3]	0	R	Temp	Temperature Value in 2s complement format
	[15]	0	R	Sign	Sign Bit. Indicates if temperature value is negative or positive

Manufacturer ID Register

This 8-bit read-only register stores the manufacturer ID in Bit D3 to Bit D7 and the silicon revision in Bit D0 to Bit D2

Table 10. Manufacturer ID Register

Address	Data Bit	Default Value	Type	Name	Description
011	[2:0]	?000	R	Rev ID	Contains the silicon revision identification number
	[7:3]	11000	R	Man ID	Contains the manufacturer identification number

T_{CRIT} Setpoint Register

This 16-bit read/write register stores the critical over temperature limit value. A critical over temperature event occurs when the temperature value stored in the temperature value register exceeds the value stored in this register. The CT pin is activated if a critical over temperature event occurs The temperature is stored in twos complement format with the MSB being the temperature sign bit. When reading from this register, the MSBs are clocked out first.

Table 11. T_{CRIT} Setpoint Register

Address	Data Bit	Default Value	Type	Name	Description
100	[15:0]	0x4900	R/$\overline{W}$	T_{CRIT}	Critical over temperature limit, stored in 2's complement format. The default setting is +147°C

T_{HYST} Setpoint Register

This 8-bit read/write register stores the temperature hysteresis value for the T_{HIGH}, T_{LOW}, and T_{CRIT} temperature limits. The temperature hysteresis value is stored in straight binary format using the four LSBs. Increments are possible in steps of 1°C from 0°C to +15°C. The value in this register is added to the T_{HIGH} and T_{CRIT} values, and subtracted from the T_{LOW} value, to implement hysteresis,

Table 12. T_{HYST} Setpoint Register

Address	Data Bit	Default Value	Type	Name	Description
101	[3:0]	0x5	R/$\overline{W}$	T_{HYST}	Hysteresis value ,from0°C to +15°C. Stored in straight binary format. The default setting is 5°C
	[7:	X	R/$\overline{W}$	N/A	Not Used

T_{HIGH} Setpoint Register

This 16-bit read/write register stores the over temperature limit value. An over temperature event occurs when the temperature value stored in the temperature value register exceeds the value stored in this register. The INT pin is activated if an over temperature event occurs The temperature is stored in twos complement format with the MSB being the temperature sign bit. When reading from this register, the MSBs are clocked out first.

Table 13. T_{HIGH} Setpoint Register

Address	Data Bit	Default Value	Type	Name	Description
110	[15:0]	0x2000	R/$\overline{W}$	T_{HIGH}	Over temperature limit, stored in 2's complement format. The default setting is +64°C

T_{LOW} Setpoint Register

This 16-bit read/write register stores the under temperature limit value. An under temperature event occurs when the temperature value stored in the temperature value register is less than the value stored in this register. The INT pin is activated if an under temperature event occurs. The temperature is stored in twos complement format with the MSB being the temperature sign bit. When reading from this register, the MSBs are clocked out first. The default setting has the T_{LOW} limit at 10°C.

Table 14. T_{LOW} Setpoint Register

Address	Data Bit	Default Value	Type	Name	Description
111	[15:0]	0x0500	R/$\overline{W}$	T_{LOW}	Under temperature limit, stored in 2's complement format. The default setting is +10C

SERIAL INTERFACE

The ADT7310 has a 4-wire serial peripheral interface (SPI). The interface has a data input pin (DIN) for inputting data to the device, a data output pin (DOUT) for reading data back from the device, and a data clock pin (SCLK) for clocking data into and out of the device. A chip select pin ($\overline{CS}$) enables or disables the serial interface. $\overline{CS}$ is required for correct operation of the interface. Data is clocked out of the AD7T7312 on the negative edge of SCLK, and data is clocked into the device on the positive edge of SCLK.

SPI Command Byte

All data transactions on the bus begin with the master taking $\overline{CS}$ from high to low and sending out the command byte. This indicates to the ADT7310 whether the transaction is a read or a write and provides the address of the register for the data transfer. Table 15 shows the command byte.

Table 15. Command Byte

C7	C6	C5	C4	C3	C2	C1	C0
0	R/$\overline{W}$	Register Address			Continuous read	0	0

Bit C7 of the command byte must be set to 0 to successfully begin a bus transaction. The SPI interface does not work correctly if a 1 is written into this bit.

