NCT214

±1°C Temperature Monitor with Series Resistance Cancellation

The NCT214 is a dual-channel digital thermometer and undertemperature/overtemperature alarm, intended for use in PCs and thermal management systems. It is register-compatible with the ADM1032 and ADT7461. A feature of the NCT214 is series resistance cancellation, where up to 1.5 kΩ (typical) of resistance in series with the temperature monitoring diode can be automatically cancelled from the temperature result, allowing noise filtering. The NCT214 has a configurable ALERT outputon the same bus.

An ALERT

output signals when the on-chip or remote temperature is out of range. The THERM output is a comparator output that allows on/off control of a cooling fan. The ALERT output can be reconfigured as a second THERM output, if required.

Features

- On-chip and Remote Temperature Sensor
- 0.25°C Resolution/1°C Accuracy on Remote Channel
- 1°C Resolution/1°C Accuracy on Local Channel
- Series Resistance Cancellation Up to 1.5 kΩ
- Extended, Switchable Temperature Measurement Range 0°C to +127°C (Default) or –64°C to +191°C
- Register-compatible with ADM1032 and ADT7461
- 2-wire SMBus/I^{2}C Serial Interface with SMBus Alert Support
- Programmable Over/Undertemperature Limits
- Offset Registers for System Calibration
- Up to Two Overtemperature Fail-safe THERM Outputs
- 240 μA Operating Current, 5 μA Standby Current
- This Device is Pb-Free, Halogen Free and is RoHS Compliant

Applications

- Desktop and Notebook Computers
- Industrial Controllers
- Smart Batteries
- Automotive
- Embedded Systems

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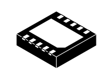

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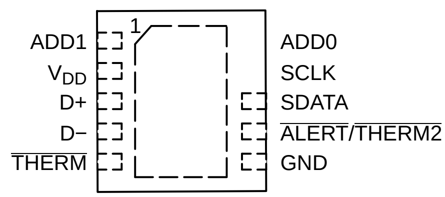
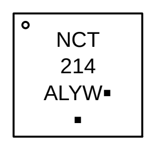
PIN ASSIGNMENT



(Top View)

MARKING DIAGRAM



NCT214 = Specific Device Code
A = Assembly Location
L = Wafer Lot
Y = Year
W = Work Week
▪ = Pb-Free Package

(Note: Microdot may be in either location)

ORDERING INFORMATION

See detailed ordering and shipping information in the package dimensions section on page 18 of this data sheet.

