

# Temperature Sensor for I<sup>2</sup>C BUS

## Monolithic IC MM3286 Series

### Outline

This IC is used as a digital temperature sensor that supports I<sup>2</sup>C BUS and has the built-in temperature sensor and  $\Delta$ - $\Sigma$  type A/D converter. This IC is always accessible for acquiring the temperature data, and it can detect abnormal temperature because it has a separate open drain output terminal that can operate as thermostat.

This IC features low consumption current and has the interface that supports I<sup>2</sup>C BUS, and thus it is suitable for a variety of applications.

### Features

1. Low consumption current (75 $\mu$ A typ.)
2. Shutdown mode to minimize consumption current
3. Interface supporting I<sup>2</sup>C BUS
4. Capable of carrying up to 8 ICs in the bus.
5. Thermostat function (The number of detections is programmable up to 6 times.)
6. Temperature data has 9-bit resolution in which 1 LSB is 0.5°C.

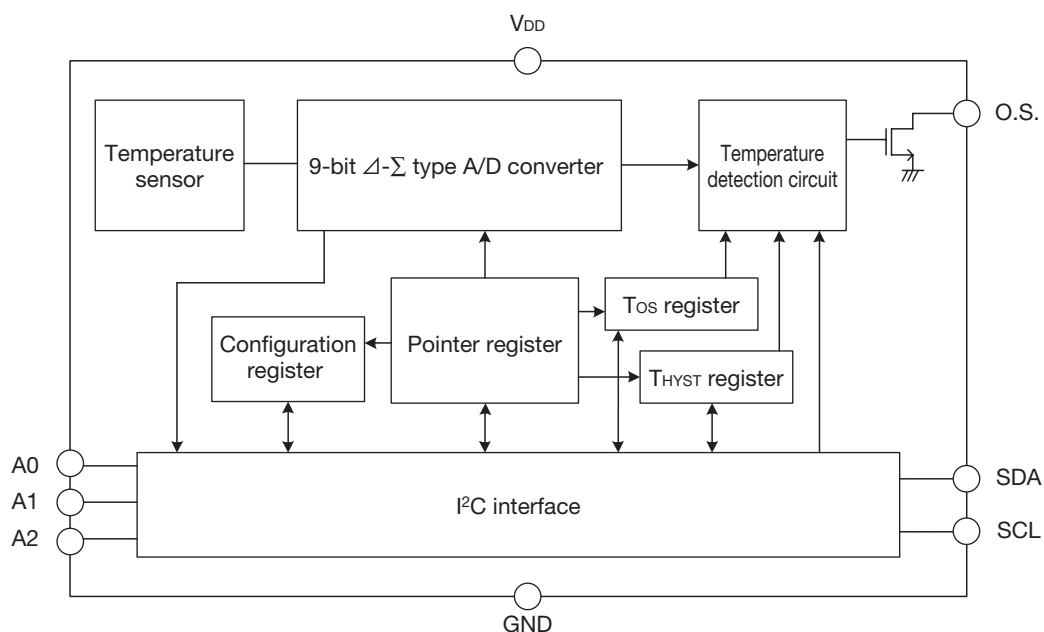
### Package

SOP-8D

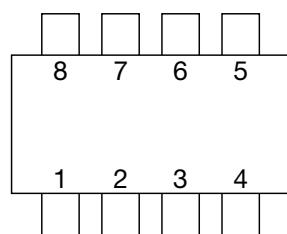
### Applications

1. LCD TV
2. PC
3. PC server/Network server
4. System temperature monitoring
5. Equipment OA

## Block Diagram



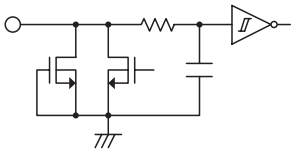
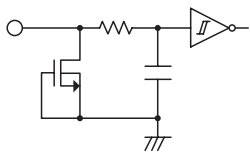
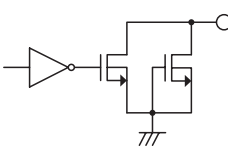
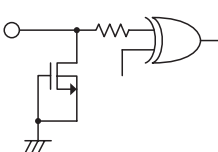
## Pin Assignment



