# 2SMPB-02B
Digital Barometric Pressure Sensor

High accuracy and small size barometric pressure sensor with low current consumption

- Measure barometric pressure and temperature with high accuracy
- Built in low noise 24bit ADC
- Digital control and output via I²C/SPI interface
- Automatically power down non-working circuit to minimize power consumption
- Individual calibration parameters stored in OTP* (*One Time Programmable - ROM)

RoHS compliant
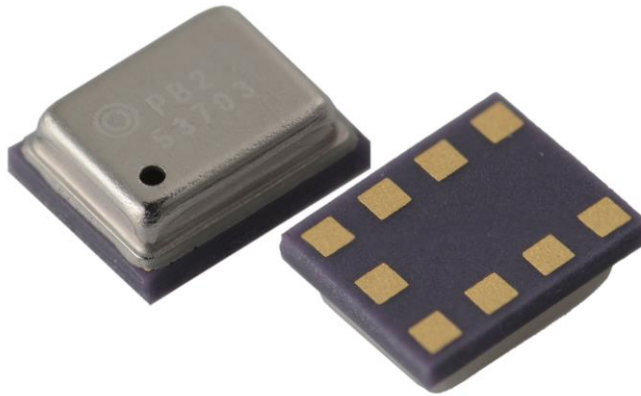
Application Example
- ・Indoor navigation (floor detection)
- ・Car navigation (to distinguish highway and frontage road)
- ・Altimeter
- ・Activity monitor (to detect up and down of stairs)
- ・Life log
- ・Weather forecast

Target Devices Example
- ・Smart Phones / Tablet PCs
- ・Wearable devices, such as watch type, band type, clip type or glasses type
- ・GPS devices
- ・Healthcare devices such as pedometer

Packaging Information
■Standard Models with Surface Mounting Terminals

Structure	Packaging	Model	Minimum Packing Unit
LGA 9pin	Tape and Reel	2SMPB-02B	3,500

Table of Contents

1. Ratings, Specifications and Functions

1.1 Use conditions and recommended operating conditions

Type of Pressure	Absolute pressure
Medium	Air (*1)
Operating Pressure Range	30kPa to 110kPa

Note. *1: Never use corrosive gases.

1.2 Absolute Maximum Ratings

Item	Symbol	Rating	Unit	Remark
Power Supply Voltage	Vddmax	4.0	V	
Input Voltage (other than power)	Vmax	-0.2〜Vopr+0.2	V	
Maximum Pressure	Pmax	800	kPa	
Storage Temperature	Tstr	-40〜85	degC	with no condensation or icing
Storage Humidity	Hstr	10〜95	%RH	with no condensation or icing
ESD (HBM)	Vhbm	±2000	V	
ESD (MM)	Vmm	±200	V	
ESD (CDM)	Vcdm	±500	V	

1.3 Operating Ratings

Item	Symbol	Min	Typ	Max	Unit	Remark
Operating Voltage	Vopr	1.71	1.8	3.6	V	VDD
	Vio	1.20	1.8	3.6	V	VDDIO
Operating Temperature	Topr	-40	-	85	degC	

1.4 Electrical Characteristics

Item	Symbol	Condition	Min	Typ	Max	Unit
Average Current *	Ihp	1sample/s force-mode Ultra High Accuracy	-	21.4	-	uA
Operating Current Consumption	Iddp	Pressure mode	-	640	800	uA
	Iddt	Temperature mode	-	410	520	uA
Sleep Mode Current Consumption	Isleep		-	1.1	2.3	uA
Measureable Pressure Range	Popr		30	-	110	kPa
Absolute Pressure Accuracy	Pabs1	90-110kPa,0-40℃	-100	-	100	Pa
Relative Pressure Accuracy *	Prel1	Ultra High Accuracy	-	±3.9	-	Pa
rms Noise *	Pnois	Ultra High Accuracy	-	1.3	-	Pa
Absolute Temperature Accuracy	Tabs	90-110kPa,0-40℃	-2	-	2	degC
Pressure Resolution *	Pres		-	0.06	-	Pa
Temperature Resolution *	Tres		-	0.0002	-	degC
Power Supply Rejection Ratio (DC)	Ppsrr	101.3kPa,0-40℃, 1.71-3.6V Base on VDD=1.8V	-9.4	-	9.4	Pa

(At Ta=25 degC, VDD=1.8V, unless otherwise noted)

Note * Above characteristics are guaranteed by design.

1.5 Digital Interface Characteristics

Item	Symbol	Condition	MIN	TYP	MAX	Unit
Digital Input Low Voltage	Vil_d		-	-	Vio*0.2	V
Digital Input High Voltage	Vih_d		Vio*0.8	-	-	V
Digital Input Hysterisis Voltage	Vidhys		Vio*0.1	-	-	V
Digital Output Low Voltage(I²C)	Vol_d1	Io=3mA (SDI) *1)	0	-	Vio*0.2	V
Digital Output Low Voltage(SPI)	Vol_d2	Io=1mA (SDI,SDO) *1)	0	-	Vio*0.2	V
Digital Output High Voltage1 (SPI) (Vio>=1.62V)	Voh_d1	Io=1mA (SDI,SDO) *1)	Vio*0.8	-	-	V
Digital Output High Voltage2 (SPI) (Vio>=1.2V)	Voh_d2	Io=1mA (SDI,SDO) *1)	Vio*0.6			
Leakage Current at Output OFF	Ioff	SDI,SDO	-10	-	10	uA
Internal Pullup Resistor	Rpullup	CSB	70	120	190	kohm
I²C Load Capacitance	Cb	SDI,SCK	-	-	400	pF
Load Capacitance of Reset Terminal	Crst		-	-	20	pF
Pulse Width of Asynchronous Reset	Trst		100	-	-	μsec
Power On Startup Time	Tstart		-	-	10	msec

Note. *1) "Io" is the load current of the output terminal.
   *2) Undescribed items are compliant with the I²C specification.
       About detailed I²C bus information, please refer to the I²C bus specification and user manual presented by NXP.

1.6 Characteristics by Oversampling setting (Force mode)

Oversampling setting	Pressure oversampling	Temperature oversampling	Measurement time Typ.	ODR @standby 1ms Typ.	Average Current Typ. @1sample/sec force-mode	rms Noise Typ.
unit	-	-	msec	Hz	uA	Pa
High speed	2	1	5.5	153	4.1	5.2
Low power	4	1	7.2	121	5.2	3.7
Standard	8	1	10.6	86	7.3	2.6
High accuracy	16	2	18.3	51	12.0	1.8
Ultra High accuracy	32	4	33.7	28	21.4	1.3

(At Ta=25 degC, VDD=1.8V, CPU Clock Frequency=300kHz, unless otherwise noted)

Note. *1) These characteristics are guaranteed by design.
   *2) ODR is defined as Output data rate at standby time 1msec.

1.7 rms Noise by IIR Filter Selection

Oversampling setting	Typical rms Noise in Pressure [Pa]					
	IIR filter coefficient					
	off	2	4	8	16	32
High speed	5.2	2.5	1.6	1.1	0.8	0.5
Low power	3.7	1.8	1.1	0.8	0.5	0.4
Standard	2.6	1.3	0.8	0.5	0.4	0.3
High accuracy	1.8	0.9	0.6	0.4	0.3	0.3
Ultra High accuracy	1.3	0.6	0.4	0.3	0.3	0.2

(At Ta=25 degC, VDD=1.8V, unless otherwise noted)

Note. *1) IIR : Infinite Impulse Response.
   *2) These characteristics are guaranteed by design.
   *3) Initial setting of the IIR filter coefficient is "off".

1.8 Bandwidth by IIR Filter Selection

Oversampling setting	Typical Bandwidth [Hz]					
	IIR filter coefficient					
	off	2	4	8	16	32
High speed	153.0	35.3	14.7	6.8	3.3	1.6
Low power	121.0	28.0	11.6	5.4	2.6	1.3
Standard	86.0	19.9	8.3	3.8	1.8	0.9
High accuracy	51.0	11.8	4.9	2.3	1.1	0.5
Ultra High accuracy	28.0	6.5	2.7	1.2	0.6	0.3

(At Ta=25 degC, VDD=1.8V, unless otherwise noted)

Note. *1) These characteristics are guaranteed by design.
*2) Initial setting of the IIR filter coefficient is "off".

1.9 Filter selection based on use cases

| Example use case	Oversampling setting	Pressure over sampling times	Temp. over sampling times	Specification (Typ.)			
				IIR filter coefficient	Current consumption [uA]	ODR [Hz] (Example)	rms Noise [Pa]
Weather monitoring	High speed	×2	×1	off	1.2	0.05	5.2
Drop detection	Low power	×4	×1	off	407	100	3.7
Elevator detection	Standard	×8	×1	4	63.4	10	0.8
Stair detection	High accuracy	×16	×2	8	219	20	0.4
Indoor navigation	Ultra high accuracy	×32	×4	32	570	28	0.2

(At Ta=25 degC, VDD=1.8V, unless otherwise noted)

Note. These characteristics are guaranteed by design.

