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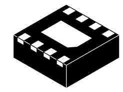
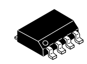
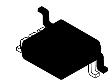


DFN8
CASE 506AA

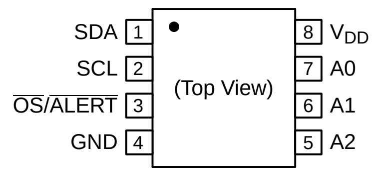


SOIC8
CASE 751

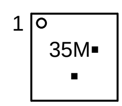


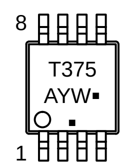
Micro8™
CASE 846A

PIN ASSIGNMENT

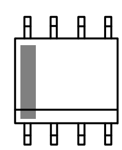


MARKING DIAGRAMS





M = Date Code
A = Assembly Location
Y = Year
W = Work Week
▪ = Pb-Free Package



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

The NCT375 is a two-wire serially programmable temperature sensor with an over-temperature/interrupt output pin to signal out of limit conditions. This is an open-drain pin and can operate in either comparator or interrupt mode. Temperature measurements are converted into digital form using a high resolution (12 bit), sigma-delta, analog-to-digital converter (ADC). The device operates over the –55°C to +125°C temperature range.

Communication with the NCT375 is accomplished via the SMBus/I^{2}C interface. Three address selection pins, A2, A1 and A0, can be used to connect up to 8 NCT375s to a single bus. Through this interface the NCT375s internal registers may be accessed. These registers allow the user to read the current temperature, change the configuration settings and adjust the temperature limits.

The NCT375 has a wide supply voltage range of 3.0 V to 5.5 V. The average supply current is 575 μA at 3.3 V. It also offers a shutdown mode to conserve power. The typical shutdown current is 3 μA.

The NCT375 is available in three, space saving packages – 8-lead DFN, 8-lead Micro8™ and 8-lead SOIC and is also fully pin and register compatible with the NCT75, LM75 and TCN75.

Features

- 12-bit Temperature-to-Digital Converter
- Input Voltage Range from 3.0 V to 5.5 V
- Temperature Range from 55°C to +125°C
- SMBus/I^{2}C Interface
- Overtemperature Indicator
- Support for SMBus/ALERT
- Shutdown Mode for Low Power Consumption
- One-shot Mode
- Available in 8-pin DFN, 8-pin Micro8™ and SOIC Packages
- These Devices are Pb-Free, Halogen Free/BFR Free and are RoHS Compliant

Applications

- Computer Thermal Monitoring
- Thermal Protection
- Isolated Sensors
- Battery Management
- Office Electronics
- Electronic Test Equipment
- Thermostat Controls
- System Thermal Management

ORDERING INFORMATION

See detailed ordering and shipping information in the package dimensions section on page 13 of this data sheet.

Table 2. ABSOLUTE MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Supply Voltage	V_{DD}	−0.3 to +7	V
Input Voltage on SCL, SDA, A2, A1, A0 and $\overline{\text{OS}}/\overline{\text{ALERT}}$.		−0.3 to V_{DD} + 0.3	V
Input Current on SDA, A2, A1, A0 and $\overline{\text{OS}}/\overline{\text{ALERT}}$.	I_{IN}	−1 to +50	mA
Maximum Junction Temperature	$T_{J(max)}$	150.7	°C
Operating Temperature Range	T_{OP}	−55 to 125	°C
Storage Temperature Range	T		

Table 5. ELECTRICAL CHARACTERISTICS
($T_A = T_{MIN}$ to T_{MAX}, V_{DD} = 3.0 V to 5.5 V. All specifications for −55°C to +125°C, unless otherwise noted.)

