

# DATA SHEET HSPPAD146A

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## 1. OVERVIEW

HSPPAD146A is the 3.1x3.1mm footprint and 2.6mm height digital interface pressure sensor designed as waterproof for barometer system and water depth measurement system. Barometric and water pressure is detected by MEMS sensor element using piezo resistive bridge circuit formed on the silicon diaphragm. The sensor element is connected to ASIC for signal conditioning. ASIC has 17-bit ADC and temperature compensation capability. The ASIC output compensated pressure values. In addition to the compensation, this product supports averaging and filtering for lower noise, and FIFO function. I2C interface is prepared for communication.

## 2. FEATURES

- Pressure Range 30 to 1700 kPa ( +9000m in altitude and 150m in depth )
- Supply Voltage 1.7 to 3.6 V (Typical 1.8V)
- Operating Temperature -40 to +85 °C
- Package Small LGA Package: 3.1mm x 3.1mm x 2.6mm
- Digital interface I2C
- Current Consumption 1.8uA (Low power setting)
- Noise RMS 0.017kPa (High resolution setting)
- Sampling rate 200Hz max (Continuous mode)
- Lead free, RoHS instruction, Halogen free conforming

**3. ABSOLUTE MAXIMUM RATINGS**

Table 1 : Absolute maximum ratings

Item	Symbol	Unit.	Specification			Notes
			min.	Typ.	max.	
Max supply voltage	VDD	[V]	-0.5	-	4.0	-
Max load pressure	Pmax	[kPa]	-	-	3000	-
Storage temperature	Tstg	[°C]	-40	-	+125	-
ESD		[V]	-2000	-	+2000	HBM

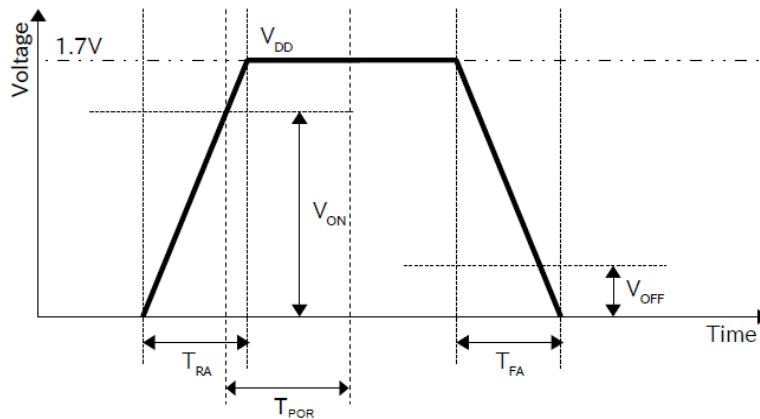
**4. ELECTRICAL CHARACTERISTICS**

Table 2 : Electrical Characteristics

Item	Symbol	Unit	Specification			Notes
			min.	Typ.	max.	
Operating temperature	Topr	[°C]	-40		+85	
Pressure range	Popr	[kPa]	30		1700	
Supply voltage	VDD	[V]	1.7	1.8	3.6	
Current consumption	IDD	[uA]		1.8		@1Hz sampling, Low power setting, 25°C
Standby current		[uA]		0.1		T=25°C
Pressure RMS noise		[kPa]		0.039		Low power setting
		[kPa]		0.017		High resolution setting
Maximum measurement rate		[Hz]		200		Continuous mode
Pressure resolution		[Pa/LSB]		13		
Pressure absolute accuracy		[kPa]		±2.0		50 to 700kPa 0 to 40°C
		[kPa]		±4.0		700 to 1100kPa 0 to 40°C
Temperature accuracy		[°C]		±2.0		0 to 60°C
Solder drift		[kPa]	-2.0		+1.0	
Long term drift		[kPa]		±1.0		12 months

**5. POWER UP AND DOWN SEQUENCE**

Power up and down sequence must be followed the specification in the table 3.



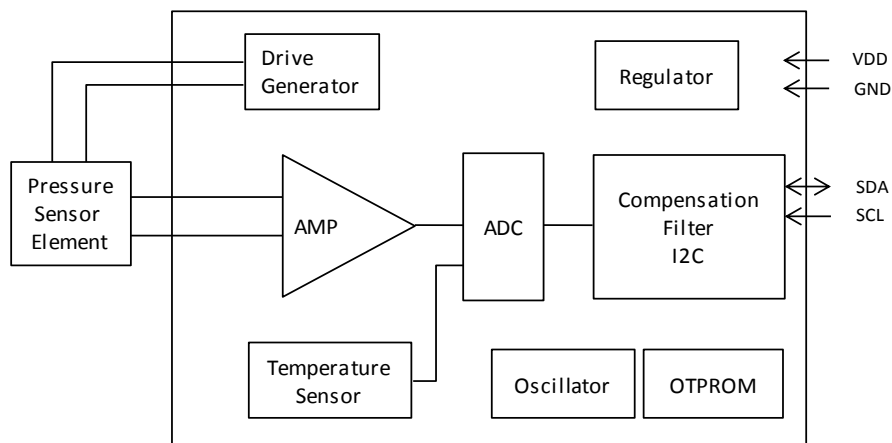
**Fig. 1 : Power up and down sequence**

**Table 3 : Power up and down specifaion**

Items	Symbol	Min	Typ	Max	Unit
ON voltage	$V_{ON}$	-	-	1.6	V
OFF voltage	$V_{OFF}$	0.5	-	-	V
Rise time	$T_{RA}$	0.1	-	2.0	mS
Fall time	$T_{FA}$	0.1	-	2.0	mS
POR time	$T_{POR}$	-	-	2.2	mS
OFF time	$T_{OFF}$	100	-	-	mS

Until POR is done, register access from host device is ignored. POR will take 2.2msec after VDD reaches ON voltage. Consecutive power on after VDD sink below  $V_{OFF}$ , must wait  $T_{OFF}$  to perform POR correctly.

