### Industry Standard Digital Temperature Sensor in CSP Package with 2-wire Interface

The NCT475 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  $-55^{\circ}$ C to  $+125^{\circ}$ C temperature range.

Communication with the NCT475 is accomplished via the SMBus/I<sup>2</sup>C interface which is compatible with industry standard protocols. Through this interface the NCT475s 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 NCT475 has a wide supply voltage range of 3.0 V to 5.5 V. The average supply current is 575  $\mu$ A at 3.3 V. It also offers a shutdown mode to conserve power. The typical shutdown current is 3  $\mu$ A.

#### ABSOLUTE MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Supply Voltage	V <sub>DD</sub>	–0.3 to +7	V
Input voltage on SCL, SDA, and A1.		–0.3 V to V <sub>DD</sub> + 0.3 V	V
Input current on SDA and A1.	I <sub>IN</sub>	–1 to +50	mA
Maximum Junction Temperature	T <sub>J(max)</sub>	150.7	°C
Operating Temperature Range	T <sub>OP</sub>	-55 to 125	°C
Storage Temperature Range	T <sub>STG</sub>	-65 to 160	°C
ESD Capability, Human Body Model (Note 2)	ESD <sub>HBM</sub>	2000	V
ESD Capability, Machine Model (Note 2)	ESD <sub>MM</sub>	200	V

Stresses exceeding those listed in the Maximum Ratings table may damage the device. If any of these limits are exceeded, device functionality should not be assumed, damage may occur and reliability may be affected.

1. Refer to ELECTRICAL CHARACTERISTICS and APPLICATION INFORMATION for Safe Operating Area.

This device series incorporates ESD protection and is tested by the following methods: ESD Human Body Model tested per AEC-Q100-002 (EIA/JESD22-A114)

ESD Machine Model tested per AEC-Q100-003 (EIA/JESD22-A115)

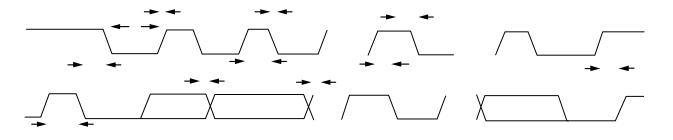
#### **OPERATING RANGES (Note 3)**

Rating		Min	Max	Unit
Operating Input Voltage	V <sub>in</sub>	3.0	5.5	V
Operating Ambient Temperature Range		-55	125	°C

Functional operation above the stresses listed in the Recommended Operating Ranges is not implied. Extended exposure to stresses beyond the Recommended Operating Ranges limits may affect device reliability. 3. Refer to ELECTRICAL CHARACTERISTICS and APPLICATION INFORMATION for Safe Operating Area.

#### SMBUS TIMING SPECIFICATIONS

Parameter	Symbol	Test Conditions	Min	Тур	Max	Unit
Serial Clock Frequency	f <sub>SCL</sub>		DC	-	400	kHz
Start Condition Hold Time	t <sub>HD:STA</sub>		0.6	-	-	μs
Stop Condition Setup Time	t <sub>SU:STO</sub>	90% of SCL to 10% of SDA	100	-	-	ns
Clock Low Period	t <sub>LOW</sub>		1.3	-	-	μs
Clock High Period	t <sub>HIGH</sub>		O.6	-	-	μs
Start Condition Setup Time	t <sub>SU:STA</sub>	90% of SCL to 90% of SDA	100	-	-	ns
Data Setup Time	t <sub>SU:DAT</sub>	10% of SDA to 10% of SCL	100	-	-	ns
Data Hold Time (Note 4)	t <sub>HD:DAT</sub>	10% of SCL to 10% of SDA	0	-	76	ns
SDA/SCL Rise Time	t <sub>R</sub>		-	300	-	ns
SDA/SCL Fall Time	t <sub>F</sub>		-	300	-	ns
Minimum RESET Pulse Width	t <sub>RESET</sub>		1.3	-	-	μs
Bus Free Time Between STOP and START Conditions	t <sub>BUF</sub>		1.3	-	-	μs



#### FUNCTIONAL DESCRIPTION

The NCT475 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 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 NCT475 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 TOS register limit (default =  $80^{\circ}$ 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 NCT475 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 NCT475, performing a conversion, comparing the new temperature with the programmed limit and then going back into shutdown mode.