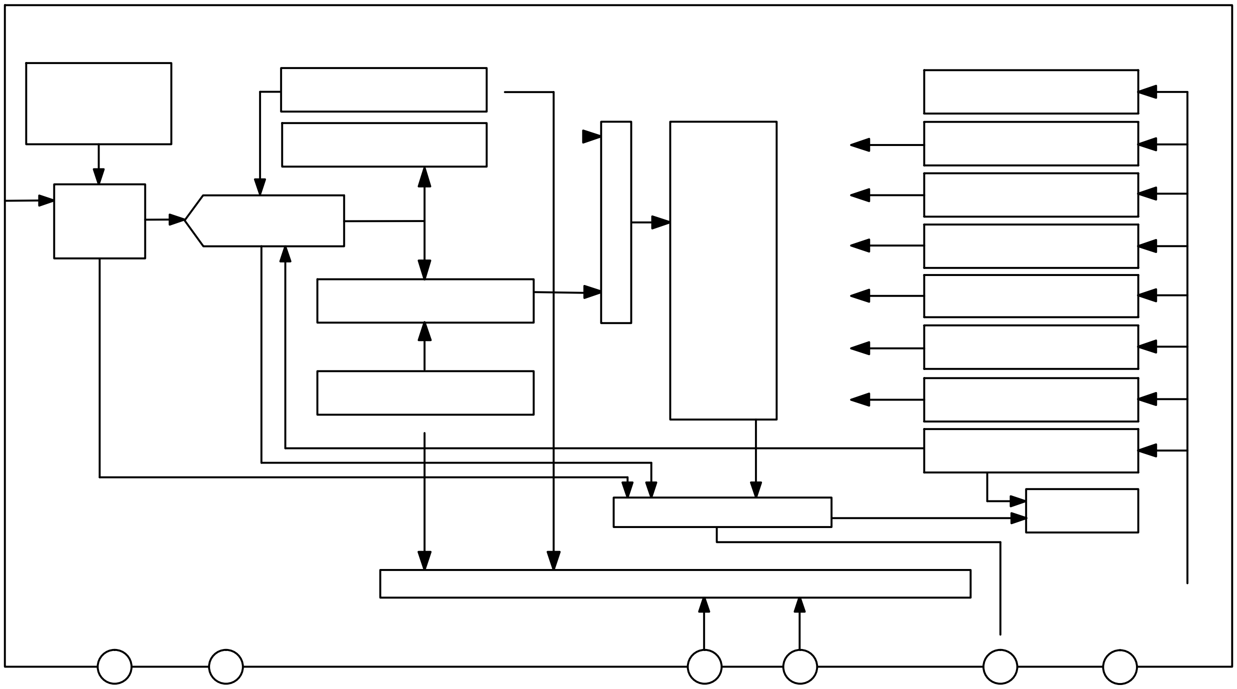


Figure 1. Functional Block Diagram

Table 5. ELECTRICAL CHARACTERISTICS (T_A = −40°C to +125°C, V_{DD} = 3.0 V to 3.6 V, unless otherwise noted)

Parameter	Conditions	Min	Typ	Max	Unit
Power Supply					
Supply Voltage, V_{DD}		3.0	3.30	3.6	V
Average Operating Supply Current, I_{DD}	0.0625 Conversions/Sec Rate (Note 1) Standby Mode	− −	240 5.0	350 30	µA
Undervoltage Lockout Threshold	V_{DD} Input, Disables ADC, Rising Edge	−	2.55	−	V
Power-on Reset Threshold		1.0	−	2.5	V
Temperature-to-Digital Converter					
Local Sensor Accuracy	0°C ≤ T_A ≤ +70°C 0°C ≤ T_A ≤ +85°C −40°C ≤ T_A ≤ +100°C	− − −	− − −	±1.0 ±1.5 ±2.5	°C
Resolution		−	1.0	−	°C
Remote Diode Sensor Accuracy	0°C ≤ T_A ≤ +70°C, −55°C ≤ T_D (Note 2) ≤ +150°C 0°C ≤ T_A ≤ +85°C, −55°C ≤ T_D (Note 2) ≤ +150°C −40°C ≤ T_A ≤ +100°C, −55°C ≤ T_D (Note 2) ≤ +150°C	− − −	− − −	±1.0 ±1.5 ±2.5	°C
Resolution		−	0.25	−	°C
Remote Sensor Source Current	High Level (Note 3) Middle Level (Note 3) Low Level (Note 3)	− − −	220 82 13.5	− − −	µA
Conversion Time	From Stop Bit to Conversion Complete, One-shot Mode with Averaging Switched On	−	40	52	ms
	One-shot Mode with Averaging Off (that is, Conversion Rate = 16-, 32-, or 64-conversions per Second)	−	6.0	8.0	ms
Maximum Series Resistance Cancelled	Resistance Split Evenly on both the D+ and D– Inputs	−	1.5	−	kΩ
Open-drain Digital Outputs ($\overline{\text{THERM}}$, $\overline{\text{ALERT}}$/THERM2)					
Output Low Voltage, V_{OL}	I_{OUT} = −6.0 mA	−	−	0.4	V
High Level Output Leakage Current, I_{OH}	$V_{OUT} = V_{DD}$	−	0.1	1.0	µA
SMBus/I²C Interface (Note 3 and 4)					
Logic Input High Voltage, V_{IH} SCLK, SDATA		1.4	−	−	V
Logic Input Low Voltage, V_{IL} SCLK, SDATA		−	−	0.8	V
Hysteresis		−	500	−	mV
SDA Output Low Voltage, V_{OL}		−	−	0.4	mA
Logic Input Current, I_{IH}, I_{IL}		−1.0	−	+1.0	µA
SMBus Input Capacitance, SCLK, SDATA		−	5.0	−	pF
SMBus Clock Frequency		−	−	400	kHz
SMBus Timeout (Note 5)	User Programmable	−	25	64	ms
SCLK Falling Edge to SDATA Valid Time	Master Clocking in Data	−	−	1.0	µs

1. See Table 9 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/I²C Timing Specifications section for more information.
5. Disabled by default. Detailed procedures to enable it are in the Serial Bus Interface section of the datasheet.

