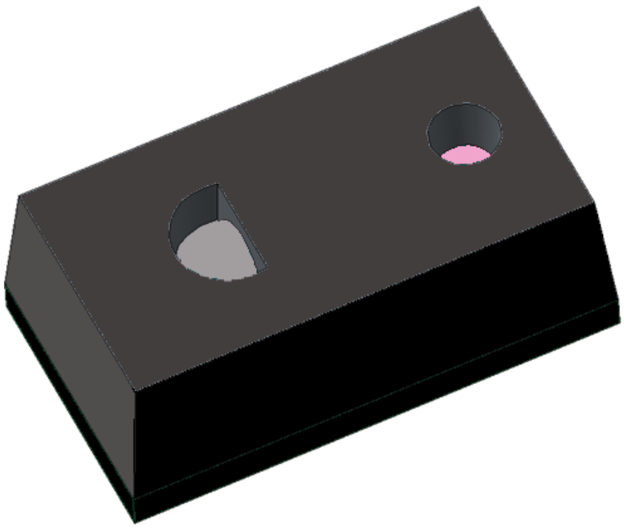
GP2AP03VT USER MANUAL

Time-of-Flight ranging Sensor



Contents

1. Abstract

GP2AP03VT is a ToF(Time of Flight) sensor that implemented a TDC(Time-to-Digital Conversion) circuit.

1.1. Features

- This product is composed of following two chips in one package, which is IC with a built-in single photon avalanche diode (SPAD) (Infrared photodiode by infrared light band pass filter) for range sensor, and infrared VCSEL.
- This sensor adopts TDC circuit system. The crosstalk characteristic from cover panel is good.
- This sensor can implement the automatic crosstalk compensate function by software. Effects of crosstalk can also be suppressed when stains such as fingerprints or facial oil adheres to the cover panel.
- The maximum communication speed of I^2C is 1MHz.
- This sensor has a function to reduce the influence of disturbance light.

1.2. Application

Proximity sensor, face detect, camera AF, robot, home appliances, toilet facility, personel computer , etc.

2. I^2C interface

2.1. I^2C bus interface

Table 1 shows the description of the SDA and SCL terminals.

Table 1 SDA and SCL terminals.

Name	Description
SCL	Clock
SDA	Data bus

Basic data format are as follows.

DATA: Data which write into internal register/read from internal register.

SLAVE ADDRESS:0x29

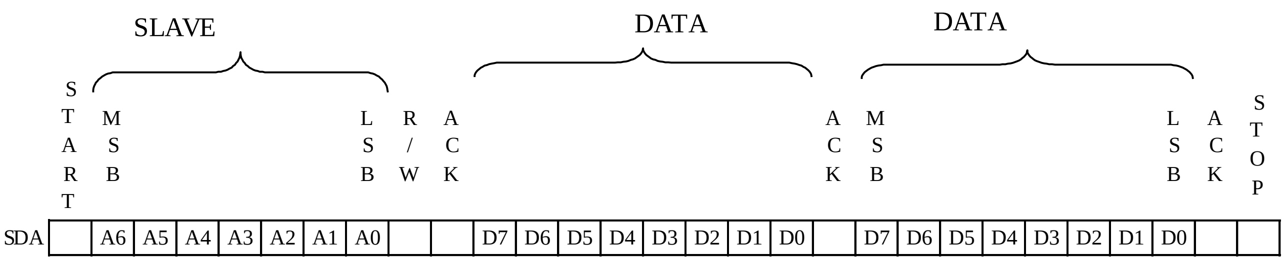


Fig.1 I^2C Basic data format

Table 2 I^2C slave address

ADDRESS	A6	A5	A4	A3	A2	A1	A0	R/W
	0	1	0	1	0	0	1	X

2.2. Write format

After the data write, you can write data to the next address sequentially (* 1). Data writing ends when the stop condition is entered.

