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## Contact us

Tel: +86-755-8981 8866 Fax: +86-755-8427 6832
Email & Skype: info@chipsmall.com Web: www.chipsmall.com
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# NCT7509Y

# NCT7509W

# Nuvoton Thermal Sensor IC with Fan Control

Date: Aug/15/2012 Revision: 1.0

## *Table of Content-*

# 1. GENERAL DESCRIPTION

The NCT7509 is a Nuvoton Hardware Monitor IC, contains 1 remote and 1 on-die temperature sensor and 1 fan controller with SMBus™ interface. The remote sensor is diode-connected transistor, such as 2N3904 or the thermal diode integrated in Computer Processor Units (CPU) and Graphics Processor Units (GPU). The NCT7509 also supports offset adjust register to correct the errors that casued by different thermal diodes.

The fan controller in NCT7509 support PWM (pulse width modulation) fan output modes for Nuvoton SMART FAN™ control - "Thermal Cruise™" mode and "SMART FAN™ IV" mode. In the "Thermal Cruise™" mode, temperatures of CPU/GPU and the system can be maintained within specific programmable ranges under the hardware control. SMART FAN™ IV provides 8 sets of temperatures setting points to program 6 slopes linear fan speed vs. temperature transfer function. NCT7509 also supports close-loop fan controller based on RPM. The NCT7509 provides an easy to implement cooling and quiet solution with maximum safety and flexibility.

The NCT7509 supports 2 wire alert signals which ALERT# is for processor event notification and T_CRIT is for thermal shutdown.

# 2. FEATURES

## 2.1 Fan Speed Monitoring and Control

- Support 256 steps PWM modes fan speed control
- Thermal Cruise™" and SMART FAN™IV to control the fan speed
- Enhanced Smart Fan algorithm, SMART FAN™ IV, supports multi-tracking of fan control vs. temperature and registers for each fan control output.
- Closed-loop fan controller via RPM setting
- Manual Mode for specific application

## 2.2 Temperature Measurement

- Measure the temperature with high accuracy
- One local on-die thermal sensor
- One remote temperature sensor with current mode

## 2.3 Event Notification

- Supports 2 alert outputs : ALERT# and T_CRIT#
- Event notification via ALERT# signal for over temperature and fan error
- ALERT# output supports SMBus™ 2.0 ARA function
- T_CRIT# point supports Hardware Power-on setting

## 2.4 General

- I²C® Compatible System Management bus (SMBus™)
- 3.3V±5% $V_{DD}$ operation
- 10-pin MSOP and DFN Green Package (Halogen-free)

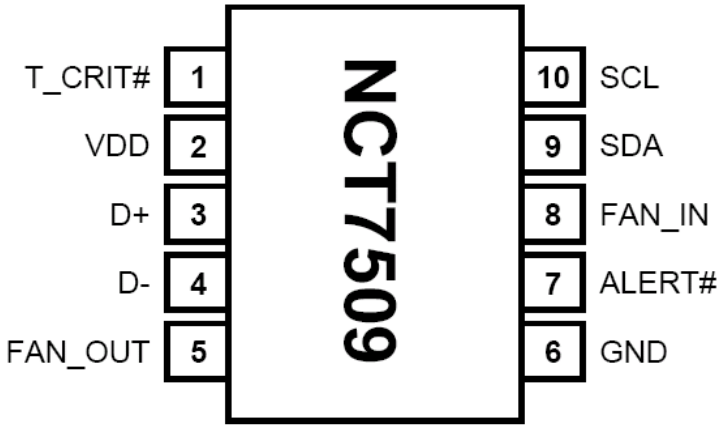
## 3. KEY SPECIFICATIONS

| PARAMETER | RATING |
|---|---|
| Local temperature range and accuracy | -40°C to +125°C |
| | Typ. ± 2°C (20°C~40°C) |
| | Max. ± 3°C (-40°C~125°C)*1 |
| Remote temperature range and accuracy | -40°C to +127°C |
| | Typ. ± 1°C (25°C ~70°C) |
| | Typ. ± 2°C (-40°C ~127°C) |
| | Max. ± 3°C (-40°C~127°C)*2 |
| Supply voltage | 3.3V ± 5% |
| Operating supply current | 3 mA typ. |
| ADC resolution include sign bit | 10 Bits |

*1 Guaranteed by design from -40~125 degreeC, 100% tested at 85 degreeC.

*2 Guaranteed by design from -40~127 degreeC, 100% tested at 85 degreeC.

## 4. PIN CONFIGURATION



# 5. PIN DESCRIPTION

## 5.1 PIN TYPE DISCRIPTION

| PIN TYPE | PIN ATTRIBUTE |
|---|---|
| $OD_{12}$ | Open-drain output pin with 12 mA sink capability |
| $IN_{ts}$ | TTL level input pin and schmitt trigger |
| AIN | Input pin (Analog) |
| P | Power or Ground Pin |

## 5.2 PIN DISCRIPTION

| PIN NO. | PIN NAME | I/O | FUNCTION |
|---|---|---|---|
| **1** | **T_CRIT#** | $OD_{12}$ | T_CRIT alarm output, for interrupt or shutdown control |
| **2** | **VDD** | P | DC Power supply, Voltage input 3.3V±5% |
| **3** | **D+** | AIN | Connect to Thermal Diode Anode |
| **4** | **D-** | AIN | Connect to Thermal Diode Cathode |
| **5** | **FAN_OUT** | $OD_{12}$ | Fan speed control PWM output |
| **6** | **GND** | P | Power supply ground |
| **7** | **ALERT#** | $OD_{12}$ | Alarm output, for interrupt control |
| **8** | **FAN_IN** | $IN_{ts}$ | Fan tachometer input |
| **9** | **SDA** | $IN_{ts}$/ $OD_{12}$ | SMBus™ bi-directional data |
| **10** | **SCL** | $IN_{ts}$ | SMBus™ Clock |

# 6. FUNCTION DESCRIPTION

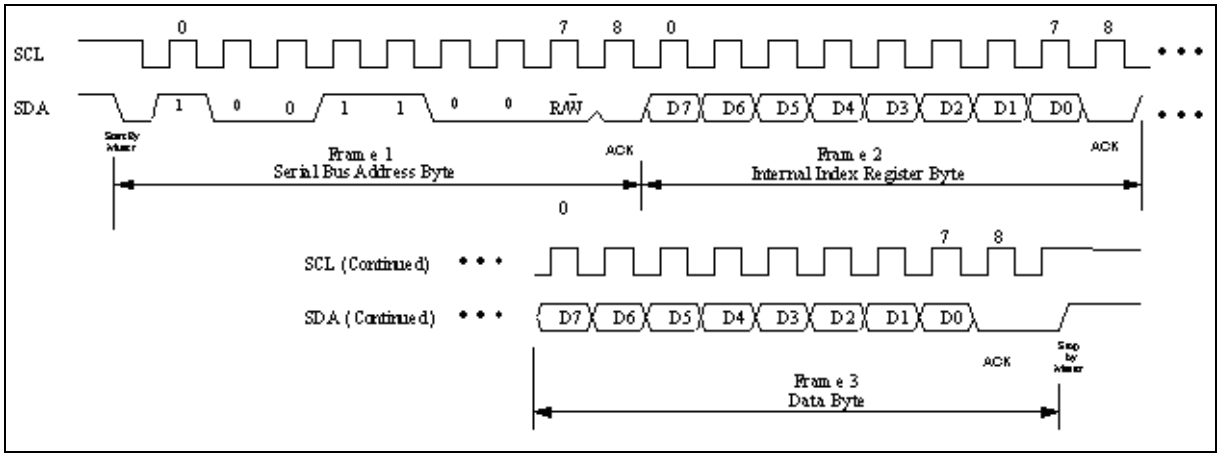
## 6.1 General Description

NCT7509 is SMBus™ interface device to provides on-die temperature sensor and 1 set of thermal inputs for CPU/GPU thermal diode sensor, 2 wire alert signals which ALERT# is for processor event notification and T_CRIT# is for thermal shutdown,1set fan speed input and output which support PWM(Pulse Width Modulation) fan control.