2. Connection

### 2.1 Block Diagram
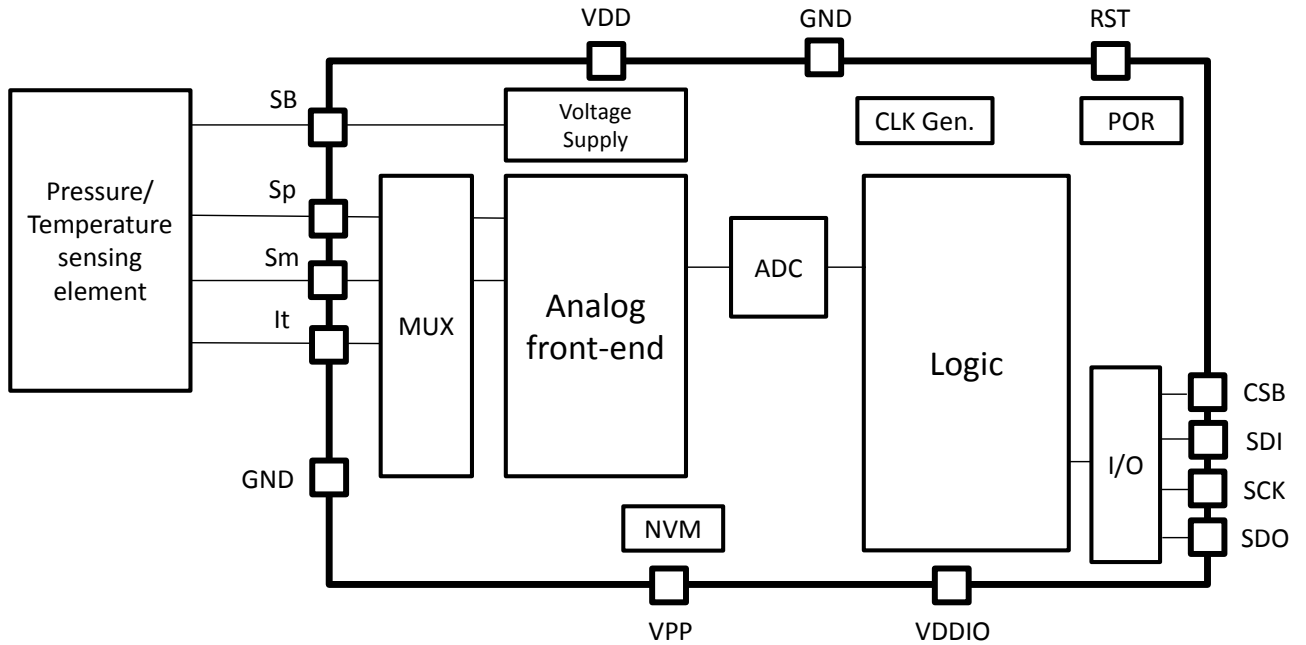
2.2 Pin Description and Layout

Top View

Bottom View
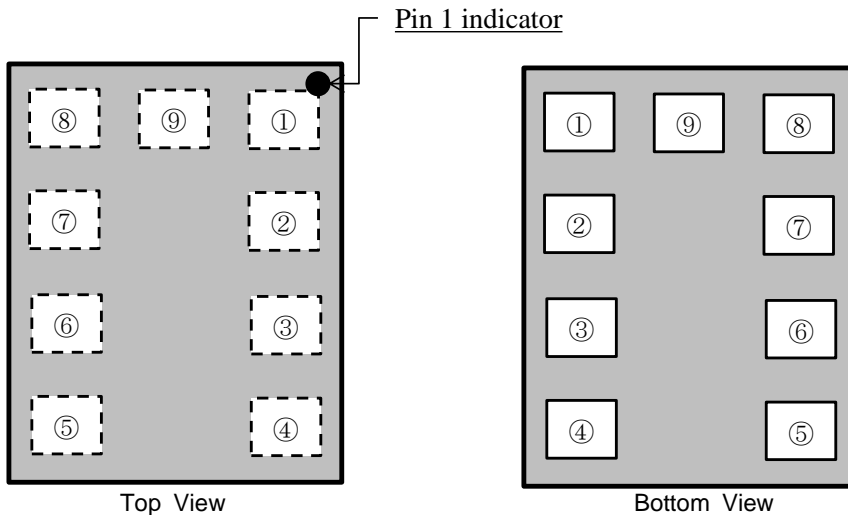
Pin Description

No.	Symbol	Description	
		SPI	I²C
1	RST	Asynchronous Reset *1)	
2	CSB	CSB	VDDIO
3	SDI	SDI/SDO	SDA
4	SCK	SCK	SCL
5	SDO	SDO	ADDR
6	VDDIO	Power Terminal for Digital IO	
7	GND	Ground Terminal	
8	VDD	Power Terminal	
9	VPP	NVM Writing Terminal *2)	

Note.   *1)   If you do not need the reset function, please just have the layout design of PCB of
connecting both No. 1 (RST) pin and No. 7 (GND) pin into the ground of PCB.
Please refer "4.8 Reset Function" for the case of using the reset function.
 *2)   Pin 9 is only used internally in OMRON. Please leave the pin disconnected.
If Pin 9 is connected with any other Pin electrically, the sensor will not work properly.

2.3 Typical Connection Diagram

(1) I²C mode
Corresponding to 100Kbit/s (at Standard Mode), 400Kbit/s (at Fast Mode) and 3.4Mbit/s (at High Speed Mode)
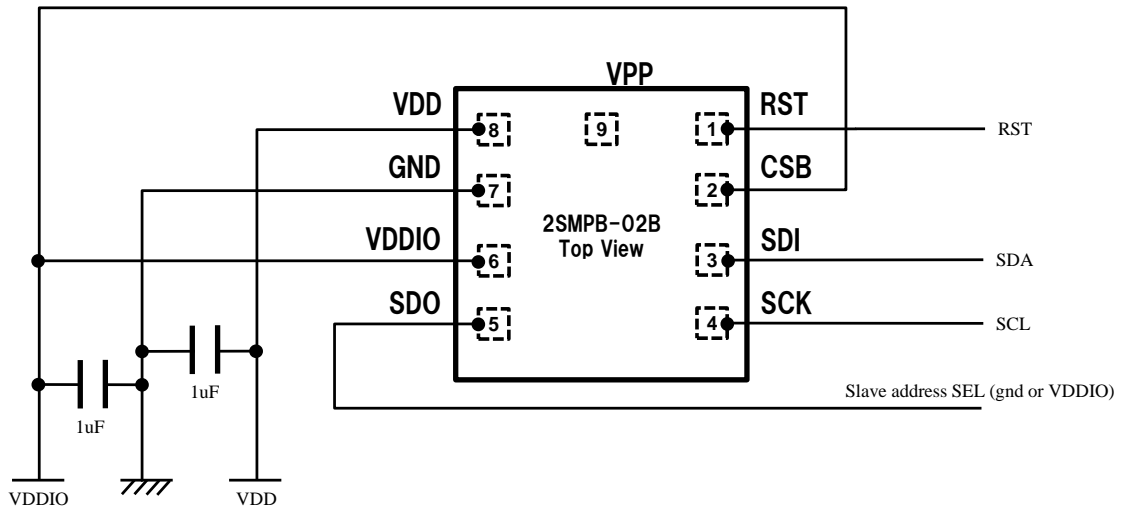
(2) 4-wire SPI mode (Corresponding to 10Mbit/s)
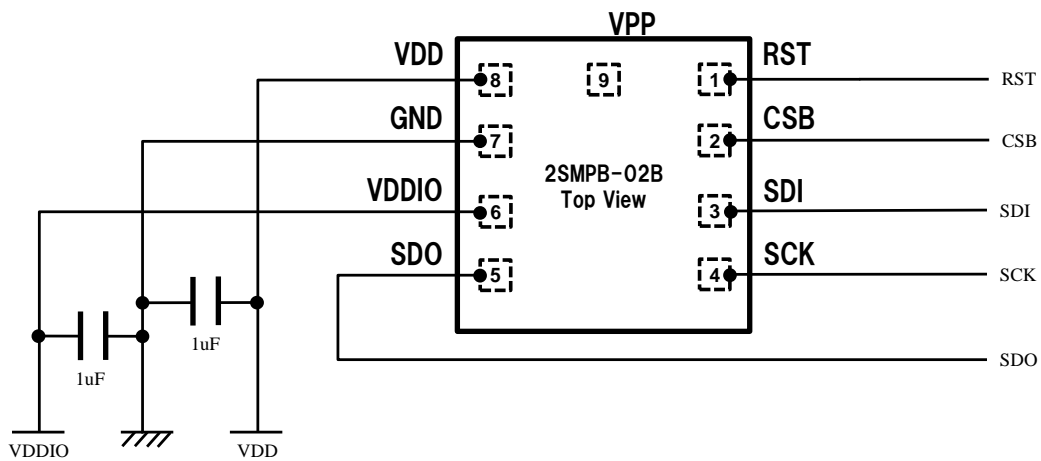
(3) 3-wire SPI mode (Corresponding to 10Mbit/s)
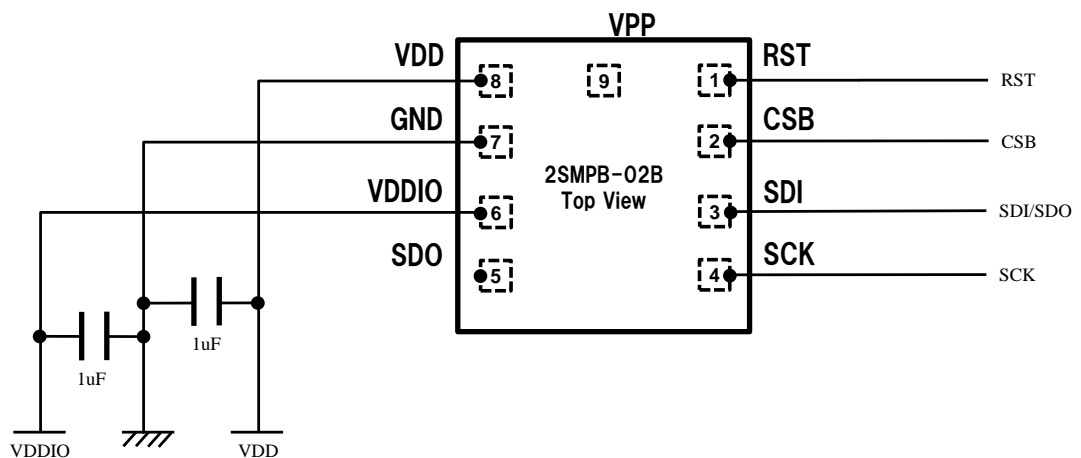
3. Dimensions

(unit: mm)

3.1 Package

    Package Type : LGA (Land Grid Array) 9pin
    Package Size : 2.00×2.50×0.85 mm

3.2 Mounting PAD Dimensions

(Top View)：Recommended

3.3 Marking structure

Pin 1 indicator

PB2B
XXXXX

Pressure Port

4. Operations

4.1 Communication Mode

This sensor is corresponding to I²C and SPI communication.
Digital interface terminal functions for each communication mode are as below.