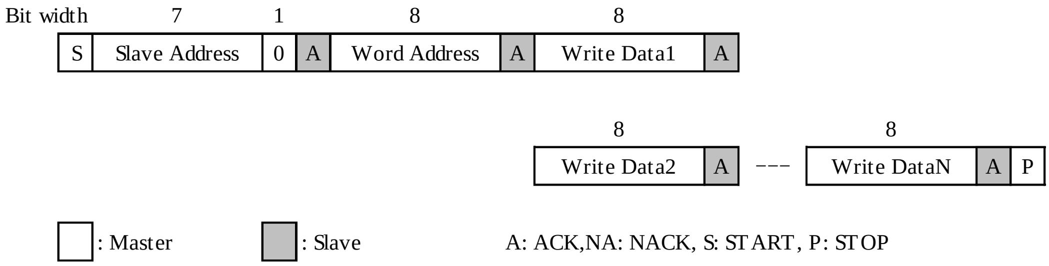


Fig.2 I²C write format

(*1) However, sequential writing that is from Word Address 0x37 to 0x38 is not possible.

2.3. Read format

After reading the data, enter ACK to read data the next address sequentially (* 1). Enter NACK to end the data read.
Since it supports repeat start conditions, you can delete the stop conditions after setting the Word Address. The read data can be read without opening the I2C bus.

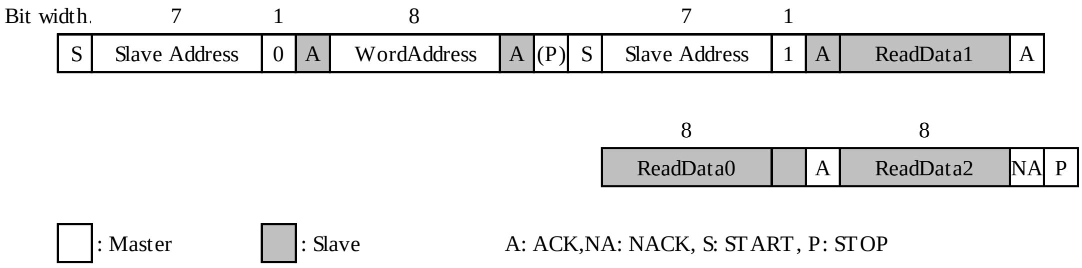


Fig.3 I²C read format

(*1) However, sequential reading that is from Word Address 0x37 to 0x38 is not possible.

2.4. Others and Notes

This product doesn't support Clock-stretch function and General-call-address function.

3. Operation

3.1. Operation overview

Figure 4 shows the operation flow of the GP2AP03VT sensor.

(1) Power on
When power is supplied to the sensor, the power-on reset circuit inside the IC circuit operates to initialize the registers and then enter the power down state.

(2) Initialization
By executing the initialization function via I^2C, set the value in the register of the sensor.

(3) Start measurement
Measurement is started by executing the measurement start function, and automatically returns to the power down state when the measurement is completed.

(4) Read data, Calculation
The host can read the measurement result via I^2C and calculate the distance value by carrying out calculation processing. Approximately 6 msec of data reading time is required at I^2C communication speed 400 kHz.

(5) Restart
To continue measurement, execute the measurement start function again.

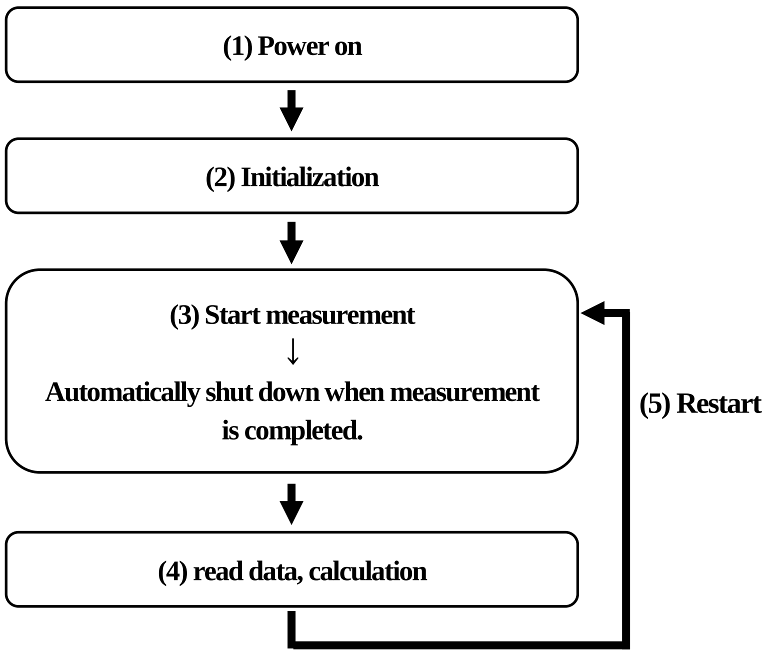


Fig.4 Operational flow

3.2. Distance

The distance value can be obtained by reading the measured value via I^2C and calculating it. The distance value is output in mm for the sample code range1. Status flag is output to range1_status. If the status flag range1_status is not 0x00, an error will occur during measurement and the distance value cannot be obtained correctly. Table 3 shows the meaning of the status flag range1_status.

