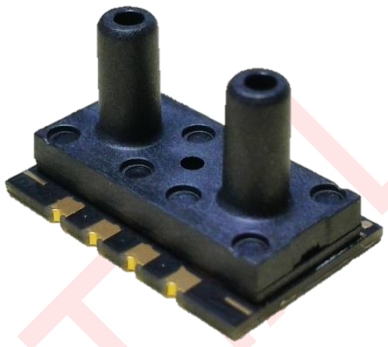
Formosa Measurement Technology Inc. Ltd.

FPS221 series (preliminary)

Digital differential pressure sensor

Features

- Supply voltage:
  1.7 to 5.5V(V_{DD})
  1.2 to 5.5V(V_{DDIO})
- 20、70hPa、100kPa pressure range
- Standby current <0.1μA
- I^2C, SPI serial interface
- 0-5V ratiometric analog output
- Calibrated and temperature compensated



Application Examples

- Air flow measurement
- HVAC
- Industrial control
- Leak detection
- Air filter monitoring

Descriptions

The FPS221 is a new generation of high resolution digital pressure sensor. The FPS221 is a digital pressure sensor which consists of a MEMS piezoresistive pressure sensor and a signal conditioning ASIC. The ASIC include a low noise instrument amplifier, a 24bits sigma-delta ADC, a 12bits DAC, and digital sensor Calibration logics. The FPS221 could provide both I^2C and SPI interface to communicate with microcontroller. And FPS221 also provide 0-5V ratiometric analog output feature.

Pressure calibrated and temperature compensated were key features of the FPS221. The data stored in OTP memory could be used to calibrate the FPS221. The calibration algorithm is performed in DSP core. The output data, either pressure or temperature, read via serial interfaces are all calibrated. The FPS221 is low power and supply voltage designed and suitable for portable devices or battery-supplied ones.

Ordering information

Part No.	Pressure type	Pressure range	Output interface	Note
FPS221-D20H5T	Diff.	0～20 hPa	SPI/ I^2C/ 0-5V	0～0.29 PSI
FPS221-E20H5T	Diff.	-20～20 hPa	SPI/ I^2C/ 0-5V	-0.29～0.29 PSI
FPS221-D70H5T	Diff.	0～70 hPa	SPI/ I^2C/ 0-5V	0～1 PSI
FPS221-D10K5T	Diff.	0～100 kPa	SPI/ I^2C/ 0-5V	0～14.5 PSI

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1 Functional Block and Pin Descriptions

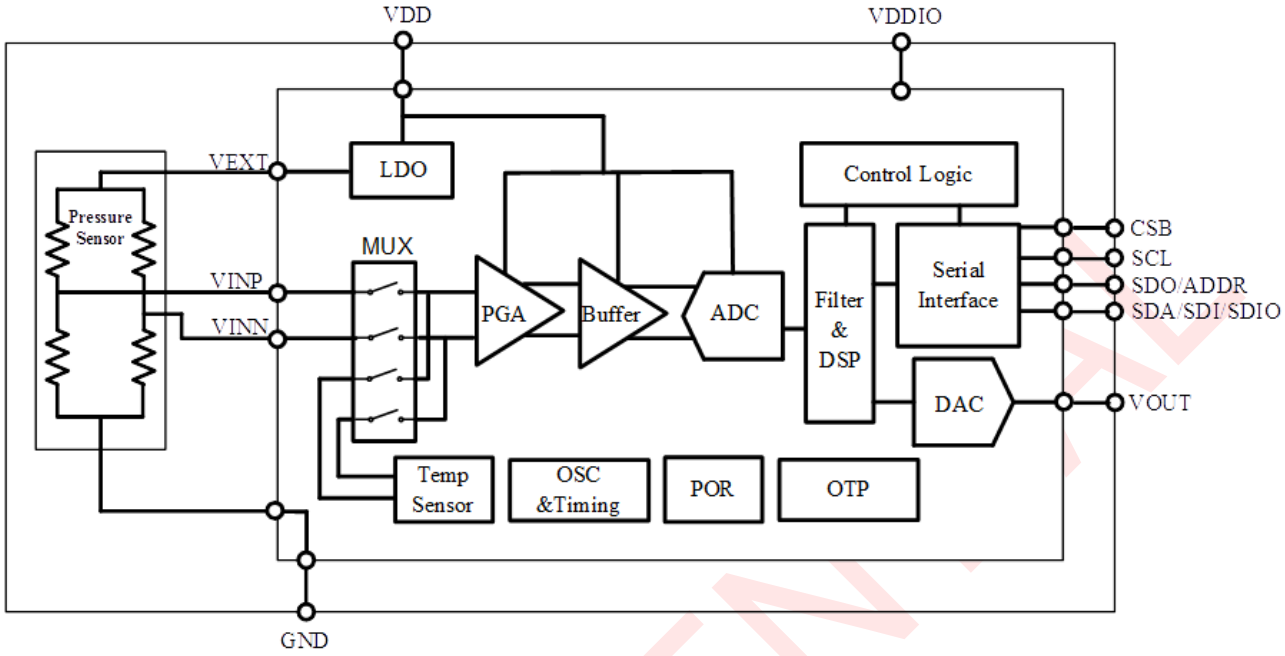
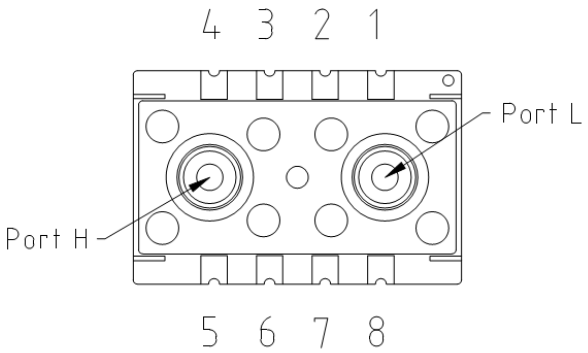