SOP-8D  
(TOP VIEW)

|   |                 |
|---|-----------------|
| 1 | SDA             |
| 2 | SCL             |
| 3 | O.S.            |
| 4 | GND             |
| 5 | A <sub>2</sub>  |
| 6 | A <sub>1</sub>  |
| 7 | A <sub>0</sub>  |
| 8 | V <sub>DD</sub> |

## Pin Description

| Pin No. | Pin name        | Functions                        | Internal equivalent circuit diagram                                                   |
|---------|-----------------|----------------------------------|---------------------------------------------------------------------------------------|
| 1       | SDA             | I <sup>2</sup> C BUS data I/O    |    |
| 2       | SCL             | I <sup>2</sup> C BUS clock input |    |
| 3       | O.S.            | Temperature detection output     |    |
| 4       | GND             | GND                              |                                                                                       |
| 5       | A <sub>2</sub>  | Slave address setup              |  |
| 6       | A <sub>1</sub>  |                                  |                                                                                       |
| 8       | A <sub>0</sub>  |                                  |                                                                                       |
| 8       | V <sub>DD</sub> | Power supply                     |                                                                                       |

## Absolute Maximum Ratings (Ta=25°C)

| Item                   | Symbol               | Ratings                     | Units |
|------------------------|----------------------|-----------------------------|-------|
| Maximum supply voltage | V <sub>DD max.</sub> | -0.3~+6.0                   | V     |
| Maximum output voltage | V <sub>OUT</sub>     | -0.3~(V <sub>DD</sub> +0.3) | V     |
| Allowable loss         | P <sub>d</sub>       | 300                         | mW    |
| Storage temperature    | T <sub>STG</sub>     | -65~+150                    | °C    |

## Recommended Operating Conditions

| Item                     | Symbol              | Ratings   | Units |
|--------------------------|---------------------|-----------|-------|
| Operating supply voltage | V <sub>DD OPR</sub> | +3.0~+5.5 | V     |
| Operating temperature    | T <sub>OPR</sub>    | -40~+125  | °C    |

## Electrical Characteristics (Except where noted otherwise Ta=25°C, V<sub>DD</sub>=3.3V)

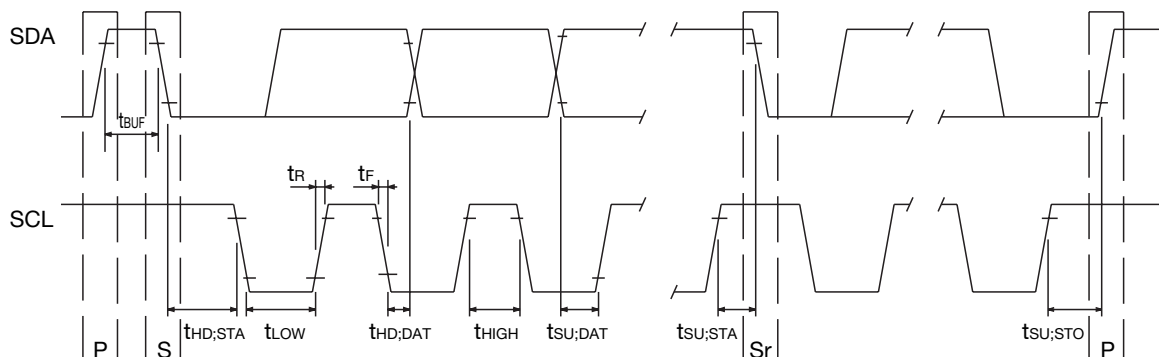
### Temperature - to - digital converter characteristics

| Item                              | Symbol          | Measurement conditions  | Min. | Typ. | Max. | Units |
|-----------------------------------|-----------------|-------------------------|------|------|------|-------|
| Temperature detection accuracy *1 | A <sub>C</sub>  | -25°C≤Ta≤100°C          |      |      | ±2.0 | °C    |
|                                   |                 | -40°C≤Ta≤125°C          |      |      | ±3.0 |       |
| Temperature data update time      | T               |                         |      | 2    |      | ms    |
| Supply current                    | I <sub>DD</sub> | Normal operation        |      | 75   | 150  | μA    |
|                                   |                 | Shutdown mode           |      | 1    |      |       |
| O.S. output saturation voltage    | V <sub>S</sub>  | I <sub>OUT</sub> =4.0mA |      |      | 0.4  | V     |

Note : \*1 The specification values of temperature detection accuracy show values when supply voltage is 3.3V.  
Temperature data vary by +1°C/V (typ.) against supply voltage.