Parameter	Test Conditions	Min	Typ	Max	Unit
TEMPERATURE SENSOR AND ADC					
Accuracy at V_{DD} = 3.0 V to 5.5 V	T_A = 0°C to +70°C T_A = −25°C to +100°C T_A = −55°C to +125°C	– – –	– – –	±1 ±2 ±3	°C
ADC Resolution		–	12	–	Bits
Temperature Resolution		–	0.0625	–	°C
Temperature Conversion Time	One-shot Mode	–	48.5	–	ms
Update Rate		–	80	–	ms
POWER REQUIREMENTS					
Supply Voltage		3.0	–	5.5	V
POR Threshold		2.75	–	–	V
Supply Current	Peak Current while Converting and I^2C Interface Inactive	–	–	0.8	mA
Average Current	Average Current over 1 Conversion Cycle	–	0.44	0.575	mA
Shutdown Mode at 3.3 V	Supply Current in Shutdown Mode	–	3	12	μA
$\overline{OS/ALERT}$ OUTPUT (OPEN DRAIN)					
Output Low Voltage, V_{OL}	I_{OL} = 4 mA	–	0.15	0.4	V
Pin Capacitance		–	10	–	pF
High Output Leakage Current, IOH	$\overline{OS/ALERT}$ Pin Pulled Up to 5.5 V	–	0.1	5	μA
DIGITAL INPUTS (SDA, SCL)					
Input Current	V_{IN} = 0 V to V_{DD}	–	–	1	μA
Input Low Voltage, V_{IL}	V_{DD} = 3.3 V (Note 3)	–	–	0.3 x V_{DD}	V
Input High Voltage, V_{IH}	V_{DD} = 3.3 V (Note 3)	0.7xV_{DD}	–	–	V
SCL, SDA Glitch Rejection	Input Filtering Suppresses Noise Spikes of Less than 50 ns	–	–	50	ns
Pin Capacitance		–	3	–	pF
DIGITAL OUTPUT (SDA) (OPEN DRAIN)					
Output High Current, I_{OH}	V_{OH} = 5 V	–	–	1	μA
Output Low Voltage, V_{OL}	I_{OL} = 3 mA	–	–	0.4	V
Output Capacitance, C_{OUT}		–	3	–	pF

Product parametric performance is indicated in the Electrical Characteristics for the listed test conditions, unless otherwise noted. Product performance may not be indicated by the Electrical Characteristics if operated under different conditions.

3. Guaranteed by characterization, not production tested.

APPLICATION INFORMATION

Functional Description

The NCT375 temperature sensor converts an analog temperature measurement to a digital representation by using an on-chip measurement transistor and a 12 bit Delta-Sigma ADC.

The device includes an open drain $\overline{\text{ALERT}}$ output which can be used to signal that the programmed temperature limit has been exceeded.

The two main modes of operation are normal and shutdown mode. In normal mode the NCT375 performs a new temperature conversion every 80 ms. This new value is then updated to the temperature value register (address 0x00) and also compared to the T_{OS} register limit (default = 80°C). If the temperature value register is read during the conversion sequence the value returned is the previously stored value. A bus read does not affect the conversion that is in progress.

In shutdown mode temperature conversion is disabled and the temperature value register holds the last valid temperature reading. The NCT375 can still be communicated with in this mode as the interface is still active. The device mode is controlled via bit 0 of the configuration register.

While in shutdown mode a conversion can be initiated by writing an arbitrary value to the one-shot register (0x04). This has the effect of powering up the NCT375, performing a conversion, comparing the new temperature with the programmed limit and then going back into shutdown mode.

The $\overline{\text{OS}}$/$\overline{\text{ALERT}}$ pin can be configured in many ways to allow it to be used in many different system configurations.

The overtemperature output can be configured to operate as a comparator type output (which is self clearing once the temperature has returned below the hysteresis value) or an interrupt type output (which requires the master to read an internal register AND the temperature to return below the hysteresis value before going into an inactive state). The $\overline{\text{ALERT}}$ pin can also be configured as an active high or active low output.

Temperature Measurement Results

The results of the on chip temperature measurements are stored in the temperature value register and compared with the T_{OS} and T_{HYST} limit register.

The temperature value, T_{OS} and T_{HYST} registers are 16 bits wide and have a resolution of 0.0625°C. The data is stored as a 12 bit 2s complement word. The data is left justified, D15 is the MSB and is the sign bit. The four LSBs (D3 to D0) are always 0 as they are not part of the result.