Fig. 1 Functional Block Diagram of FPS221



Pin No.	Pin Name	Description
1	VOUT	Analog output
2	CSB	Chip Select
3	V_{DDIO}	Power supply for I/O circuits
4	V_{DD}	Power supply for core circuits
5	GND	Ground
6	SDO/ADDR	Serial data output in 4-wire SPI mode Address select in I^2C mode
7	SCL	Serial clock
8	SDA/SDI/SDIO	Serial data input/output in I^2C mode(SDA) Serial data input in 4-wire SPI mode(SDI) Serial data input/output in 3-wire SPI mode (SDIO)
Port H/L	Inlets for high/low pressure	Port H is for high pressure input and Port L for low one. Please make sure to keep that the pressure in port H is always higher than Port L.

2 Electrical Characteristic

Parameter	Symbol	Conditions	Min	Typ	Max	Units	Notes
Pressure Range							
FPS221-D20HDT			0		20	hPa	
FPS221-E20HDT			-20		20	hPa	
FPS221-D70HDT			0		70	hPa	
FPS221-D10KDT			0		100	kPa	
Operating Temperature Range			-40		125	ºC	
Supply Voltage	V_{DD}		1.7	3.3	5.5	V	
	V_{DDIO}		1.2		5.5	V	
Supply Current							
Pressure measurement							
Ultra low power	I_{DD}	1 conversion/sec.		3.0	3.5	μA	
Standard				4.7	6.4		
High resolution				7.7	8.9		
Ultra high resolution				13.9	16.0		
Temperature measurement				1.9	2.2		
Peak Current During Conversion							
Pressure measurement	I_{peak}			1.51		mA	
Temperature measurement				0.95			
Standby Current	I_{sd}			<0.1		μA	
Conversion time							
Pressure measurement							
Ultra low power				2.2	2.5	ms	
Standard				3.3	3.7		
High resolution				5.4	6.0		
Ultra high resolution				9.8	10.7		
Temperature measurement				2.2	2.5		
Relative Pressure Accuracy		40～85℃	-6		6	%FS	2
		0～40℃	-2		2		
		-20～0℃	-4		4		
		-40～-20℃	-6		-6		
Absolute Pressure Accuracy		40～85℃	-6		6	%FS	3
		0～40℃	-3		3		
		-20～0℃	-5		5		
		-40～-20℃	-6		-6		
Noise in pressure (20hPa)							
Ultra low power				0.096	0.283	Pa	RMS noise, 5
Standard				0.065	0.2		
High resolution				0.049	0.142		
Ultra high resolution				0.038	0.101		
Noise in pressure (70hPa)							
Ultra low power				0.664	2.92	Pa	RMS noise, 5
Standard				0.482	2.065		
High resolution				0.361	1.46		
Ultra high resolution				0.268	1.033		
Noise in pressure (100kPa)							
Ultra low power				3.109	4.663	Pa	RMS noise, 5
Standard				2.2	3.3		
High resolution				1.557	2.336		
Ultra high resolution				1.104	1.655		
Analog output mode							
Analog output voltage		0%FS		0.5		V	10%VDD
VDD=5V		100%FS		4.5			90%VDD
Resolution				12		bit	4

Resistive load of output buffer	Rload		1k			Ohm	4
Capacitive load of output buffer	Cload				15	nF	4
Absolute temperature accuracy		@25℃ 0～65℃	-1.5 -2	±0.5 ±1	1.5 2	℃	5
Soldering drift		After solder reflow		TBD			
Long term stability		12 months		TBD			

1. All the data were measured with 3.3V supply voltage at a temperature of 25±3℃, unless otherwise noted.
2. Maximum error of pressure reading over the pressure range after offset adjusted at one pressure point.
3. Maximum error of pressure reading over the pressure range.
4. Only for analog output mode.
5. Only for digital output mode.