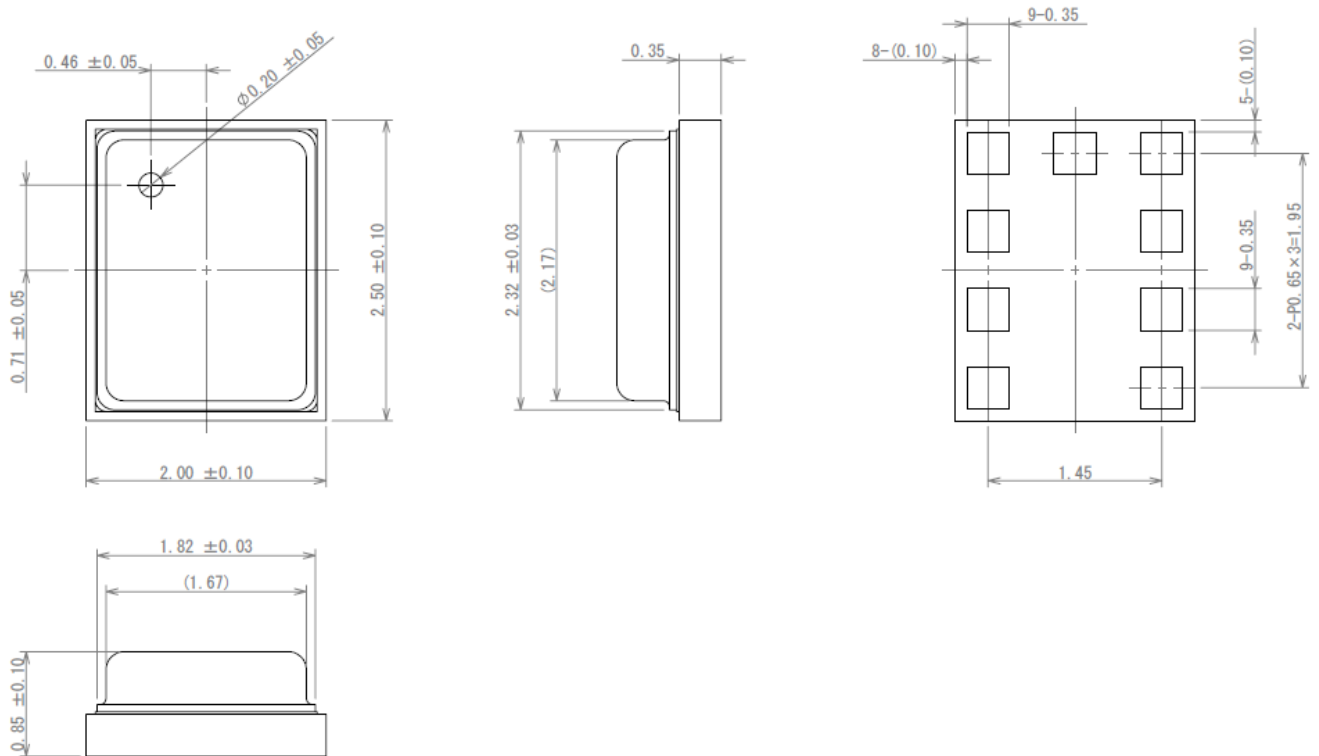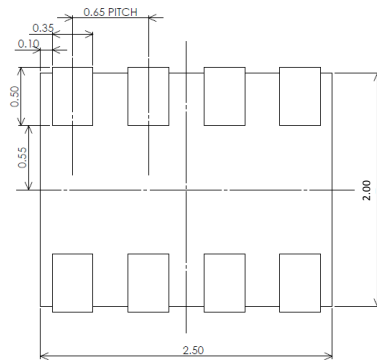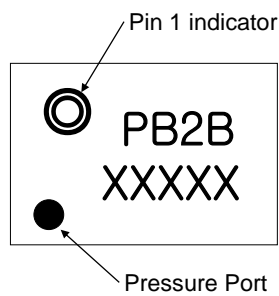| Communication mode	CSB	SDI	SCK	SDO	Remark
I²C	VDDIO	SDA	SCL	GND/VDDIO	SDO=GND→70h、SDO=VDDIO→56h
SPI 3 Wires	CSB	SDI/O	SCK	-	spi3w Register = 1
SPI 4 Wires	CSB	SDI	SCK	SDO	spi3w Register = 0

When changing the communication mode, also see Typical Connection Diagram section.
1) I²C mode becomes effective by pulling CSB up to VDDIO.
2) SPI mode becomes effective by pulling CSB down to GND.
3) Once CSB is pulled down, SPI mode would not be changed unless otherwise Power on Reset (POR) or Asynchronous Reset. Switching between SPI 3-Wire mode and SPI 4-Wire mode can be configured with the register value of "spi3w". Refer to IO_SETUP register section for more detail.
4) Default mode after POR or Asynchronous Reset will be I²C mode.

4.2 Power Mode

This sensor has three power modes and it can be switched by setting CTRL_MEAS register.
Refer to the "CTRL_MEAS" register section for more detail.
· Sleep mode
· Normal mode
· Forced mode
Transition diagram for each mode is as follows.
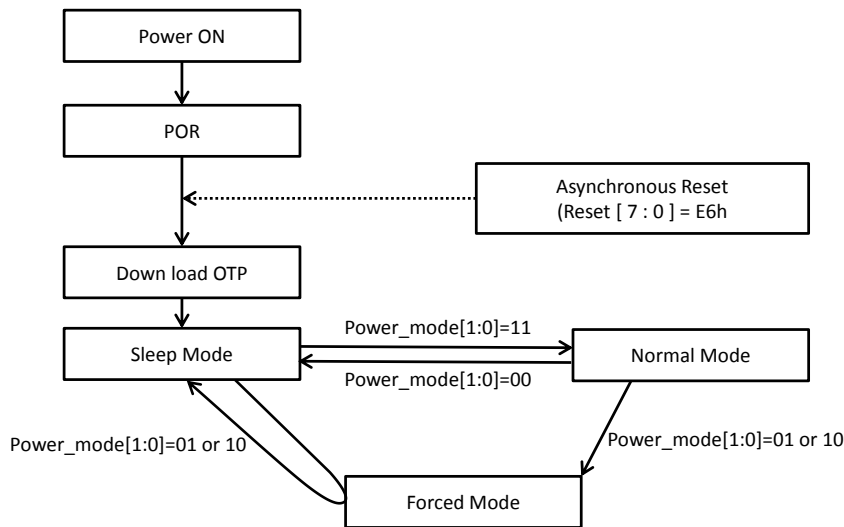
1) **Sleep Mode (Power Reduction Mode)**
No measurements are performed.
I²C/SPI interface and each register can be accessed even if the sensor is in sleep mode.

2) **Forced Mode**
In case of Forced Mode, a single measurement is performed. When the set up measurement is finished, the sensor returns to Sleep Mode after storing the measurement data to the register.
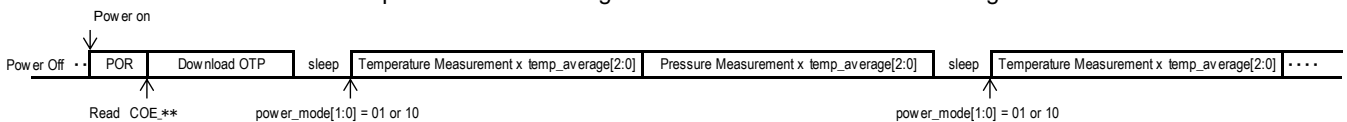
3) **Normal Mode**
In case of Normal Mode, the measurements are performed repeatedly between a measurement period and a standby period. The standby time can be configured by "t_stanby[1:0]" register. Be sure to consider that the data must be read from the master side after a Normal Mode.
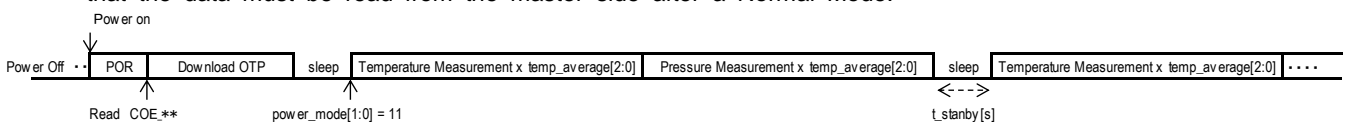
4.3 Compensation of Pressure and Temperature