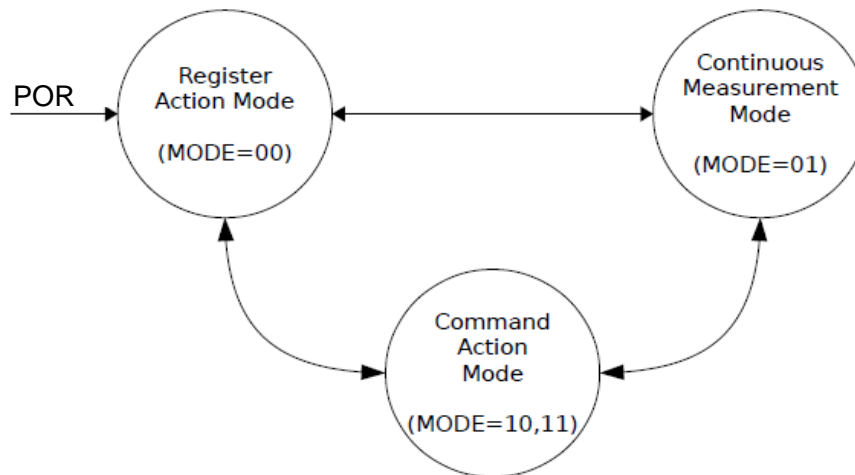
**6. BLOCK DIAGRAM**



**Fig. 2 : Block Diagram**

**7. MODES**

Mode transition diagram is shown below. Mode can be set by CTL1.MODE[1:0] in Register 0x0F. After POR or Software reset, mode is set to Register Action Mode.



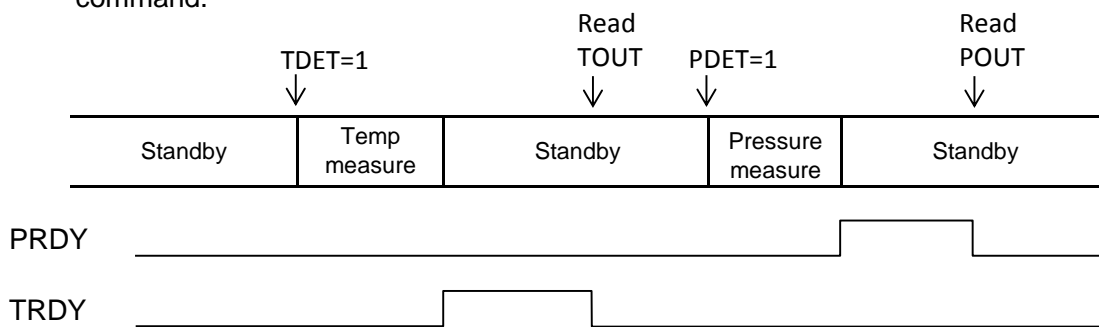
**Fig. 3 : Mode transition**

**Table 4 : Mode setting**

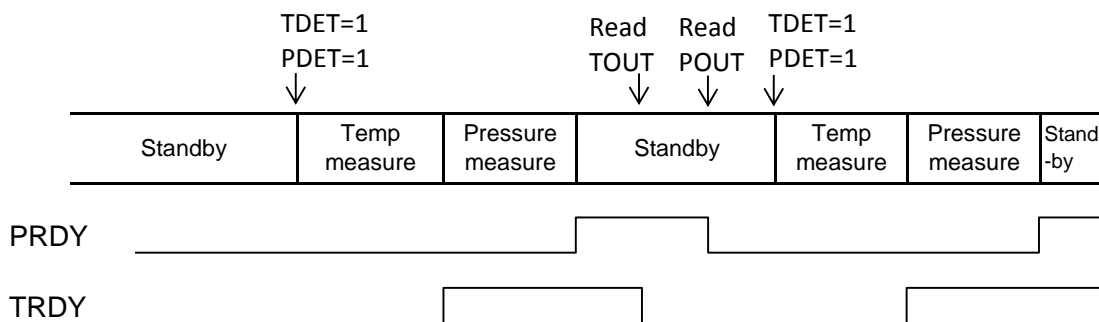
CTL2.MODE	Measurement Mode	Notes
00	Register Action Mode	Execute measurement by accessing Register ACTL1.
01	Continuous Measurement Mode	Automatically repeat measurement by specified frequency
10 or 11	Command Action Mode	Execute measurement by receiving Action Commands

**7.1 Register Action Mode**

Register Action Mode allows access to ACTL1 and execute each functions by setting "1" for each bit. Temperature measurement and Pressure measurement is performed by setting TDET and PDET to 1, respectively. When TDET and PDET are set to "1" at the same time, Temperature measurement is done, followed by Pressure measurement. If the PDET is performed independently, the latest temperature data is used for pressure data compensation. Temperature data is stored into register address 0x09 and 0x0A, and compensated pressure data is in 0x04 to 0x06. After data store, TRDY and PDRY in STAT register is changed to "1", and TDET and PDET back to "0". TDET and PDET are accessible during measurement, but they will be effective after the measurement. Only PDRP is effective right away. After measurement, device goes to stand-by state and minimizes current consumption, then waiting for next command.



**Fig. 4 : Timing chart in Register Action Mode (PDET and TDET are executed individually)**



**Fig. 5 : Timing chart in Register Action Mode (PDET and TDET are executed at same time)**

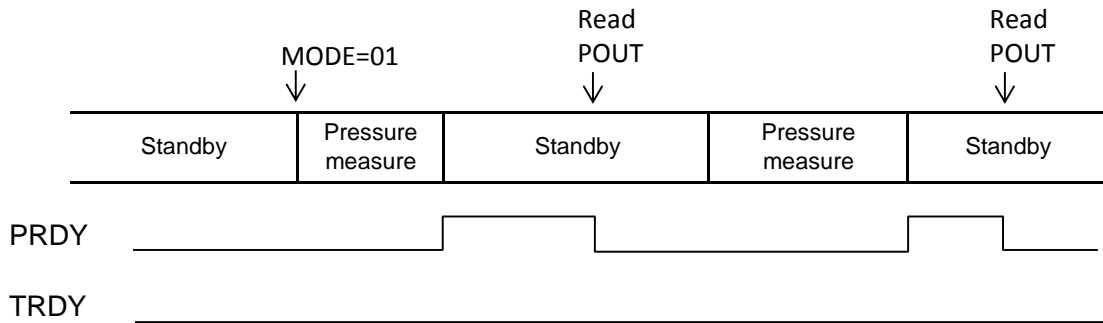
**7.2 Continuous Measurement Mode**

Continuous Measurement Mode executes measurement with specified frequency by CTL2.ODR. In order to move into this mode, CTL2.PMES must be set "1". Measurement is started immediately after mode transition and following measurement is repeated. In this mode, regulator will not be inactive in standby period and keeps consuming current. If ODR is changed in this mode, new measurement will be performed immediately and repeat following measurement. However, ODR change is done in measurement period, new measurement will start right after the measurement finished.