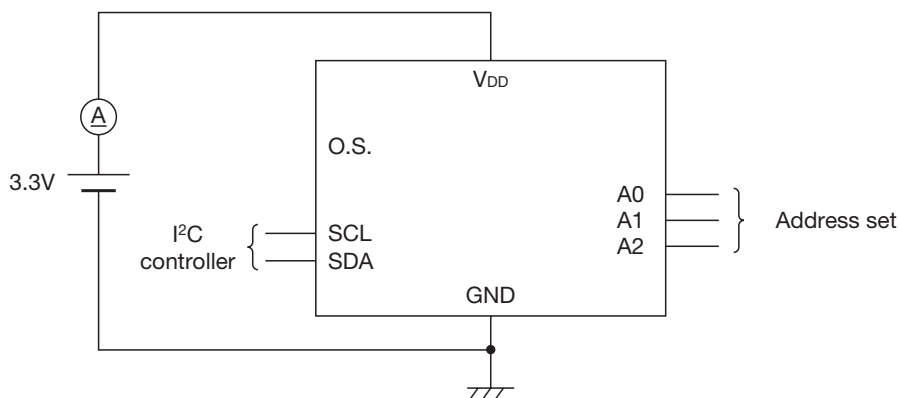
### Logic Electrical characteristics

| Item                         | Symbol              | Measurement conditions | Min. | Typ. | Max.            | Units |
|------------------------------|---------------------|------------------------|------|------|-----------------|-------|
| Input voltage L              | V <sub>IL</sub>     |                        | 0    |      | 0.7             | V     |
| Input voltage H              | V <sub>IH</sub>     |                        | 2.1  |      | V <sub>DD</sub> |       |
| SDA low level output voltage | V <sub>OL</sub>     | SDA sink 3mA           | 0.0  |      | 0.4             | V     |
| High level input current     | I <sub>IH</sub>     | SDA, SCL=3.3V          | -10  |      | 10              | μA    |
| Low level input current      | I <sub>IL</sub>     | SDA, SCL=0.4V          | -10  |      | 10              | μA    |
| Clock frequency              | f <sub>SCL</sub>    |                        |      |      | 400             | kHz   |
| Data transfer wait time      | t <sub>BUF</sub>    |                        | 1.3  |      |                 | μs    |
| SCL start hold time          | t <sub>HD;STA</sub> |                        | 0.6  |      |                 | μs    |
| SCL low level hold time      | t <sub>LOW</sub>    |                        | 1.3  |      |                 | μs    |
| SCL high level hold time     | t <sub>HIGH</sub>   |                        | 0.6  |      |                 | μs    |
| Start condition setup time   | t <sub>SU;STA</sub> |                        | 0.6  |      |                 | μs    |
| SDA data hold time           | t <sub>HD;DAT</sub> |                        | 0    |      |                 | μs    |
| SDA data setup time          | t <sub>SU;DAT</sub> |                        | 100  |      |                 | ns    |
| SDA, SCL rise time           | t <sub>R</sub>      |                        |      |      | 300             | ns    |
| SDA, SCL fall time           | t <sub>F</sub>      |                        |      |      | 300             | ns    |
| Stop condition setup time    | t <sub>SU;STO</sub> |                        | 0.6  |      |                 | μs    |