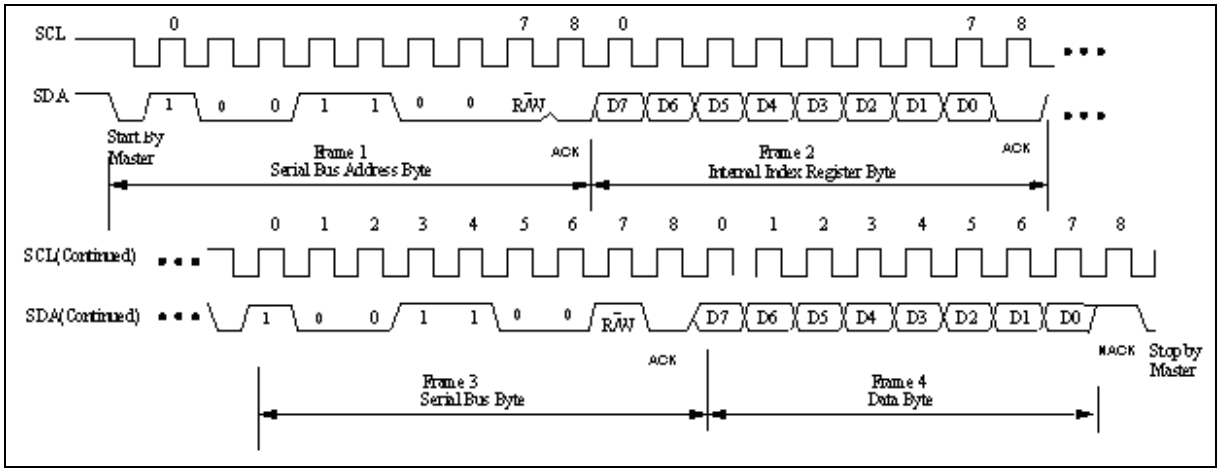
## 6.2 Access Interface

NCT7509 provides SMBus™ to access the internal register. It supports SMBus™ byte write and byte read protocols.

### 6.2.1 Data write to the internal register




### 6.2.2 Data read from the internal register



## 6.3 Address Setting

NCT7509 I2C/SMBus™ address is 1001100xb (x is R/W bit).

## 6.4 Temperature Measurement Data Format

### 6.4.1 The local temperature (on-die) data with 8-bit 2`s complement format.

| TEMPERATURE | 8-BIT DIGITAL OUTPUT |
|---|---|
| +127°C | 0111,1111 |
| +25°C | 0001,1001 |
| +2°C | 0000,0010 |
| +1°C | 0000,0001 |
| +0°C | 0000,0000 |
| - 1°C | 1111,1111 |
| - 2°C | 1111,1110 |
| - 25°C | 1110,0111 |
| - 128°C | 1000,0000 |

### 6.4.2 The remote temperature data with 11-bit 2`s complement format.

| TEMPERATURE | 8-BIT DIGITAL OUTPUT HIGH BYTE | 3-BIT DIGITAL OUTPUT LOW BYTE |
|---|---|---|
| +127.875°C | 0111,1111 | 111X,XXXX |
| +25.750°C | 0001,1001 | 110X,XXXX |
| +2.250°C | 0000,0010 | 010X,XXXX |
| +1.125°C | 0000,0001 | 001X,XXXX |
| +0.000°C | 0000,0000 | 000X,XXXX |
| - 1.125°C | 1111,1110 | 111X,XXXX |
| - 2.250°C | 1111,1101 | 110X,XXXX |
| - 25.750°C | 1110,0110 | 010X,XXXX |
| - 127.875°C | 1000,0000 | 001X,XXXX |

## 6.5 ALERT# Output

The NCT7509 ALERT# pin is an active-low open-drain output pin which is triggered when measured temperature exceeds the limitation defined in the limit registers. There are three types of ALERT#

output mode: the ALERT# output comparator mode, the ALERT# output interrupt mode, and the ALERT# output SMBus™ ALERT# mode.

### 6.5.1 ALERT# Output Comparator Mode

Figure 1 shows the mechanism of the ALERT# output comparator mode. In this mode, the ALERT# pin will be alerted if the monitored temperature is out-of-limit and the ALERT# pin keeps low until the temperature goes back to the target range.

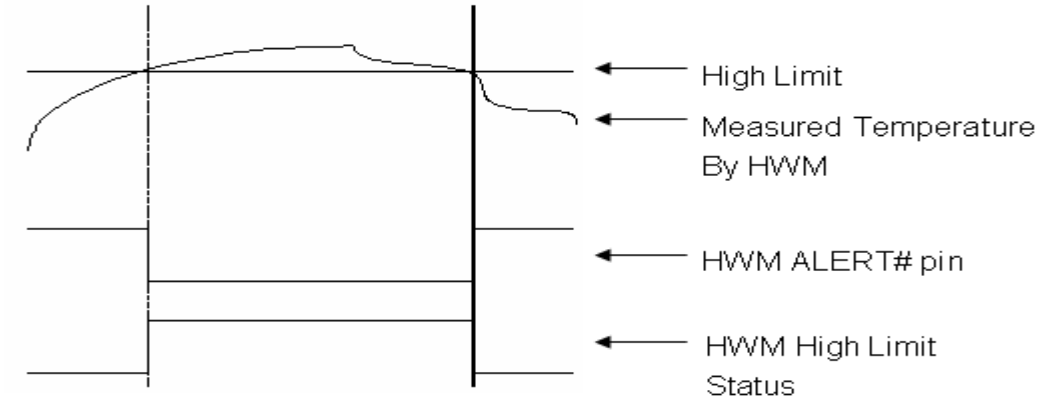



Figure 1

### 6.5.2 ALERT# Output Interrupt Mode

Figure 2 shows the mechanism of the ALERT# output interrupt mode. In this mode, the NCT7509 will set the ALERT mask bit of Configuration Register during a read of the Status Register if any flag in Status Register, except the ADC_Busy flag and Remote Diode Open flag, is set. This prevents further ALERT# triggering until the master has reset the ALERT mask bit (write 0 to Alert_MSK), at the end of the interrupt service routine. The Status Register flags are cleared only upon a read Status Register command from the master and will be re-alerted at the end of the next temperature conversion if the measured temperature still falls outside of the allowed range.

