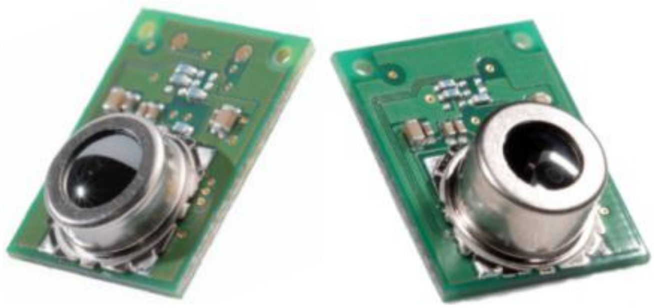
Application Note 01

Usage of D6T-44L / -8L / -1A Thermal sensor



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1 Outline

This application note provides a supplement to the data sheet for the D6T series non-contact temperature sensor – by adding special instructions and usage information.

*Please see Omron's website for the most current datasheet.

2 Structure

The D6T series sensors are made up of a cap with silicon lens, MEMS thermopile sensor chips, and dedicated analog circuit and a logic circuit for converting to a digital temperature value on a single board through one connector.

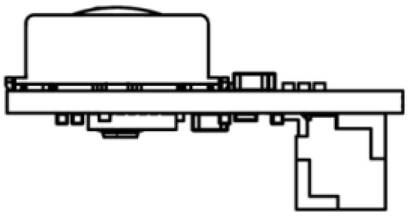

Fig.1 Module outline (Reference)

3 Dimensions

Small PCB is one of the features (14mm x 18mm and 11.6mm x 12mm). The module also has a retention area and holes usable for proper alignment. For connector details please see Section6.

4 Operating principle

An outline of the basic measuring operation is as follows.

- The silicon lens collects radiated heat (far-infrared ray) emitted from an object onto the thermopile sensor in the module. (※1)
- The radiated heat (far-infrared ray) produces an electromotive force on the thermopile sensor.
- The analog circuit calculates the temperature of an object by using the electromotive force value and a measured temperature value inside the module.(※2)
- The measured value is outputted through an I2C bus.

(※1) D6T-1A-01/-02 use the silicon filter.

(※2) D6T-1A-01 / D6T-1A-02 / D6T-8L-09 calculate the measured value (Object temperature) by using a temperature conversion circuit in the ASIC.

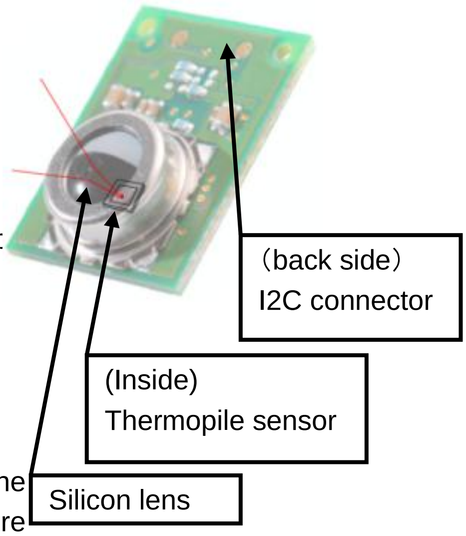

Fig.2 Module construction

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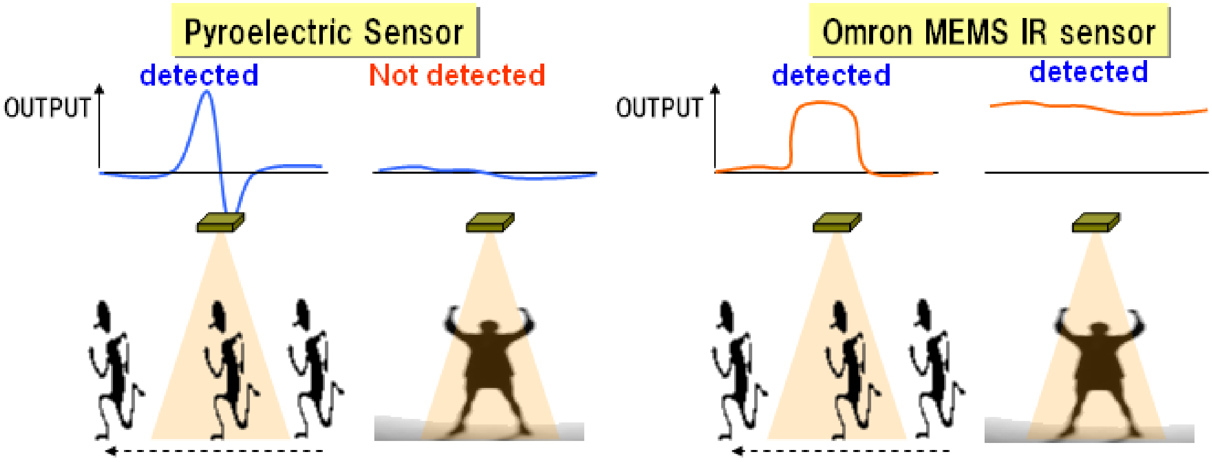
5 Features

The non-contact temperature sensor measures the surface temperature of an object. D6T-44L-06 and D6T-8L-06 and D6T-1A-01/02 have sensor chip arrays of 16 channels (4x4) and 8 channels (1x8) and 1 channel (1x1) respectively. By mounting the signal processing circuit close to the sensor chip, a low noise temperature measurement is realized.

