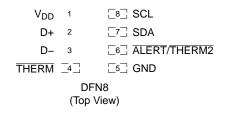
WW = Work Week = Pb-Free Device (Note: Microdot may be in either location)

### **PIN ASSIGNMENTS**



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### **ORDERING INFORMATION**

See detailed ordering and shipping information on page ' this data sheet.

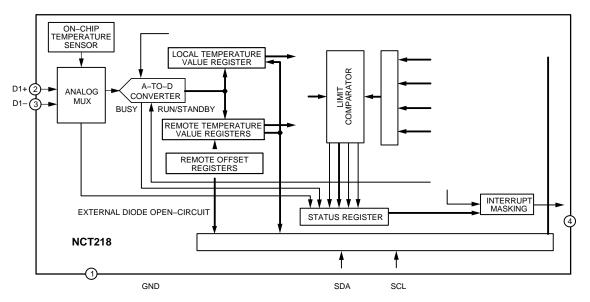


Figure 1. Functional Block Diagram

### Table 2. ABSOLUTE MAXIMUM RATINGS (Note 1)

| Rating                                   | Symbol              | Value                          | Unit |
|--|---------------------|--------------------------------|------|
| Supply Voltage (V <sub>DD</sub> ) to GND | V <sub>DD</sub>     | -0.3, +3                       | V    |
| D+                                       |                     | –0.3 to V <sub>DD</sub> + 0.25 | V    |
| D- to GND                                |                     | -0.3 to +0.6                   | V    |
| SCL, SDA, ALERT, THERM                   |                     | -0.3 to +5.25                  | V    |
| Input current on D-                      |                     | ±1                             | mA   |
| Input current on SDA, THERM              | I <sub>IN</sub>     | -1, +50                        | mA   |
| Maximum Junction Temperature             | T <sub>J(max)</sub> | 150.7                          | °C   |
| Operating Temperature Range              | TOP                 | -40 to 125                     |      |

Table 4. ELECTRICAL CHARACTERISTICS $(T_A = T_{MIN} \text{ to } T_{MAX}, V_{DD} = 1.6 \text{ V to } 2.75 \text{ V}. \text{ All specifications for } -40^{\circ}\text{C to } +125^{\circ}\text{C}, \text{ unless otherwise noted.})$ 

| Parameter  | Test Conditions   | Min | Тур | Max         | Unit |  |
|--|---|-----|-----|-------------|------|--|
| TEMPERATURE SENSOR   | TEMPERATURE SENSOR  |     |     |             |      |  |
| Measurement Range  |   | -40 |     | +125        | °C   |  |
| REMOTE SENSOR ACCURACY   |   |     |     |             |      |  |
| $V_{DD} = 1.6 V \text{ to } 2.75 V$<br>$T_A = 25^{\circ}\text{C} \text{ to } 85^{\circ}\text{C}$ | $T_{D} = -40^{\circ}C \text{ to } +125^{\circ}C$  |     |     | ±1          | °C   |  |
| LOCAL SENSOR ACCURACY  |   |     |     |             |      |  |
| V <sub>DD</sub> = 1.6 V to 2.75 V  | $T_A = 25^{\circ}C \text{ to } 85^{\circ}C$<br>$T_A = -40^{\circ}C \text{ to } +125^{\circ}C$ |     |     | ±1.75<br>±3 | °C   |  |

### Theory of Operation

The NCT218 is a local and remote temperature sensor and over/under temperature alarm, with the added ability to automatically cancel the effect of 500  $\Omega$  (typical) of resistance in series with the temperature monitoring diode. When the NCT218 is operating normally, the on-board ADC operates in a free running mode. The analog input multiplexer alternately selects either the on-chip temperature sensor to measure its local temperature or the remote temperature sensor. The ADC digitizes these signals and the results are stored in the local and remote temperature value registers.