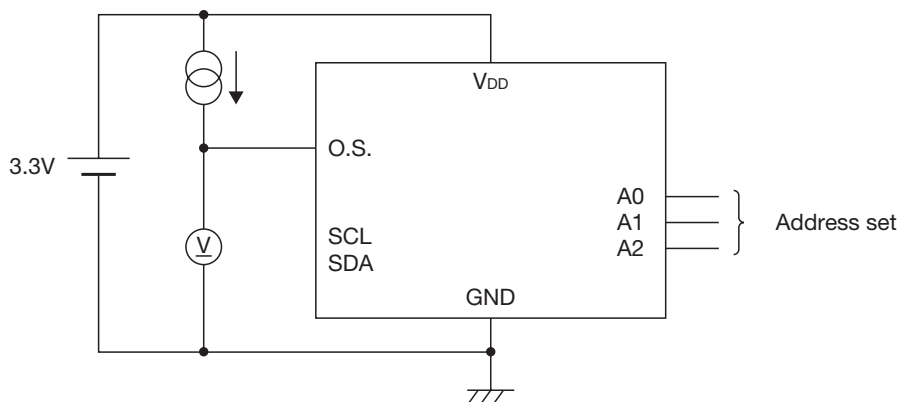


## Measuring Circuit

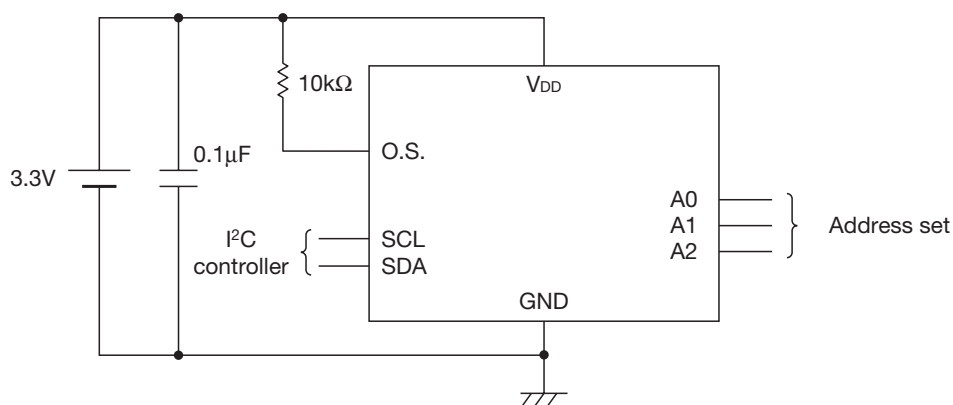
### ■ Temperature data update time Supply current



### ■ O.S. output saturation voltage

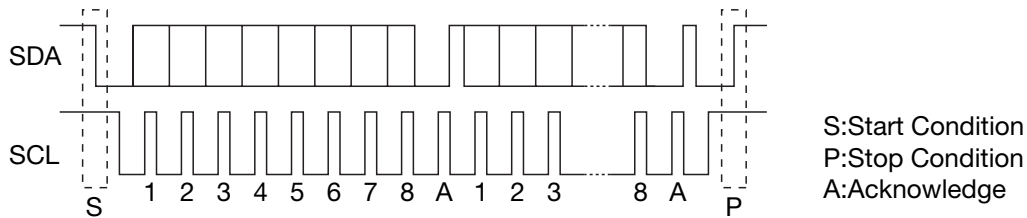


## Application Circuit



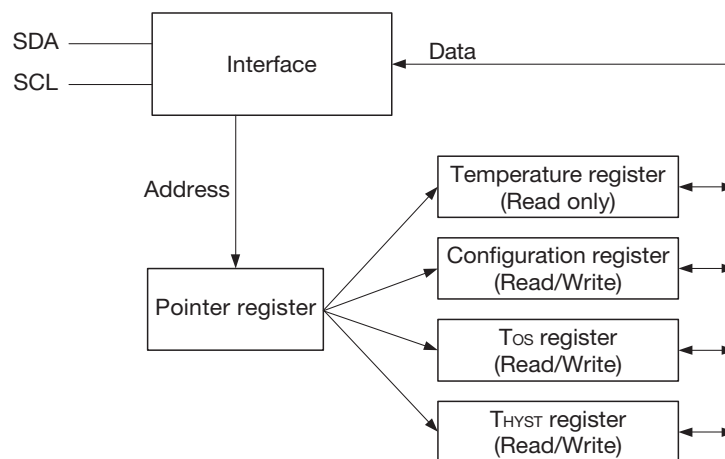
- Mitsumi shall not assume any liability for any accident or damage caused by use of this circuit.
- Mitsumi shall not assume any liability for any issues related to industrial property rights and/or other rights owned by third parties or shall not grant any license regarding use of this circuit.