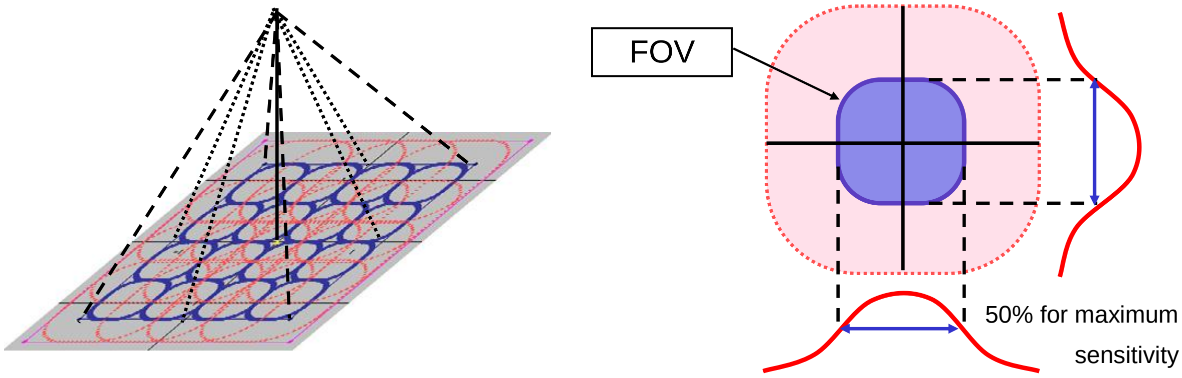
The module can also be used for detecting the presence of human beings. Omron's non-contact temperature sensor can solve the shortcomings of a conventional pyroelectric sensor, which cannot catch the signal of a stationary person because the sensor detects the change of signal [in principle]. Moreover, Omron's non-contact temperature sensor continually detects the far-infrared ray of an object, while the pyroelectric models do not.



(a) Pyroelectric sensor output (b) Non-contact temperature sensor output

Fig.3 Difference between pyroelectric and non-contact temperature sensor

The non-contact temperature sensor achieves its sensitivity characteristic over an object view angle by using a silicon lens. FOV (Field Of View) – an indication of view angle – is generally specified as an area angle of 50% for maximum sensitivity.



(a) D6T-44L-06 FOV (16ch) image (b) FOV and XY axis for a element

Fig.4 Sensitivity characteristics: FOV Image

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Please note that the sensitivity area is wider than the FOV specified area. When an object to be measured is smaller than the sensitivity area, the background temperature effects the measurements.

Though Omron’s D6T sensor corrects a temperature measurement value by using a reference heat source (blackbody furnace), the measurement’s value is influenced by the emissivity of the specific material of the object to be measured, and the surface shape of the occupant relative to the sensitivity area.

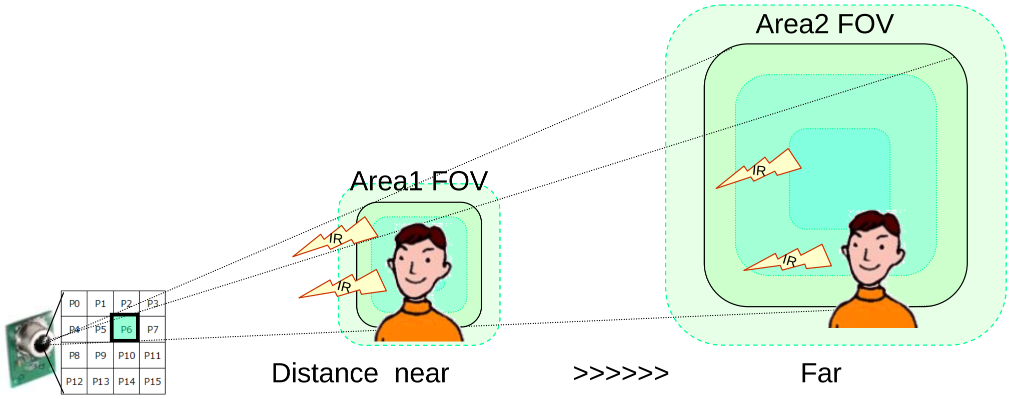

Fig.5 Changing factor of measurement by distance

Note: The occupied area in FOV becomes smaller with increasing distance and the background temperature prevails.

In cases where a D6T sensor is used for detecting human beings, the application will be limited to close range when the detection programming scheme only judges by temperature value. To extend the detection distance, improvements to the judgment accuracy can be made via software programming, considering time change, heat source location and human being movement.

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6 Usage

6.1 Connector

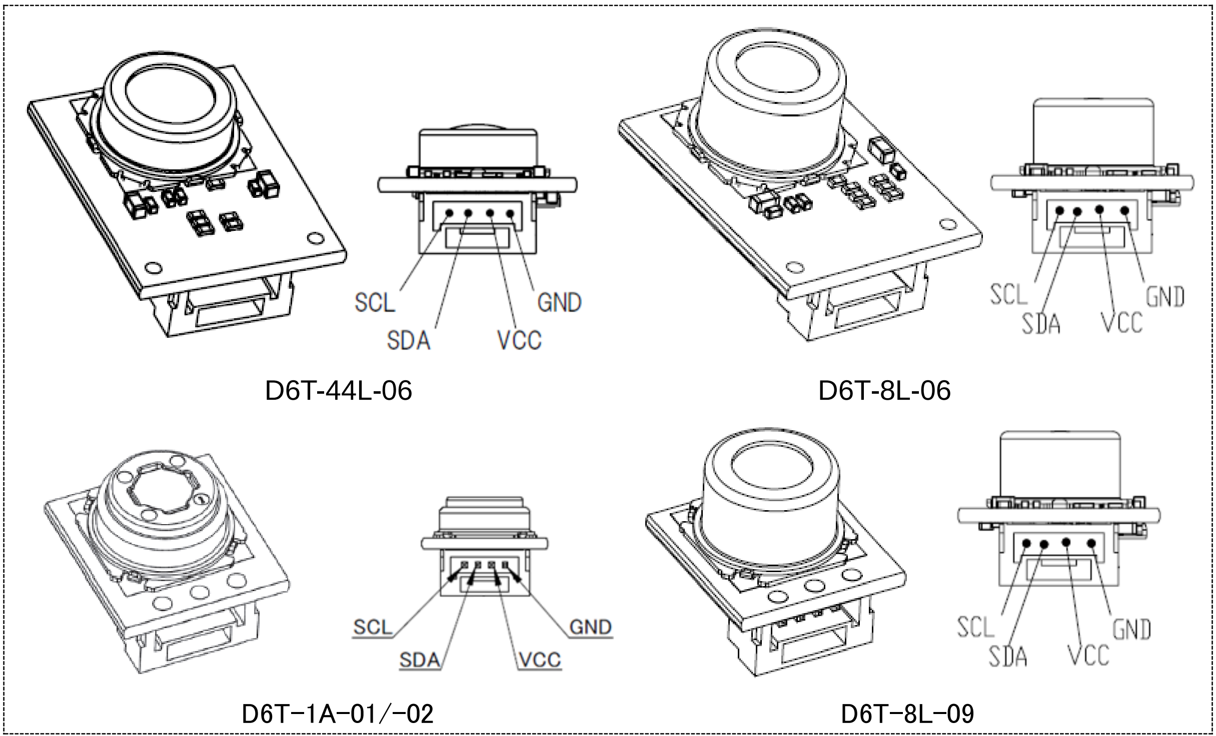

Fig.6 Connector outline

Connector pin

Table.1 Pin

1	GND	Ground
2	VCC	Power source (5V +/-10%)
3	SDA	I2C(5V) Data line
4	SCL	I2C(5V) Clock line

One Connector (used inside sensor) : JST p/n SM04B-GHS-TB

To connect to the system, use the following four-pin mating connector.