Table 3 Error status

range1_status	Error	Description
0x00	VALID_DATA	Valid data.
0x01	VCSEL_SHORT	When the VCSEL is short-circuited. When this error occurs, it operates to turn off the VCSEL current value inside the IC. (*1)
0x02	LOW_SIGNAL	The amount of reflected light obtained from the detected object is small.
0x04	LOW_SN	The ratio of the reflected light from the detected object and the noise due to disturbance light is small.
0x08	TOO_MUCH_AMB	Disturbance light is large.
0x10	WAF	Wrap around error.(*2)
0x20	CAL_ERROR	Internal calculation error.
0x80	CROSSTALK_ERROR	Crosstalk from the panel is large.

(*1) The VCSEL_SHORT error may occur not only when the VCSEL is short-circuited, but also when the voltage applied to the sensor drops significantly. If it occurs, write 0x00 to address 2EH or execute the initialization function to clear the error.

(*2) The ToF sensor emits light multiple times for measurement. If the reflected light from an object separated by about 2700 mm or more is returned, it may be indistinguishable from the reflected light from a short-distance object at the next time emission. This phenomenon is detected by performing a measurement (WAF measurement) that changes the emission cycle, and is output as a WAF error.

3.3. Basic characteristics

Table 4 shows the Basic characteristics.

Table 4 GP2AP03VT Basic characteristics

Parameter	Value	Remarks
Minimum ranging distance	2.5mm	VCSEL current setting : IF=31mA Detected object : white card(88% reflectance) Environment : Indoor, no infrared
Maximum ranging distance	100mm	VCSEL current setting : IF=31mA Detected object : black card(5% reflectance) Environment : Indoor, no infrared
Ranging speed	33ms	I^2C communication speed is 400 kHz
Average current consumption	1.7mA	Total current of VDD and VDDV terminals 80ms cycle

4. Calibration at user factory

This sensor usually uses a cover panel mounted in front of the sensor. The distance value will be affected by the reflection(crosstalk) from the cover panel. It is necessary to calibrate it at the user factory and get the compensate value. Figure 5 shows the calibration flow.
In the calibration process, offset calibration and crosstalk calibration must be performed in this order.
Save the compensate value get by calibration in the non-volatile memory (NVM) on the user's host side, and set it when using it as a product. Please refer to the GP2AP03VT software manual for details on how to perform calibration and how to use the calibration values.

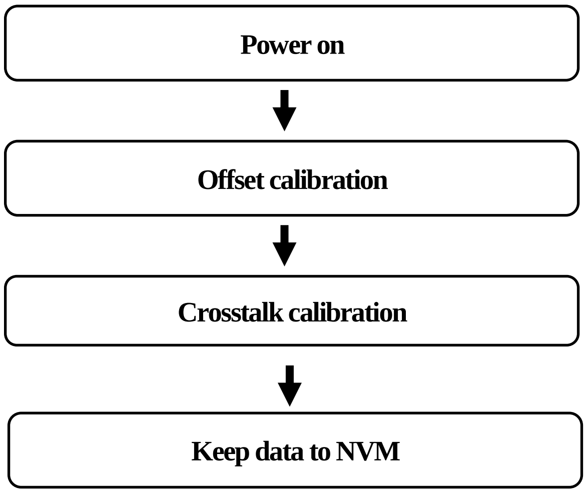


Fig.5 Calibration flow

4.1. Offset calibration

Figure 6 shows concept image of offset calibration. The distance value measured by mounting the cover panel in front of the sensor may differ from the actual distance value. Offset calibration is performed at the user factory to get the compensate value.
The values that can be get by offset calibration are offset_short1 and offset_short2. All values are represented by 8-bit width (negative numbers are in 2's complement notation).