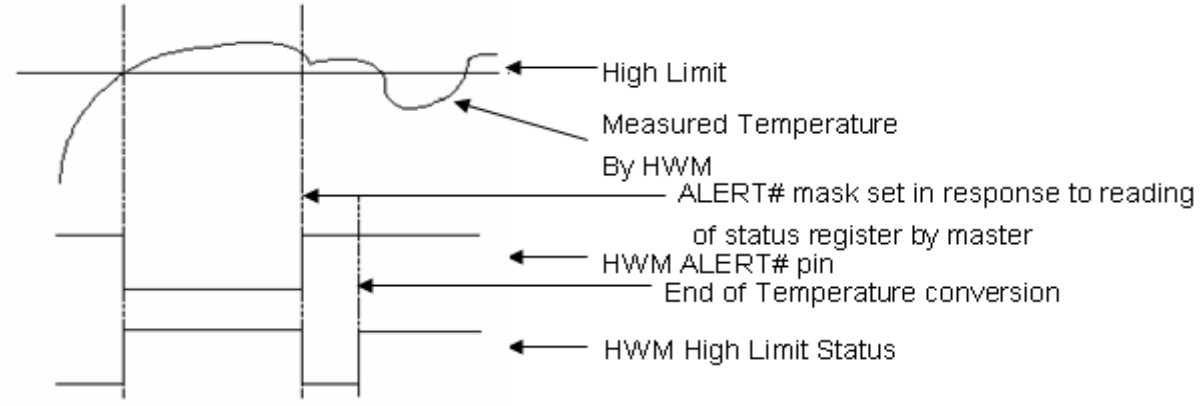



Figure 2

### 6.5.3 ALERT# Output SMBus™ alert Mode

Figure 3 shows the mechanism of the ALERT# output SMBus™ alert mode. In this mode, the ALERT# output of the NCT7509 is connected to the SMBus™ alert line which has more than one device connected to it. Through such and implementation, SMBus™ alert mode can assist the master in resolving which salve generates an interrupt. When the measured temperature falls outside of the allowed range, the ALERT# pin will be pulled low and the corresponding alert flags in Status Register will be set to 1. The ALERT mask bit will just be set if there is a read command for Status Register or when SMBus™ ALERT Response Address (ARA) occurs from master (Alert Response Address is 0001100x). Meanwhile, the NCT7509 will generate and return its own address to the master. If the temperature never falls outside of the allowed range, the latched ALERT# pin can release by the reset ALERT mask bit and the latched corresponding alert flags in Status Register can release by reading command for Status Register.

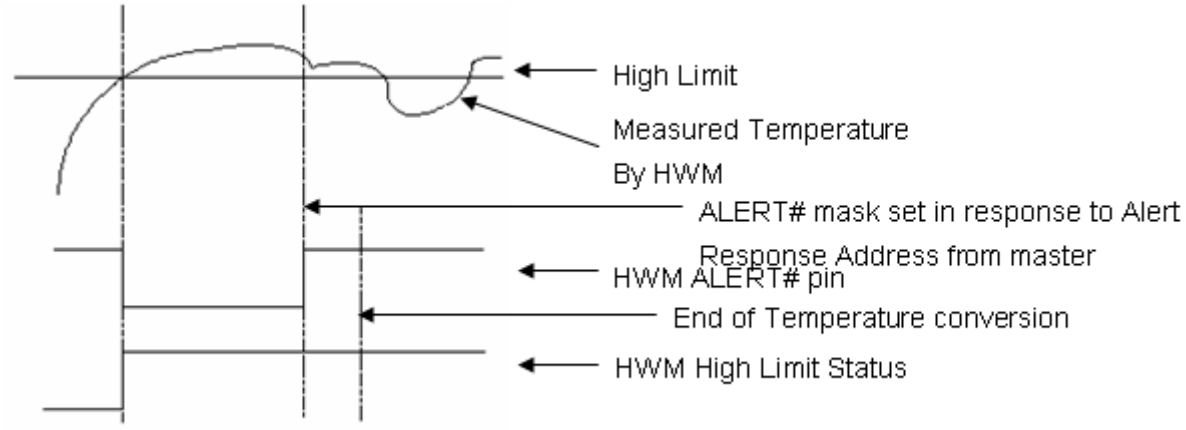



Figure 3

### 6.6 T_CRIT# Output

T_CRIT# output pulls low when the measured temperature exceeds the critical temperature setting. Once the T_CRIT# output pulls low, it will not be set high until the measured temperature is lower than "T_CRIT – TH", where TH is Temperature Hysteresis. Status Register will not be reset until it is read and the temperature conversion falls below the T_CRIT set point, the ALERT-MSK bit of Configuration Register will be set after Status Register read. Figure 4 shows this mechanism.

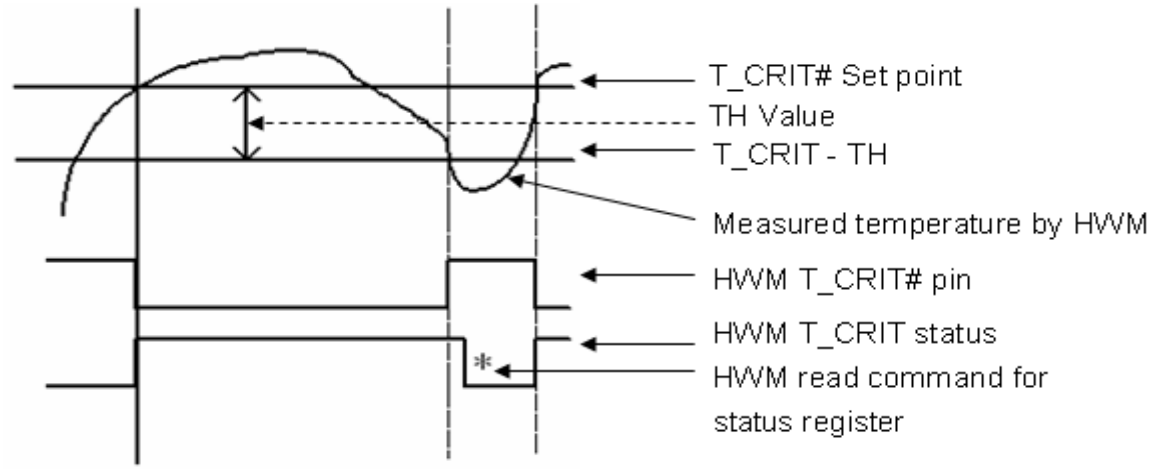



Figure 4

## 6.7 FAN_IN Count Calculation

The FAN_IN tachometer high byte and low byte are combined to 12-bitCountValue. Real RPM (Rotate per Minute) calculation should follow the formula:

$$FanSpeed(RPM) = \frac{1.35 \times 10^6}{(12 - bitCountValue) \times (FanPoles/4)}$$

In this formula, FanPoles stands for the number of NS pole pairs inside the fan. Normally an N-S-N-S Fan (FanPoles=4) generates 2 pulses after completing one rotation.