Contact : JST p/n SSHL-002T-P0.2 (4pcs).

Housing : JST p/n GHR-04V-S

A difference in appearance is height of lens and PCB size. For detailed dimensions, please refer to the data sheet.

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6.2 Electrical connection

Case 1: Direct connection. The voltage of MCU Power source is 5V.

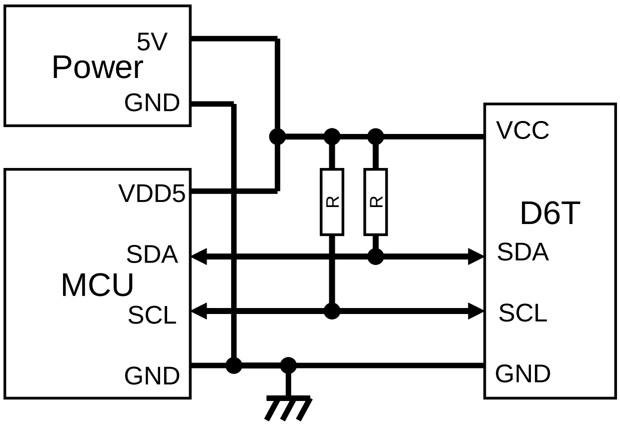

Fig.7 (a) Direct connection

Case 2: Direct connection. 3V MCU (5V-tolerant I2C port)

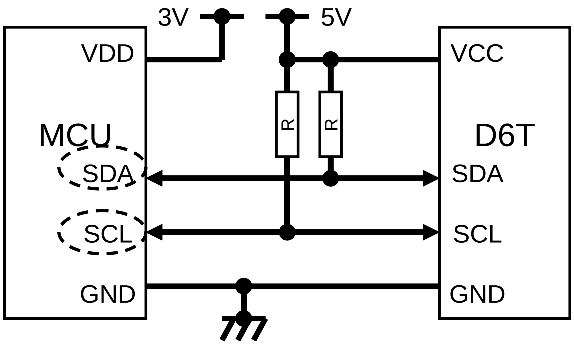

Fig.7 (b) 5V-tolerant

Case 3: Using I2C level translating IC.

(not 5V-tolerant, other LV-devices exist on the same I2C-bus)

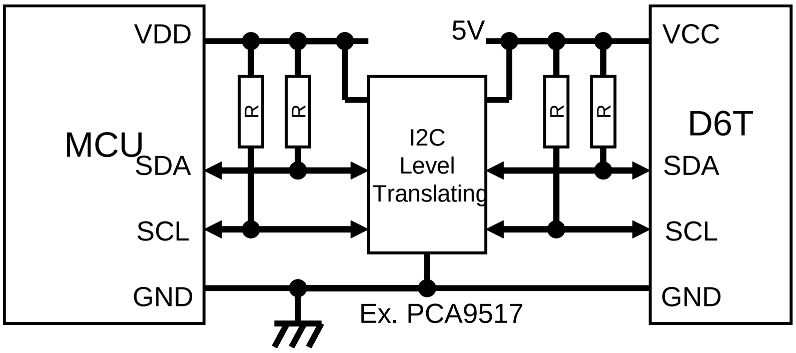

Fig.7 (c) Using I2C level translating IC

Pull-Up Resistor :

Impedance value is decided by user. (see I2C[100kHz] specification note.)

(Most case : About 3k to 10k ohm)

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Case 4: Software I2C. using Bi-directional Open Drain GPIO ports.
(MCU has no I2C module inside.)
Note: Wait routine for Clock-Stretching is required – to be prepared by the user.

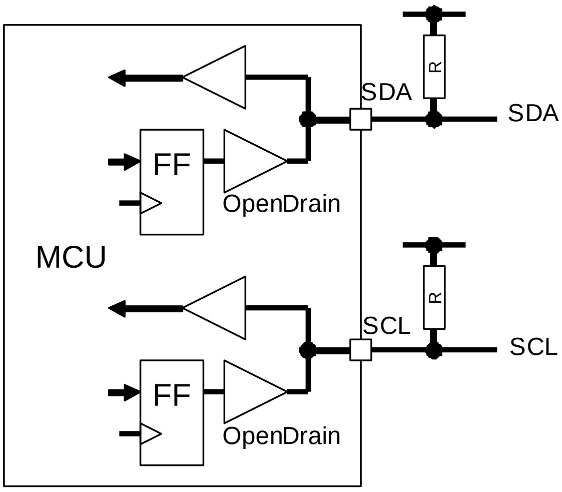

Fig.7 (d) Using GPIO-ports

Case5: Using I2C bus switch IC. Ex. PCA9545(4ch) , PCA9548(8ch)
(multiple D6T sensors)