## I<sup>2</sup>C BUS



The bus system, I<sup>2</sup>C BUS is the system internal to the equipment, and is used to transfer the data with 2 lines, SDA and SCL. The data is transferred for every byte and at the end of every byte transfer the acknowledgment is inserted. The data transmit and receive are started with MSB first from Start condition.

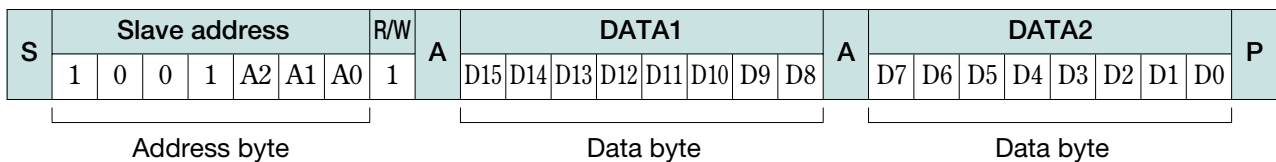
MM3286 has a pointer register and 4 data registers that are selected with the pointer register.



### [I<sup>2</sup>C Data Format]

#### Read mode

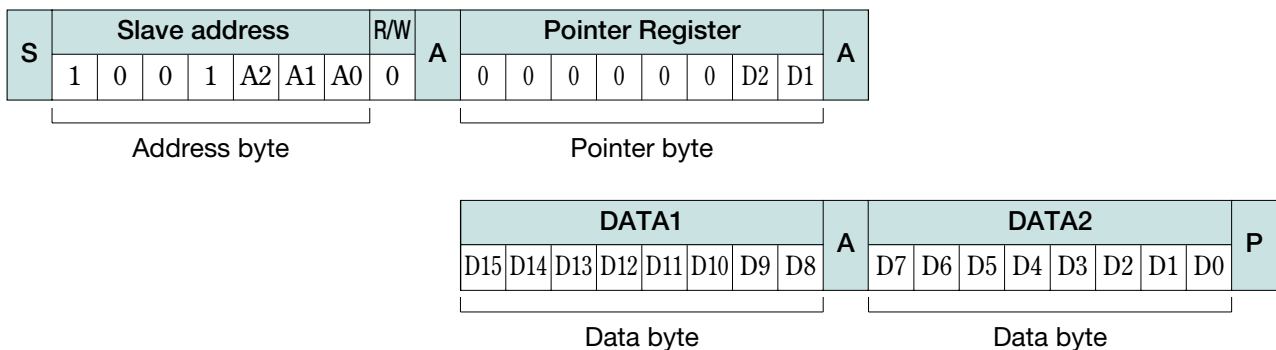
In Temperature, Configuration, T<sub>OS</sub> and T<sub>HYST</sub> registers, data format in the Read mode is set up as shown below.



\*When the selected register is the Configuration register, the data byte is 1byte only.

#### Write mode

In Configuration, T<sub>OS</sub> and T<sub>HYST</sub> registers, data format in the Write mode is set up as shown below.



\* When the Configuration register is selected with the pointer byte, the data byte is 1byte only.

**[Register construction]**

**Pointer register**

| P7 | P6 | P5 | P4 | P3 | P2 | P1                | P0 |
|----|----|----|----|----|----|-------------------|----|
| 0  | 0  | 0  | 0  | 0  | 0  | Selected register |    |

**(1) P0-P1: Register selection**

| P1 | P0 | Selected register                                                       |
|----|----|-------------------------------------------------------------------------|
| 0  | 0  | Temperature register (Read only, Default setup when power is injected.) |
| 0  | 1  | Configuration register (Read/Write)                                     |
| 1  | 0  | T <sub>HYST</sub> register (Read/Write)                                 |
| 1  | 1  | T <sub>OS</sub> register (Read/Write)                                   |

**(2) P2-P7: Set and fix 0 in these bits.**

**Temperature register (Read only)**

| D15 | D14  | D13  | D12  | D11  | D10  | D9   | D8   | D7  | D6 | D5 | D4 | D3 | D2 | D1 | D0 |
|-----|------|------|------|------|------|------|------|-----|----|----|----|----|----|----|----|
| MSB | Bit7 | Bit6 | Bit5 | Bit4 | Bit3 | Bit2 | Bit1 | LSB | X  | X  | X  | X  | X  | X  | X  |