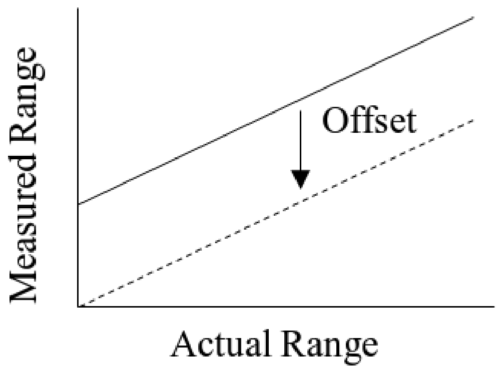


Fig.6 Offset calibration

4.2. Crosstalk calibration

This sensor adopts the TDC method, and it creates a histogram inside the IC and calculates the distance value from the histogram. Figure 7 shows the histogram when there is no cover panel. A histogram of only the detected objects is created. Figure 8 shows the histogram when cover panel is installed. In this case,a histogram of cover panel will be created near to the histogram of the detected objects, and the sensor can not calculate the correct distance value.
Therefore, it is necessary to perform crosstalk calibration for each device at user factory to get the compensate value. The compensate value is data_xtalk. This value is expressed in our original 14bit floating point notation.

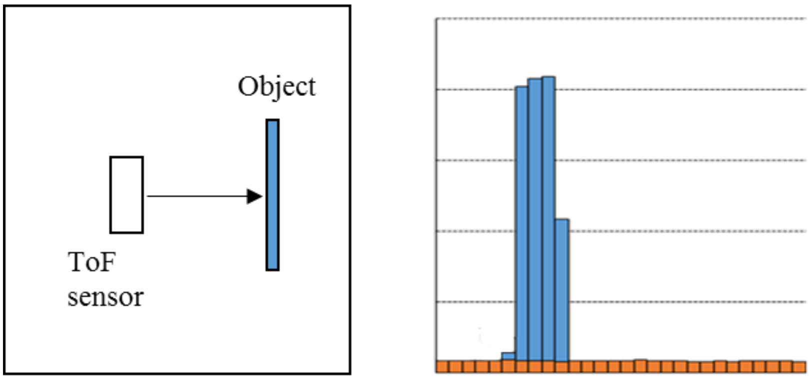


Fig.7 Histgram without cover panel

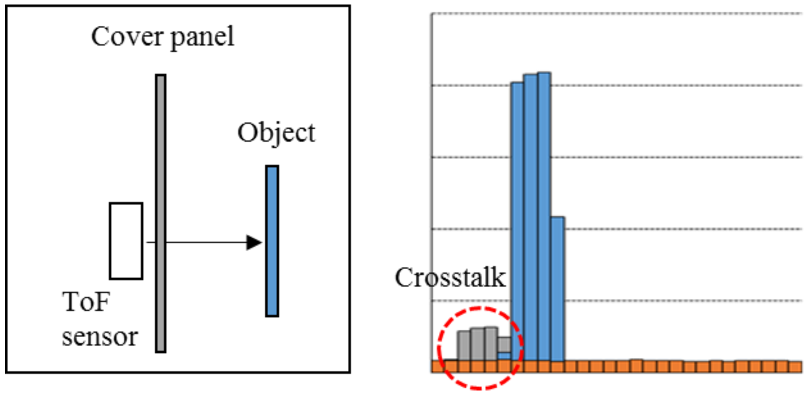


Fig.8 Histgram with cover panel

NOTE:
The crosstalk value tends to increase as the cover panel installation position moves away from the sensor or dirt or scratches adhere to it.

5. Functional description

5.1. Register map

Table 5 shows the register map.

Table 5 Register map

Address	NAME	BIT 7	6	5	4	3	2	1	0	Initial value
00h	COMMAND00H	OP3	-							0x00
01h	COMMAND01H	RESERVED						FLAG	FUSE	0x00
02h	COMMAND02H	0	0	INTEN	1	0	1	INTTYPE	RST	0x00
04h	COMMAND04H	-				IDRV[3:0]				0x00
05h-0Eh	-	RESERVED								0x00
0Fh	OFFSET1	OFFSET CALIBRATION DATA1[7:0]								0x00
10h	OFFSET2	OFFSET CALIBRATION DATA2[7:0]								0x00
11h-15h	-	RESERVED								0x00
16h	CROSSTALK	CROSSTALK CALIBRATION DATA[7:0]								0x00
17h		-		CROSSTALK CALIBRATION DATA[13:8]						0x00
18h-2Ah	-	RESERVED								0x00
2Bh	MEASUREMENT TIME							CONV[1:0]		0x00
32h-40h	-	RESERVED								0x00
41h	DEVICE ID	0	0	1	0	1	1	1	1	0x00
42h-54h	-	RESERVED								0x00

NOTE:
In order to calculate the measurement distance, it is necessary to read the measurement data from the sensor and calculate it. To get the measurement distance on your software, please refer to the sample code provided and GP2AP03VT Software Manual.