This section describes a typical measurement procedure and a calculation method after POR. This sensor has compensation coefficients in internal Non Volatile Memory (NVM). The compensated pressure can be calculated by using these values.

```
                    ┌─────────────┐
                    │    START    │
                    └──────┬──────┘
                           │
        ┌──────────────────▼──────────────────┐     ┌───┐
        │ ① Configure IO mode setting by       │     │   │ : Read/Write Values through Digital I/F
        │   "IO_STUP" register                 │     └───┘
        └──────────────────┬──────────────────┘
                           │                         ┌───┐
        ┌──────────────────▼──────────────────┐     │   │ : Calculation by User MCU
        │ ② Read Compensation Coefficients     │     └───┘
        │   from N.V.M. ( COE_** )              │
        └──────────────────┬──────────────────┘
                           │
        ┌──────────────────▼──────────────────┐
    ┌──▶│ ③ Configure Averaging Times and      │
    │   │   Power Mode                         │
    │   └──────────────────┬──────────────────┘
    │                      │
    │   ┌──────────────────▼──────────────────┐
    │   │ ④ Read Uncompensated                 │
    │   │   Temperature Value ( TEMP_TXDx )    │
    │   └──────────────────┬──────────────────┘
    │                      │
    │   ┌──────────────────▼──────────────────┐
    │   │ ⑤ Read Uncompensated                 │
    │   │   Pressure Value ( PRESS_TXDx )      │
    │   └──────────────────┬──────────────────┘
    │                      │
    │   ┌──────────────────▼──────────────────┐
    │   │ ⑥ Compensate Temperature Value       │
    │   └──────────────────┬──────────────────┘
    │                      │
    │   ┌──────────────────▼──────────────────┐
    │   │ ⑦ Compensate Pressure Value          │
    │   └──────────────────┬──────────────────┘
    └──────────────────────┘
```
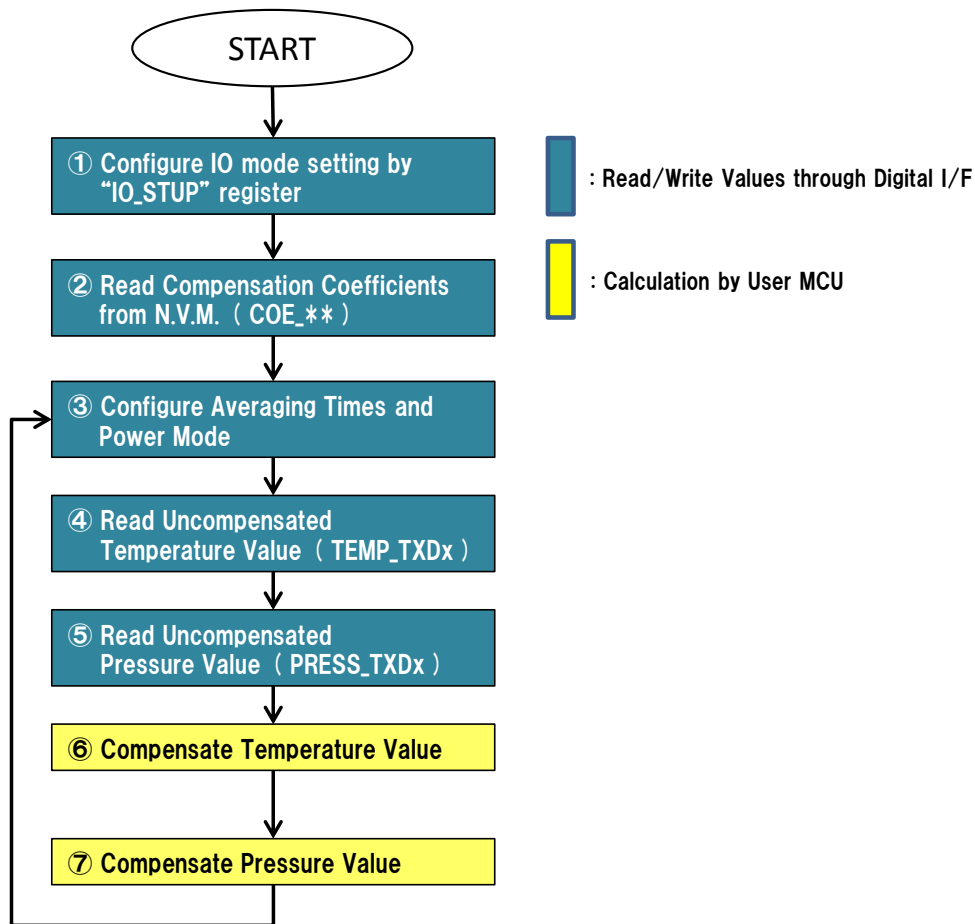
MSB of PRESS_TXDx, TEMP_TXDx and COE_** are sign bit.

① Configure IO mode setting. Refer to IO_SETUP register section for more detail.
② Read compensation coefficients which are stored in NVM. This procedure is sufficient just once after POR.
   These values are used for a compensation calculation at the step ⑥ and ⑦.
③ Configure averaging times and power mode. Refer to CTRL_MEAS register section for more detail.
④ Read raw temperature data which are stored in TEMP_TXDx registers.
⑤ Read raw pressure data which are stored in PRESS_TXDx registers.
⑥ Compensated temperature can be calculated by using the below formula and the values of the step ② and ④.

$$Tr = \frac{-ba - \sqrt{ba^2 - 4aa(ca - Dt)}}{2aa}$$

Tr Calculation Result of Temperature (Tr/256 = Temperature [degreeC])
   e.g.) If Tr Value is 6400 LSB,

$$Temperature\,(degreeC) = \frac{Tr\,Value\,(LSB)}{Scaling\,Factor} = \frac{6400\,LSB}{256\,LSB/degree\,C} = 25.00\,degreeC$$

Dt Raw Temperature Data [digit] (20-24bits measurement value of TEMP_TXDx Reg.)
aa Compensation Coefficient of PTAT (Coefficient made from COE_PTAT31 and COE_PTAT32 Reg.)
ba Compensation Coefficient of PTAT (Coefficient made from COE_PTAT21 and COE_PTAT22 Reg.)
ca Compensation Coefficient of PTAT (Coefficient made from COE_PTAT11 and COE_PTAT13 Reg.)

⑦   (1) Correction pressure without temperature compensation can be calculated by using the below formula and the values of the step ② and ⑤.

$$Pl = \frac{-bp + \sqrt{bp^2 - 4ap(cp - Dp)}}{2ap}$$

Pl   Calculation result of Pressure [Pa]
Dp   Raw Pressure Data [digit] (20-24bits measurement value of PRESS_TXDx Reg.)
ap   Compensation Coefficient of Pressure (Coefficient made from COE_PR31 and COE_PR32 Reg.)
bp   Compensation Coefficient of Pressure (Coefficient made from COE_PR21 and COE_PR22 Reg.)
cp   Compensation Coefficient of Pressure (Coefficient made from COE_PR11 and COE_PR13 Reg.)

(2) The compensated pressure for temperature can be calculated by using the below formula and the results of step ③、⑥ and ⑦(1) .

$$Po = \frac{Pl}{at \times Tr^2 + bt \times Tr + (ct + 1)}$$

Po   Final compensated Pressure. This result is an absolute pressure value. [Pa]
at   Compensation Coefficient of Temperature (Coefficient made from COE_TEMP31 and COE_TEMP32 Reg.)
bt   Compensation Coefficient of Temperature (Coefficient made from COE_TEMP21 and COE_TEMP22 Reg.)
ct   Compensation Coefficient of Temperature (Coefficient made from COE_TEMP11 and COE_TEMP12 Reg.)

- **How to get compensation coefficients**
  Each compensation coefficients(ap, bp, at, bt, ct, aa, ba) can be calculated by using the below formula and conversion factors. The other coefficients(cp, ca) are 24bits offset value, so raw digit stored in registers can be used.

$$K = A + \frac{S \times OTP}{32767}$$

K	Conversion factor		OTP		
	A	S	23-16bit	15-8bit	7-0bit
aa	0.0E+00	4.2E-04		COE_PTAT31	COE_PTAT32
ba	-1.6E+02	8.0E+00		COE_PTAT21	COE_PTAT22
ca	Offset value with 24bits length		COE_PTAT11	COE_PTAT12	COE_PTAT13
ap	0.0E+00	3.0E-05		COE_PR31	COE_PR32
bp	3.0E+01	1.0E+01		COE_PR21	COE_PR22
cp	Offset value with 24bits length		COE_PR11	COE_PR12	COE_PR13
at	0.0E+00	8.0E-11		COE_TEMP31	COE_TEMP32
bt	-6.6E-06	1.6E-06		COE_TEMP21	COE_TEMP22
ct	4.0E-02	8.5E-03		COE_TEMP11	COE_TEMP12

- **TEMP(PRESS)_TXDx : Temperature and Pressure data : TXD0, TXD1 or TXD2**
  This sensor holds ADC data with 22 to 24 bits accuracy. It can be obtained as each 24 bits data. If there are redundant data, the low order positions will be filled by zero (0). The shaded regions as shown below are valid data area.

bit	24	23	22	...	5	4	3	2	1	Note
22bits output	D21	D20	D19	...	D2	D1	D0	0	0	Temp/Press_ave=001
23bits output	D22	D21	D20	...	D3	D2	D1	D0	0	Temp/Press_ave=010
24bits output	D23	D22	D21	...	D4	D3	D2	D1	D0	Temp/Press_ave=011～111

※Dn(D23～D0) : Sensor Data ……The value of n bit (1 or 0)
※The raw measurement values are unsigned 24bits values. The values need to do subtraction with 2^{23}
  at 24bits output mode. Here is a programing example for Dt and Dp calculation.