**(1) D0-D6: Undefined bits**

**(2) D7-D15: Temperature data bits. Temperature is expressed with two's complement where 1 LSB is 0.5°C.**

**Configuration register (Read Write)**

| D7 | D6 | D5 | D4                                    | D3 | D2                         | D1                     | D0                         |
|----|----|----|---------------------------------------|----|----------------------------|------------------------|----------------------------|
| 0  | 0  | 0  | Setup of the number of O.S. detection |    | Selection of O.S. polarity | Selection of O.S. mode | Selection of shutdown mode |

**(1) D0: Selection of shutdown mode**

| D0 | Shutdown mode    |
|----|------------------|
| 0  | Normal operation |
| 1  | Shutdown         |

**(2) D1: Selection of O.S. mode**

| D1 | O.S. mode       |
|----|-----------------|
| 0  | Comparator mode |
| 1  | Latch mode      |

**(3) D2: Selection of O.S. polarity**

| D2 | O.S. polarity |
|----|---------------|
| 0  | Active Low    |
| 1  | Active High   |

**(4) D3-D4: Setup of the number of O.S. detection**

| D4 | D3 | Number of O.S. detection |
|----|----|--------------------------|
| 0  | 0  | 1                        |
| 0  | 1  | 2                        |
| 1  | 0  | 4                        |
| 1  | 1  | 6                        |

**(5) D2-D7: Retain 0 in these bits during the normal operation.**

\*The default value at the time of power injection is 0 for all the bits from D0 to D7.

**T<sub>OS</sub> and T<sub>HYST</sub> registers (Read/Write)**

| D15 | D14  | D13  | D12  | D11  | D10  | D9   | D8   | D7  | D6 | D5 | D4 | D3 | D2 | D1 | D0 |
|-----|------|------|------|------|------|------|------|-----|----|----|----|----|----|----|----|
| MSB | Bit7 | Bit6 | Bit5 | Bit4 | Bit3 | Bit2 | Bit1 | LSB | X  | X  | X  | X  | X  | X  | X  |

**(1) D0-D6: Undefined bits**

**(2) D7-D15: Data bits for setting up temperature**

\*The default value at the time of power injection is 80°C for T<sub>OS</sub> (T<sub>OS</sub>=80°C) and 75°C for T<sub>HYST</sub> (T<sub>HYST</sub>=75°C).

## Functional Descriptions

### [Temperature Data Format]

Temperature data has a resolution of 9 bits (8 bits and 1 sign), 1LSB of which is 0.5°C, and is expressed with two's complement.

| Temperature | Digital output |      |
|-------------|----------------|------|
|             | Binary code    | Hex  |
| +125°C      | 0 1111 1010    | 0FAh |
| +100°C      | 0 1100 1000    | 0C8h |
| +80°C       | 0 1010 0000    | 0A0h |
| +60°C       | 0 0111 1000    | 078h |
| +40°C       | 0 0101 0000    | 050h |
| +25°C       | 0 0011 0010    | 032h |
| +0.5°C      | 0 0000 0001    | 001h |
| 0°C         | 0 0000 0000    | 000h |
| -0.5°C      | 1 1111 1111    | 1FFh |
| -10°C       | 1 1110 1100    | 1ECh |
| -25°C       | 1 1100 1110    | 1CEh |
| -40°C       | 1 1011 0000    | 1B0h |

### [O.S Output Temperature Detection Function]

Temperature detection function of O.S. output has 2 modes, Comparator mode and Latch mode. Output polarity in any mode has 2 types, Active Low (default type) and Active High. In order to avoid false detection of temperature, the number of temperature detection is selectable, where the maximum number is 6.

Mode, polarity and number of detections of O.S. output are selectable with the Configuration register.

#### Comparator mode

In the Comparator mode, the O.S. output becomes active when temperature is  $T_{OS}$  or more and it becomes inactive when temperature is  $T_{HYST}$  or less.