5.2. Registar setting

Table 6 shows recommended register setting values. Since register setting values are dynamically controlled according to sensor operating conditions, be sure to use the function of sample code.

Table 6 Register setting

<table>
<tr><th>Address</th><th>Setting value</th><th></th><th>Address</th><th>Setting value</th><th></th></tr>
<tr><td>00h *1</td><td>0x80</td><td>R/W</td><td>1Ah</td><td>0xAA</td><td>R/W</td></tr>
<tr><td>01h</td><td>-</td><td>R</td><td>1Bh</td><td>0xAA</td><td>R/W</td></tr>
<tr><td>02h</td><td>0x34</td><td>R/W</td><td>1Ch</td><td>0xAA</td><td>R/W</td></tr>
<tr><td>03h</td><td>0x00</td><td>R/W</td><td>1Dh</td><td>0xAA</td><td>R/W</td></tr>
<tr><td>04h</td><td>0x07</td><td>R/W</td><td>1Eh</td><td>0xF4</td><td>R/W</td></tr>
<tr><td>05h</td><td>0x0C</td><td>R/W</td><td>1Fh</td><td>0xF7</td><td>R/W</td></tr>
<tr><td>06h</td><td>0x67</td><td>R/W</td><td>28h</td><td>0x84</td><td>R/W</td></tr>
<tr><td>07h</td><td>0xDF</td><td>R/W</td><td>29h</td><td>0x00</td><td>R/W</td></tr>
<tr><td>0Dh</td><td>0x82</td><td>R/W</td><td>2Ah</td><td>0x0B</td><td>R/W</td></tr>
<tr><td>0Eh</td><td>0x02</td><td>R/W</td><td>2Bh</td><td>0x03</td><td>R/W</td></tr>
<tr><td>0Fh *2</td><td>offset1</td><td>R/W</td><td>2Eh</td><td>-</td><td>R</td></tr>
<tr><td>10h *2</td><td>offset2</td><td>R/W</td><td>41h</td><td>0x2F</td><td>R</td></tr>
<tr><td>11h</td><td>0x98</td><td>R/W</td><td>43h</td><td>0xC0</td><td>R/W</td></tr>
<tr><td>12h</td><td>0x00</td><td>R/W</td><td>45h</td><td>0x04</td><td>R/W</td></tr>
<tr><td>13h</td><td>0x15</td><td>R/W</td><td>47h</td><td>0x20</td><td>R/W</td></tr>
<tr><td>14h</td><td>0x64</td><td>R/W</td><td>4Dh</td><td>0x06</td><td>R/W</td></tr>
<tr><td>15h</td><td>0x01</td><td>R/W</td><td>4Eh *3</td><td>0x2B or 0x3E</td><td>R/W</td></tr>
<tr><td>16h *3</td><td>Crosstalk set data L</td><td rowspan="2">R/W</td><td>50h</td><td rowspan="4">Trimming value at Sharp' factory</td><td>R</td></tr>
<tr><td>17h *3</td><td>Crosstalk set data H</td><td>51h</td><td>R</td></tr>
<tr><td>18h</td><td>Crosstalk output data L</td><td rowspan="2">R</td><td>52h</td><td>R</td></tr>
<tr><td>19h</td><td>Crosstalk output data H</td><td>53h</td><td>R</td></tr>
</table>

*1 Measurement starts when 0x80 is written.
*2 Offset value at user factory.
*3 Be sure to write the register using the function of the sample code.

5.3. Register functions

5.3.1. Operating mode

Set 00h register after setting other registers.

Table 7 Register 00h operation mode setting

Address	NAME	7	6	5	4	3	2	1	0
00h	COMMAND00H	OP3	-						

Measurement can be started by setting 1 in the OP3 register. When one measurement is completed, the OP3 register automatically returns to 0. Do not clear the OP3 register.