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

The limit registers are programmed and the device controlled and configured via the serial  $I^2C$ . The contents of any register are also read back via the  $I^2C$ . Control and configuration functions consist of switching the device between normal operation and standby mode, selecting the temperature measurement range, masking or enabling the <u>ALERT</u> output, switching Pin 6 between <u>ALERT</u> and <u>THERM2</u>, and selecting the conversion rate.

### **Series Resistance Cancellation**

Parasitic resistance to the D+ and D- inputs to the NCT218, seen in series with the remote diode, is caused by a variety of factors, including PCB track resistance and track length. This series resistance appears as a temperature of set in the remote sensor's temperature measurement. This error typically causes a 0.5°C offset per ohm of parasitic resistance in series with the remote diode.

The NCT218 automatically cancels the effect of this series resistance on the temperature reading, giving a more accurate result, without the need for user characterization of this resistance. The NCT218 is designed to automatically cancel typically up to 150  $\Omega$  of resistance. By using an advanced temperature measurement method, this process is transparent to the user. This feature permits resistances to be added to the sensor path to produce a filter, allowing the part to be used in noisy environments. See the section on Noise Filtering for more details.

### Temperature Measurement Method

A simple method of measuring temperature is to exploit the negative temperature coefficient of a diode, measuring the base emitter voltage ( $V_{BE}$ ) of a transistor operated at constant current. However, this technique requires calibration to null the effect of the absolute value of  $V_{BE}$ , which varies from device to device.

The technique used in the NCT218 measures the change in VBE when the device operates at three different currents. Previous devices used only two operating currents, but it is the use of a third current that allows automatic cancellation of resistances in series with the external temperature sensor. Figure 4 shows the input signal conditioning used to measure the output of an external temperature sensor. This figure shows the external sensor as a substrate transistor, but it can equally be a discrete transistor. If a discrete transistor is used, the collector is not grounded but is linked to the base. To prevent ground noise interfering with the measurement, the more negative terminal of the sensor is not referenced to ground, but is biased above ground by an internal resistor at the D- input. C1 may be added as a noise filter (a recommended maximum value of 1000 pF). However, a better option in noisy environments is to add a filter, as described in the Noise Filtering section. See the Layout Considerations section for more information on C1.

To measure  $\Delta V$ 

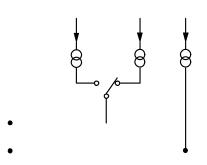


Figure 4. Input Signal Conditioning

# Table 6. TEMPERATURE DATA FORMAT (Temperature High Byte)

| Temperature | Binary              | Offset Binary<br>(Note 1) |
|-------------|---------------------|---------------------------|
| -55°C       | 0 000 0000 (Note 2) | 0 000 1001                |
| 0°C         | 0 000 0000          | 0 100 0000                |
| +1°C        | 0 000 0001          | 0 100 0001                |
| +10°C       | 0 000 866w1.com     |                           |

Conversion Rate Register The conversion rate register is Address 0x04 at read and Address 0x0A at write. The lowest four bits of this register

### Table 9. STATUS REGISTER BIT ASSIGNMENTS

| Bit | Name              | Function  |  |
|-----|-------------------|---|--|
| 7   | BUSY              | 1 when ADC is converting                        |  |
| 6   | LHIGH<br>(Note 4) | 1 when local high temperature limit is tripped  |  |
| 5   | LLOW<br>(Note 4)  | 1 when local low temperature limit is tripped   |  |
| 4   | RHIGH<br>(Note 4) | 1 when remote high temperature limit is tripped |  |
| 3   | RLOW<br>(Note 4)  | 1 when remote low temperature limit is tripped  |  |
| 2   | OPEN<br>(Note 4)  | 1 when remote sensor is an open circuit         |  |
| 1   | RTHRM             | 1 when remote THERM limit is tripped            |  |
| 0   | LTHRM             | 1 when local THERM limit is tripped             |  |

 These flags stay high until the status register is read or they are reset by POR unless Pin 6 is configured as <u>THERM2</u>. 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 register can also be used to nullify the effect of varying nf, the non-ideality factor of the remote sensing diode. By default the NCT218 is trimmed to operate with an nf value of 1.008 but the offset register allows other diodes to be used without affecting the temperature result.