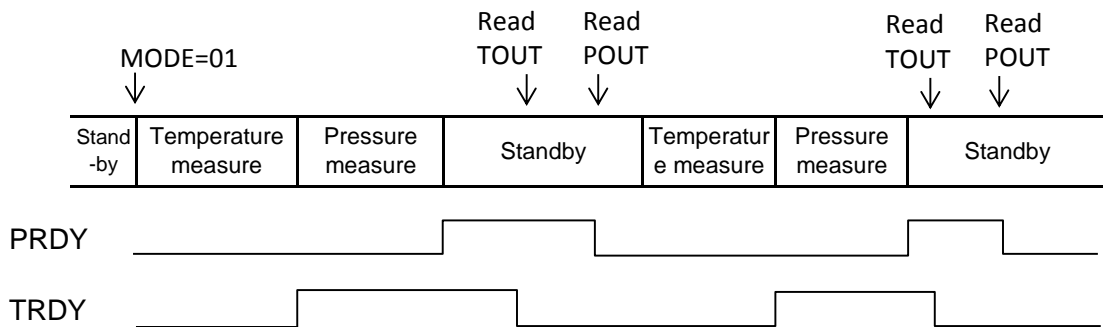


**Table 5 : ODR and Sampling frequency**

ODR	Sampling Frequency	Sampling Period
00	1Hz	1000ms
01	10Hz	100ms
10	100Hz	10ms
11	200Hz	5ms



**Fig. 6 :Timing chart in Continuous Measurement Mode (PMES=1, TMES=0)**



**Fig. 7 :Timing chart in Continuous Measurement Mode (PMES=1, TMES=1)**

**7.3 Command Action Mode**

In Command Action Mode, several functions are performed by write access the register address. Each actions are the same with setting "1" at same bit name in ACTL1 and ACTL2 in Register Action Mode.

**Table 6 : Action Commands**

Address	Name	Function
20h	PDET	Perform pressure measurement
22h	TDET	Perform temperature measurement
26h	SRST	Perform software reset
29h	PTDET	Perform pressure and temperature measurement

**8. FUNCTIONS**

**8.1 FIFO**

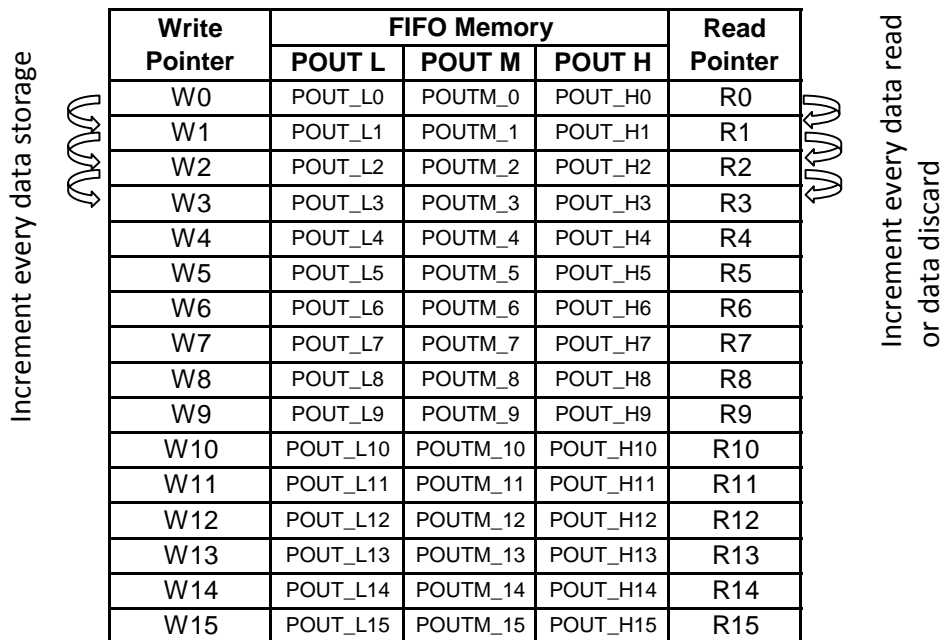
There are 16 steps FIFO for Pressure read data. FIFO function can be enabled by setting FCTL.FFEN=1.

**Table 7 : FCTL.FFEN setting**

FCTL.FFEN	Description
0	FIFO disabled
1	FIFO enabled

Write pointer is incremented when the sensor data is stored into FIFO memory, and next data is stored to next register. Read Pointer is incremented when the sensor data is read.

Number of stored data is indicated by FFST.FP, if the FP (FIFO Pointer) is greater or equal to WMT (Water Mark Pointer) then FFST.FFEV becomes "1". All 16 steps FIFO memory are filled by the sensor data, the most oldest data is discarded and Read Pointer is incremented. All data in FIFO memory is discarded when FFEN is set to "0".



8.2 Averaging

Table 8 : AVCL.AVG setting

AVCL.AVG	Number of data to average	
	Register Action and Command Action Mode	Continuous Mode
000	no average	no average
001	x 2	x 2
010	x 4	x 4
011	x 8	x 8
100	x 16	x 16
101	x 32	x 16
110	x 64	x 16
111	x 128	x 16

Table 9 : AVCL.TFRQ setting

000	Once before first pressure measurement
001	Once every 64 pressure measurement
010	Once every 32 pressure measurement
011	Once every 16 pressure measurement
100	Once every 8 pressure measurement
101	Once every 4 pressure measurement
110	Once every 2 pressure measurement
111	Every time

8.2.1 In Register Action Mode and Command Action Mode

Averaging function can be activated by setting AVCL.AVG. In Register Action Mode and Command Action mode, simple average is calculated. Measurement is performed after the command PDET is issued. Temperature is measured by specified frequency by AVCL.TFRQ. The measurement repeats until specified number of data is collected. Each data are temperature compensated with the latest temperature data. Then, average is calculated and the result is stored into POUT.

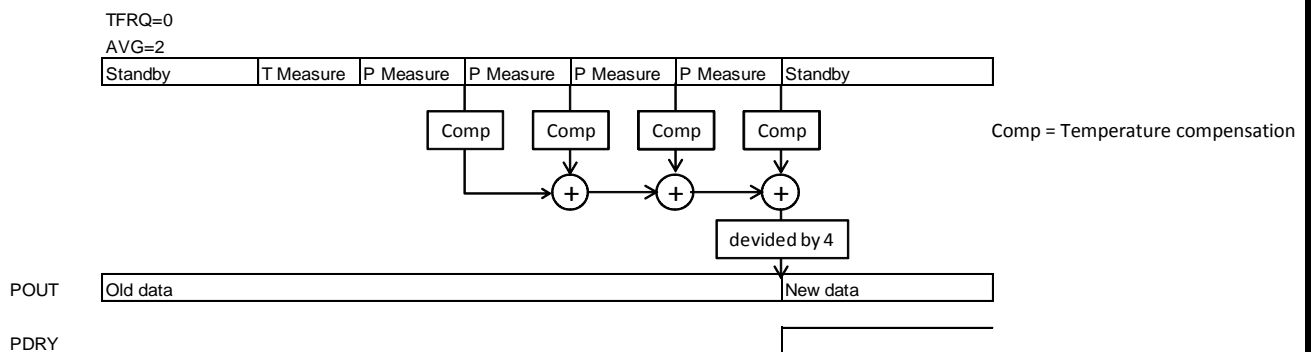


Fig. 8 Average calculation (TFRQ=0, AVG=2)