Bit C6 is the read/write bit; 1 indicates a read, and 0 indicates a write.

Bits [C5:C3] contain the target register address. You can only read or write to one register per bus transaction.

Bit C2 activates a continuous read mode on the temperature value register only. When this bit is set, the serial interface is configured so that the temperature value register can be continuously read. When the command word is 01010100 (0x54), the contents of the temperature value register can be read out without requiring repeated writes to set the address bits. Simply sending 16 SCLK clocks to the ADT7310 clocks the contents of the temperature value register onto the DOUT pin. See **Error! Reference source not found.** section for more information.

Writing Data

Data is written to the ADT7310 in 8 or 16-bits, depending on the addressed register. The first byte written to the device is the command byte, with the read/write bit set to 0. The master then supplies the 8-bit or 16-bit input data on the DIN line. The ADT7310 clocks the data into the register addressed in the command byte on the positive edge of SCLK. The master finishes the write by pulling $\overline{CS}$ high.

Figure 16 shows a write to an 8-bit register, and Figure 17 shows a write to a 16-bit register.

The master must begin a new write transaction on the bus , for every register write. Only one register is written to per bus transaction.

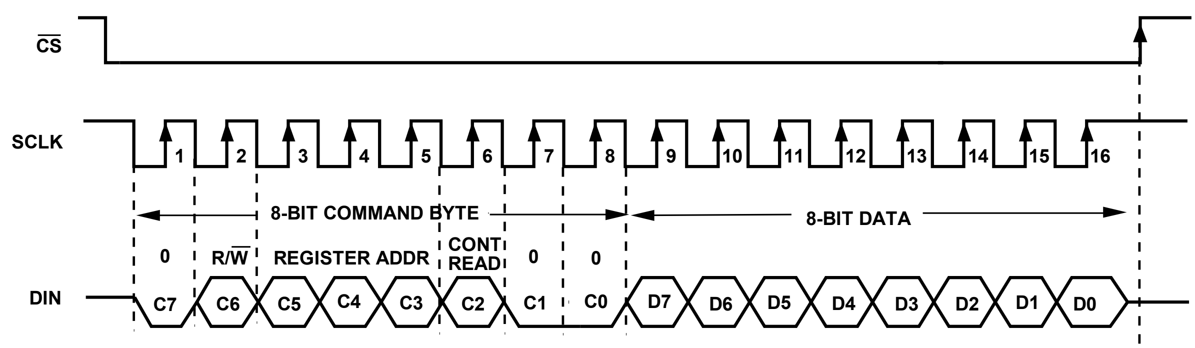


Figure 16. Writing to an 8-bit Register

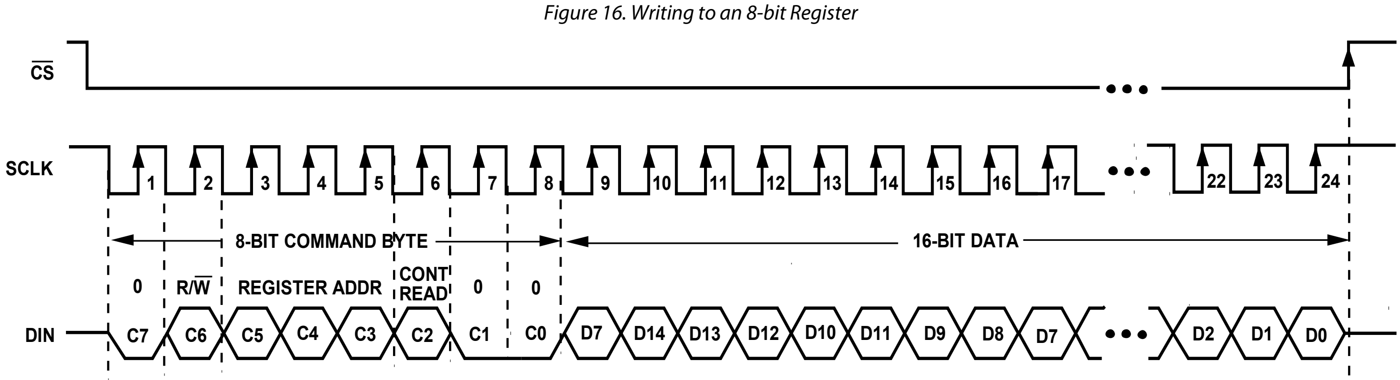


Figure 17. Writing to a 16-bit Register

Reading Data

A read transaction begins when the master writes the command byte to the ADT7310 with the read/write bit set to 1. The master then supplies 8 or 16 clock pulses, depending on the addressed register, and the ADT7310 clocks out data from the addressed register on the DOUT line. Data is clocked out on the first falling edge of SCLK following the command byte.