## 6.8 FAN_OUT Duty Cycle Calculation

The NCT7509 provides 1 set of PWM for fan speed control. The duty cycle of PWM can be programmed by an 8-bit register. The expression of duty cycle can be represented as follow formula:

$$\text{Duty} - \text{cycle}(\%) = \frac{\text{Programmed 8 - bit Register Value}}{255} \times 100\%$$

## 6.9 SMART FAN™ IV Control Parameters

In SMART FAN™ IV Mode, there are some Fan control parameters as below descriptions:

### 6.9.1 Step Up Time / Step Down Time

SMART FAN™ IV is designed for the smooth operation of the fan. The Up Time / Down Time register defines the time interval between successive duty increases or decreases. If this value is set too small, the fan will not have enough time to speed up after tuning the duty and sometimes may result in unstable fan speed. On the other hand, if Up Time / Down Time is set too large, the fan may not work fast enough to dissipate the heat. This register should never be set to 0, otherwise, the fan duty will be abnormal.

### 6.9.2 Fan Output Start-up Value

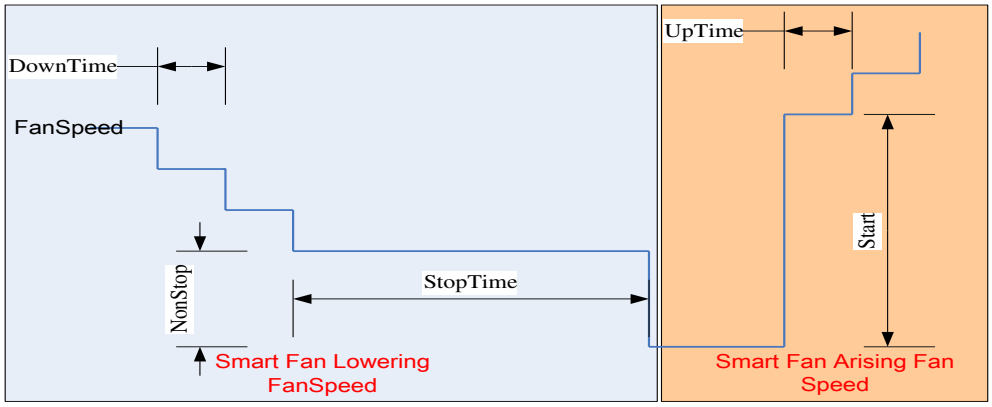
From still to rotate, the fan usually needs a higher fan output value to generate enough torque to conquer the restriction force. Thus the Fan Output Start-up Value is used to turn on the fan with the specified output value.

### 6.9.3 Fan Output Nonstop Value

It takes some time to bring a fan from still to working state. Therefore, Nonstop value are designed with a minimum fan output to keep the fan working when the system does not require the fan to help reduce heat but still want to keep the fast response time to speed up the fan.

### 6.9.4 Fan Output Stop Time

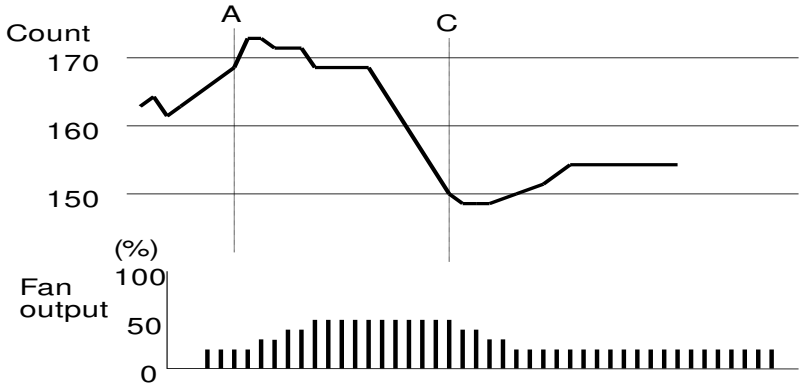
A time interval is specified to turn off the fan if SMART FAN™ IV continuously requests to slow down the fan which has already reached the Stop time.




**Smart Fan Control Parameters Figure**

## 6.10 Speed Cruise Mode

Fan Speed Cruise mode keeps the fan speed in a specified range. This range is defined by a fan speed count and an interval (e.g., 160 ± 10). As long as the fan speed count is in the specified range, fan output remains the same. If the fan speed count is higher than the high end (e.g., 170), fan output increases to make the count lower. If the fan speed count is lower than the low end (e.g., 150), fan output decreases to make the count higher. One example is illustrated in this figure.




**Mechanism of Fan Speed Cruise™ Mode**

## 6.11 Thermal Cruise Mode

Thermal Cruise mode is an algorithm to control the fan speed to keep the temperature source around the Target Temperature of Temperature Inputs. If the temperature source detects temperatures higher or lower than the target temperatures with Hysteresis of Temperature, Smart Fan Control will take actions to speed up or slow down the fan to keep the temperature within the tolerance range.

Thermal Cruise mode controls the fan speed to keep the temperature in a specified range. This range is defined by a temperature and the interval (e.g., 55 °C ± 3 °C). As long as the current temperature remains below the low end of this range (i.e., 52 °C), the fan is off. Once the temperature exceeds the low end, the fan turns on at a start up speed defined (e.g., 20% output). Thermal Cruise mode then controls the fan output according to the current temperature. Three conditions may occur:

(1) If the temperature still exceeds the high end, fan output increases slowly. If the fan is operating at full speed but the temperature still exceeds the high end, a warning message is issued to protect the system.

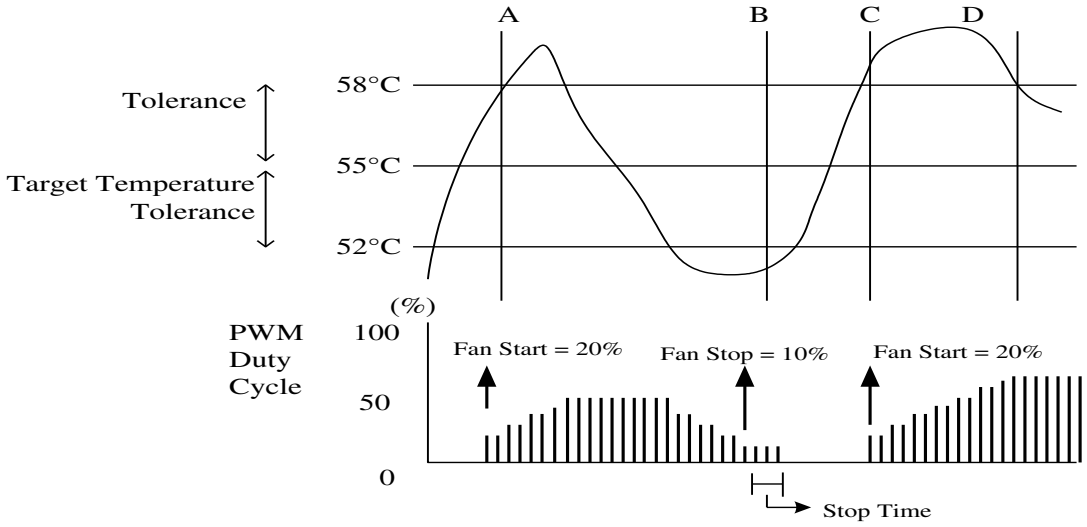
(2) If the temperature falls below the high end (e.g., 58°C) but remains above the low end (e.g., 52 °C), fan output remains the same.

(3) If the temperature falls below the low end (e.g., 52 °C), fan output decreases slowly to zero or to a specified “Nonstop value”. This nonstop value is specified in **Address 5A$_{HEX}$.** The fan remains at the nonstop value for the period of time defined in **Address 5B$_{HEX}$.**

In general, Thermal Cruise mode means

- if the current temperature is higher than the high end, increase the fan speed;
- if the current temperature is lower than the low end, decrease the fan speed;
- otherwise, keep the fan speed the same.