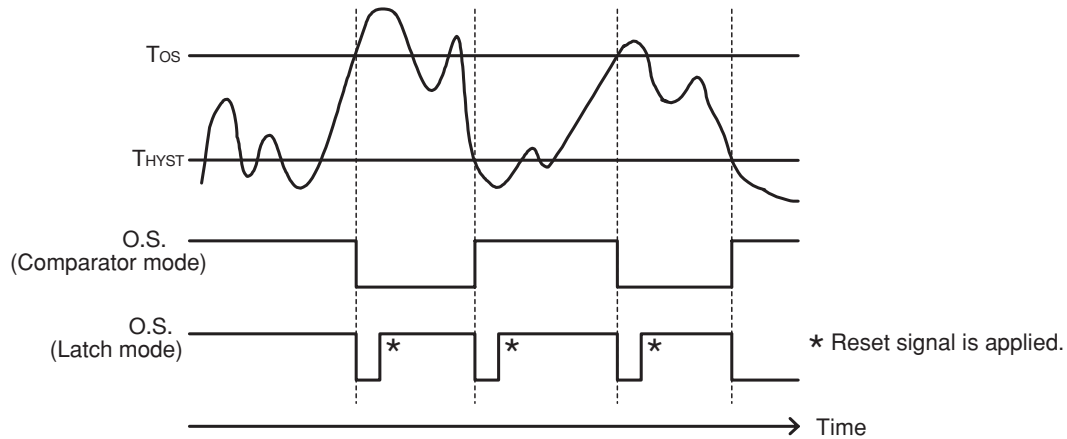
#### Latch mode

The O.S output becomes active when temperature is  $T_{OS}$  or more and remains active until it is reset. The reset condition is to read out temperature into any one of registers or to select the shutdown mode. When the output becomes active due to temperature exceeding  $T_{OS}$  and then it is reset, it is necessary for the output to become active again that temperature should be  $T_{HYST}$  or less.



### Temperature detection operation timing chart

The next chart illustrates the timing of temperature detection operation when the O.S polarity is in the Active Low mode. In the Active High mode, the polarity is inverted but operations are same as they are in the Active Low mode.



### Number of detections

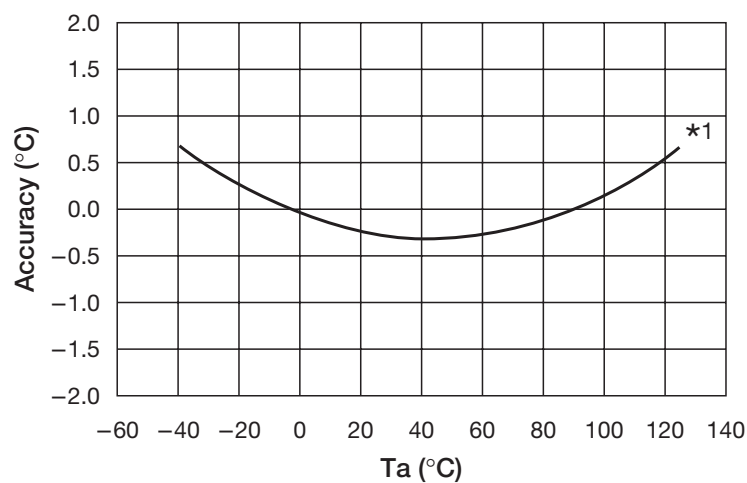
In order to avoid faulty detection in noisy environment, it is possible to set multiple numbers of detections of the O.S. output. With this function, the O.S. output is determined after detecting temperature for this preset number of times. In other words, the active status of O.S. output changes only when all the temperature detected for the preset number of times are  $T_{OS}$  or more, or when temperature detected for the preset number of times are  $T_{HYST}$  or less. The active status does not change in other cases than the above. The number of detections can be selectable with the Configuration register from 1, 2, 4, and 6.

### [Shutdown mode]

The shutdown mode becomes active by setting 1 in the shutdown mode selection bit in the Configuration register. In the shutdown mode, the consumption current is typically 1 $\mu$ A to allow the power consumption in the standby mode to be reduced. Note that even in the shutdown mode it is possible to set up  $T_{OS}$  and  $T_{HYST}$  and to read the data from or write the data in the Configuration register.

## Characteristics

### Ambient temperature - accuracy



Note : \*1 The characteristics graph shows an approximate curved line.

### Ambient temperature - supply current