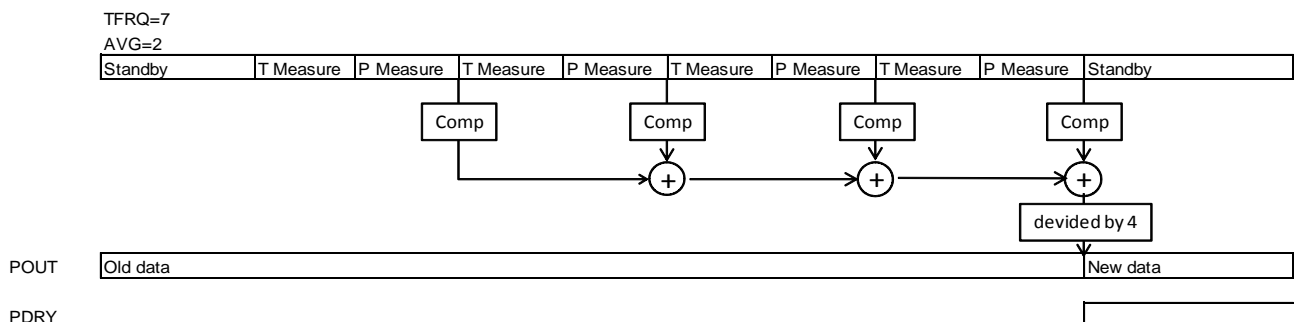
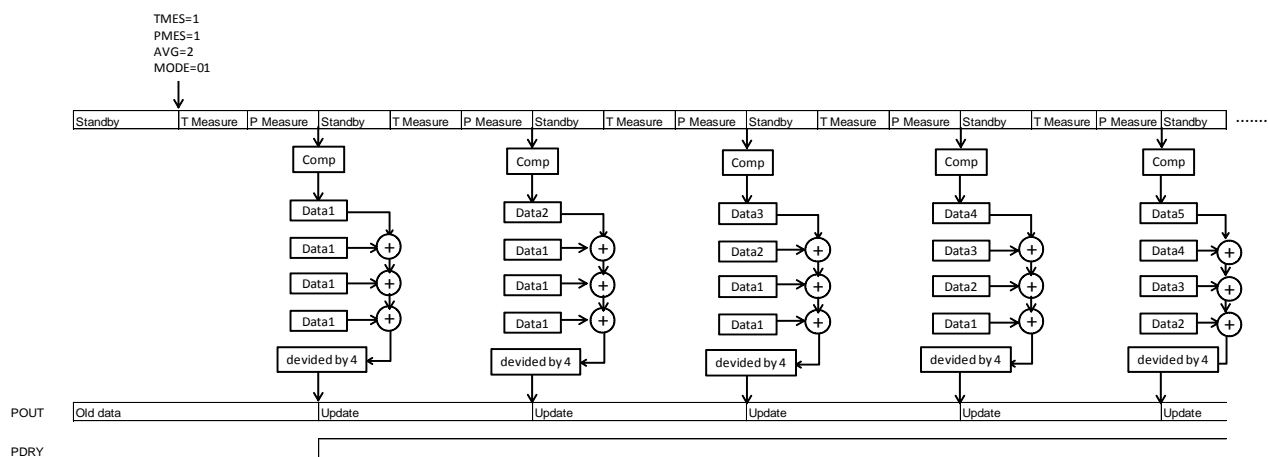


Fig. 9 Average calculation (TFRQ=07 AVG=2)

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### 8.2.2 In Continuous Mode

In Continuous Mode, moving average is calculated. Set CTL2.MODE=01 with AVCL.AVG>0, periodical measurement is started. Average is calculated when every measurement is done and the result is stored into POUT. Moving average can update averaged data at every measurement, so sampling rate won't be compromised. When first few measurement, number of data is not sufficient to specified average number, in this case necessary data is supplemented by initial data.



**Fig. 10 Moving Average calculation**

### 8.3 CIC Filter

Digital output data from  $\Delta\Sigma$ ADC is processed at CIC filter in the digital block. Number of TAP can be specified at CTL1.PTAP. Output data accuracy is increased by larger number of TAP, however, current consumption is increased too. This TAP setting is effective to pressure reading only and fixed for temperature.

**Table 10 : CTL1,PTAP setting**

PTAP	Name	Tap count	Pressure Measurement time
00	Ultra Low Power	32	260 uS
01	Low Power	64	356 uS
10	High Accuracy	128	548 uS
11	Ultra Accuracy	256	932 uS

Measurement time is typical value and not guaranteed. Temperature measurement time (416uS) is not included.

### 8.4 Software Reset

Software reset is performed by setting ACTL2.SRST to "1" or send action command SRST. Once software reset command is detected, digital regulator is disabled and all register values are reset. Then transfer to Register Action Mode and Standby state. After Software reset command, command can not be received for 2.2msec to complete POR.

**8.5 Flag Function**

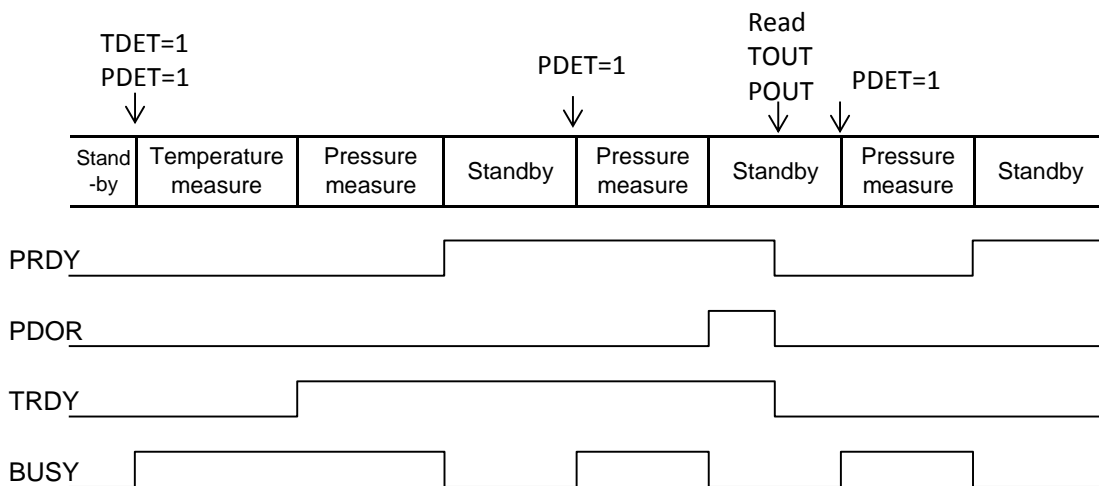
Following flag function can be used. The status is checked by reading FFST or STAT register.