$$Dt = ((TEMP\_TXD2) << 16) + ((TEMP\_TXD1) << 8) + (TEMP\_TXD0) - pow(2,23)$$

$$Dp = ((PRESS\_TXD2) << 16) + ((PRESS\_TXD1) << 8) + (PRESS\_TXD0) - pow(2,23)$$

4.4 Implementing Register List

Register Name	I2C Addr.	SPI Addr.	R/W	Data (bit7–bit0)	Discriptions	Initial
TEMP_TXD0	0xFC	0x7C	R/−	t_txd0[7:0]	Temperature DATA [8:1] in 24bits	00h
TEMP_TXD1	0xFB	0x7B	R/−	t_txd1[7:0]	Temperature DATA [16:9] in 24bits	00h
TEMP_TXD2	0xFA	0x7A	R/−	t_txd2[7:0]	Temperature DATA [24:17] in 24bits (∗)	00h
PRESS_TXD0	0xF9	0x79	R/−	p_txd0[7:0]	Pressure DATA [8:1] in 24bits	00h
PRESS_TXD1	0xF8	0x78	R/−	p_txd1[7:0]	Pressure DATA [16:9] in 24bits	00h
PRESS_TXD2	0xF7	0x77	R/−	p_txd2[7:0]	Pressure DATA [24:17] in 24bits (∗)	00h
IO_SETUP	0xF5	0x75	R/W	t_stanby[2:0] (bit7:5), spi3_sdim (bit2), spi3w (bit0)	t_stanby[2:0] : Standby time setting spi3w : SPI mode setting (4-wire, 3-wire) spi3_sdim : Select output type of SDI terminal	00h
CTRL_MEAS	0xF4	0x74	R/W	temp_average[2:0] (bit7:5), press_average[2:0] (bit4:2), power_mode[1:0] (bit1:0)	temp_average[2:0] : Temperature Averaging Times press_average[2:0] : Pressure Averaging Times power_mode[1:0] : Power mode setting	00h
DEVICE_STAT	0xF3	0x73	R/−	measure (bit3), otp_update (bit0)	measure : Status of measurement otp_update : Status of OTP data access	00h
I2C_SET	0xF2	0x72	R/W	master_code[2:0] (bit2:0)	Master code setting at I2C HS mode	01h
IIR	0xF1	0x71	R/W	filter[2:0] (bit2:0)	IIR filter co-efficient setting	00h
RESET	0xE0	0x60	−/W	reset[7:0]	When inputting "E6h", a software reset will be occurred.	00h
CHIP_ID	0xD1	0x51	R/−	chip_id[7:0]	CHIP_ID1 : 5C	5Ch
COE_PTAT32	0xB4	0x34	R/−	coe_ptat32[7:0]	2nd order correction coefficient of PTAT : aa[7:0] in 16bits	—
COE_PTAT31	0xB3	0x33	R/−	coe_ptat31[7:0]	2nd order correction coefficient of PTAT : aa[15:8] in 16bits (∗)	—
COE_PTAT22	0xB2	0x32	R/−	coe_ptat22[7:0]	correction coefficient of PTAT : ba[7:0] in 16bits	—
COE_PTAT21	0xB1	0x31	R/−	coe_ptat21[7:0]	correction coefficient of PTAT : ba[15:8] in 16bits (∗)	—
COE_PTAT13	0xAF	0x2F	R/−	coe_ptat13[7:0]	Offset value of PTAT : ca[7:0] in 24bits	—
COE_PTAT12	0xAE	0x2E	R/−	coe_ptat12[7:0]	Offset value of PTAT : ca[15:8] in 24bits	—
COE_PTAT11	0xAD	0x2D	R/−	coe_ptat11[7:0]	Offset value of PTAT : ca[23:16] in 24bits (∗)	—
COE_TEMP32	0xAC	0x2C	R/−	coe_temp32[7:0]	2nd order correction coefficient of Temperature : at[7:0] in 16bits	—
COE_TEMP31	0xAB	0x2B	R/−	coe_temp31[7:0]	2nd order correction coefficient of Temperature : at[15:8] in 16bits (∗)	—
COE_TEMP22	0xAA	0x2A	R/−	coe_temp22[7:0]	1st order correction coefficient of Temperature : bt[7:0] in 16bits	—
COE_TEMP21	0xA9	0x29	R/−	coe_temp21[7:0]	1st order correction coefficient of Temperature : bt[15:8] in 16bits (∗)	—
COE_TEMP12	0xA8	0x28	R/−	coe_temp12[7:0]	correction coefficient of Temperature : ct[7:0] in 16bits	—
COE_TEMP11	0xA7	0x27	R/−	coe_temp11[7:0]	correction coefficient of Temperature : ct[15:8] in 16bits (∗)	—
COE_PR32	0xA6	0x26	R/−	coe_pr32[7:0]	2nd order correction coefficient of Pressure : ap[7:0] in 16bits	—
COE_PR31	0xA5	0x25	R/−	coe_pr31[7:0]	2nd order correction coefficient of Pressure : ap[15:8] in 16bits (∗)	—
COE_PR22	0xA4	0x24	R/−	coe_pr22[7:0]	1st order correction coefficient of Pressure : bp[7:0] in 16bits	—
COE_PR21	0xA3	0x23	R/−	coe_pr21[7:0]	1st order correction coefficient of Pressure : bp[15:8] in 16bits (∗)	—
COE_PR13	0xA2	0x22	R/−	coe_pr13[7:0]	Offset value of Pressure : cp[7:0] in 24bits	—
COE_PR12	0xA1	0x21	R/−	coe_pr12[7:0]	Offset value of Pressure : cp[15:8] in 24bits	—
COE_PR11	0xA0	0x20	R/−	coe_pr11[7:0]	Offset value of Pressure : cp[23:16] in 24bits (∗)	—

(∗) MSB of PRESS_TXDx, TEMP_TXDx and COE_** are sign bit.

IO_SETUP : IO SETUP Register

Register Name	I²C Addr.	SPI Addr.	Length	R/W	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0	initial
IO_SETUP	0xF5	0x75	8bits	R/W	t_stanby[2:0]			-	-	spi3_sdim	-	spi3w	0x00

bit7～5   t_stanby[2:0] : Standby time setting

000	001	010	011	100	101	110	111
1ms	5ms	50ms	250ms	500ms	1s	2s	4s

bit3～4   Reserved : keep these bits at 0
bit2   spi3_sdim[2] : Select output type of SDI terminal
    0 : Lo / Hiz output
    1 : Lo / Hi output
bit1   Reserved : keep this bit at 0
bit0   spi3w[0] : Change mode between SPI 4-wire and SPI 3-wire
    0 : 4-wire (Default)
    1 : 3-wire

CTRL_MEAS : Measurement Condition Control Register

Register Name	I²C Addr.	SPI Addr.	Length	R/W	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0	initial
CTRL_MEAS	0xF4	0x74	8bits	R/W	temp_average[2:0]			press_average[2:0]			power_mode[1:0]		0x00

bit7,6,5 temp_average[2:0]   Averaging times setting for Temperature measurement (skip means no measurement.）

000	001	010	011	100	101	110	111
skip	1	2	4	8	16	32	64

bit4,3,2 press_average[2:0]   Averaging times setting for Pressure measurement（skip means no measurement.）

000	001	010	011	100	101	110	111
skip	1	2	4	8	16	32	64

bit1,0   power_mode[1:0]   Operation mode setting
  00   : Sleep mode
  01,10   : Forced mode
  11   : Normal mode

DEVICE_STAT : Device Status Register

Register Name	I²C Addr.	SPI Addr.	Length	R/W	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0	initial
DEVICE_STAT	0xF3	0x73	8bits	R	-	-	-	-	measure	-	-	otp_update	0x00

bit7～4 Reserved : keep these bits at 0
bit3   measure   Device operation status. This value automatically changes.
    0:        Finish a measurement -- waiting for next measurement
    1:        On a measurement -- waiting for finishing the data store
bit2,1   Reserved : keep these bits at 0
bit0   otp_update   The status of OTP data access. This value automatically changes.
    0:        No accessing OTP data
    1:        While accessing OTP data

I²C_SET : Master code setting

Register Name	I²C Addr.	SPI Addr.	Length	R/W	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0	initial
I²C_SET	0xF2	0x72	8bits	R/W	-	-	-	-	-	master_code[2:0]			0x01

bit7～3   Reserved : keep these bits at 0
bit2,1,0 master code[2:0]   Master code setting at I²C high-speed mode.

000	001	010	011	100	101	110	111
0x08	0x09	0x0A	0x0B	0x0C	0x0D	0x0E	0x0F

IIR : IIR filter co-efficient setting Register

Register Name	I²C Addr.	SPI Addr.	Length	R/W	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0	initial
IIR	0xF1	0X71	8bits	R/W	-	-	-	-	-		filter[2:0]		0x00

bit7〜3 Reserved : keep these bits at 0
bit2,1,0 filter[2:0]　　　　IIR filter co-efficient setting
　　　　　　　　　　　　Write access to this register address, IIR filter will be initialized.

　　　　Note. Initial setting of the IIR filter coefficient is "OFF"

.
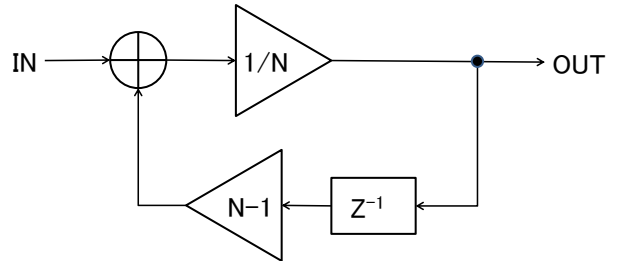
000	001	010	011	100	101	110	111
OFF	N=2	N=4	N=8	N=16	N=32	N=32	N=32

RESET : Reset Control Register

Register Name	I²C Addr.	SPI Addr.	Length	R/W	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0	initial
RESET	0xE0	0x60	8bits	W				reset[7:0]					0x00

bit7〜0 reset[7:0]　　　　When input "E6h", the software reset will be effective.
　　　　　　　　　　　　Except for that, nothing is to happen.

CHIP_ID : Chip ID Confirmation Register

Register Name	I²C Addr.	SPI Addr.	Length	R/W	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0	initial
CHIP_ID	0xD1	0x51	8bits	R				chip_id[7:0]					0x5C

bit7〜0 chip_id[7:0]　　　　5C

4.5 I²C Protocol

(1) I²C Slave Address

The 2SMPB-02 module I²C slave address is shown below.