The read transaction finishes when the master takes $\overline{CS}$ high.

The master must begin a new read transaction on the bus , for every register read. Only one register is read from per bus transaction However, in continuous read mode, Command Byte[C2] =1, the temperature value register can be read from continuously. The master sends 16 clock pulses on SCLK , and the temperature value is clocked out on DOUT.

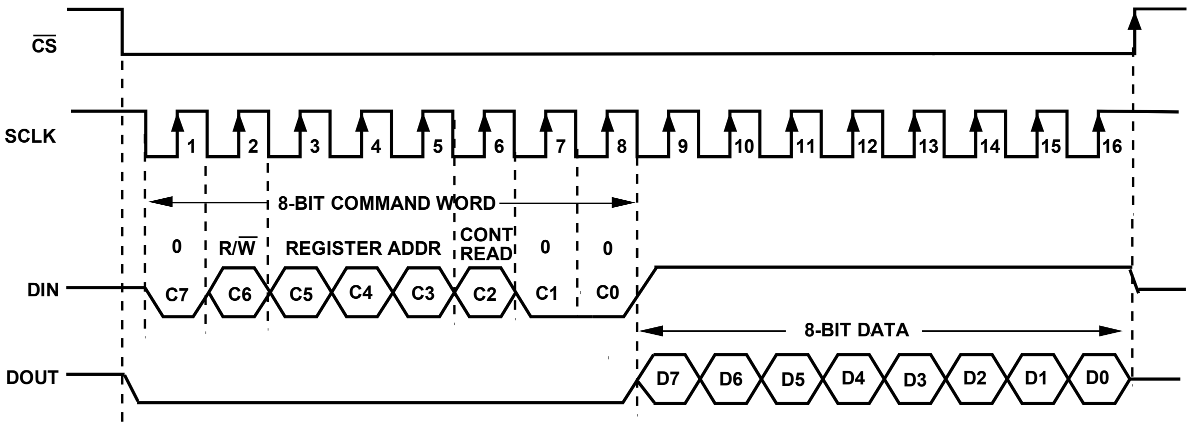


Figure 18/ Read from an 8-bit Register

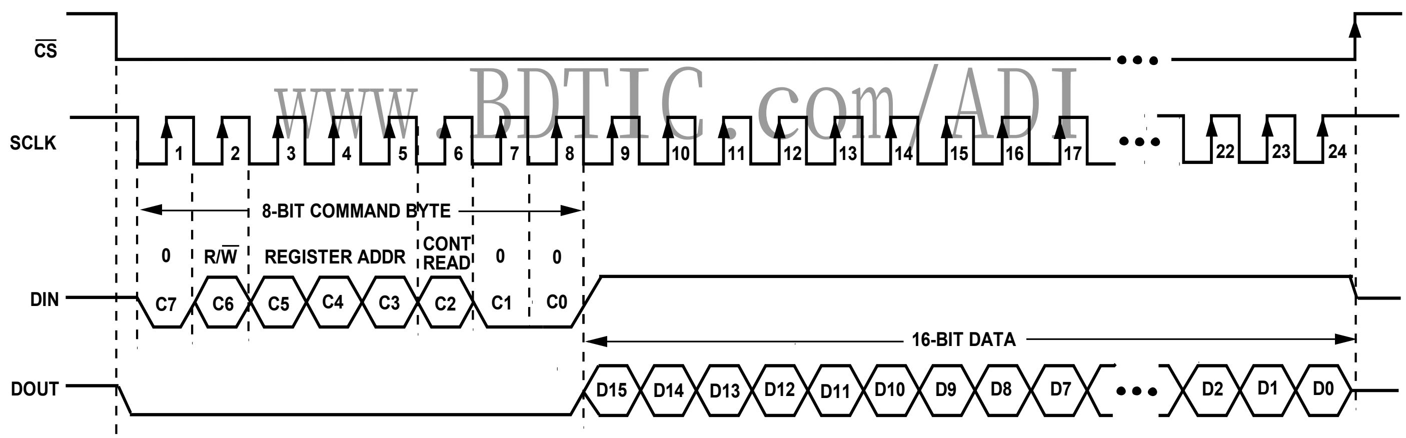


Figure 19. Read from a 16-bit Register

Interfacing to DSPs or Microcontrollers

The ADT7412 can be operated with $\overline{CS}$ used as a frame synchronization signal. This scheme is useful for DSP interfaces. In this case, the first bit (MSB) is effectively clocked out by $\overline{CS}$, because $\overline{CS}$ normally occurs after the falling edge of SCLK in DSPs. SCLK can continue to run between data transfers, provided the timing numbers are obeyed