The following figures illustrate two examples of Thermal Cruise mode.




**Mechanism of Thermal Cruise™ Mode (PWM Duty Cycle)**

## 6.12 SMART FAN™ IV & Close Loop Fan Control Mode

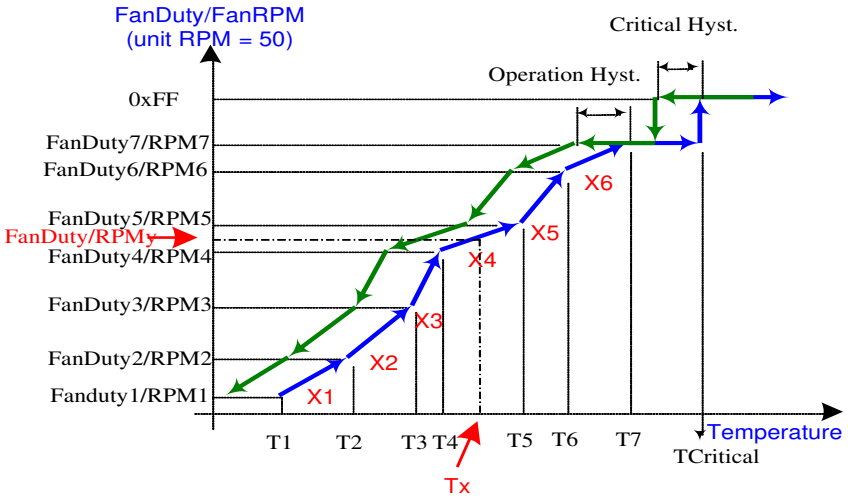
SMART FAN™ IV and Close Loop Fan Control Mode offer 6 slopes to control the fan speed.

The 6 slopes can be obtained by setting FanDuty/RPM1~FanDuty/RPM7 and T1~T7 through the registers. When the temperature rises, FAN Output will calculate the target FanDuty/RPM based on the current slope. For example, assuming Tx is the current temperature and FanDuty/RPMy is the target, then the slope:

$$X4 = \frac{(FanDuty5/RPM5) - (FanDuty4/RPM4)}{(T5 - T4)}$$

Fan Output:

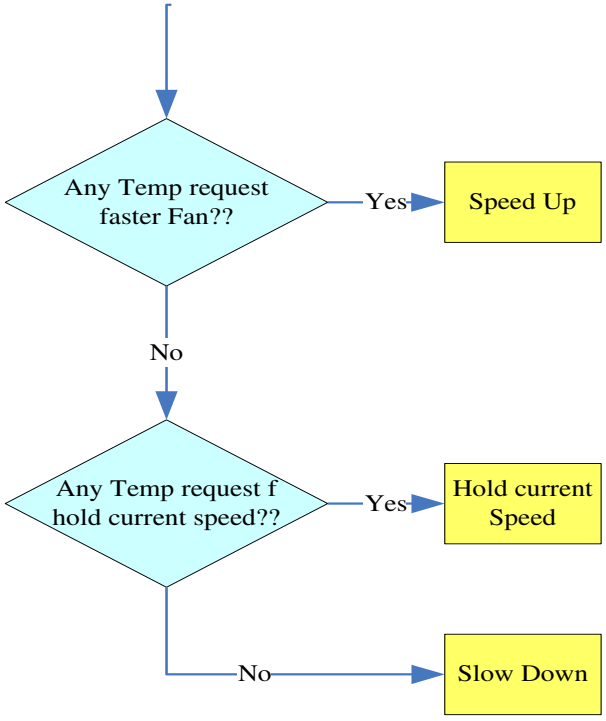
$$Target\ FanDuty\ or\ RPM = (FanDuty4\ or\ RPM4) + (Tx - T4) \cdot X4$$




**SMART FAN™ IV & Close Loop Fan Control Mechanism**

In addition, SMART FAN™ IV & Close Loop Fan Control can also set up Critical Temperature and Hysteresis. If the current temperature exceeds Critical Temperature, external fan will be forced by maximum FanDuty to meet the largest target FanDuty or RPM, Which is 0xFF. The target FanDuty & RPM value will be determined in accordance to the slope only when the temperature falls below (TCritical – Criticl Hyst.)

NCT7509 provide 2 temperature source selects to map the fan, the algorithm will make a decision to control the fan as below figure:

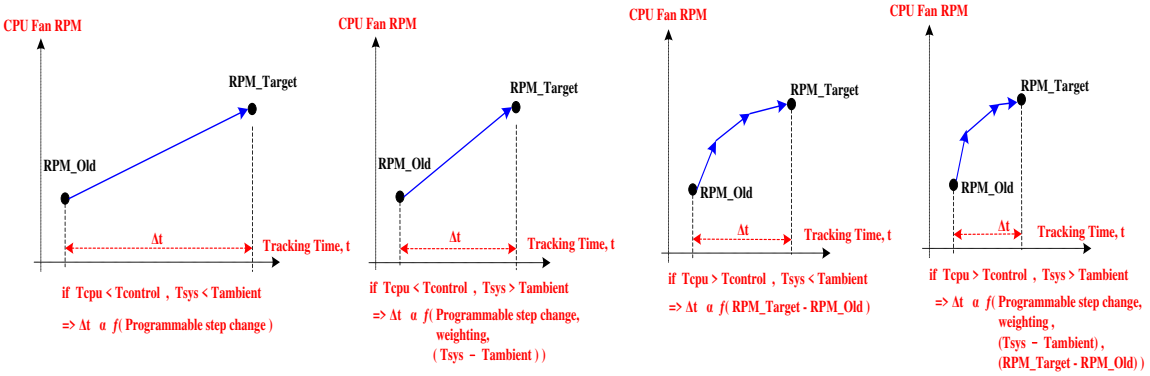



## 6.13 Dynamic Fast Tracking Feature

In the SMART FAN™ IV & Close Loop Control Mode, in order to have a faster Fan Duty update response to external temperature variation, NCT7509 involves a Dynamic Fast Tracking mode. That how fast could be reached is depended on user's configuration and how rapid temperature variation.

In addition to independent temperature control method, which means that one external fan would be controlled by only one temperature source, NCT7509 also support combined temperature control method. User could conjugate CPU & System temperature with CPU fan to obtain a better thermal management on the system level through this feature.

Per appropriate configuration, fan control response time could come out following behavior.




In this demonstration, CPU & System temperature will link to CPU fan response.