While the ADC of the NCT375 can theoretically measure temperatures in the range of 128°C to 127°C, the NCT375 is guaranteed to measure from 55°C to +125°C.

Table 6 shows the relevant temperature bits for a 12 bit temperature reading. A 2-byte read is required to obtain the full 12 bit temperature reading. If an 8 bit (1°C resolution) reading is required then a single byte read is sufficient.

Table 6. 12-BIT TEMPERATURE DATA FORMAT

Temperature	Binary Value D15 to D4	Hex Value
−55°C	1100 1001 0000	0xC90
−25°C	1110 0111 0000	0xE70
−0.0625°C	1111 1111 1111	0xFFF
0°C	0000 0000 0000	0x000
+0.0625°C	0000 0000 0001	0x001
+25°C	0001 1001 0000	0x190
+75.25°C	0100 1011 0100	0x4B4
+100°C	0110 0100 0000	0x640
+125°C	0111 1101 0000	0x7D0

Temperature Data Conversion

12-bit Temperature Data Format

Positive Temperature = ADC Code (decimal)/16
Example 190h = 400d/16 = +25°C

Negative Temperature = (ADC Code(decimal) 4096)/16
Example E70h = (3696d – 4096)/16 = 25°C

One-shot Mode

One of the features of the NCT375 is a One-shot Temperature Measurement Mode. This mode is useful if reduced power consumption is a design requirement.

To enable one-shot mode bit 5 of the configuration register needs to be set. Once, enabled, the NCT375 goes immediately into shutdown mode. Here, the current consumption is reduced to a typical value of 3 μA. Writing address 0x04 to the address pointer register initiates a one-shot temperature measurement. This powers up the NCT375, carries out a temperature measurement, and then powers down again. The data written to this register is irrelevant and is not stored. It is the write operation that causes the one-shot conversion.

Temperature Register

The temperature measured by the parts internal sensor is stored in this 16-bit read only register. The data is stored in twos complement format with the MSB as the sign bit. The 8 MSBs must be read frist followed by the 8 LSBs.

Table 10. TEMPERATURE VALUE REGISTER

MSB LSB

D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
0	0	0	0	0	0										

[redacted]

Table 13. T_{OS} REGISTER

MSB **LSB**

D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
0	1	0	1	0	0	0	0	0	0	0	0	X	X	X	X

Serial Interface

Control of the NCT375 is carried out via the SMBus/I^2C compatible serial interface. The NCT375 is connected to this bus as a slave device, under the control of a master device.

Serial Bus Address

Control of the NCT375 is carried out via the serial bus. The NCT375 is connected to this bus as a slave device under the control of a master device. The NCT375 has a 7-bit serial address. The four MSBs are fixed and set to 1001 while the 3 LSBs can be configured by the user using pins 5, 6 and 7 (A2, A1 and A0). Each of these pins can be configured in one of two ways low or high. This gives eight different address options listed in Table 14 below. The state of these pins is continually sampled and so can be changed after power up.

Table 14. SERIAL BUS ADDRESS OPTIONS

MSBs				LSBs			Address
A6	A5	A4	A3	A2	A1	A0	Hex
1	0	0	1	0	0	0	0x48
1	0	0	1	0	0	1	0x49
1	0	0	1	0	1	0	0x4A
1	0	0	1	0	1	1	0x4B
1	0	0	1	1	0	0	0x4C
1	0	0	1	1	0	1	0x4D
1	0	0	1	1	1	0	0x4E
1	0	0	1	1	1	1	0x4F

The NCT375 also features a SMBus/I^2C timeout function whereby the SMBus/I^2C interface times out after the specified time when there is no activity on the SDA line. After this time, the NCT375 resets the SDA line back to its idle state (high impedance) and waits for the next start condition.