**8.5.1 STATUS Register**

STAT register indicates following status.

**Table 11 : STAT and FFST Register function**

Register	Name	Flag	Condition to be "1"	Condition to be "0"
STAT	BUSY	Busy flag	Pressure or Temperature sensor is in measurement.	In standby state.
	TRDY	Temperature measurement completion flag	TDET was executed and temperature measurement is completed.	TOUT is read. FFEN is changed.
	PDOR	Pressure data over run flag	a) FIFO is disabled Old data is discarded and updated by new data in POUT. b) FIFO is enabled The most oldest data is discarded with FFEN=1 and FP=16.	a) FIFO is disabled POUT is read. b) FIFO is enabled POUT is read. FFEN is changed.
	PRDY	Pressure measurement completion flag	a) FIFO is disabled Pressure measurement is completed. b) FIFO is enabled FP>=1	a) FIFO is disabled POUT is read. b) FIFO is enabled FP=0. FFEN is changed.
FFST	FFEV	FIFO event flag	FP>=WMT	FP<WMT Change FFEV



**Fig. 11 :Timing chart in Continuous Measurement Mode (PMES=1, TMES=1)**

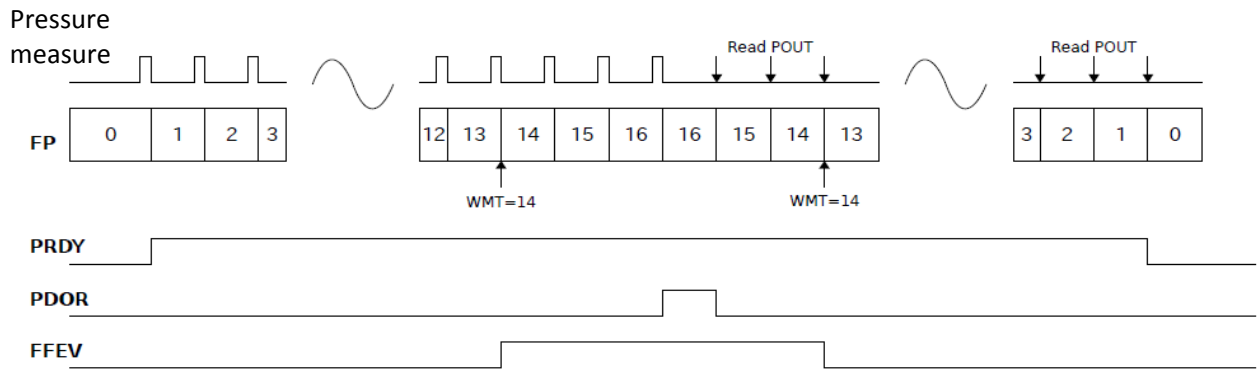
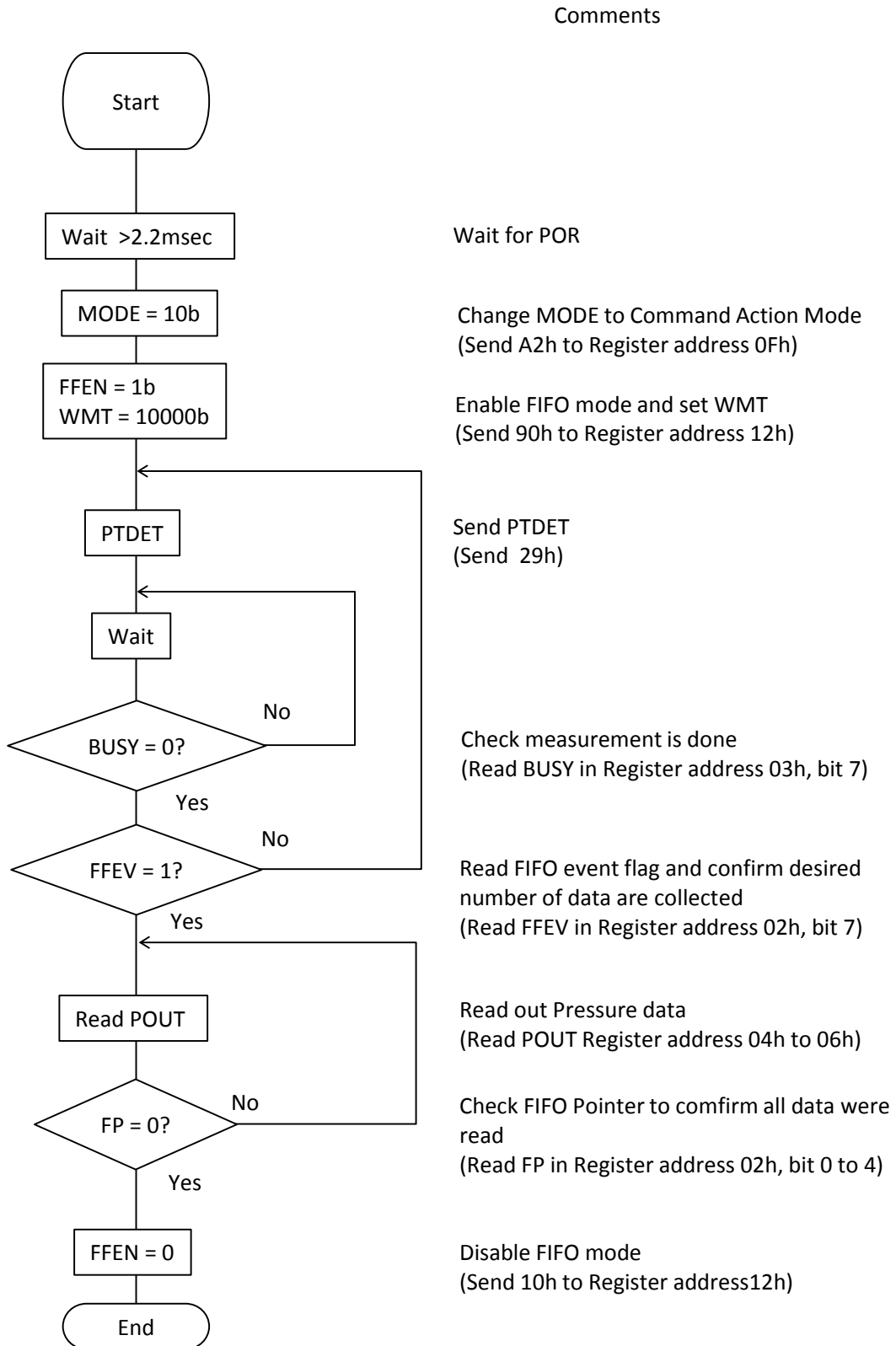


Fig. 12 :Timing chart in FIFO mode

**9. SAMPLE FLOW CHART**

This flow chart is showing from Power on to pressure measurement in Command Action Mode with 16-step FIFO.