# 7. REGISTER SUMMARY

## 7.1 Register Map

| Idx | Register Name | Attr | Dft | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | LDT Readout | RO | 00 | MNTREG_LT[7:0] | | | | | | | |
| 1 | RT1 Temp MSB | RO | 00 | MNTREG_RT1[10:3] | | | | | | | |
| 2 | Alert Status | RO | 00 | ADC_Busy | STS_LTHA | Reserved | STS_RT1HA | STS_RT1LA | STS_RT1O | STS_RT1C | STS_TACH |
| 3 | Configuration [R] | RW | 15 | ALERT_MSK | STOP_Mnt | DIS_FANOUT | EN_FANIN | Reserved | EN_RT1 | EN_WTC | EN_FaultQueue |
| 4 | Conversion Rate [R] | RW | 08 | Reserved | | | | ConvRate[3:0] | | | |
| 5 | LT Alert Temp [R] | RW | 46 | LT_HAT[7:0] | | | | | | | |
| 6 | Reserved | | | Reserved | | | | | | | |
| 7 | RT1 High Alert Temp MSB [R] | RW | 46 | RT1_HAT[10:3] | | | | | | | |
| 8 | RT1 Low Alert Temp MSB [R] | RW | D8 | RT1_LAT[10:3] | | | | | | | |
| 9 | Configuration [W] | RW | 15 | ALERT_MSK | STOP_Mnt | DIS_FANOUT | EN_FANIN | Reserved | EN_RT1 | EN_WTC | EN_FaultQueue |
| A | Conversion Rate [W] | RW | 08 | Reserved | | | | ConvRate[3:0] | | | |
| B | LT Alert Temp [W] | RW | 46 | LT_HAT[7:0] | | | | | | | |
| C | Reserved | | | Reserved | | | | | | | |
| D | RT1 High Alert Temp MSB [W] | RW | 46 | RT1_HAT[10:3] | | | | | | | |
| E | RT1 Low Alert Temp MSB [W] | RW | D8 | RT1_LAT[10:3] | | | | | | | |
| F | One Shot Conversion | WO | FF | | | | | | | | |
| 10 | RT1 Temp LSB | RO | 00 | MNTREG_RT1[2:0] | | | | Reserved | | | |
| 11 | RT1 Offset Temp MSB | RW | 00 | OFFSET_RT1[10:3] | | | | | | | |
| 12 | RT1 Offset Temp LSB | RW | 00 | OFFSET_RT1[2:0] | | | | Reserved | | | |
| 13 | RT1 High Alert Temp LSB | RW | 00 | RT1_HAT[2:0] | | | | Reserved | | | |
| 14 | RT1 Low Alert Temp LSB | RW | 00 | RT1_LAT[2:0] | | | | Reserved | | | |
| 16 | Alert Mask | RW | 06 | MSK_LTH | Reserved | MSK_RT1H | MSK_RT1L | Reserved | MSK_RT1C | MSK_TACH | |
| 19 | RT1 Critical Temp | RW | -- | RT1_CT[7:0] | | | | | | | |
| 20 | Reserved | | | Reserved | | | | | | | |
| 21 | Critical Temp Hysteresis | RW | 0A | Reserved | | | | CTH[4:0] | | | |
| 2D | Customer Data Log Register 1 | RW | 00 | CustomerLogReg1[7:0] | | | | | | | |
| 2E | Customer Data Log Register 2 | RW | 00 | CustomerLogReg2[7:0] | | | | | | | |
| 2F | Customer Data Log Register 3 | RW | 00 | CustomerLogReg3[7:0] | | | | | | | |
| 40 | FAN Count Readout MSB | RO | 00 | FANIN[11:4] | | | | | | | |
| 41 | FAN Count Readout LSB | RO | 00 | FANIN[3:0] | | | | Reserved | | | |
| 42 | FAN Count High | RW | FF | FANIN_HL[11:4] | | | | | | | |

| Idx | Register Name | Attr | Dft | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Limit MSB | | | | | | | | | | |
| 43 | FAN Count High Limit LSB | RW | E0 | FANIN_HL[3:0] | | | | Reserved | | | |
| 44 | FanctrlDutyCycle | RW | 80 | FANDuty | | | | | | | |
| 45 | Configuration Register 1 | RW | 00 | Share_Sour_Temp2 | | Share_Sour_Temp1 | | EN_ShareMode | | EN_SpeedCruise | |
| 46 | Configuration Register 2 | RW | 10 | Reserved | | Temp2FanSelect | | Temp1FanSelect | | FanControlMode | |
| 47 | Configuration Register 3 | RW | A1 | PWMPOL | | Reserved | | Temp2_Sour_Sel | | Temp1_Sour_Sel | |
| 48 | Configuration Register 4 | RW | 00 | Reserved | | | | TwoDimension | SimpleMode | | FastTracking |
| 49 | Dynamic feature Register 1 | RW | 50 | Tcontrol | | | | | | | |
| 4A | Dynamic feature Register 2 | RW | 3C | Tbound | | | | | | | |
| 4B | Dynamic feature Register 3 | RW | 35 | DownFan_Tol_FanDuty | | | Weight_SYS | | | Reserved | |
| 4C | Dynamic feature Register 4 | RW | 52 | Unstable_Depth | | | StepCng_Up | | | StepCng_Down | |
| 4D | Dynamic feature Register 5 | RW | 02 | FCount_FDuty_Weight_High (Twodimension = 1) | | | | FCount_FDuty_Step_High (Twodimension = 1) | | | |
| 4E | Dynamic feature Register 6 | RW | 02 | FCount_FDuty_Weight_Mid (Twodimension = 1) | | | | FCount_FDuty_Step_Mid (Twodimension = 1) | | | |
| 4F | Dynamic feature Register 7 | RW | 04 | FCount_FDuty_Weight_Low (Twodimension = 1) | | | | FCount_FDuty_Step_Low (Twodimension = 1) | | | |
| 50 | Dynamic feature Register 8 | RW | 0A | Generic_Tol_FanInCount | | | | | | | |
| 51 | Dynamic feature Register 9 | RW | 99 | RPM_Boundary_High[7:0] | | | | | | | |
| 52 | Dynamic feature Register 10 | RW | 1C | RPM_Boundary_Low[7:0] | | | | | | | |
| 53 | Dynamic feature Register 11 | RW | 12 | RPM_Boundary_High[11:8] | | | | RPM_Boundary_Low[11:8] | | | |
| 54 | Dynamic feature Register 12 | RW | 05 | DownFan_Tol_ FanInCount_High[7:0] | | | | | | | |
| 55 | Dynamic feature Register 13 | RW | 0A | DownFan_Tol_FanInCount_Low[7:0] | | | | | | | |
| 56 | Fanctl Step Up Time | RW | 0A | UpTime | | | | | | | |
| 57 | Fanctl Step Down Time | RW | 0A | DownTime | | | | | | | |
| 58 | PWM1 Prescalar | RW | 84 | CKSEL | | | | FanOutDivisor[6:0] | | | |
| 59 | Fanctl Start Duty Cycle | RW | 30 | StartDutyCycle | | | | | | | |
| 5A | Fanctl Nonstop Duty Cycle | RW | 10 | NonStopDutyCycle | | | | | | | |
| 5B | Stop Time of Fanctl | RW | FF | StopTime | | | | | | | |
| 5C | FANIN Target speed (HB) | RW | 60 | TargetFanInCount[11:4] | | | | | | | |
| 5D | FANIN Target speed (LB) | RW | 00 | TargetFanInCount[3:0] | | | | Reserved | | | |
| 5E | Target Speed Tolerance | RW | 10 | Reserved | | | | TOL_FanInCount[5:0] | | | |
| 5F | Temp1 Target Temperature | RW | 46 | TargetTemp1 | | | | | | | |
| 60 | Temp2 Target Temperature | RW | 46 | TargetTemp2 | | | | | | | |
| 61 | Temp1 Hysteresis | RW | 2B | Reserved | | | Criti_HysT1 | | | Oper_HysT1 | |
| 62 | Temp2 Hysteresis | RW | 2B | Reserved | | | Criti_HysT2 | | | Oper_HysT2 | |