The OS/ALERT pin can be configured in many ways to allow it to be used in many different system configurations.

The over temperature 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 ALERT pin can also be configured as an active high or active low output.

While the ADC of the NCT475 can

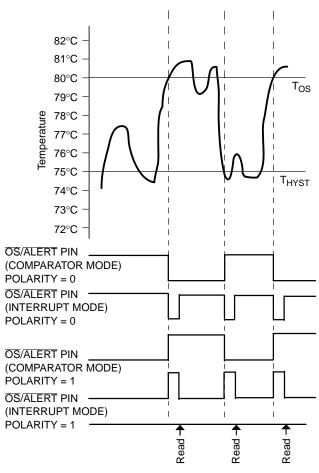


Figure 4. One-shot OS/ALERT Pin Operation

#### FAULT QUEUE

A fault is defined as when the temperature exceeds a pre–defined temperature limit. This limit can be programmed in the  $T_{HYST}$  and the  $T_{OS}$  setpoint registers. Bits 3 and 4 of the configuration register determine the number of faults necessary to trigger the OS/ALERT pin. Up to six faults can be programmed to prevent false tripping when the NCT475 is used in a noisy temperature environment. In order for the OS/ALERT output to be set these faults must occur consecutively.

#### REGISTERS

The NCT475 contains six registers for configuring and reading the temperature: the address pointer register, 4 data registers and a one-shot register. The configuration register, the address pointer register and the one-shot register are all 8 bits wide while the temperature register,  $T_{HYST}$  and  $T_{OS}$  registers are all 16 bits wide. All registers, except for the

temperature register, can be be read from and written to (the temperature register is read only). The power on state and address of each register are listed in Table 4.

#### Address Pointer Register

The address pointer register is used to select which register is to respond to a read or write operation. The three LSBs (P2, P1 & P0) of this write only register are used to select the appropriate register. On power up this register is loaded with a value of 0x00 and so points to the temperature register. Table 2 shows the bits of the address pointer register and Table 3 shows the pointer address selecting each of the registers available.

Table 2. ADDRESS POINTER REGISTER

		P6	P5	P4	P3	P2	P1	P0
Default	0	0	0	0	0	0	0	0

Table 3. REGISTER ADDRESSES SELECTION

P2	P1	P0	Register Selected
0	0	0	Stored Temperature
0	0	1	Configuration
0	1	0	T <sub>HYST</sub> set point
0	1	1	T <sub>OS</sub> set point
1	0	0	One-shot

#### Table 4. NCT475 REGISTER SET

Register		Power–O Val	
Address	Register Name	Hex	°C
0x00 (R)	Stored Temperature Value	0x0000	0
0x01 (R/W)	Configuration	0x00	-
0x02 (R/W)	T <sub>HYST</sub>	0x4B00	75
0x03 (R/W)	T <sub>OS</sub>	0x5000	80
0x04 (R/W)	One-Shot	0xXX	-

#### Temperature Register

The temperature measured by the parts internal sensor is storea Q.9071 re Tc(0x04 (R/W))TjET317.934 29egisn s8ng9()209 r9070

#### Configuration Register

This 8-bit read/write register is used to configure the NCT475 into its various modes of operation. The different modes are listed in Table 6 and explained in more detail below.

#### Table 6. CONFIGURATION REGISTER

	Configuration	Default Value
D7	OS/SMBus Alert	0
D6	Reserved	0
D5	One-shot Mode	0
D4	Fault-queue	0
D3	Fault-queue	0
D2	OS/Alert pin polarity	0
D1	Cmp/Int Mode	0
D0	Shutdown Mode	0

D7: OS/SMBus Alert Mode.

D7 = 0 SMBus alert disabled, pin operates as an over temperature shutdown pin. (Default)

D7 = 1 Enable SMBus alert functionality for the NCT475.