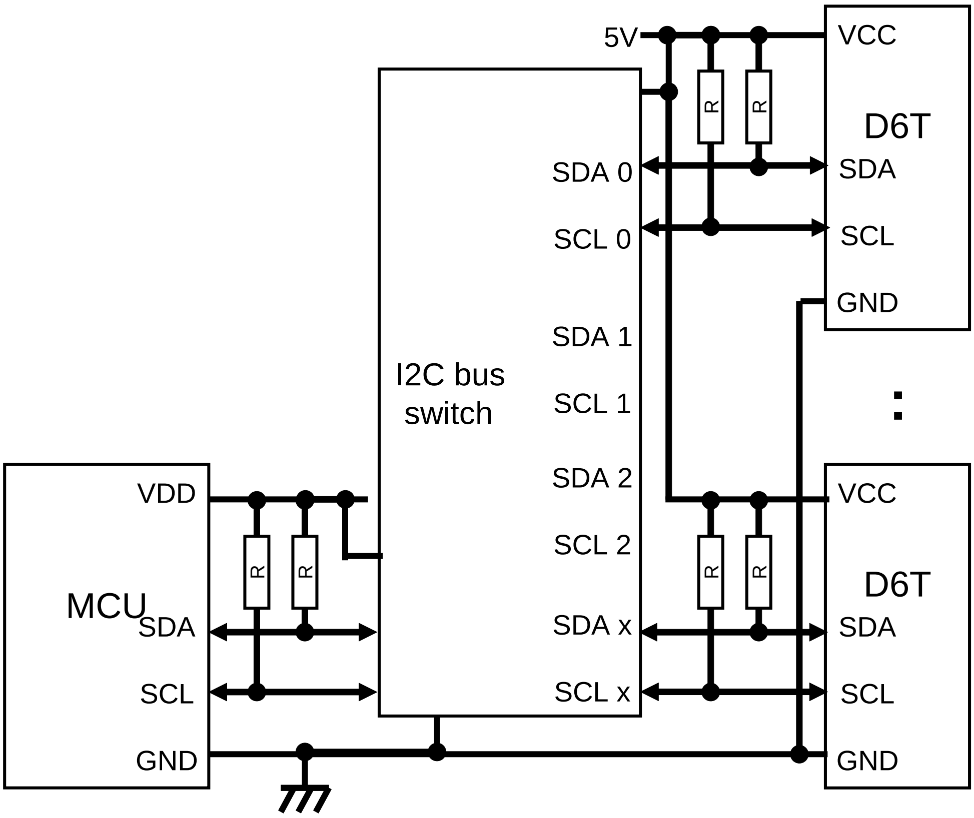

Fig.7 (e) Using I2C bus switch IC

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6.3 I2C port setting

Table.2 I2C port parameters

Device Address	7bit : 0001_010b 8bit (with R/W bit) Read : 15h , Write : 14h
Data bit width	8bit (MSB-first)
Clock Frequency	max 100kHz
Control for Clock-stretching	On (Auto waiting) /Except for D6T-1A-01,D6T-1A-02,D6T-8L-09 *see Section 6.5

Start	Address W	Command W (4Ch)	Repeat Srart	Address R	PTAT (Lo)	PTAT (Hi)	P0 (Lo)	P0 (Hi)
P1 to P13 (Lo,Hi)			P6 (Lo)	P6 (Hi)	P7 (Lo)	P7 (Hi)	PEC	Stop

Output data : 35 bytes

(a) 16ch (D6T-44L-06)

Start	Address W	Command W (4Ch)	Repeat Srart	Address R	PTAT (Lo)	PTAT (Hi)	P0 (Lo)	P0 (Hi)
P1 to P5 (Lo,Hi)			P6 (Lo)	P6 (Hi)	P7 (Lo)	P7 (Hi)	PEC	Stop

Output data : 19 bytes

(b) 8ch (D6T-8L-06)

Start	Address W	Command W (4Ch)	Repeat Srart	Address R	PTAT (Lo)	PTAT (Hi)	P0 (Lo)	P0 (Hi)	PEC	Stop

Output data : 5 bytes

(c) 1ch (D6T-1A-01/D6T-1A-02)

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	Start	Address W (14h)	Command W (02h)	Command W (00h)	Command W (01h)	Command W (EEh)	Stop		
	Start	Address W (14h)	Command W (05h)	Command W (90h)	Command W (3Ah)	Command W (B8h)	Stop		
	Start	Address W (14h)	Command W (03h)	Command W (00h)	Command W (03h)	Command W (8Bh)	Stop		
	Start	Address W (14h)	Command W (03h)	Command W (00h)	Command W (07h)	Command W (97h)	Stop		
	Start	Address W (14h)	Command W (02h)	Command W (00h)	Command W (00h)	Command W (E9h)	Stop		
※	Start	Address W (14h)	Command W (02h)	Repeat Srart	Command R (15h)	Command R (00h)	Command R (00h)	Stop	
※	Start	Address W (14h)	Command W (05h)	Repeat Srart	Command R (15h)	Command R (90h)	Command R (3Ah)	Stop	
※	Start	Address W (14h)	Command W (03h)	Repeat Srart	Command R (15h)	Command R (00h)	Command R (07h)	Stop	
	Start	Address W	Command W (4Ch)	Repeat Srart	Address R	PTAT (Lo)	PTAT (Hi)	P0 (Lo)	P0 (Hi)
	P1 to P5 (Lo,Hi)			P6 (Lo)	P6 (Hi)	P7 (Lo)	P7 (Hi)	PEC	Stop

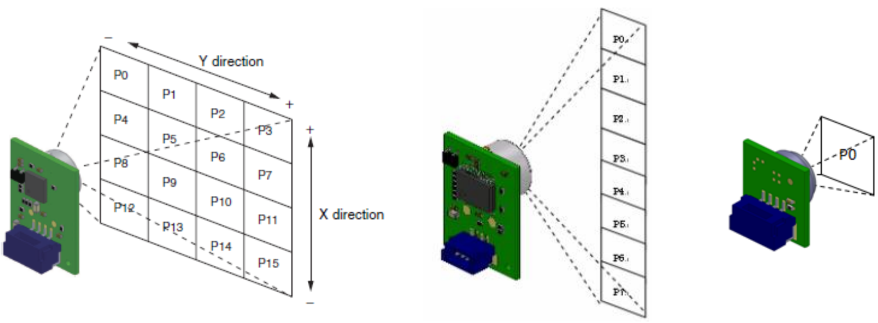
Output data : 19 bytes

(※)This is a Read command to check if it had been correctly set in the internal register. It is possible to skip.

(d) 8ch (D6T-8L-09)

Fig.8 I2C port data chart

Table.3 Output data format

PTAT	The value of the reference temperature, inside the sensor module. Temperature data (PTAT&Pn) is 16bit-width, singed, 10 times value of degC. D15 bit in Output of ambient temperature and object temperature is a sign bit. <Example> 25.0 degC = 250 (High byte Data = 0x00、 Low byte Data = 0xFA) -25.0 degC = -250 (High byte Data = 0xFF、 Low byte Data = 0x06)
P0 ～ P15 (D6T-44L-06) P0 ～ P7 (D6T-8L-06) (D6T-8L-09) P0 (D6T-1A-01) (D6T-1A-02)	Measured value. Pixel order is below. 
PEC	Packet error check code. Based on the “SM bus” specification.