| Idx | Register Name | Attr | Dft | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 63 | Table 1 Transition Point 1 | RW | 0A | Temp1Table_TR1 | | | | | | | |
| 64 | Table 1 Transition Point 2 | RW | 14 | Temp1Table_TR2 | | | | | | | |
| 65 | Table 1 Transition Point 3 | RW | 1E | Temp1Table_TR3 | | | | | | | |
| 66 | Table 1 Transition Point 4 | RW | 28 | Temp1Table_TR4 | | | | | | | |
| 67 | Table 1 Transition Point 5 | RW | 32 | Temp1Table_TR5 | | | | | | | |
| 68 | Table 1 Transition Point 6 | RW | 3C | Temp1Table_TR6 | | | | | | | |
| 69 | Table 1 Transition Point 7 | RW | 55 | Temp1Table_TR7 | | | | | | | |
| 6A | Table 1 Critical Point | RW | 5A | Temp1Table_TRCritical | | | | | | | |
| 6B | Table 1 Y-axis Transition Point 1 | RW | 28 | Temp1Table_FL1 | | | | | | | |
| 6C | Table 1 Y-axis Transition Point 2 | RW | 50 | Temp1Table_FL2 | | | | | | | |
| 6D | Table 1 Y-axis Transition Point 3 | RW | 78 | Temp1Table_FL3 | | | | | | | |
| 6E | Table 1 Y-axis Transition Point 4 | RW | 96 | Temp1Table_FL4 | | | | | | | |
| 6F | Table 1 Y-axis Transition Point 5 | RW | B4 | Temp1Table_FL5 | | | | | | | |
| 70 | Table 1 Y-axis Transition Point 6 | RW | D2 | Temp1Table_FL6 | | | | | | | |
| 71 | Table 1 Y-axis Transition Point 7 | RW | F0 | Temp1Table_FL7 | | | | | | | |
| 72 | Table 2 Transition Point 1 | RW | 19 | Temp2Table_TR1 | | | | | | | |
| 73 | Table 2 Transition Point 2 | RW | 1E | Temp2Table_TR2 | | | | | | | |
| 74 | Table 2 Transition Point 3 | RW | 23 | Temp2Table_TR3 | | | | | | | |
| 75 | Table 2 Transition Point 4 | RW | 28 | Temp2Table_TR4 | | | | | | | |
| 76 | Table 2 Transition Point 5 | RW | 2D | Temp2Table_TR5 | | | | | | | |
| 77 | Table 2 Transition Point 6 | RW | 32 | Temp2Table_TR6 | | | | | | | |
| 78 | Table 2 Transition Point 7 | RW | 37 | Temp2Table_TR7 | | | | | | | |
| 79 | Table 2 Critical Point | RW | 3C | Temp2Table_TRCritical | | | | | | | |
| 7A | Table 2 Y-axis Transition Point 1 | RW | 28 | Temp2Table_FL1 | | | | | | | |
| 7B | Table 2 Y-axis Transition Point 2 | RW | 50 | Temp2Table_FL2 | | | | | | | |
| 7C | Table 2 Y-axis Transition Point 3 | RW | 78 | Temp2Table_FL3 | | | | | | | |
| 7D | Table 2 Y-axis Transition Point 4 | RW | 96 | Temp2Table_FL4 | | | | | | | |
| 7E | Table 2 Y-axis Transition Point 5 | RW | B4 | Temp2Table_FL5 | | | | | | | |
| 7F | Table 2 Y-axis Transition Point 6 | RW | D2 | Temp2Table_FL6 | | | | | | | |
| 80 | Table 2 Y-axis Transition Point 7 | RW | F0 | Temp2Table_FL7 | | | | | | | |
| BF | RT Filter & Alert mode | RW | 00 | Reserved | | | RT1F | | | Alert_MD | |
| FD | CID (Chip ID) | RO | 50 | 50h | | | | | | | |

| Idx | Register Name | Attr | Dft | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *FE* | VID (Vendor ID) | RO | 50 | 50h | | | | | | | |
| *FF* | DID (Device ID) | RO | 9x | 9xH (x=0,1,2…) | | | | | | | |

## 7.2 Register Detail

### 7.2.1 Local Diode Temperature Readout Register

Location : Address 00h

Type : Read Only

Power on default value : 00

| BIT | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|
| Name | Local Diode Temperature Readout Value. The real temperature value calculation is referred to TEMPERATURE MEASUREMENT DATA FORMAT. | | | | | | | |
| Value | SIGN | 64 | 32 | 16 | 8 | 4 | 2 | 1 |

### 7.2.2 Remote Diode 1 Temperature Readout (MSB) Register

Location : Address 01h

Type : Read Only

Power on default value : 00

| BIT | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|
| Name | Remote Diode 1 Temperature Readout Value. The real temperature value calculation is referred to TEMPERATURE MEASUREMENT DATA FORMAT. | | | | | | | |
| Value | SIGN | 64 | 32 | 16 | 8 | 4 | 2 | 1 |

### 7.2.3 Alert Status Register

Location : Address 02h

Type : Read Only

Power on default value : 00

| BIT | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|
| Name | ADC_Busy | STS_LTHA | Reserved | STS_RT1HA | STS_RT1LA | STS_RT1O | STS_RT1C | STS_TACH |
| Default | 0 | 0 | | 0 | 0 | 0 | 0 | 0 |

| BIT | FLAG NAME | DESCRIPTION |
|---|---|---|
| 7 | ADC_Busy | If set to ‘1’ indicates ADC is busy converting. |
| 6 | STS_LTHA | If set to ‘1’ indicates a measured Local Diode Temperature Higher than Local High set point (High Limit). |
| 5 | Reserved | |
| 4 | STS_RT1HA | If set to ‘1’ indicates a measured Remote Diode1 Temperature higher than Remote High set point (High Limit). |

| BIT | FLAG NAME | DESCRIPTION |
|---|---|---|
| 3 | STS_RT1LA | If set to '1' indicates a measured Remote Diode1 Temperature lower than Remote Low set point (Low Limit). |
| 2 | STS_RT1O | If set to '1' indicates a Remote Diode1 disconnect. |
| 1 | STS_RT1C | If set to '1' indicates a Remote Diode1 Critical Temperature alarm. |
| 0 | STS_TACH | If set to '1' indicates Tachometer count is higher than Tachometer Limit. |