$\overline{CS}$ can be tied to ground, and the serial interface operated in a 3-wire mode. DIN, DOUT and SCLK are used to communicate with the ADT7310 in this mode.

For microcontroller interfaces, it is recommended that SCLK idles high between data transfers.

Serial Interface Reset

The serial interface can be reset by writing a series of 1s on the DIN input. If a Logic 1 is written to the ADT7310 line for at least 32 serial clock cycles, the serial interface is reset. This ensures that the interface can be reset to a known state if the interface gets lost due to a software error or some glitch in the system. Reset returns the interface to the state in which it is expecting a write to the communications register. This operation resets the contents of all registers to their power-on values. Following a reset, the user should allow a period of 500 μs before addressing the serial interface.

INT & CT OUTPUTS

The INT and CT pins are open drain, and require a pull-up resistor to Vcc .By default, these outputs operate as active low. It is possible to change them to active high operation by writing to the configuration register bit 2 for the CT pin , and bit 3 for the INT pin. Note that, when operated in active high mode, the CT and INT pins should be pull-up to V_{CC} through a large resistor, for example 50kΩ, to minimize current drain.

INT OVERTEMPERATURE MODES

The ADT7310 INT pin has two temperature interrupt modes, comparator mode and interrupt mode. The comparator mode is the default power-up overtemperature mode. The INT output pin becomes active when the temperature is greater than the temperature stored in the T_{HIGH} setpoint register or less than the temperature stored in the T_{LOW} setpoint register. How this pin reacts after this event depends on the overtemperature mode selected.

Figure 20 illustrates the comparator and interrupt modes for events exceeding the T_{HIGH} limit with both pin polarity settings.

Figure 21 illustrates the comparator and interrupt modes for events exceeding the T_{LOW} limit with both pin polarity settings.

Comparator Mode

In comparator mode, the INT pin returns to its inactive status when the temperature measured drops below the $T_{HIGH} - T_{HYST}$ limit or rises above the $T_{LOW} + T_{HYST}$ limit.

Putting the ADT7310 into shutdown mode does not reset the INT state in comparator mode.

Interrupt Mode

In interrupt mode, the INT pin goes inactive when any ADT7310 register is read. Once the INT pin is reset, it goes active again only when the temperature is greater than the temperature stored in the T_{HIGH} setpoint register or less than the temperature stored in the T_{LOW} setpoint register.

Placing the ADT7310 into shutdown mode resets the INT pin in the interrupt mode.