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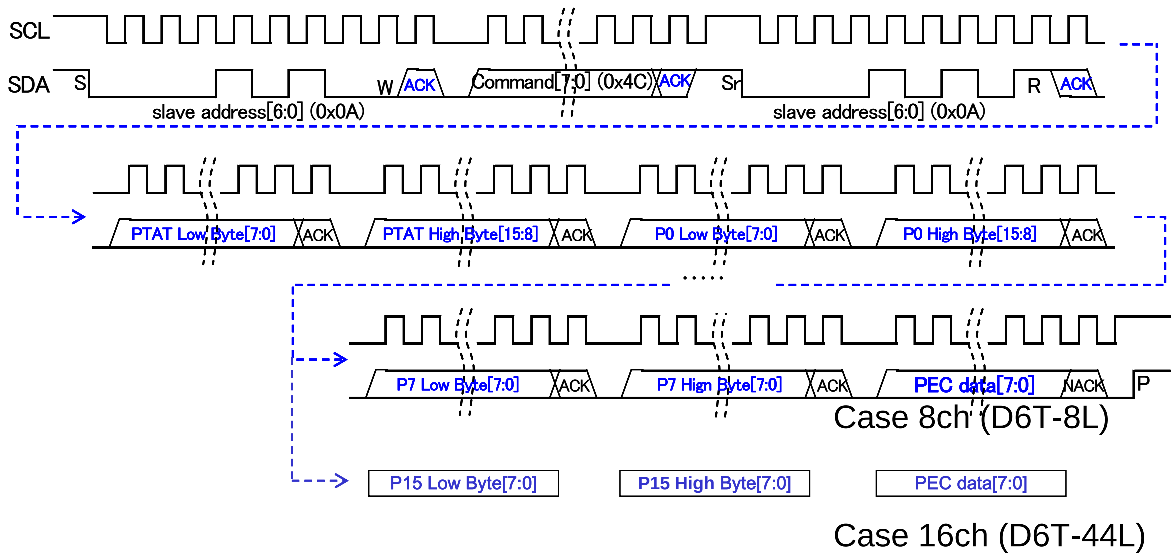
Signal chart



"S"	: Start Condition
"Sr"	: Repeat Start Condition
"P"	: Stop Condition
"W/R"	: Write (Lo) / Read (Hi)
"ACK"	: Acknowledge reply
"NACK"	: No-acknowledge reply

For each term, please see the I2C specification.

Fig.9 Signal chart

(D6T-8L-06 / D6T-44L-06 / D6T-1A-01 / D6T-1A-02)

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For D6T-8L-09, Wait for 20 msec after the power supply, please perform the following processing before work shown in Fig.9.

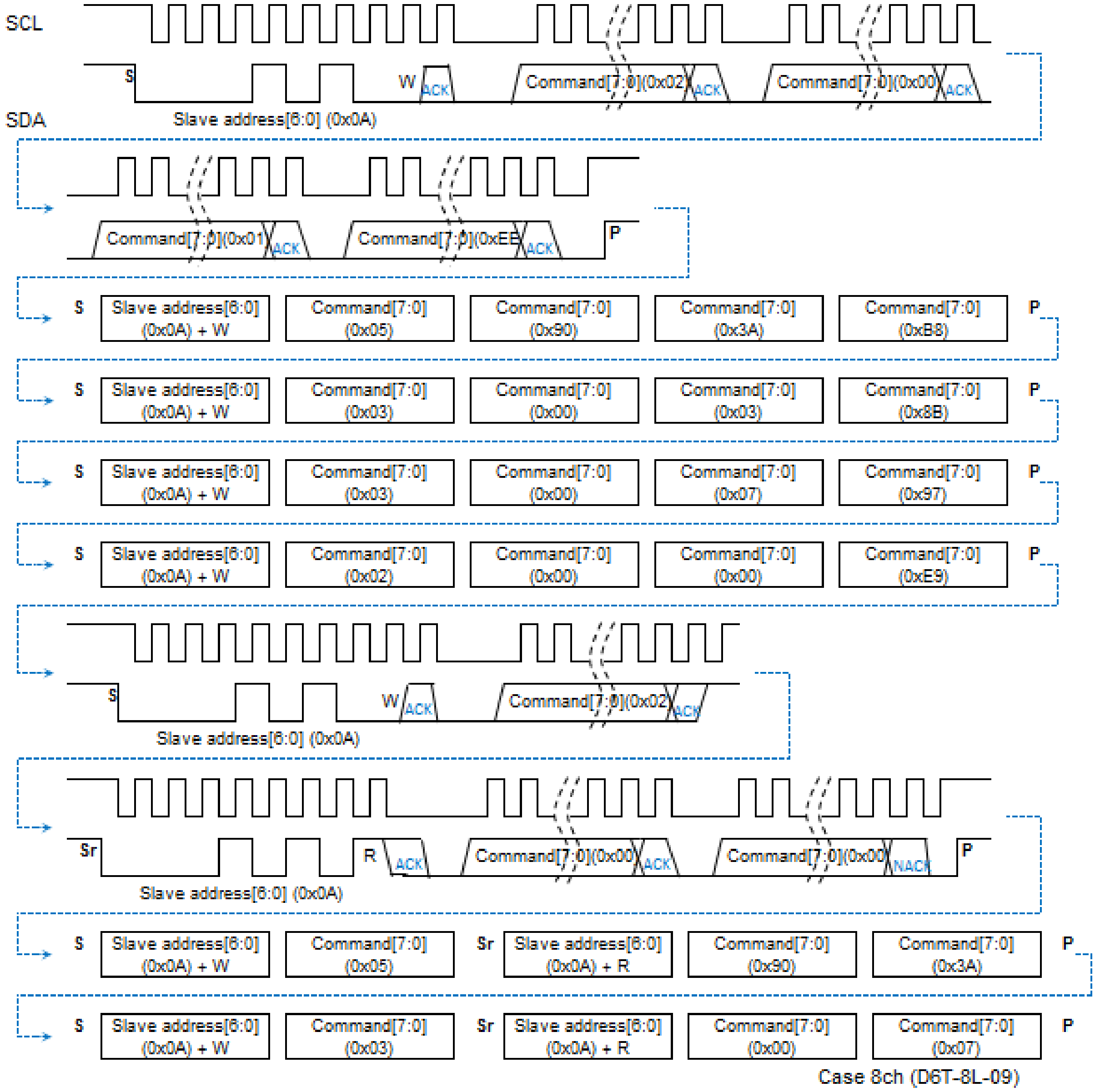

Fig.10 Signal chart (D6T-8L-09)