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 SDA, while the serial clock line SCL remains high. This indicates that an address/data stream is going to 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 a read/write ($R/\overline{W}$) bit, which determines the direction of the data transfer i.e. whether data is written to, or read from, the slave device. The peripheral with the address corresponding 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 $R/\overline{W}$ bit is a zero then the master writes to the slave device. If the $R/\overline{W}$ bit is a one then the master reads from the slave device.
2. Data is sent over the serial bus in sequences of nine clock pulses, eight bits of data followed by an acknowledge bit from the receiver of data. 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.
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 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.

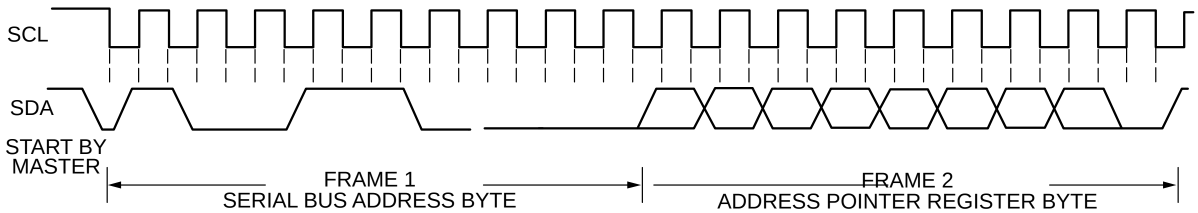
Any number of bytes of data can be transferred over the serial bus in one operation. However, it is not possible to mix read and write in one operation because the type of operation is determined at the beginning and cannot subsequently be changed without starting a new operation.

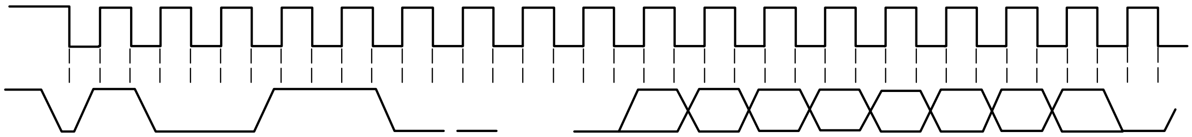
Writing Data

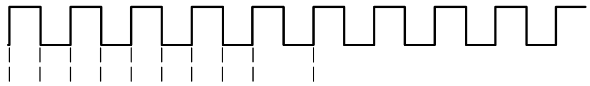
There are two types of writes used in the NCT375:

Setting up the Address Pointer Register for a Register Read

To read data from a particular register, the address pointer register must hold the address of the register being read. To configure the address pointer register a single write operation (shown in Figure 5). It consists of the device address


SCL
SDA
START BY
MASTER
FRAME 1
SERIAL BUS ADDRESS BYTE
FRAME 2
ADDRESS POINTER REGISTER BYTE





Reading Data

Reading data from the NCT375 is done in two different ways depending on the register being read. The configuration register is only 8 bits wide so a single byte read is used for this (shown in Figure 8). This consists of the device address followed by the data from the register.

Reading the data in the temperature value register requires a two byte read (shown in Figure 9). This consists of the device address, followed by two bytes of data from the temperature register (the first byte is the MSB). In both cases the address pointer register of the register being read must be written to prior to performing a read operation.

$\overline{\text{OS}}/\overline{\text{ALERT}}$ Output Overtemperature Modes

The $\overline{\text{OS}}/\overline{\text{ALERT}}$ output pin can operate in two different modes – overtemperature mode and SMBus alert mode. The pin defaults to overtemperature mode on power up. This means that it becomes active when the measured temperature meets or exceeds the limit stored in the T_{OS} setpoint register. At this point it can deal with the event in