**Fig. 13 : Example flow chart**

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## 10. TYPICAL REGISTER SETTING

**Table 12 : Typical settings**

Setting	Application	MODE	PTAP	AVG	TFRQ	ODR [Hz]	Measurement Period [mS] (*1)	Current [uA]	Noise [Pa]	Noise in depth [mm]
Fastest Dynamic motion detection	Handheld device	Continuous	11	x 16	NA	200	NA	356	8	0.8
Dynamic motion detection	Handheld device	Continuous	11	x 16	NA	100	NA	181	8	0.8
Depth navigation	Depth detection	Continuous	11	x 16	NA	10	NA	23.6	8	0.8
1Hz Single shot High resolution	On demand water depth detection	Register Action or Command Action	11	x 8	0	1 (*2)	8	11.2	17	1.7
1Hz Single shot Low power	Low power depth detection	Register Action or Command Action	11	x 1	0	1 (*2)	1	1.8	39	3.9
1/60Hz Single shot Low power	Low frequency depth detection	Register Action or Command Action	11	x 1	0	1/60 (*2)	1	0.03	39	3.9

\*1 : Measurement period in usec. In other words, necessary time period after receiving command.  
Not applicable for Continuous mode.

\*2 : Sampling frequency must be controlled by command from host device.



**11. INTERFACE SPECIFICATIONS**

**11.1 I2C Slave Interface**

I2C interface specification conforms Philips I2C-BUS Specification version 2.1 and NXP UM10204 I2C-BUS Specification and user manual Rev.03-19 June 2007. The slave address is 1001001x (x= Write:0, Read:1). Standard mode (100kHz), Fast mode (400kHz), Fast mode plus (1MHz) and High-speed mode (3.4MHz) are supported. Multiple read and write is supported and register address is automatically incremented every read or write.

High-speed mode is selected when master code (00001xxx) is received instead of slave address. Once master code is received, the product return NAK.

The device works in Fast mode plus and High-speed mode with power supply less than 2.5V. Please contact us, if the device needs to be operated in those mode with or higher power supply. Different factory calibration will be done before shipment.

Bus protocol definitions

- S: Start condition
- SAD+W: Slave Address + write bit
- SAD+R: Slave Address + read bit
- SAD+R/W: Slave Address + read or write bit
- SAK: Slave Acknowledge
- REG: Register Address (2<sup>nd</sup> byte)
- Sr: Repeat Start condition
- A: (Master) Acknowledge
- /A: (Master) Non-Acknowledge
- DATA: Data (load)
- P: Stop condition
- M-code: Master code (00001XXX)

Read Formats

One byte read flow

<i>master</i>	S	SAD+W		REG		SR	SAD+R			/A	P
<i>slave</i>			SAK		SAK			SAK	DATA		

Multiple byte reads flow

<i>master</i>	S	SAD+W		REG		SR	SAD+R			A		/A	P
<i>slave</i>			SAK		SAK			SAK	DATA		DATA		

Write Format

One byte write flow

<i>master</i>	S	SAD+W		REG		DATA		P
<i>slave</i>			SAK		SAK		SAK	

Multiple byte writes flow

<i>master</i>	S	SAD+W		REG		DATA		DATA		P
<i>slave</i>			SAK		SAK		SAK		SAK	

HS mode data transfer

HS mode is enable after writing Mcode.

<i>speed</i>	F/S-mode				Hs-mode						FS-
<i>master</i>	S	Mcode	/A	SR	SAD+R/W		DATA	/A	P		
<i>slave</i>						A	DATA	A			
									Hs- continue		
<i>master</i>									SR	SAD+R/W	

12. REGISTER MAP

Reg add	Name	Cust. R/W/A	Test R/W/A	Full Name	Bit assignment								Init. Value
					bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0	
00	WIA	R	R	Who I am	0	1	0	0	1	0	0	1	49
01	INFO	R	R	Information	0	0	1	1	0	0	0	1	31
02	FFST	R	R	FIFO Status	FFE	-	-	FP[4:0]				00	
03	STAT	R	R	Status	BUSY	-	-	TRDY	-	PDOR	-	PRDY	00
04	POUTL	R	R	Pressure Output Low	POUT[7:0]								00
05	POUTM	R	R	Pressure Output Middle	POUT[15:8]								00
06	POUTH	R	R	Pressure Output High	-	-	-	-	-	-	-	POUT[16]	00
09	TOUTL	R	R	Temperature Output Low	TOUT[7:0]								00
0A	TOUTH	R	R	Temperature Output High	TOUT[15:8]								19
0E	CTL1	RW	RW	Control 1	-	-	-	-	-	-	-	PTAP[1:0]	13
0F	CTL2	RW	RW	Control 2	TMES	-	PMES	-	ODR[1:0]		MODE[1:0]		A0
10	ACTL1	RW	RW	Action Control 1	-	-	-	-	TDET	-	PDET	-	00
11	ACTL2	RW	RW	Action Control 2	SRST	-	-	-	-	-	-	-	00
12	FCTL	RW	RW	FIFO Control	FFEN	-	-	WMT[4:0]				10	
13	AVCL	RW	RW	Average Control	-	-	TFRQ[2:0]			AVG[2:0]			38
1C	PNUM	R	R	Product Number	0	0	1	0	0	0	0	1	21
20	PDET	AC	AC	Pressure Detection Command	-	-	-	-	-	-	-	-	-
22	TDET	AC	AC	Temperature Detection Command	-	-	-	-	-	-	-	-	-
26	SRST	AC	AC	Software Reset Command	-	-	-	-	-	-	-	-	-
29	PTDET	AC	AC	P&T Detection Command	-	-	-	-	-	-	-	-	-

Registers marked "-" must not be changed.

13. REGISTER DESCRIPTION

**WIA (Who I am) Address:00h (Read only)**

bit	Name	Initial	Description
7:0	WIA	49h	Fixed value

**INFO (Information) Address:01h (Read only)**

bit	Name	Initial	Description
7:0	INFO	31h	Fixed value

**FFST (FIFO Status) Address:02h (Read only)**

bit	Name	Initial	Description
7	FFEV	0b	FIFO event flag. 0: FP<WMT 1: FP>=WMT
6:5	-	-	-
4:0	FP	00000b	Number of data stored in FIFO memory. 5bit = 0~16.