#### D6: Reserved

Write 0 to this bit.

D5: One-Shot Mode

D5 = 0 Part is in normal mode and converting every 60 ms. (Default)

D5 = 1 Setting this bit puts the part into one-shot mode. The part is normally powered down in this mode until the one shot register is written to. Once this register is written to one conversion is performed and the part returns to its shutdown state.

#### D[4:3]: Fault Queue

D4 D3 These two bits determine how many over temperature conditions occur before the OS/Alert pin is triggered. This helps to prevent false triggering of the output.

- 0 = 1 Fault (Default)
- 0 1 = 2 Faults
- 1 0 = 4 Faults
- 2 1 = 6 Faults
- D2: OS/Alert pin polarity

This selects the polarity of the OS/Alert output pin.

D2 = 0 Output is active low. (Default)

D2 = 1 Output is active high.

#### D1: Cmp/Int

D1 = 0 Comparator mode. (Default)

D1 = 1 Interrupt mode.

D0: Shutdown

D0 = 0 Normal mode – part is fully powered. (Default)

D0 = 1 Shutdown mode – all circuitry except for the SMBus interface is powered down. Write a 0 to this bit to power up again.

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#### SERIAL INTERFACE

Control of the NCT475 is carried out via the SMBus/I<sup>2</sup>Ccompatible serial interface. The NCT475 is connected to this bus as a slave device, under the control of a master device.

#### Serial Bus Address

Control of the NCT475 is carried out via the serial bus. The NCT475 is connected to this bus as a slave device under the control of a master device.

There are two NCT475 device options called NCT475A and NCT475B. Each device supports two possible addresses depending on Ball A2 (named A1) is connected high or low. The NCT475 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 Ball A2 (named A1). The ball A2 can be connected to VDD or ground.

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#### READING DATA

Reading data from the NCT475 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.

#### OS/ALERT OUTPUT OVERTEMPERATURE MODES

The OS/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 one of two ways which depends on the mode it is in. The two overtemperature modes are comparatormode and interrupt mode. Comparator is the default mode on power

up. More information on comparator and interrupt modes alsong with the SMBus alert mode are explained below.

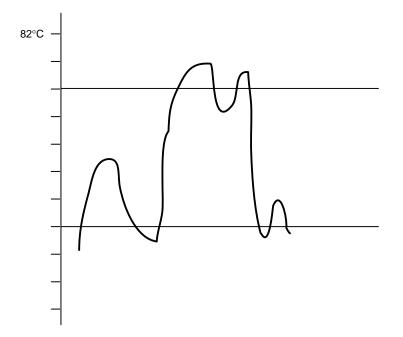
#### **Comparator Mode**

In Comparator Mode, the OS/ALERT pin becomes active when the measured temperature equals or exceeds the limit stored in the  $T_{OS}$  setpoint register. The pin returns to its inactive status when the temperature drops below the  $T_{HYST}$  setpoint register value.

NOTE: Shutdown mode does not reset the output state for comparator mode.

#### Interrupt Mode

In the interrupt mode, the OS/ALERT pin becomes active when the temperature equals or exceeds the  $T_{OS}$  limit for a consecutive number of faults. It can be reset by performing a read operation on any register in the NCT475. The output can only become active again when the  $T_{OS}$  limit has been equalled or exceeded. Figure 11 shows how both the interrupt and comparator modes operate in relation to the output pin (OS/ALERT). It also shows the operation of the polarity in the configuration register.



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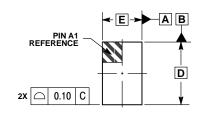
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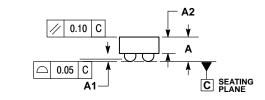
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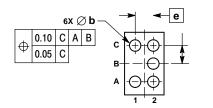
	MILLIMETERS			
DIM	MIN	MAX		
Α		0.60		
A1	0.18	0.22		

b	0.24	0.30	
D	1.355 BSC		
Е	0.845 BSC		
е	0.40 BSC		

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