### 7.2.4 Configuration Register

Location : Address 03h and 09h

Type : Read/Write

Power on default value : 15

| BIT | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|
| Name | ALERT_ MSK | STOP_ Mnt | DIS_FA NOUT | EN_FAN IN | RESER VED | EN_RT1 | EN_WT C | EN_Faul tQueue |
| Default | 0 | 0 | 0 | 1 | | 1 | 0 | 1 |

| BIT | DESCRIPTION |
|---|---|
| 7 | **ALERT_MSK** – ALERT# function is enable<br>0 = Enable<br>1 = Disable |
| 6 | **STOP_Mnt** – Stop Monitor and entry Standby<br>0 = Monitor<br>1 = Stop Monitor |
| 5 | **DIS_FANOUT**– Disable PWM FANOUT.<br>0 = Enable PWM FANOUT<br>1 = Disable PWM FANOUT |
| 4 | **EN_FANIN**– Enable FANIN monitoring.<br>0 = Disable<br>1 = Enable |
| 2 | **EN_RT1** – Enable Remote Diode 1 monitoring.<br>0 = Disable<br>1 = Enable |
| 1 | **EN_WTC**– Enable Override POR Value of Critical Temperature<br>0 = Disable<br>1 = Enable |
| 0 | **EN_FaultQueue**– Enable Fault Queue function<br>0 = Disable. ALERT# and T_CRIT# will be generated if monitor result of any channel is above or below high/low setting point.<br>1 = Enable. ALERT# and T_CRIT# will be generated if monitor result of any channel is |

| BIT | DESCRIPTION |
|---|---|
| | consecuite three times above or below high/low setting point. |

### 7.2.5 Conversion Rate Register

Location : Address 04h and 0Ah

Type : Read/Write

Power on default value : 08

| BIT | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|
| Name | Reserved | | | | ConvRate | | | |
| Default | | | | | 1 | 0 | 0 | 0 |

| BIT<D7:D0> | FREQUENCY/TIME |
|---|---|
| 00h | 0.0625Hz / 16sec |
| 01h | 0.125Hz / 8sec |
| 02h | 0.25Hz / 4sec |
| 03h | 0.5Hz / 2sec |
| 04h | 1Hz / 1sec |
| 05h | 2Hz / 0.5sec |
| 06h | 4Hz / 0.25sec |
| 07h | 8Hz / 0.125sec |
| 08h | 16Hz / 0.0625sec |
| 09h-FFh | Reserved |

### 7.2.6 Local Diode Temperature Alert Temperature Register

Location : Address 05h and 0Bh

Type : Read/Write

Power on default value : 46

| BIT | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|
| Name | LDT Alert Temperature | | | | | | | |
| Value | SIGN | 64 | 32 | 16 | 8 | 4 | 2 | 1 |
| Default | $46_{HEX}$ (70℃) | | | | | | | |

### 7.2.7 Remote Diode 1 Temperature High Alert Temperature (MSB) Register

Location : Address 07h and 0Dh

Type : Read/Write

Power on default value : 46

| BIT | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|
| Name | RT1 High Alert Temperature High Byte | | | | | | | |

| Value | SIGN | 64 | 32 | 16 | 8 | 4 | 2 | 1 |
|---|---|---|---|---|---|---|---|---|
| Default | $46_{HEX}$ (70℃) | | | | | | | |

### 7.2.8 Remote Diode 1 Temperature Low Alert Temperature (MSB) Register

Location : Address 08h and 0Eh

Type : Read/Write

Power on default value : D8

| BIT | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|
| Name | RT1 Low Alert Temperature High Byte | | | | | | | |
| Value | SIGN | 64 | 32 | 16 | 8 | 4 | 2 | 1 |
| Default | $D8_{HEX}$ (-40℃) | | | | | | | |

### 7.2.9 One Shot Conversion Register

Location : Address 0Fh

Type : Write Only

| BIT | DESCRIPTION |
|---|---|
| 7-0 | One Shot Conversion – When enter Stop Monitor state, to fill any value into this register will trigger one temperature conversion cycle. |

### 7.2.10 Remote Diode 1 Temperature Readout (LSB) Register

Location : Address 10h

Type : Read Only

Power on default value : 00

| BIT | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|
| Name | Remote Diode 1 Temperature Readout Value. The real temperature value calculation is referred to TEMPERATURE MEASUREMENT DATA FORMAT. | | | Reserved | | | | |
| Value | 0.5 | 0.25 | 0.125 | 0 | | | | |

### 7.2.11 Remote Diode 1 Temperature Offset Register (MSB) Register

Location : Address 11h

Type : Read/Write

Power on default value : 00

| BIT | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|
| Name | RT1 OFFSET VALEU High Byte | | | | | | | |
| Value | SIGN | 64 | 32 | 16 | 8 | 4 | 2 | 1 |
| Default | $00_{HEX}$ | | | | | | | |

### 7.2.12 Remote Diode 1 Temperature Offset Register (LSB) Register

Location : Address 12h

Type : Read/Write

Power on default value : 00

| BIT | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|
| Name | RT1 OFFSET VALUE Low Byte | | | | | | | |
| Value | 0.5 | 0.25 | 0.125 | | | | | |
| Default | $00_{HEX}$ | | | | | | | |

### 7.2.13 Remote Diode 1 Temperature High Alert Temperature (LSB) Register

Location : Address 13h

Type : Read/Write

Power on default value : 00

| BIT | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|
| Name | RT1 High Alert Temperature Low Byte | | | | | | | |
| Value | 0.5 | 0.25 | 0.125 | | | | | |
| Default | $00_{HEX}$ | | | | | | | |

### 7.2.14 Remote Diode 1 Temperature Low Alert Temperature (LSB) Register

Location : Address 14h

Type : Read/Write

Power on default value : 00

| BIT | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|
| Name | RT1 Low Alert Temperature Low Byte | | | | | | | |
| Value | 0.5 | 0.25 | 0.125 | | | | | |
| Default | $00_{HEX}$ | | | | | | | |

### 7.2.15 Alert Mask Register

Location : Address 16h

Type : Read/Write

Power on default value : 06

| BIT | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|
| Name | MSK_LTH | Reserved | | MSK_RT1H | MSK_RT1L | Reserved | MSK_RT1C | MSK_TACH |
| Default | 0 | | | 0 | 0 | | 1 | 0 |

| BIT | DESCRIPTION |
|---|---|
| 7 | MSK_LTH – Local Diode Temperature High Alert Mask<br>0 = Alert is not masked |

| BIT | DESCRIPTION |
|---|---|
| | 1 = Alert is masked |
| 4 | MSK_RT1H– Remote Diode 1 Temperature High Alert Mask<br>0 = Alert is not masked<br>1 = Alert is masked |
| 3 | MSK_RT1L– Remote Diode 1 Temperature Low Alert Mask<br>0 = Alert is not masked<br>1 = Alert is masked |
| 1 | MSK_RT1C– Remote Diode 1 Temperature Critical Mask<br>0 = Alert is not masked<br>1 = Alert is masked |
| 0 | MSK_TACH– Fan Tachometer Alert Mask<br>0 = Alert is not masked<br>1 = Alert is masked |

### 7.2.16 Remote Diode 1 Critical Temperature Register

Location : Address 19h

Type : Read/Write

Power on default value : Power on trapping after power up 100ms

| BIT | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|
| Name | RT1 Critical Temperature<br>The format of Temperature is 8-bit 2's complement and the range is –128℃~127℃. | | | | | | | |
| Value | SIGN | 64 | 32 | 16 | 8 | 4 | 2 | 1 |
| Default | Hardware Strapping | | | | | | | |

The default value is trapping after power up 100ms by different pull-up resistors of ALERT# pin :

| PULL-UP RESISTOR | | TEMPERATURE (℃) |
|---|---|---|
| ALERT# | 2KΩ | 75 |
| | 7.5KΩ | 90 |
| | 10.5KΩ | 100 |
| | 14KΩ | 105 |
| | 18.7KΩ | 110 |