**STAT (Status) Address:03h (Read only)**

bit	Name	Initial	Description
7	BUSY	0b	Busy state flag. 0: Standby state 1: In Busy state
6	-	-	-
5	-	-	-
4	TRDY	0b	Temperature measurement completion flag 0: No data update or data was read 1: New data is ready
3	-	-	-
2	PDOR	0b	Data over run flag 0: No data update or data was read 1: Old data is discarded
1	-	-	-
0	PRDY	0b	Pressure measurement completion flag 0: No data update or data was read 1: New data is ready

**POUT (Pressure Output) Address:04h~06h (Read only)**

bit	Name	Initial	Description
23:17	-	-	-
16:0	POUT	00000h	17bit Pressure output 0~131071 Pressure [Pa] = POUT[LSB] x 13

**TOUT (Temperature Output) Address:09h~A0h (Read only)**

bit	Name	Initial	Description
15:0	TOUT	1900h	16bit temperature data -32768~32767 (Two's complement) Temperature [°C] = TOUT[LSB] / 256

**CTL1 (Control 1) Address:0Eh (Read/Write)**

bit	Name	Initial	Description
7:5	-	-	-
4	-	-	-
3:2	-	-	-
1:0	PTAP	11b	sinc filter Tap count 00: 32-tap, Ultra low power 01: 64-tap, Low power 10: 128-tap, High accuracy 11: 256-tap, Ultra accuracy

**CTL2 (Control 2) Address:0Fh (Read/Write)**

bit	Name	Initial	Description
7	TMES	1b	Temperature measurement 0: Disable temperature measurement in Continuous mode. 1: Eable temperature measurement in Continuous mode.
6	-	-	-
5	PMES	1b	Pressure measurement 0: Disable pressure measurement in Continuous mode. 1: Eable pressure measurement in Continuous mode.
4	-	-	-
3:2	ODR	00b	Sampling rate 00: 1Hz 01: 10Hz 10: 100Hz 11: 200Hz
1:0	MODE	00b	Mode setting 00: Register Action Mode 01: Continuous Measurement Mode 10: Command Action Mode 11: Command Action Mode

**ACTL1 (Action Control 1) Address:10h (Read/Write)**

bit	Name	Initial	Description
7:4	-	-	-
3	TDET	0b	Temperature measurement in Register Action Mode 0: Not measure 1: Measure
2	-	-	-
1	PDET	0b	Pressure measurement in Register Action Mode 0: Not measure 1: Measure
0	-	-	-

**ACTL2 (Action Control 2) Address:11h (Read/Write)**

bit	Name	Initial	Description
7	SRST	0b	Software Reset 0: None 1: Execute Software Reset
6:0	-	-	-

**FCTL (FIFO Control) Address:12h (Read/Write)**

bit	Name	Initial	Description
7	FFEN	0b	FIFO enabler 0: Disable 1: Enable
6:5	-	-	-
4:0	WMT	10000b	FIFO threshold 5bit 0~16.

**AVCL (Average Control) Address:13h (Read/Write)**

bit	Name	Initial	Description
7:6	-	-	-
5:3	TFRQ	111b	Frequency of temperature measurement 000: Only first time 001: Once every 64 times 010: Once every 32 times 011: Once every 16 times 100: Once every 8 times 101: Once every 4 times 110: Once every 2 times 111: Every time
2:0	AVG	000b	Number of data to average (In Continuous Mode) 000: No average 001: x 2 (x 2) 010: x 4 (x 4) 011: x 8 (x 8) 100: x 16 (x 16) 101: x 32 (x 16) 110: x 64 (x 16) 111: x 128 (x 16)

**PNUM (Product Number) Address:1Ch (Read only)**

bit	Name	Initial	Description
7:0	PNUM	21h	Fixed value for HSPPAD146A

14. MECHANICAL INFORMATION

14.1 Pin Layout

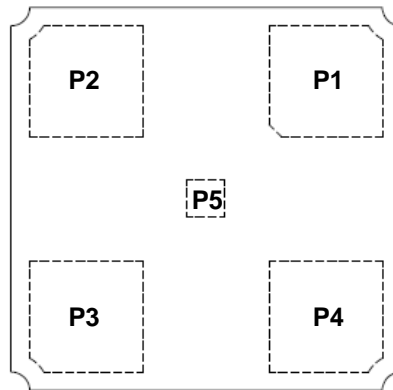


Fig.14 : Pin layout (Top view)

Table13 : Pin assign

P#	Name	Description
P1	GND	Ground
P2	VDD	Voltage supply
P3	SCL	Serial clock
P4	SDA	Serial data input/output
P5	NC	-