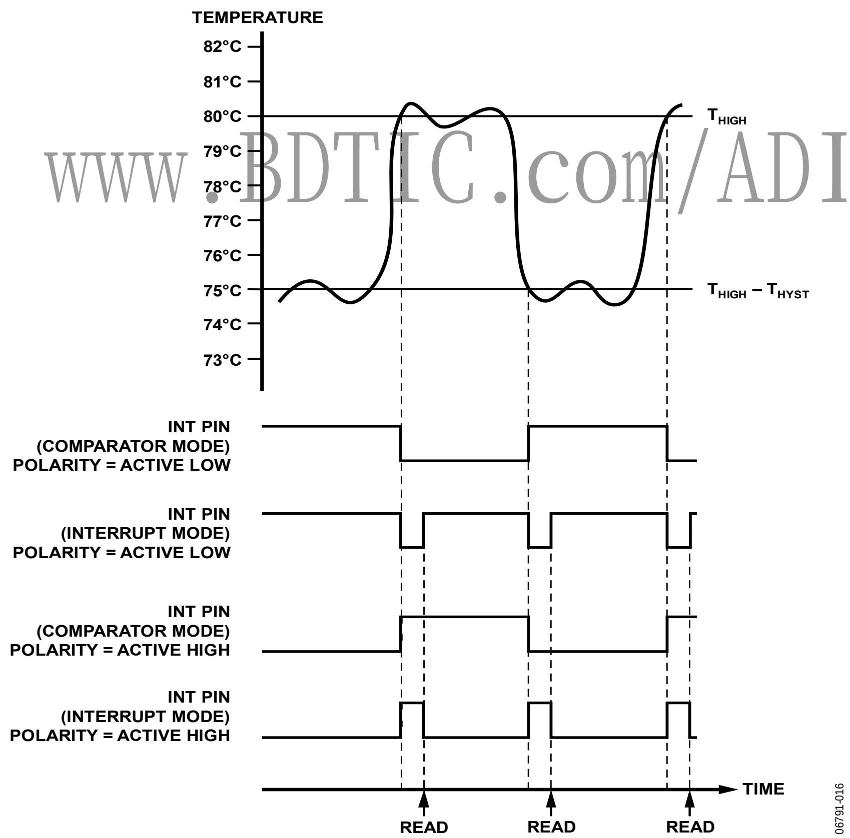


Figure 20. INT Output Temperature Response Diagram for T_{HIGH} Overtemperature Events

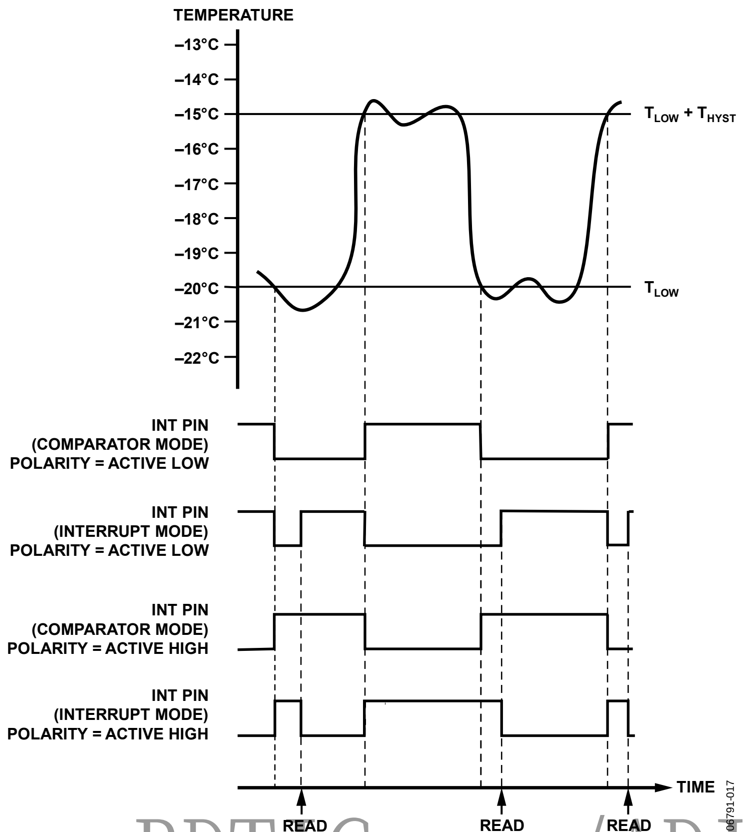


Figure 21. INT Output Temperature Response Diagram for T_{LOW} Overtemperature Events

APPLICATION INFORMATION

THERMAL RESPONSE TIME

The time required for a temperature sensor to settle to a specified accuracy is a function of the thermal mass of the sensor and the thermal conductivity between the sensor and the object being sensed. Thermal mass is often considered equivalent to capacitance. Thermal conductivity is commonly specified using the symbol Q, and can be thought of as thermal resistance. It is commonly specified in units of degrees per watt of power transferred across the thermal joint. Thus, the time required for the ADT7310 to settle to the desired accuracy is dependent on the package selected, the thermal contact established in that particular application, and the equivalent power of the heat source. In most applications, the settling time is best determined empirically.

SUPPLY DECOUPLING

The ADT7310 should be decoupled with a 0.1 µF ceramic capacitor between V_{DD} and GND. This is particularly important when the ADT7310 is mounted remotely from the power supply. Precision analog products, such as the ADT7310, require a well-filtered power source.

Because the ADT7310 operates from a single supply, it may seem convenient to tap into the digital logic power supply. Unfortunately, the logic supply is often a switch-mode design, which generates noise in the 20 kHz to 1 MHz range. In addition, fast logic gates can generate glitches hundreds of millivolts in amplitude due to wiring resistance and inductance.