TYPICAL PERFORMANCE CHARACTERISTICS

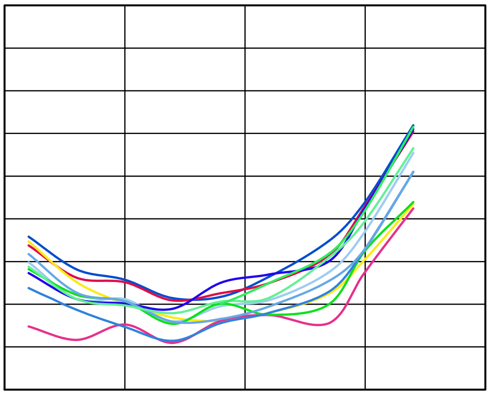


Figure 3. Local Temperature Error vs. Temperature

Figure 4. Remote Temperature Error vs. Actual Temperature

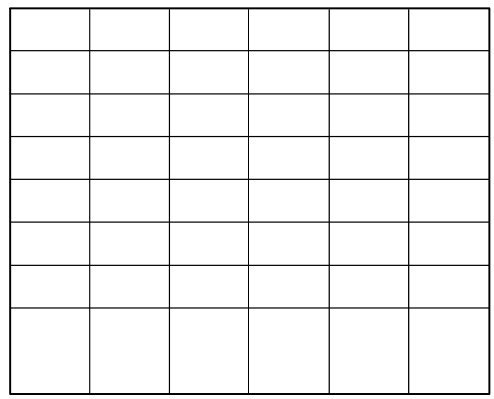
Figure 5. Temperature Error vs. D+/D− Leakage Resistance

Figure 6. Temperature Error vs. D+/D− Capacitance

Figure 7. Operating Supply Current vs. Conversion Rate

Figure 8. Operating Supply Current vs. Voltage

TYPICAL PERFORMANCE CHARACTERISTICS (Cont'd)



Theory of Operation

The NCT214 is a local and remote temperature sensor and

Figure 14. Input Signal Conditioning

Conversion Rate Register

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 10. STATUS REGISTER BIT ASSIGNMENTS

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

1. These flags stay high until the status register is read or they are reset by POR unless Pin 7 is configured as $\overline{\text{THERM2}}$. Then, only Bit 2 remains high until the status register is read or is reset by POR.

Offset Register

Offset errors can be introduced into the remote temperature measurement by clock noise or when the thermal diode is 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 Register 0x11 (high byte) and Register 0x12 (low byte, left justified). Only the upper two bits of Register 0x12 are used. The MSB of Register 0x11 is the sign bit. The minimum, programmable offset is −128°C, and the maximum is +127.75°C. The value in the offset register is added to, or subtracted from, the measured value of the remote temperature.

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

Table 11. SAMPLE OFFSET REGISTER CODES

Offset Value	0x11	0x12
−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

the data transfer, that is, whether data is 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 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 writes to the slave device. If the R/$\overline{\text{W}}$ bit is a 1, the master reads 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 can 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 pulls the data line high during the tenth clock pulse to assert a stop condition. In read mode, the master device overrides the acknowledge bit by pulling the data line high during the low period before the ninth clock pulse. This is known as no acknowledge. The master takes the data line low during the low period before the tenth clock pulse, then high during the tenth clock pulse to assert a stop condition.

Any number of bytes of data are transferable 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

Figure 20 shows how THERM and THERM2 operate together to implement two methods of cooling the system. In this example, the THERM2 limits are set lower than the THERM limits. The THERM2 output is used to turn on a fan. If the temperature continues to rise and exceeds the THERM limits, the THERM output provides additional cooling by throttling the CPU.

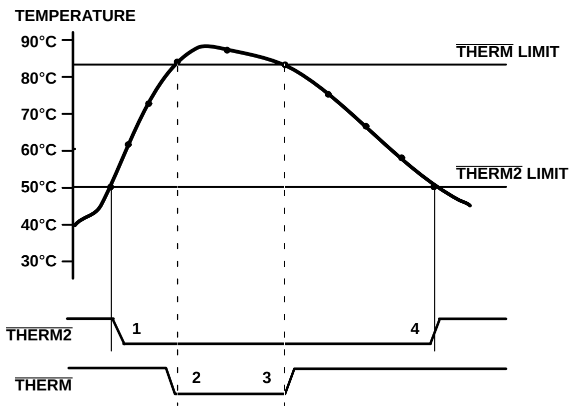


Figure 20. Operation of the THERM and THERM2 Interrupts

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

Both the external and internal temperature measurements cause THERM and THERM2 to operate as described.

Application Information

Noise Filtering

For temperature sensors operating in noisy environments, the industry standard 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 1,000 pF. Although this capacitor reduces the noise, it does not eliminate it, making it difficult to use the sensor in a very noisy environment.