14.2 Package Dimension

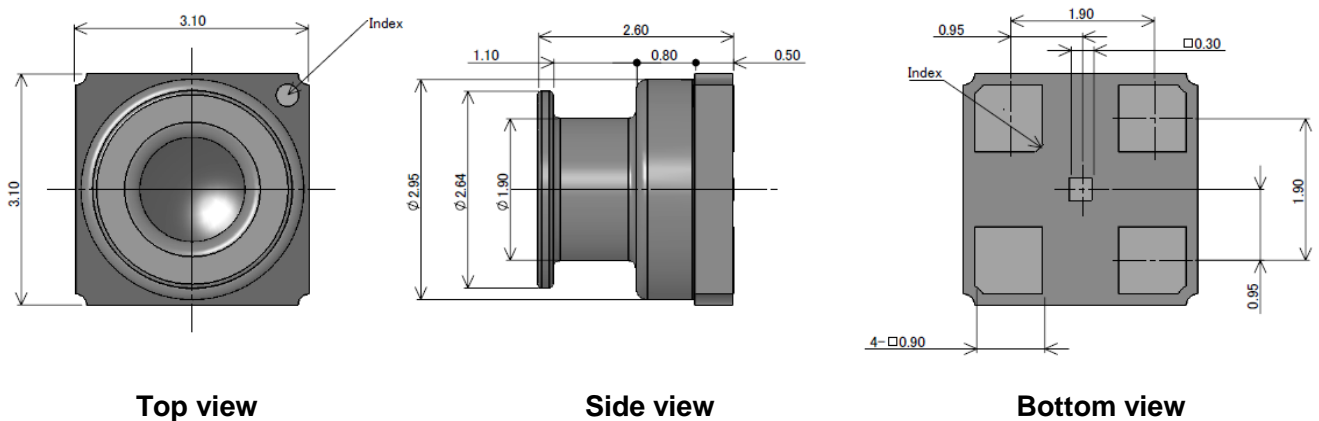


Fig. 15 : Mechanical Dimension



14.3 Recommended Land Pattern

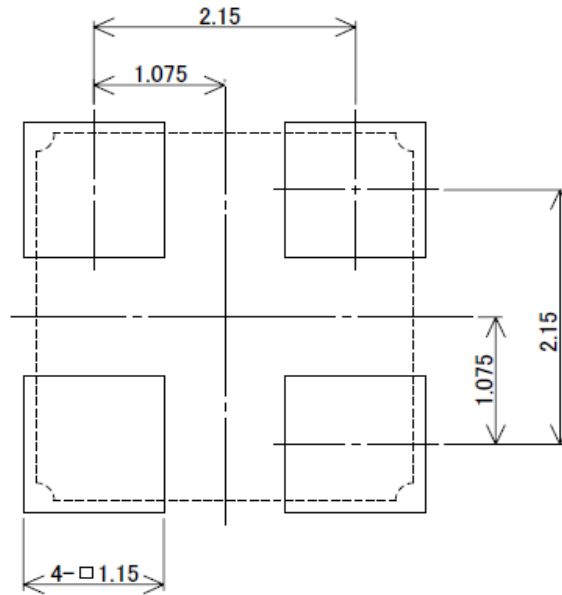


Fig. 16 : Land Pattern

14.4 Tape and Reel drawing

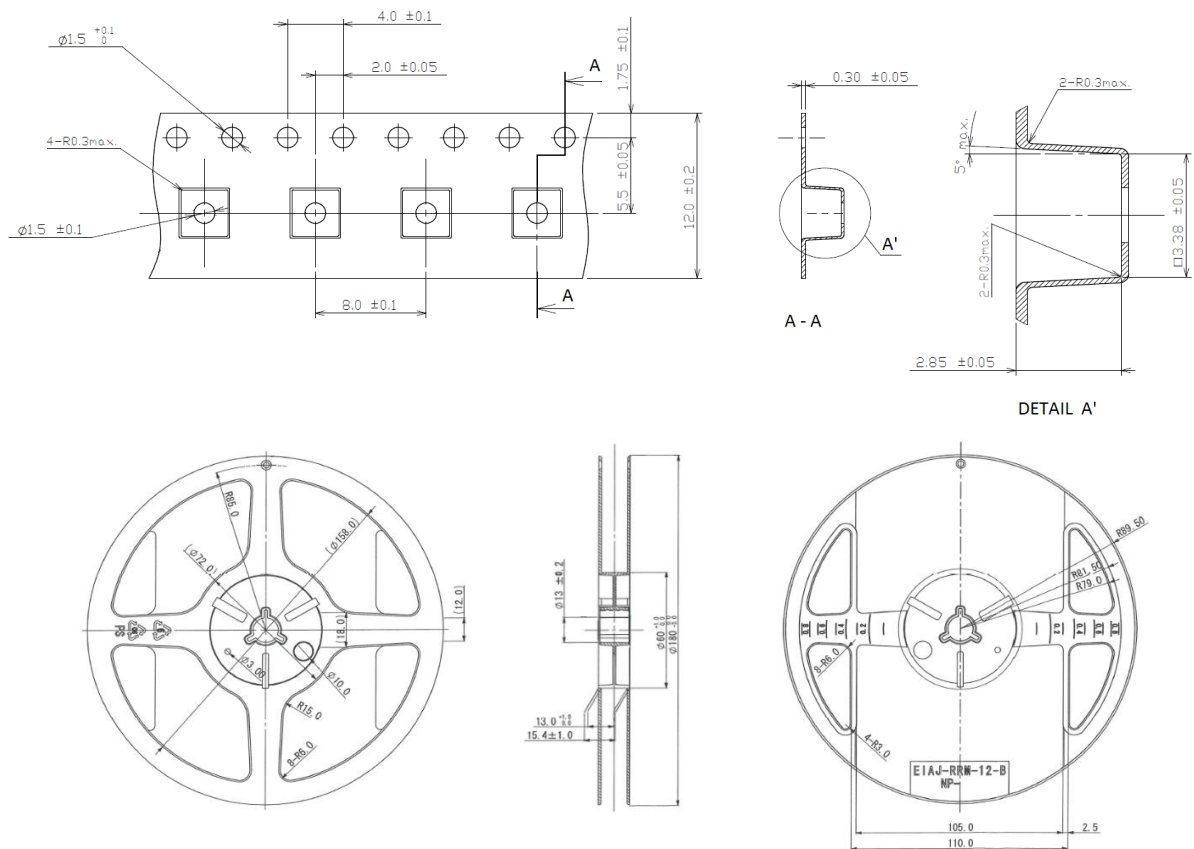


Fig. 17 : Tape and Reel dimension

Quantity per reel : 500pcs

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15. I2C CONNECTION EXAMPLE

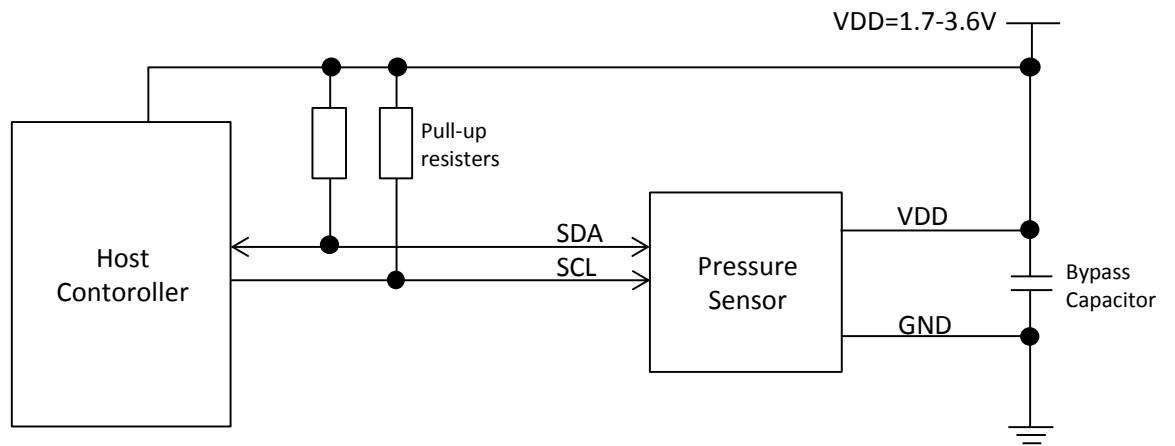


Fig.18 : I2C connection diagram

3.3kohm Pull-up resistor is recommended  
0.1uF Bypass capacitor is recommended

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