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  $-128^{\circ}$ C, and the maximum is  $+127.75^{\circ}$ 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 10. SAMPLE OFFSET REGISTER CODES

| Offset Value | 0x11      | 0x12       |
|--------------|-----------|------------|
| -128°C       | 1000 0000 | 00 00 0000 |
| -4°C         | -         |            |

### SERIAL INTERFACE

Control of the NCT218 is carried out via the I<sup>2</sup>C compatible serial interface. The NCT218 is connected to this bus as a slave device, under the control of a master device.

The NCT218 has a bus timeout feature. When this is enabled, the bus times out after typically 25 ms of no activity. After this time, the NCT218 resets the SDA line back to its idle state (high impedance) and waits for the next start condition. However, this feature is not enabled by default. Bit 7 of the consecutive alert register (Address = 0x22) should be set to enable it.

### Addressing the Device

In general, every I<sup>2</sup>C device has a 7-bit device address, except for some devices that have extended 10-bit addresses. When the master device sends a device address over the bus, the slave device with that address responds. The NCT218 is available with one device address, 0x4C.

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/W) bit, which deternimes 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/W bit is a zero then the master writes to the slave device. If the R/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

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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.

To write data to one of the device data registers, or to read data from it, the address pointer register must be set so that the correct data register is addressed. The first byte of a write operation always contains a valid address that is stored in the address pointer register. If data is to be written to the device, the write operation contains a second data byte that is written to the register selected by the address pointer register.

This procedure is illustrated in Figure 5. The device address is sent over the bus followed by R/W set to 0. This is followed by two data bytes. The first data byte is the address of the internal data register to be written to, which is stored in the address pointer register. The second data byte is the data to be written to the internal data register.

When reading data from a register there are two possibilities.

- If the address pointer register value of the NCT218 is unknown or not the desired value, it is first necessary to set it to the correct value before data can be read from the desired data register. This is done by writing to the NCT218 as before, but only the data byte containing the register read address is sent, because data is not to be written to the register see Figure 5.
   A read operation is then performed consisting of the serial bus address, R/W bit set to 1, followed by the data byte read from the data register see Figure 7.
- If the address pointer register is known to be at the desired address, data can be read from the corresponding data register without first writing to the address pointer register and the bus transaction shown in Figure 6 can be omitted.

### Notes:

- It is possible to read a data byte from a data register without first writing to the address pointer register. However, if the address pointer register is already at the correct value, it is not possible to write data to a register without writing to the address pointer register because the first data byte of a write is always written to the address pointer register.
- Some of the registers have different addresses for read and write operations. The write address of a register must be written to the address pointer if data is to be written to that register, but it may not be possible to m

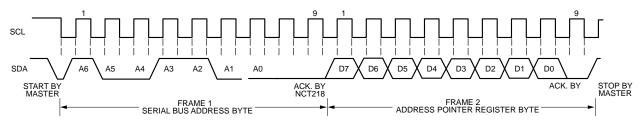


Figure 5. Writing to the Address Pointer Register

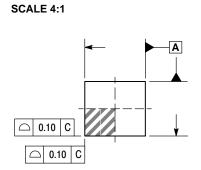
priority, in accordance with normal bus arbitration. Once the NCT218 has responded to the alert response address, it resets its ALERT output,

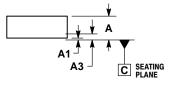
### Table 14. ORDERING INFORMATION

| Device Number | Package Type        | Shipping <sup>†</sup> |
|---------------|---------------------|-----------------------|
| NCT218MTR2G   | WDFN8<br>(Pb-Free)  |                       |
| NCT218FCT2G   | WLCSP8<br>(Pb-Free) |                       |

†For information on tape and reel specifications, including part orientation and tape sizes, please refer to our Tape and Reel Packaging Specifications Brochure, BRD8011/D.

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