Table 8 Operation setting

OP3	Setting
0	Power down state
1	Start measurement

5.3.2. Measurement completion flag and fuse read flag

The measurement completion flag and fuse read flag are output to address 01H.

Table 9 Register 01h

Address	NAME	7	6	5	4	3	2	1	0
01h	COMMAND01H	RESERVED						FLAG	FUSE

FLAG:

Outputs whether the measurement is completed.

0 : Measurement not completed

1 : Measurement completed

It will not be cleared automatically. You need to write "0" to clear it. Also, by clearing FLAG, the level output type interrupt signal is canceled.

FUSE:

Outputs whether Fuse data (OTP data inside the IC) has been read.

0: Not read

1: read

Normally reading is not required.

5.3.3. INT terminal

Set the INT terminal at register 02H.

Table 10 Register 02h INTterminal setting

Address	NAME	7	6	5	4	3	2	1	0
02h	COMMAND02H	0	0	INTEN	1	0	1	INTTYPE	RST

INTEN:

Set whether to output an interrupt signal to the INT terminal. (Table 11)

Table 11 INT terminal enable setting

INTEN	Setting
0	Don't output interrupt signal
1	Output interrupt signal

By setting INTEN to 1, the sensor outputs the interrupt signal to the INT pin after the measurement is completed.

INTTYPE:

Set the output in terrupt signal to level output or pulse output. (Table 12)

Table 12 INTYPE register setting

INTTYPE	Setting
0	level output
1	pulse output

0 : level output

After the sensor completes the measurement, the INT terminal transitions from H to L and becomes an interrupt signal. The L level output of the INT terminal is retained until the interrupt is cleared. To clear the interrupt, write "0" to the FLAG register at address 01H.

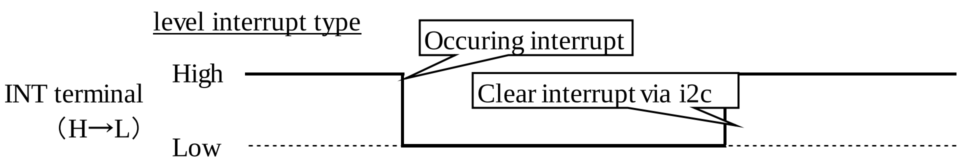


Fig.9 interrupt signal by level output

1 : pulse output

When the INT terminal transitions from H to L, an interrupt signal is generated. The INT terminal is not held at the L level and immediately returns to H. Therefore, it is not necessary to clear the FLAG register.

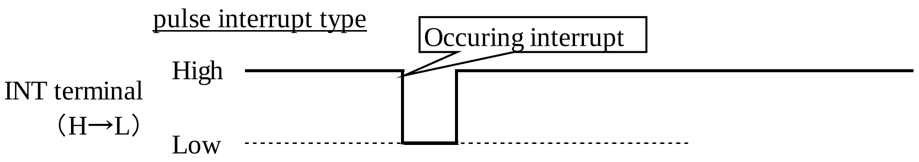


Fig.10 interrupt signal by pulse output

5.3.4. VCSEL drive current

The peak current of the VCSEL is set in the IDRV [3: 0] register (address 04H).

Table 13 Register 04h VCSEL current setting

Address	NAME	7	6	5	4	3	2	1	0
04h	COMMAND04H	0				IDRV[3:0]			

Table 14 VCSEL current setting

IDRV	Vcsel curmet [mA]
0x07	31

5.3.5. Offset register

Set the compensate value get by offset calibration in the offset register. See Chapter 4.1 for offset calibration. Set offset_short1 in the OFFSET CALIBRATION DATA1 [7: 0] register (address 0FH) and offset_short2 in the OFFSET CALIBRATION DATA2 [7: 0] register (address 10H).

Table 15 offset register setting

Address	NAME	7	6	5	4	3	2	1	0
0Fh	OFFSET1	OFFSET CALIBRATION DATA1[7:0]							
10h	OFFSET2	OFFSET CALIBRATION DATA2[7:0]							

5.3.6. Crosstalk register

Set the data_xtalk value get by crosstalk calibration in the CROSSTALK CALIBRATION DATA [13: 0] registers (address 16H, address 17H). See 4.2 for crosstalk calibration. This register setting value is optimized during measurement by the automatic crosstalk update function by software.