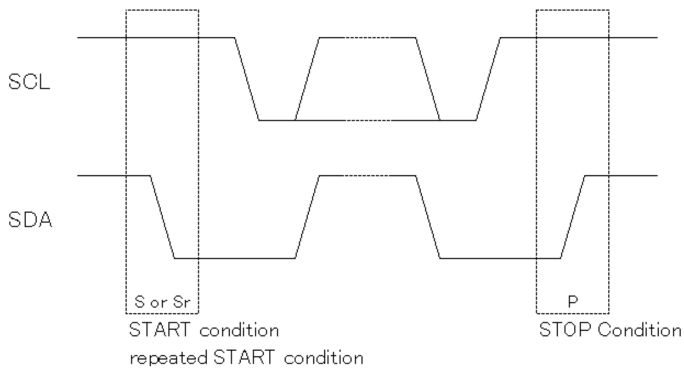

Fig.11 Start Stop condition

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6.4 Example Getting the measurement value.

(16ch : D6T-44L-06)

```
// I2C communication functions
extern  void  I2C_start();
extern  void  I2C_repeatstart();
extern  void  I2C_stop();
extern  void  I2C_send1( char addr8 , char cmd );
extern  void  I2C_getx( char addr8 , char buff[] , int length );
extern  int   D6T_checkPEC( char buf , int pPEC );

// Global var.
extern  char  readbuff[35];
extern  int   tPTAT;
extern  int   tP[16];
extern  int   tPEC;

int  D6T_getvalue()
{
    I2C_start();
    I2C_send1( 0x14 , 0x4C ); // 14h = { 0Ah(Addr7) : Write(0b) }
    I2C_repeatstart();
    I2C_getx( 0x15 , readbuff , 35 ); // 15h = { 0Ah(Addr7):Read },35 = 2*(1+16)+1
    I2C_stop();
    If(!D6T_checkPEC(readbuff,34)){
        return -1; // error
    }
    tPTAT = 256*readbuff[1] + readbuff[0];
    tP[0] = 256*readbuff[3] + readbuff[2];
    tP[1] = 256*readbuff[5] + readbuff[4];
    tP[2] = 256*readbuff[7] + readbuff[6];
    tP[3] = 256*readbuff[9] + readbuff[8];
    tP[4] = 256*readbuff[11] + readbuff[10];
    tP[5] = 256*readbuff[13] + readbuff[12];
    tP[6] = 256*readbuff[15] + readbuff[14];
    tP[7] = 256*readbuff[17] + readbuff[16];
    tP[8] = 256*readbuff[19] + readbuff[18];
    tP[9] = 256*readbuff[21] + readbuff[20];
    tP[10] = 256*readbuff[23] + readbuff[22];
    tP[11] = 256*readbuff[25] + readbuff[24];
    tP[12] = 256*readbuff[27] + readbuff[26];
    tP[13] = 256*readbuff[29] + readbuff[28];
    tP[14] = 256*readbuff[31] + readbuff[30];
    tP[15] = 256*readbuff[33] + readbuff[32];
    tPEC = readbuff[34];
    return 1;
}

measure()
{
    n = 0;
    do{
        status = D6T_getvalue();
        n++;
    }while(status < 0 && n < LOOPLIMIT);
    If(status < 0){
        // error operation.
    }
    printf( "%d, %d,%d,%d,%d,%d,%d,%d,%d ,%d,%d,%d,%d,%d,%d,%d,%d ,%d¥n" ,
        tPTAT,tP[0],tP[1],tP[2],tP[3],tP[4],tP[5],tP[6],tP[7]
        ,tP[8],tP[9],tP[10],tP[11],tP[12],tP[13],tP[14],tP[15],tPEC);
}
```

Note. The I^2C operation library function used here is composed only of standard features.

If you want to try, please use the library functions similar to that provided by the MCU vendor.

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Output Example (PTAT , P0,P1,･･･,P15 , PEC)

```
223 ,224,224,273,335,239,221,240,297 ,264,232,221,254,299,258,229,233 ,80

223 ,271,261,265,304,284,270,264,274 ,302,285,271,260,319,304,286,269 ,193

223 ,296,273,285,311,306,291,281,301 ,311,310,293,296,312,322,311,302 ,83
```

PTAT=22.3 ° C , P0=29.6 °C , P1=27.3° C , P2=28.5 °C …

Modification example (8ch : D6T-8L-06)

```
int  D6T_getvalue()
{
    I2C_start();
    I2C_send1( 0x14 , 0x4C ); // 14h = { 0Ah(Addr7) : Write(0b) }
    I2C_repeatstart();
    I2C_getx( 0x15 , readbuff , 19 ); // 15h = { 0Ah(Addr7):Read },19 = 2*(1+8)+1
    I2C_stop();
    If(!D6T_checkPEC(readbuff,18)){
        return -1; // error
    }
    tPTAT = 256*readbuff[1] + readbuff[0];
    tP[0] = 256*readbuff[3] + readbuff[2];
    tP[1] = 256*readbuff[5] + readbuff[4];
    tP[2] = 256*readbuff[7] + readbuff[6];
    tP[3] = 256*readbuff[9] + readbuff[8];
    tP[4] = 256*readbuff[11] + readbuff[10];
    tP[5] = 256*readbuff[13] + readbuff[12];
    tP[6] = 256*readbuff[15] + readbuff[14];
    tP[7] = 256*readbuff[17] + readbuff[16];
    tPEC = readbuff[18];
    return 1;
}
```

Modification example (1ch : D6T-1A-01/D6T-1A-02)

```
int  D6T_getvalue()
{
    I2C_start();
    I2C_send1( 0x14 , 0x4C ); // 14h = { 0Ah(Addr7) : Write(0b) }
    I2C_repeatstart();
    I2C_getx( 0x15 , readbuff , 5 ); // 15h = { 0Ah(Addr7):Read },5 = 2*(1+1)+1
    I2C_stop();
    If(!D6T_checkPEC(readbuff,4)){
        return -1; // error
    }
    tPTAT = 256*readbuff[1] + readbuff[0];
    tP[0] = 256*readbuff[3] + readbuff[2];
    tPEC = readbuff[4];
    return 1;
}
```

Note. This example represents a single measurement run.