SDO	I²C Slave Address (7bits)	Bit	bit7 Add[6]	bit6 Add[5]	bit5 Add[4]	bit4 Add[3]	bit3 Add[2]	bit2 Add[1]	bit1 Add[0]	bit0 R/W
High(1)	56h+R/W	Value	1	0	1	0	1	1	0	1/0
Low(0)	70h+R/W	Value	1	1	1	0	0	0	0	1/0

For example, in case of SDO=Low (0),

Write Access : Please set LSB of slave address as "0", then the address is E0h(1110_0000b). (70h<<1+WR(0))

Read Access : Please set LSB of slave address as "1", then the address is E1h(1110_0001b). (70h<<1+RD(1))

(2) I²C Access Protocol Examples

Symbol
- START : START condition
- STOP : STOP condition
- Re-START : Re-START condition for Read
- SACK : Acknowledge by Slave
- MACK : Acknowledge by Master
- MNACK：Not Acknowledge by Master

(3) Register Write Access Protocol

After the START condition, a Device Address is sent. This address is seven bits long followed by an eighth bit which is a data direction bit. A 'zero' indicates a transmission "WRITE". After that, the register address and the writing data shall be one set and it should be continuously transmitted until a STOP condition. A data transfer is always terminated by a STOP condition generated by the master.
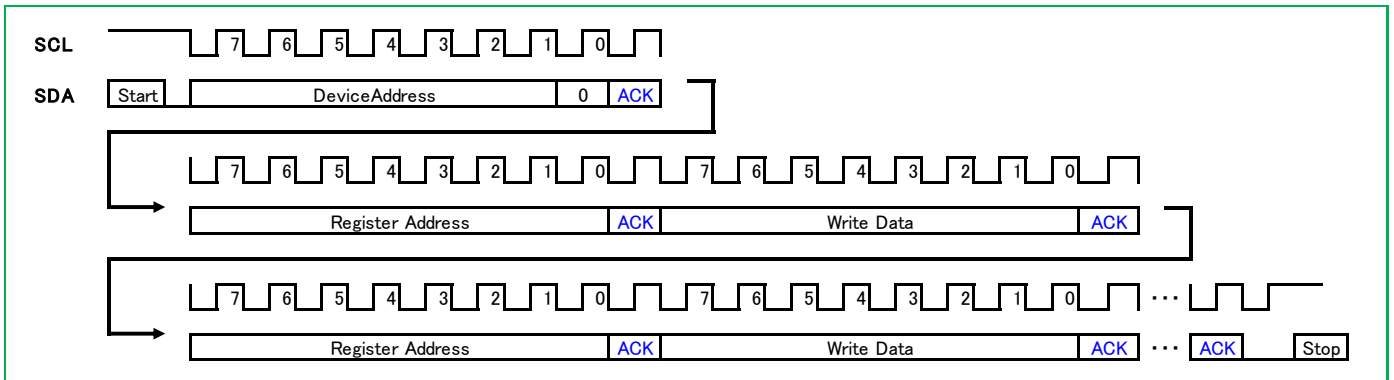
※**Black characters : Master → Slave / Blue characters : Slave → Master**
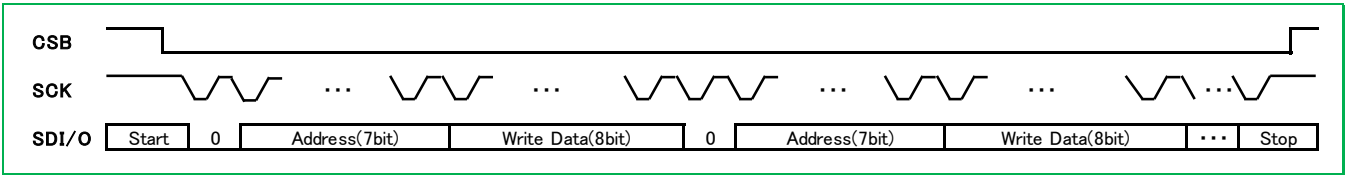
(4) Register Read Access Protocol

After a START condition, the Device Address with WRITE sign ("0") and Word Address intended to read a first data are transmitted. Next, "STOP–START" or "Re-START" condition are transmitted by the master. After that, Device Address with READ sign ("1") is transmitted by the master. Then, the slave will output the first data that is intended to read. In case of incrementing Register Address automatically, the slave will output the data repeatedly until NACK is input by the master. If Register Address becomes "0xFF", please continue to output "0xFF." Below example shows 3 bytes reading method from "0xFA" register.
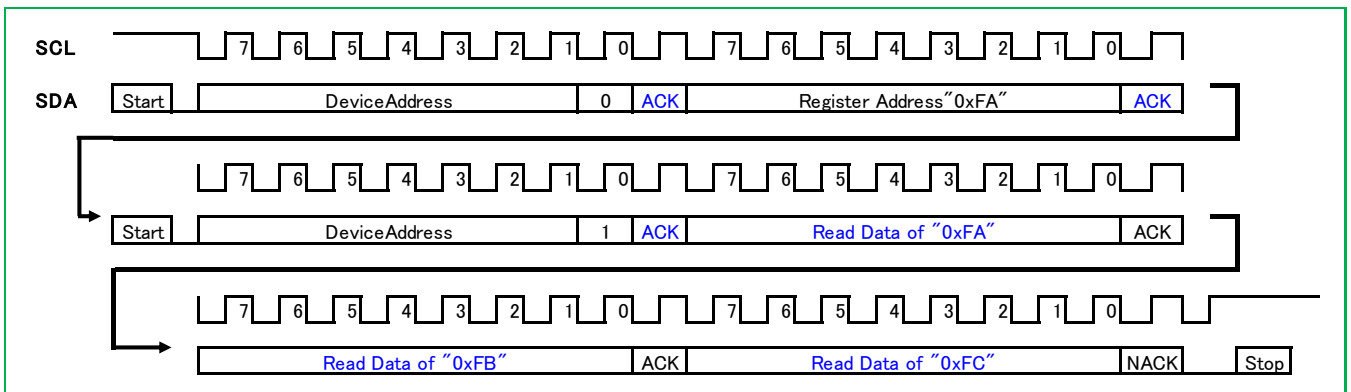
4.6 SPI Protocol
(1) SPI write
"SPI Write" needs to transmit the one set data of Register Address(Ctl.="0"+Address) and a writing data in the situation where CSB is "L". Two or more writing can be possible during CSB is "L". If CSB becomes "H", SPI communication will finish. (as well as I²C write)

CSB											
SCK											
SDI/O	Start	0	Address(7bit)	Write Data(8bit)	0	Address(7bit)	Write Data(8bit)	···	Stop		

(2) SPI read
First, "SPI read" needs to transmit Register Address(Ctl.="1"+Address) in a situation where CSB is "L".
Next, the data of the requested register address will be output from SDO. (in case of 3-wire mode, the data will be output from SDI). After that, the register address is automatically incremented by one until CSB becomes "H", the device will output the data repeatedly. (as well as I²C read)
Below shows an example of the 2 bytes reading from "0xFA" register.

CSB					
SCK					
SDI/O	Start	1	Address"0x7A"(7bit)	Read Data of "0x7A"	Read Data of "0x7B"	Stop
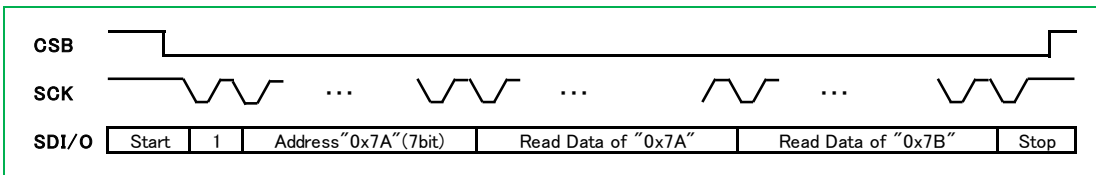
4.7 Interface specifications
(1) I²C timings

All timings apply to 100kbps（at Standard Mode）, 400kbps (at Fast Mode) and 3.4Mbps(at High Speed Mode).
For I²C timings, the following abbreviations are used :
 *1) S&F Mode = standard and fast mode
 *2) Cb = bus capacitance on SDI line
All other naming refers to I²C specification 2.1 (January 2000).
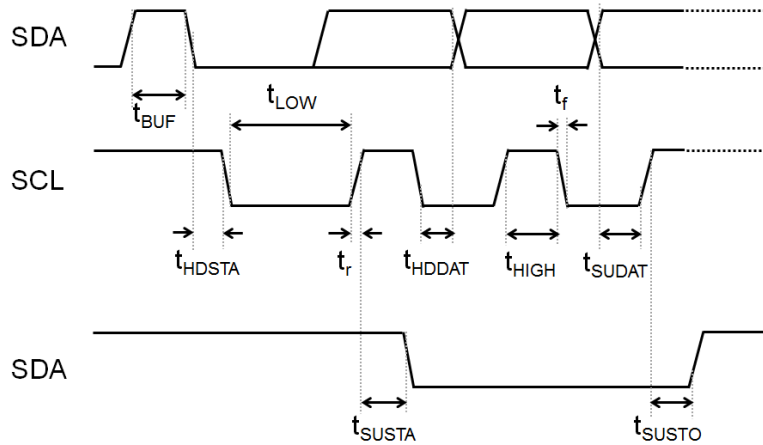
Undescribed items and symbols are compliant with the I²C specification.

Items	Symbol	Condition		min	typ	max	Units	Remark
SDI setup time	t_{SUDAT}	S&F Mode *1)		160	-	-	ns	
		HS Mode *2)	Vio=1.62V	30	-	-	ns	
		HS Mode	Vio=1.2V	55	-	-	ns	
SDI hold time	t_{HDDAT}	S&F Mode,Cb≦100pF		80	-	-	ns	
		S&F Mode,Cb≦400pF		90	-	-	ns	
		HS Mode,Cb≦ 100pF	Vio=1.62V	18	-	115	ns	
			Vio=1.2V	25	-	140	ns	
		HS Mode,Cb≦ 400pF	Vio=1.62V	24	-	150	ns	
			Vio=1.2V	45		170	ns	
SCK low pulse	t_{Low}	HS Mode,Cb≦ 100pF	Vio=1.62V	160	-	-	ns	
			Vio=1.2V	210	-	-	ns	