Table 16 crosstalk register setting

Address	NAME	7	6	5	4	3	2	1	0
16h	CROSSTALK	CROSSTALK CALIBRATION DATA[7:0]							
17h				CROSSTALK CALIBRATION DATA[13:8]					

5.3.7. Measurement time

The measurement time is set in the CONV register.

Table 17 mesurement time setting

Address	NAME	7	6	5	4	3	2	1	0
2Bh	MEASUREMENT TIME	-						CONV[1:0]	

Table 18 mesurement time

CONV[1:0]	Measuerment time [msec]
0x03	24.4

Set CONV register to 0x03

5.3.8. Software reset

Initialize all registers by writing 1 in RST register. RST register is also initialized automatically and becomes 0.

Table 15 Register 02h software reset

Address	NAME	7	6	5	4	3	2	1	0
02h	COMMAND02H	0	0	PIN3	1	0	1	0	**RST**

5.3.9. Device ID

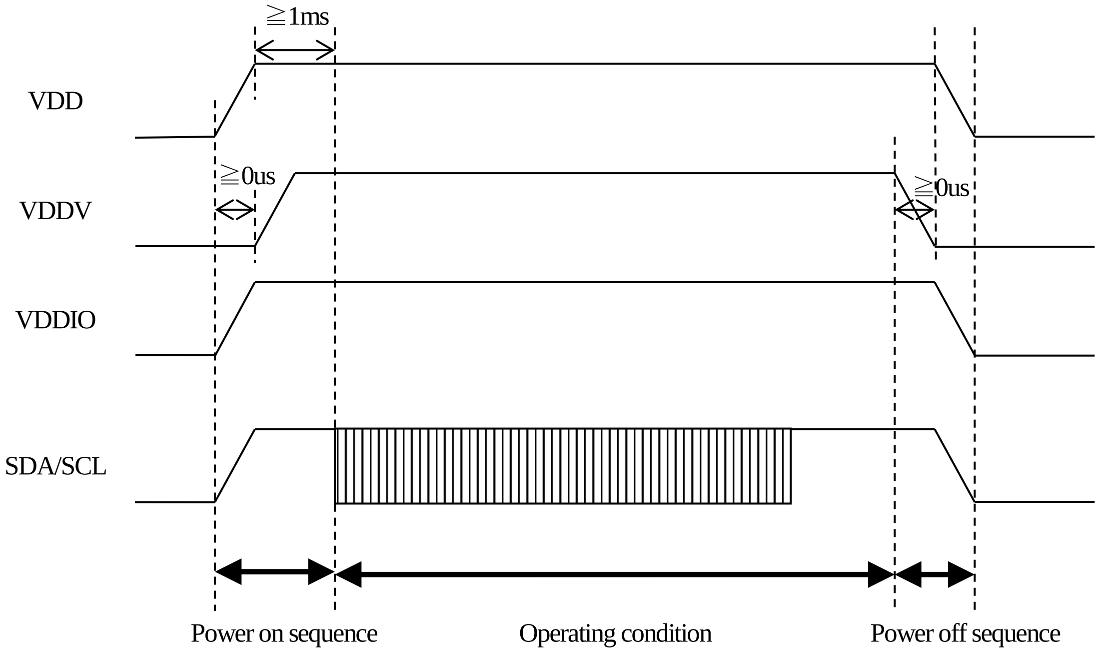
Device ID: 0x2F

Table 16 Register 41h Device ID

Address	NAME	7	6	5	4	3	2	1	0
41h	DEVICE ID	0	0	1	0	1	1	1	1

6. Power on/off sequence

The following figure 11 shows configuration sequence at Power-On and Power-Off.



- I2C communication is possible from 1ms after the VDD voltage reaches the set voltage.
- The VDDV voltage and VDDIO voltage can be started up and down at the same time as VDD, but make sure that VDDV voltage does not over the VDD voltage.

Fig.11 Power on/off sequence

7. Optical / mechanical design

7.1. FOV

Figure 12 shows the directional angle characteristics of the sensor.