The NCT214 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 NCT214 and the remote temperature sensor to operate in noisy environments. Figure 21 shows a low-pass R-C-R filter, where R = 100 Ω and C = 1 nF. This filtering reduces both common-mode and differential noise.

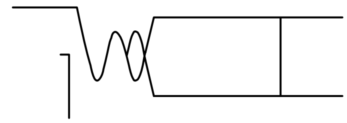


Figure 21. Filter between Remote Sensor and NCT214 Factors Affecting Diode Accuracy

- Small variation in h_{FE} (50 to 150) that indicates tight control of V_{BE} characteristics

Transistors, such as the 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. Many factors can affect this. Ideally, place the sensor 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 causes 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 is either a substrate transistor in the processor or a small package device, such as the SOT−23, placed in close proximity to it.

The on-chip sensor, however, is often remote from the processor and only monitors the general ambient temperature around the package. How accurately the temperature of the board and/or the forced airflow reflects the temperature to be measured dictates the accuracy of the measurement. Self-heating due to the power dissipated in the NCT214 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 NCT214, 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.

Layout Considerations

Digital boards can be electrically noisy environments, and the NCT214 is measuring very small voltages from the remote sensor, so care must be taken to minimize noise induced at the sensor inputs. Take the following precautions:

- Place the NCT214 as close as possible to the remote sensing diode. Provided that the worst noise sources, that is, 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 pickup, 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 μV, and thermocouple voltages are about 3 μV/°C of temperature difference. Unless there are two thermocouples with a big temperature differential between them, thermocouple voltages should be much less than 200 μV.
- Place a 0.1 μF bypass capacitor close to the V_{DD} pin. In extremely noisy environments, place an input filter capacitor across D+ and D− close to the NCT214. This capacitance can effect the temperature measurement, so ensure that any capacitance seen at D+ and D− is, at maximum, 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. A total of 6 feet to 12 feet is needed.
  For really long distances (up to 100 feet), use a shielded twisted pair, such as the Belden No. 8451 microphone cable. Connect the twisted pair to D+ and D− and the shield to GND close to the NCT214. Leave the remote end of the shield unconnected to avoid ground loops.

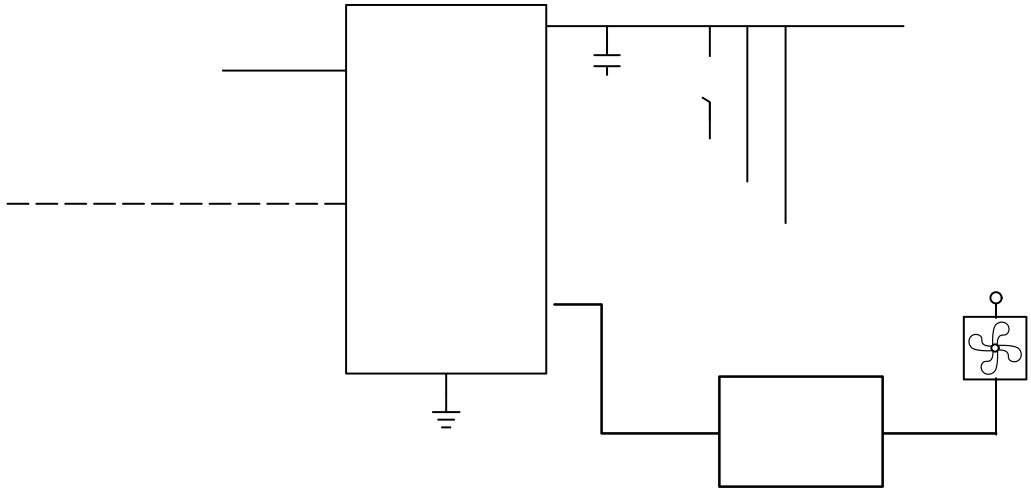


Figure 23. Typical Application Circuit

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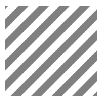
ISSUE A

DATE 02 JUL 2007

NOTES:
1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M, 1994.
2. CONTROLLING DIMENSION: MILLIMETERS.
3. DIMENSION b APPLIES TO PLATED TERMINAL AND IS MEASURED BETWEEN 0.15 AND 0.30mm FROM TERMINAL.
4. COPLANARITY APPLIES TO THE EXPOSED PAD AS WELL AS THE TERMINALS.



SEATING PLANE