(2) SPI timings

All timings are applied both to 4- and 3-wire SPI.
To reduce external noise in High-Z state, we recommend the following;
・In 4-wire mode, SDO terminal is pulled up to Vio via the resister.
・In 3-wire mode, SDI terminal is pulled up to Vio via the resister.
e.g.) R_{pullup} = 3.6kΩ @Vio=1.8V.
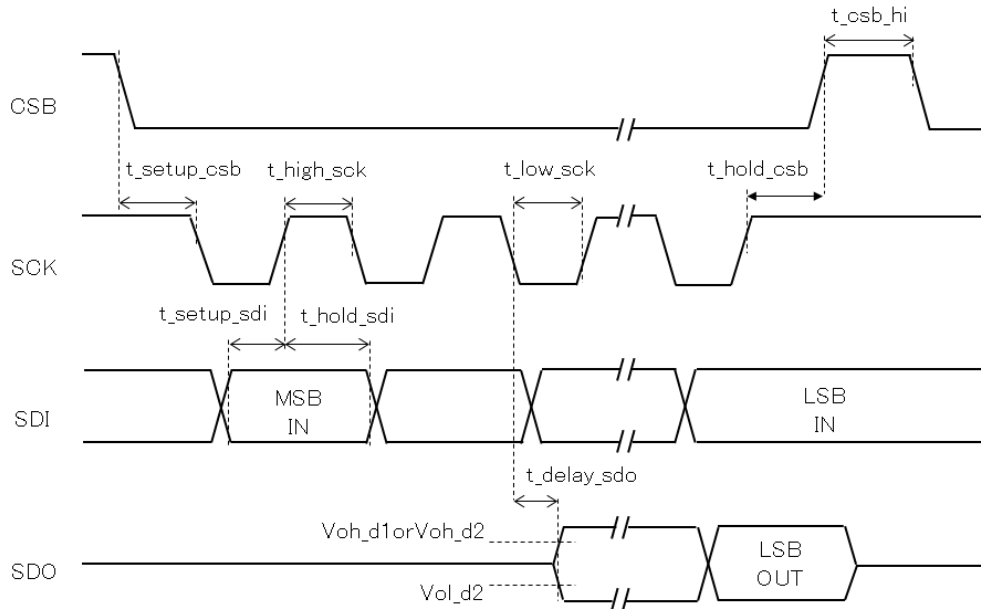
| Items	Symbol	Condition	min	typ	max	Units	Remark
SCK frequency	f_spi		—	—	10	MHz	
SCK low pulse	t_low_sck		40	—	—	ns	
SCK high pulse	t_high_sck		40	—	—	ns	
SDI setup time	t_setup_sdi		20	—	—	ns	
SDI hold time	t_hold_sdi		20	—	—	ns	
SDO output delay	t_delay_sdo	Cb=25pF,Vio=1.62V min	—	—	30	ns	
		Cb=25pF,Vio=1.2V min	—	—	40	ns	
CSB setup time	t_setup_csb		40	—	—	ns	
CSB hold time	t_hold_csb		40	—	—	ns	
CSB_HI time	t_csb_hi		100	—	—	ns	

4.8 Reset Function

The sensor is capable of resetting the operation with "Asynchronous Reset Terminal (RST pin)".

The procedure is as follows:

① Input high voltage to RST pin. (100us ≧)

② Turn off (input low voltage) and wait 10ms.

◆Reset sequence
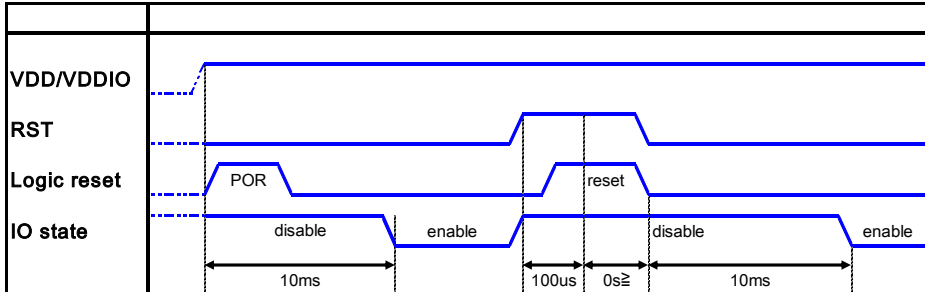
4.9 Recommended conditions of communication

In case that this sensor and other sensors are connected with a common bus line, if you use this sensor at a communication speed more than 400kbit/s,

after finishing the communication with other sensors, we recommend to provide 1 ms or more waiting time

before starting the communication with this sensor in order to ensure a stable communication (see diagram below).
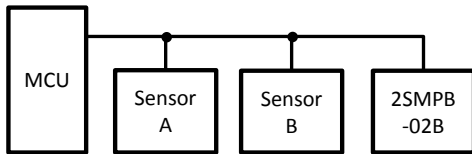
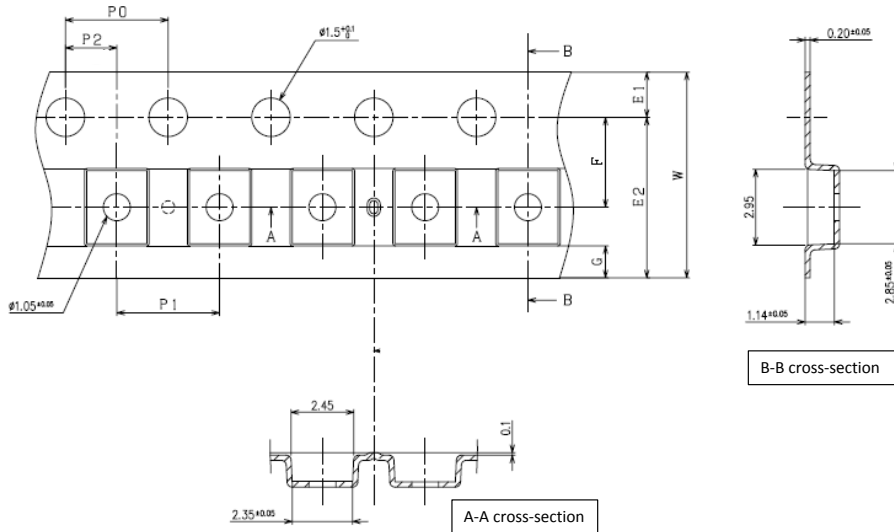◆Typical connection diagram   ◆Example of communication
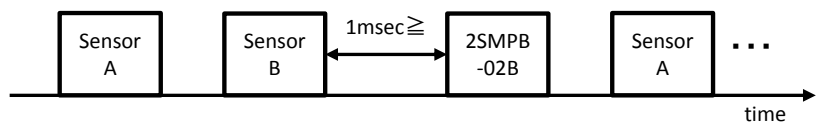
5. Packaging

5.1 Configuration of shipment

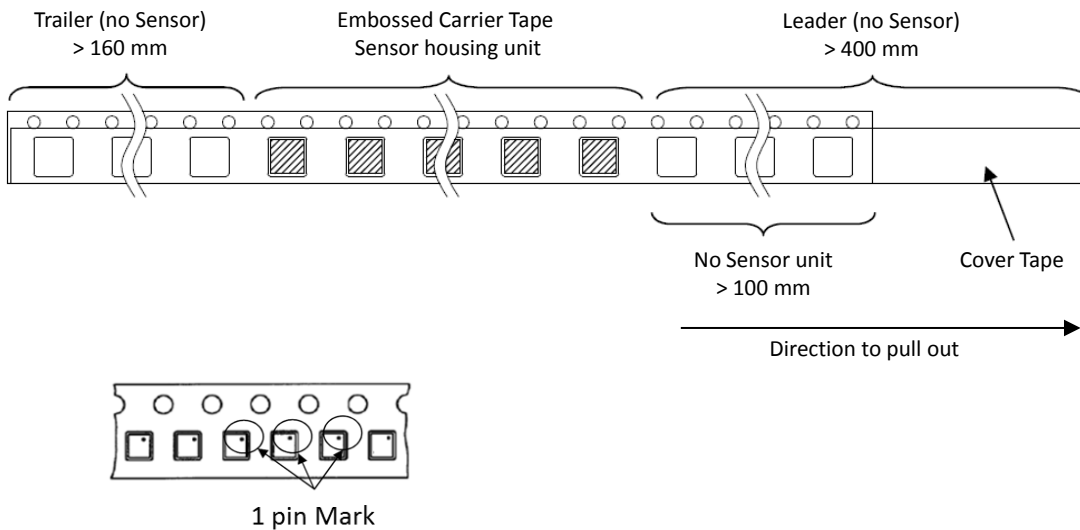| Packaging	Embossed Carrier Tape
Quantity	3,500 pcs / 1 reel 1 reel / 1 Interior box Max. 20 Interior boxes / 1 exterior box
Reel	180 mm dia.
Insert method	see below

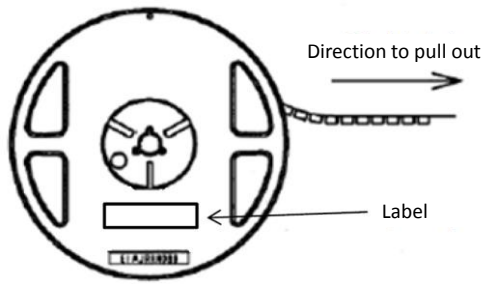   Specification of taping & reel comply with JIS C 0806-3 (IEC 60286-3).

5.2 Taping

   Emboss pitch 4 mm type & tape width 8 mm type.

Symbol	Rating
W	8.0 +0.03/-0.1
E1	1.75 +/- 0.1
F	3.50 +/- 0.05
P0	4.0 +/- 0.1
P1	4.0 +/- 0.1
P2	2.00 +/- 0.05