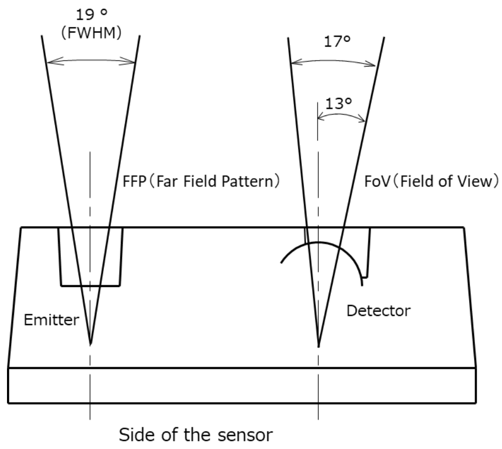


Fig.12 Light emitting angle and receiving angle

7.2. Recommended cover panel design rule

The recommended optical design is shown in Figure 13. Design so that the crosstalk value get by crosstalk calibration is 0.00625 or less(Refer to GP2AP03VT Software Manual for crosstalk value). It is recommended to separate the emitter side and detector side by a partition as shown in Fig. 13.

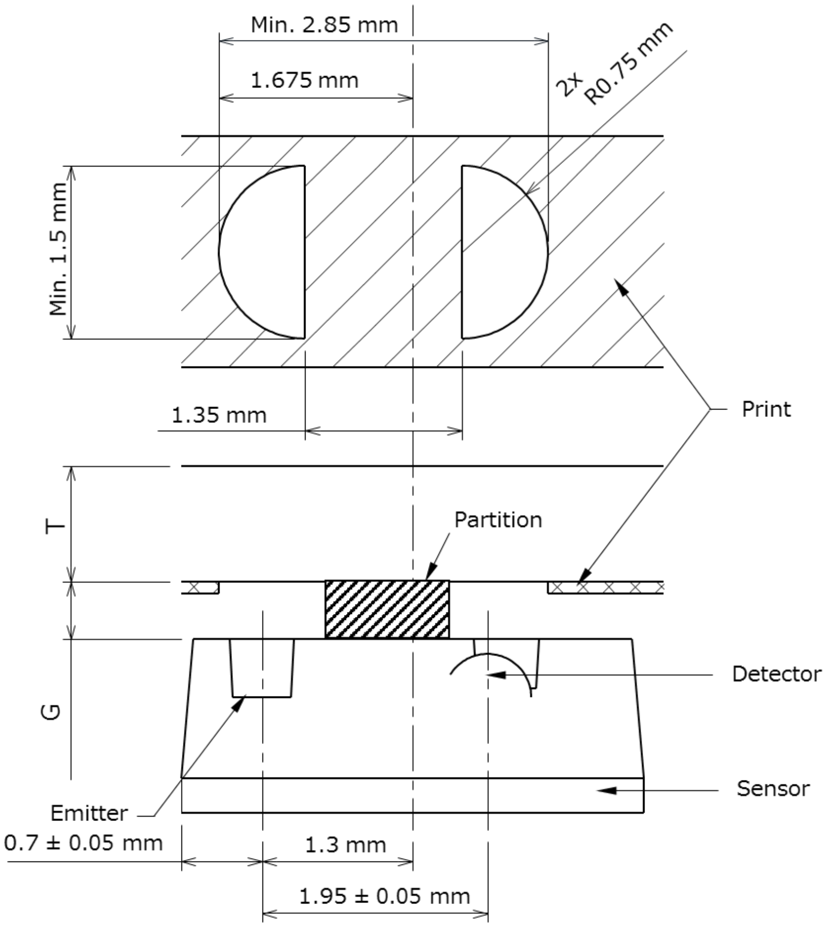


Fig.13 Recommended cover panel design

7.3. Cover panel setection guide

In order to maximize the performance of the sensor, it is recommended to design it so that the conditions in Table 21 are met.

Table 21 Recommended cover panel

	No a light shield wall	with a light shield wall
Material	PMMA / Gorilla Glass	
Transmittance	> 90% for λ> 940nm	
Roughness	< 40nm	
Thickness (T)	< 1.0mm	< 2.0mm
GAP (G)	< 0.5mm	< 1.0mm
AR/ AF coating	Recommended	
Water wetting contact angle	≦90°	

8. Software

The following software is prepared. Please check the development kit.

- GP2AP03VT Windows application manual
- Source code for MCU

Please check the software manual for software implementation in your application.

9. Support

Please contact an agent/reseller from who you purchased this product or contact our sales company in each region from the following URL.

http://www.sharp-world.com/products/device/support/call/index.html

10. Revision history

15 Apr., 2019	v100	First edition
25 Dec., 2020	v101	Completely revised