If possible, the ADT7310 should be powered directly from the system power supply. This arrangement, shown in Figure 22, isolates the analog section from the logic switching transients. Even if a separate power supply trace is not available, generous supply bypassing reduces supply-line induced errors. Local supply bypassing consisting of a 0.1 µF ceramic capacitor is critical for the temperature accuracy specifications to be achieved. This decoupling capacitor must be placed as close as possible to the ADT7310 V_{DD} pin.

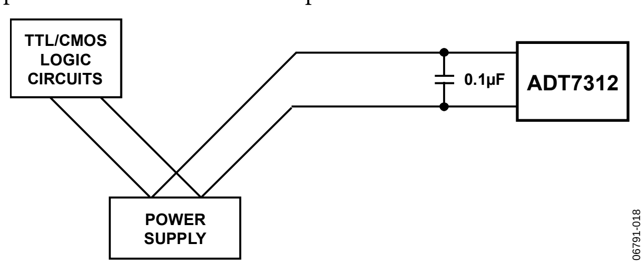


Figure 22. Use Separate Traces to Reduce Power Supply Noise

TEMPERATURE MONITORING

The ADT7310 is ideal for monitoring the thermal environment within hazardous automotive applications. The die accurately reflects the exact thermal conditions that affect nearby integrated circuits.

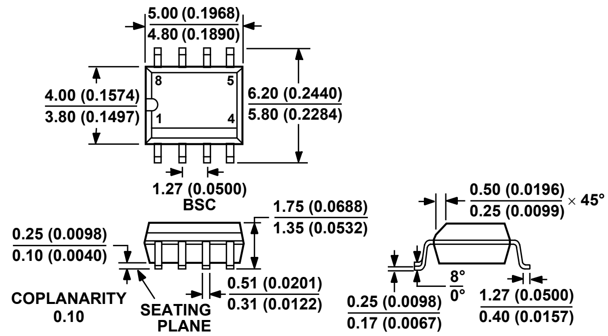
The ADT7310 measures and converts the temperature at the surface of its own semiconductor chip. When the ADT7310 is used to measure the temperature of a nearby heat source, the thermal impedance between the heat source and the ADT7310 must be considered. Often, a thermocouple or other temperature sensor is used to measure the temperature of the source, while the temperature is monitored by reading back from the ADT7310 temperature value register.

Once the thermal impedance is determined, the temperature of the heat source can be inferred from the ADT7310 output. As much as 60% of the heat transferred from the heat source to the thermal sensor on the ADT7310 die is discharged via the copper tracks and the bond pads. Of the pads on the ADT7310, the GND pad transfers most of the heat. Therefore, to measure the temperature of a heat source, it is recommended that the thermal resistance between the ADT7310 GND pad and the GND of the heat source is reduced as much as possible.

For example, use the unique properties of the ADT7310 to monitor a high power dissipation microprocessor. The ADT7310 should be mounted as close as possible to the microprocessor with wide track connection to the GND plane of the microprocessor. The ADT7310 produces a linear temperature output without requiring any external characterization.

It is not recommended to operate the device at temperatures between+125°C and +150°C for more than a total of 5000 hours. It is also not recommended to operate the device at temperatures between +150°C and +175°C for more than 100 hours. Any exposure beyond these limits or above +175°C affects device reliability.

OUTLINE DIMENSIONS



COMPLIANT TO JEDEC STANDARDS MS-012-AA

CONTROLLING DIMENSIONS ARE IN MILLIMETERS; INCH DIMENSIONS (IN PARENTHESES) ARE ROUNDED-OFF MILLIMETER EQUIVALENTS FOR REFERENCE ONLY AND ARE NOT APPROPRIATE FOR USE IN DESIGN

Figure 23. 8-Lead Standard Small Outline Package [SOIC_N]
(R-8)
Dimensions shown in millimeters

ORDERING GUIDE

Model	Temperature Range	Temperature Accuracy[1]	Package Description	Package Option
ADT7310Z[2]	–55°C to +125°C	±0.5°C	8-Lead SOIC_N	R-8

[1] Temperature accuracy is over the 0°C to +70°C temperature range.
[2] Z = RoHS Compliant Part.

NOTES

PR07789-0-9/08(PrA)