This sensor repeats the operation for each of the data measurements and updates within 250ms.

Therefore, you will be able to retrieve new data about 4 times per second.

It is not possible for the user to control the measurement timing.

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Modification example (D6T-8L-09)

```
int  D6T_getvalue()
{
    I2C_start();
    I2C_send( 0x14 , 0x02 , 0x00 , 0x01 , 0xEE );
    I2C_stop();
    I2C_start();
    I2c_send ( 0x14 , 0x05 , 0x90 , 0x3A , 0xB8 ) ;
    I2C_stop();
    I2C_start();
    I2c_send ( 0x14 , 0x03 , 0x00 , 0x03 , 0x8B ) ;
    I2C_stop();
    I2C_start();
    I2c_send ( 0x14 , 0x03 , 0x00 , 0x07 , 0x97 ) ;
    I2C_stop();
    I2C_start();
    I2c_send ( 0x14 , 0x02 , 0x00 , 0x00 , 0xE9 ) ;
    I2C_stop();

    I2C_start();
    I2C_send( 0x14 , 0x02 );
    I2C_repeatstart();
    I2C_send( 0x15 );
    I2C_get( 0x15 , readbuff , 2 ); // Expected value of 2 byte read is 0x00 and 0x00.
    I2C_stop();

    I2C_start();
    I2c_send( 0x14 , 0x05 );
    I2C_repeatstart();
    I2C_send( 0x15 );
    I2C_get( 0x15 , readbuff , 2 ); // Expected value of 2 byte read is 0x90 and 0x3A.
    I2C_stop();

    I2C_start();
    I2C_send( 0x14 , 0x03 );
    I2C_repeatstart();
    I2C_send( 0x15 );
    I2C_get( 0x15 , readbuff , 2); // Expected value of 2 byte read is 0x00 and 0x07.
    I2C_stop();

    I2C_start();
    I2C_send1( 0x14 , 0x4C ); // 14h = { 0Ah(Addr7) : Write(0b) }
    I2C_repeatstart();
    I2C_getx( 0x15 , readbuff , 19 ); // 15h = { 0Ah(Addr7):Read },19 = 2*(1+8)+1
    I2C_stop();
    If(!D6T_checkPEC(readbuff,18)){
        return -1; // error
    }
    tPTAT = 256*readbuff[1] + readbuff[0];
    tP[0] = 256*readbuff[3] + readbuff[2];
    tP[1] = 256*readbuff[5] + readbuff[4];
    tP[2] = 256*readbuff[7] + readbuff[6];
    tP[3] = 256*readbuff[9] + readbuff[8];
    tP[4] = 256*readbuff[11] + readbuff[10];
    tP[5] = 256*readbuff[13] + readbuff[12];
    tP[6] = 256*readbuff[15] + readbuff[14];
    tP[7] = 256*readbuff[17] + readbuff[16];
    tPEC = readbuff[18];
    return 1;
}
```

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6.5 PEC check routine Example

PEC is the data used for the error checking method using CRC-8. PEC and is appended to the end of the communication output. You can detect communication failures using the PEC, improving the reliability of the data. (For more information, please refer to the SMBus specification)

```
unsigned char  calc_crc( unsigned char  data )
{
   int  index;
   unsigned char  temp;

   for(index=0;index<8;index++){
      temp = data;
      data <<= 1;
      if(temp & 0x80) data ^= 0x07;
   }
   return data;
}

int  D6T_checkPEC( char buf , int pPEC );
{
   unsigned char  crc;
   int  i;

   crc = calc_crc( 0x14 );
   crc = calc_crc( 0x4C ^ crc );
   crc = calc_crc( 0x15 ^ crc );
   for(i=0;i<pPEC;i++){
      crc = calc_crc( readbuff[i] ^ crc );
   }
   return (crc == readbuff[pPEC]);
}
```

Other case : Using Stop-Start condition without Repeat Start Condition,

```
int  D6T_checkPEC( char buf , int pPEC );
{
   unsigned char  crc;
   int  i;

   crc = calc_crc( 0x15 );
   for(i=0;i<pPEC;i++){
      crc = calc_crc( readbuff[i] ^ crc );
   }
   return (crc == readbuff[pPEC]);
}
```

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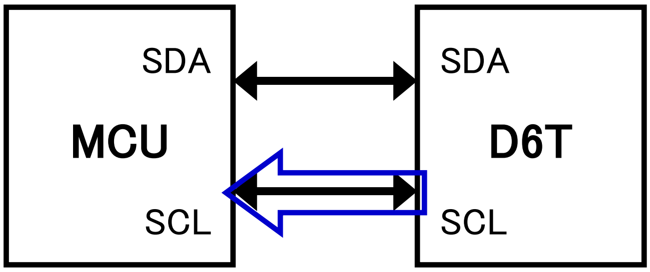
6.6 Detect routine of wait status (Clock-stretching)

Our sensor may require a wait request of the master. On the master side, it is necessary to deal with this wait process. In many I2C modules in the MCU, there is a feature that can do this automatically. However, if using the I2C software library, the user may have to deal with this wait process manually. D6T-1A-01/D6T-1A-02/D6T-8L-09 does not have a clock stretch.



Wait sequence

I2C Master	I2C Slave(D6T)
a) SCL drive to Lo for Ack.	Checking SCL status.(Lo)
(Fixed wait) **c) SCL output change to Hi-Z.** **SCL I/O mode change to Input** **d) Checking SCL status.(Hi)** **Checking …**	b) SCL drive to Lo for Wait. Wait ... : : : Wait finish e) SCL output change to Hi-Z.
f) Finish Detected. **SCL I/O mode change to Output** g) Next operation.	