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5.3 Reel

Direction to pull out

Label

Reel 180 mm dia.
comply with JIS C 0806-3 requirements

5.4 Individual packaging

Aluminium-laminated bag

Label

Reel

Aluminium-laminated bag

Label
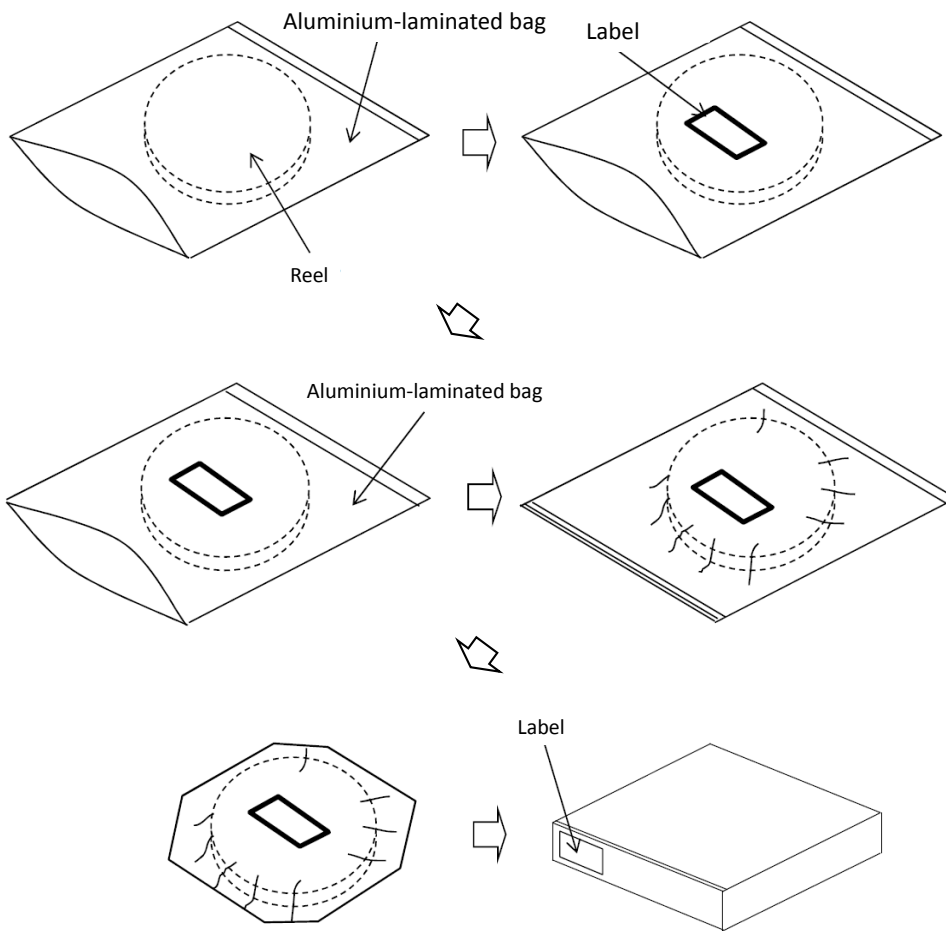
6. Recommended Soldering Method

- **Soldering method** : Air Reflow (Max 2 times)
- **Condition of Temperature** : Max.260 degreeC, within 40seconds
- **Recommended Soldering Method** :
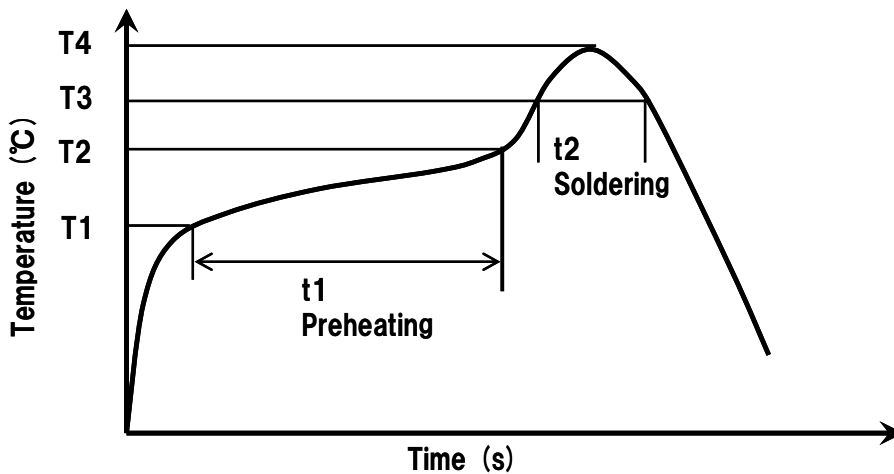
Temperature profile conditions of reflow soldering should set the temperature condition as shown in the below table and then confirm that actual conditions are met them in the table.

Item	Preheating (T1 to T2, t1)	Soldering (T3, t2)	Peak Value (T4)
Terminal	150 degreeC to 200 degreeC 60sec to 180sec.	217degreeC min. 60sec to 150sec.	260 degreeC 20sec to 40sec..

- Since the pressure sensor chip is exposed to atmosphere, cleaning fluid shall not be allowed to enter inside the sensor's case.
- We recommend that it should be used the recommended mounting PAD dimensions for the land pattern.

7. Precautions

(1) Handling

1) Only air can be used as pressure media on the product directly. It is prohibited to use pressure media including corrosive gases (e.g. organic solvents gases, sulfur dioxide and hydrogen sulfide gases), fluid and any other foreign materials.
2) The products are not water proof. The product shall be kept dry in use excluding the sensor port.
3) The product shall not be used under dew-condensing conditions. Frozen fluid on sensor chips may cause fluctuation of sensor output and other troubles.
4) The product shall be used within rated pressure. Usage at pressure out of the range may cause breakage.
5) The product may be damaged by static electricity. Charged materials (e.g. a workbench and a floor) and workers should provide measures against static electricity, including ground connection.
6) The product shall not be dropped and handled roughly.
7) The product shall not be used under dusty or damp condition.
8) Do not wash the print circuit board after the pressure sensor is mounted using solvent. It may cause a malfunction.
9) Please connect the sensor terminals according to the connection diagram.
10) The product shall not be used under high-frequency vibration including ultrasonic wave.
11) This product uses the elastic adhesive for bonding the lid, so do not add excessive stress to the lid.
12) If soldering is not fit, then this product may catch fire or get hot.
13) There is a possibility that the peripheral circuit board or some electronic part generates heat while driving this product. Please handle with care.
14) Do not tear down this product.
15) Please do not use the sensor after following case;
    - excessive shock added to the terminal of the sensor
    - the sensor lid decapped
    - the sensor dropped
16) If you use other conditions described in this document, please check yourself in advance.

(2) Environmental conditions for transport and storage
    1) The product shall not be kept with corrosive gases (e.g. organic solvents gases, sulfur dioxide and hydrogen sulfide gases).
    2) The products are not water proof. The product shall be kept dry during storage.
    3) The outer box strength may be degraded depending on the storage conditions. Please use the product in order.
    4) For this product, please keep away from direct sunlight or ultraviolet rays.
    5) The product shall be kept in appropriate conditions of temperature and humidity.
    6) The product shall not be kept under dusty or damp condition.

8. Warranty and Limited Warranty

(1) Definition
The definition of terms used in these Terms and Conditions are as follows:
    1) *Usage conditions*: Usage conditions, rating, performance, operating environment, handling instructions, cautions, prohibited use, etc. of *Omron products* described in specifications, documentations or manuals.
    2) *Customer application*: Application of *Omron products* by customers which include embedding and/or using *Omron products* in their parts/components, electronic substrates, devices, equipment or systems manufactured by customers.
    3) *Fitness*: (a) performance, (b) non-infringement of third-party intellectual property, (c) compliance with laws and regulations and (d) conformity to various standards.

(2) Caution on Descriptions
Attention is required to the following points on descriptions in specifications.
    1) Rated values and performance values are the product of tests performed for separate single conditions, including but not limited to temperature and humidity. It is not intended to warrant rated values and performance values for multiple combined conditions.
    2) Reference data are provided for reference only. *Omron* does NOT warrant that *Omron product*s work properly at all time in the range of reference data.
    3) Application examples are provided for reference only. *Omron* does NOT warrant the *Fitness* of *Omron products* under such application.
    4) *Omron* may discontinue the production of *Omron products* or change the specifications of them for the purpose of improving such products or other reasons entirely at its own discretion.

(3) Precautions
Please be aware of and accept the following when you introduce or use *Omron products*:
    1) Please use *Omron products* in compliance with *usage conditions* including rating and performance.
    2) Please confirm *fitness* of *Omron products* in your application and use your own judgment to determine the appropriateness of using them in such application. *Omron* shall not warrant the *fitness* of *Omron products* in customer application.
    3) Please confirm that *Omron products* are properly wired and installed for their intended use in your overall system.
    4) When using *Omron products*, please make sure to (i) maintain a margin of safety vis-à-vis the published rated and performance values, (ii) design to minimize risks to customer application in case of failure of *Omron products*, such as introducing redundancy, (iii) introduce system-wide safety measures to notify risks to users, and (iv) conduct regular maintenance on *Omron products* and *customer application*.
    5) *Omron products* are designed and manufactured as general-purpose products for use in general industrial products. They are not intended to be used in the following applications. If you are using *Omron products* in the following applications, *Omron* shall not provide any warranty for such *Omron products*.
        (a) Applications with stringent safety requirements, including but not limited to nuclear power control equipment, combustion equipment, aerospace equipment, railway equipment, elevator/lift equipment, amusement park equipment, medical equipment, safety devices and other applications that could cause danger/harm to people's body and life.
        (b) Applications that require high reliability, including but not limited to supply systems for gas, water and electricity, etc., 24 hour continuous operating systems, financial settlement systems and other applications that handle rights and property.
        (c) Applications under severe condition or in severe environment, including but not limited to outdoor equipment, equipment exposed to chemical contamination, equipment exposed to electromagnetic interference and equipment exposed to vibration and shocks
        (d) Applications under conditions and environment not described in specification

6)   In addition to the applications listed from (a) to (d) above, *Omron products* are not intended for use in automotive applications (including two wheel vehicles). Please do NOT use *Omron products* for automotive applications. Please contact *Omron* sales staff for products for automotive use.

(4)   Warranty Terms and Conditions
The terms and conditions for warranty of *Omron products* are as follows:
1)   Warranty period: One year after the purchase.
2)   Coverage: *Omron* will provide free replacement of the malfunctioning Omron products with the same number of replacement/alternative products
3)   Exceptions: *Omron* will not cover *Omron products* under its warranty if the cause of the malfunction falls under any of the following.
   (a)   Usage in a manner other than the original intended use for the *Omron product*.
   (b)   Usage outside of the *usage conditions*.
   (c)   Cause which could not have been foreseen with the level of science and technology at the time of shipping from *Omron*.
   (d)   Causes originating from other than *Omron* or *Omron products* (including force majeure such as but not limited to natural disasters).

(5)   Limitation of Liability
The warranty set out in these Terms and Conditions is the whole and sole liability for *Omron products*. There are no other warranties, expressed or implied. *Omron* and the distributors of *Omron products* are not liable for any damages which may arise from or be related to *Omron products*.

(6)   Export Controls
Customers of *Omron products* shall comply with all applicable laws and regulations of other relevant countries with regard to security export control, when exporting *Omron products* and/or technical documents or providing such products and/or documents to a non-resident.   *Omron* may not provide customers with *Omron products* and/or technical documents should they fail to comply with such laws and regulations.

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