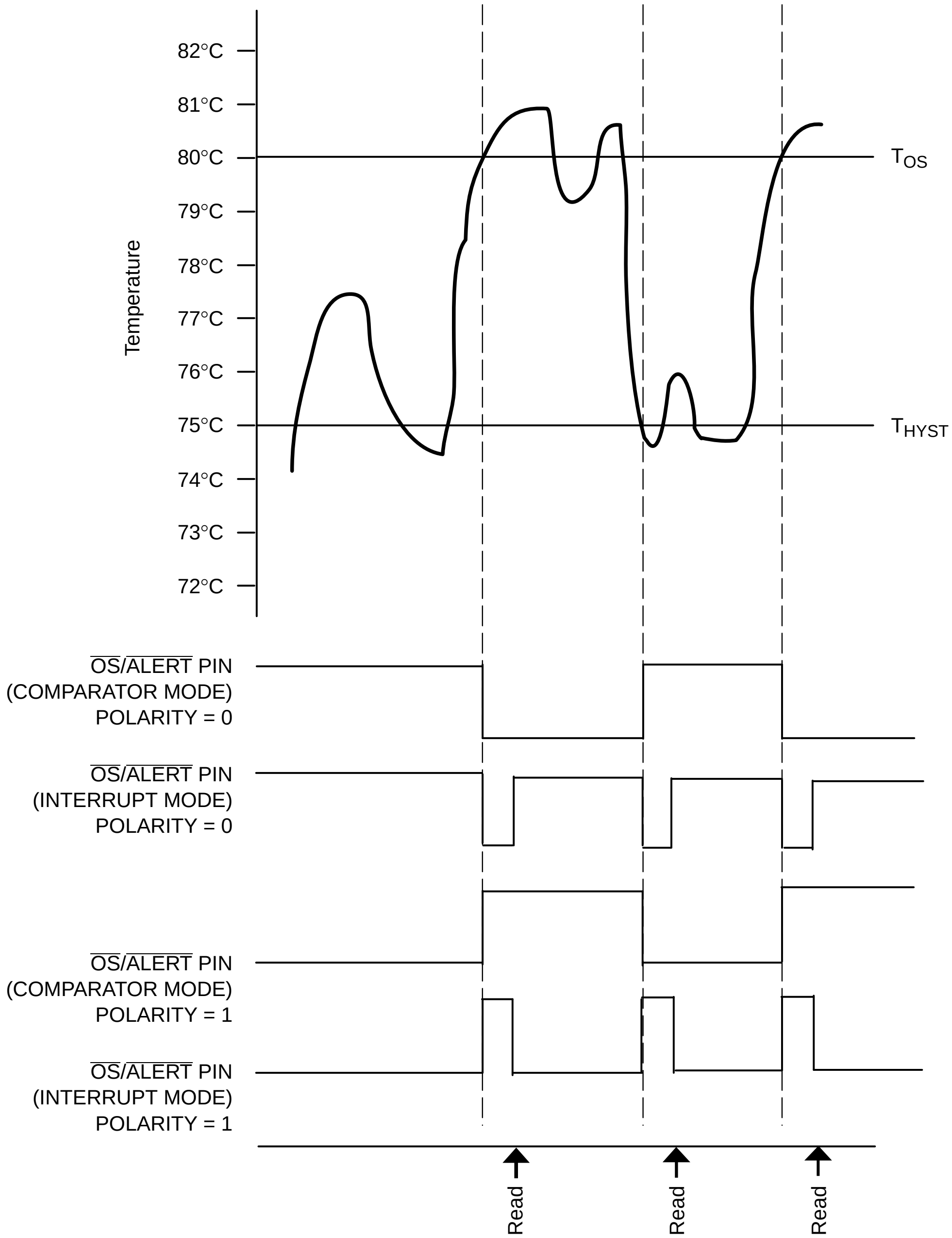


Figure 11. $\overline{OS}/\overline{ALERT}$ Output Temperature Response Diagram

[redacted]MATION

[redacted]perature Range	Temperature Accuracy	Package Description

[redacted]

DFN8 2x2, 0.5P
CASE 506AA
ISSUE F

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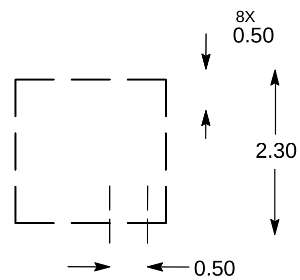
SCALE 4:1

SOLDERING FOOTPRINT*



DIMENSIONS: MILLIMETERS

*For additional information on our Pb−Free strategy and soldering details, please download the **onsemi** Soldering and Mounting Techniques Reference Manual, SOLDERRM/D.