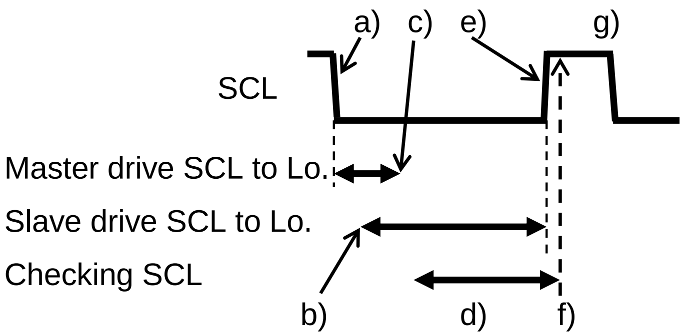


Fig.12 Detect routine of wait status

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6.7 Communication time out

It will be communication time out if Low period of SDA and SCL Line continues ~~1 sec~~ the following time.

- D6T-44L-06 / D6T-8L-06 : 1sec
- D6T-1A-01 / D6T-1A-02 / D6T-8L-09 : 70msec

In addition, If the sensor is determined that communication time-out, it returns a NACK to Write access. Read value will be FFFFh is Read access.

We recommended the check data using the PEC that can be judged to be abnormal is read value.

6.8 Cover Material

If you opt to put a cover over the sensor, carefully consider the performance of the material in regards to how well it passes through radiant heat. High-density polyethylene (HDPE, grade far infrared transmission) is a good cover material option. If the cover is thick, the transmittance decreases. It is best to use as thin a cover as possible to keep a minimal impact on detection performance. The internal sensors can then show through. (as shown in the example pictured below).

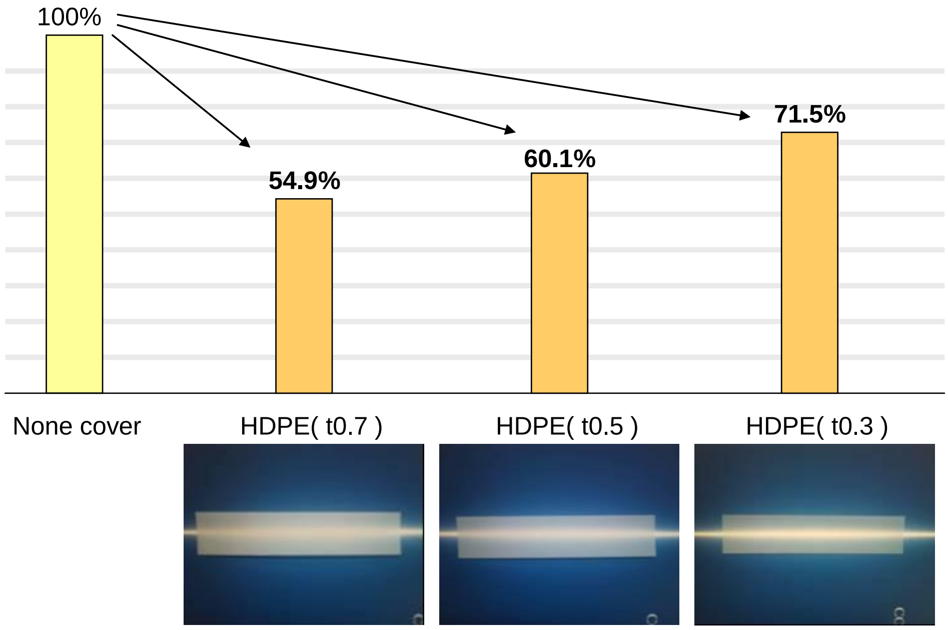

Fig.13 HDPE thickness vs. Transmittance (reference)

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7 FAQ

Question	Can the field of view (FOV) angle be increased?
Answer	No. OMRON set the FOV in consideration of the constraints imposed by the thickness and refractive index of the silicon lens. Measurement distance is reduced as the FOV of one element increases. Therefore, we can not simply widen the viewing angle. A good way to measure a wide range, is to install multiple sensors, or mount the senor on a movable/rotating base.
Question	Are there any effects on an infrared remote controller?
Answer	No. The silicon lens we are using will not pass through most near-infrared and visible light below 1.2 [μm] wavelength. Therefore, it does not affect the infrared signal of the remote controller. The far infrared rays that are emitted as radiant heat are about 4 to 14 [μm].
Question	Is it possible to distinguish between humans, animals, and appliances?
Answer	No. In the non-contact temperature module, you can only acquire surface temperature measurement data. Different objects of the same temperature will read the same. Further discrimination must be based on the behavior of the measured data to distinguish the object by software on the user side. By developing software designed with your specific application in mind, the determination accuracy may possibly be improved.
Question	What is the distance range that can detect the presence of people?
Answer	This is greatly affected by the decision performance and software installation conditions. It is also affected by the size of the object to be measured and the area of the FOV per element. A rough guideline distance is about 5 to 6 meters.
Question	Can the power consumption be reduced?
Answer	No. The D6T thermal sensor does not have a power saving mode. Therefore, in order to reduce power consumption it is necessary to shut off the power.
Question	Is there a sensor that can operate on a supply voltage of 3[V]? Is there an I2C slave address that I can change?
Answer	No. The D6T thermal sensor does not support them.

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8 Glossary

- Thermopile
  Thermal sensors utilize the Seebeck effect in which thermoelectric force is generated due to the temperature difference at the contact points between two different kinds of metal. A thermopile is created by serially connecting thermocouples. By creating hot junctions on highly heat-resistant dielectric membranes, and cold junctions on highly heat-conductive silicon, it is possible to achieve high-speed response and high-energy conversion efficiency.

- NETD (Described in the catalog)
  Noise Equivalent Temperature Difference.
  Definition: An indication of the amount of noise that is expressed as a temperature. It becomes a measure of the minimum value of the change in the measured temperature that can be determined. It is sometimes referred to as temperature resolution.

- FOV
  Field of View. FOV range is often defined in the range 50% of the peak sensitivity.

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11 History

Revision	DATE	Note
Rev 1.0	July01, 2012	New Released
Rev 2.0	Oct01, 2013	Revised
Rev 3.0	July21, 2015	Add “6.7 Communication time out” Add Type D6T-8L-09,D6T-1A-01/-02

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