3 Absolute Maximum Conditions

Parameter	Symbol	Conditions	Min	Typ	Max	Units	Notes
Supply Voltage	AVDD		-0.3		6.5	V	
	VDDIO		-0.3		6.5	V	
Analog pin voltage			-0.3		AVDD+0.3	V	
Digital output voltage			-0.3		VDDIO+0.3	V	
Storage Temperature Range			-40		125	℃	
Maximum Overpressure			>5X			FS pressure	
ESD Rating HBM				2		kV	

4 Application Information

Owing to state of the art, the FPS221 build a new standard of digital differential pressure sensor. A 24bits sigma-delta ADC and a MEMS pressure sensor are integrated in a FR5 substrate. Pressure calibrated and temperature compensated were key features of the FPS221. The FPS221 is low power and supply voltage designed and suitable for portable devices or battery-supplied ones.

The data stored in OTP memory could be used to calibrate the FPS221. The calibration algorithm is performed in DSP core. Via I^2C or SPI interface, you can get the calibrated data of pressure and temperature. And FPS521 can also provide 0-5V ratiometric analog output feature. This is usually used for industrial control application.

Application Circuit example

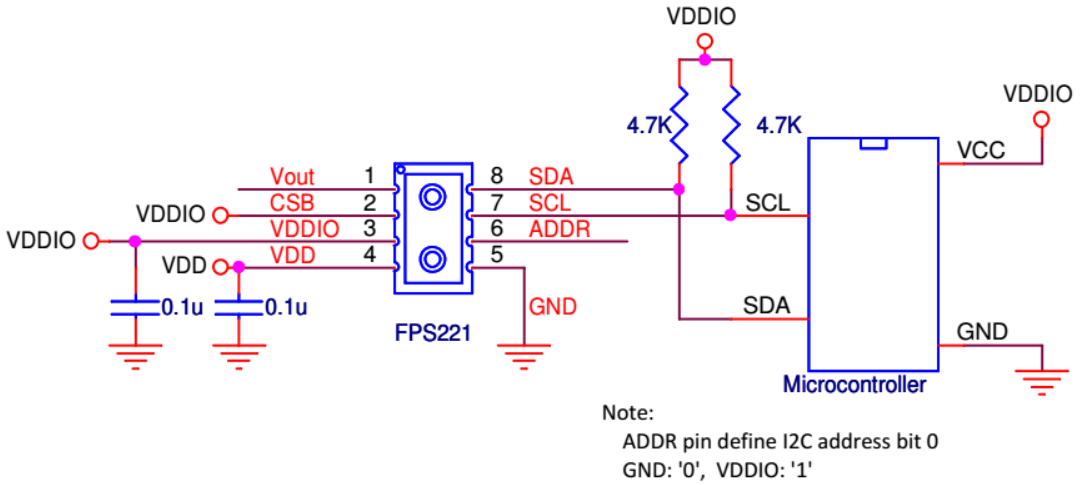


Figure. 4.1 Application circuit for I²C interface

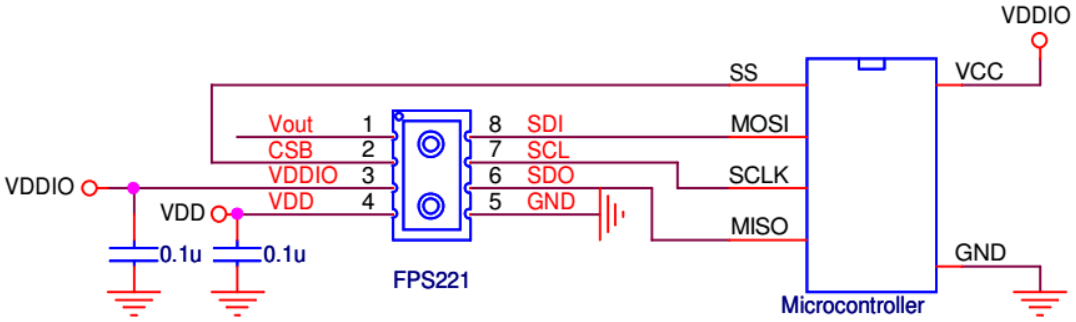


Figure 4.2 Application circuit for SPI interface

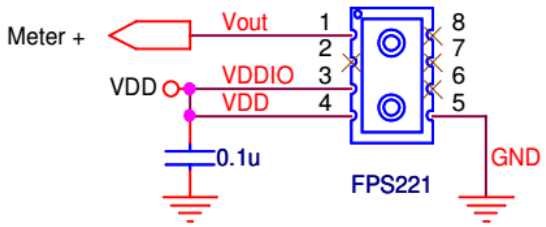


Figure 4.3 Application circuit for analog output

5 Control registers

Table 5.1 control registers

Addr	Description	R/W	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	Default
0xFA	TEMP_LSB	R	Temp_out<7:0>								0x00
0xF9	TEMP_MSB	R	Temp_out<15:8>								0x00
0xF8	DATA_LSB	R	Press_out<7:0>								0x00
0xF7	DATA_CSB	R	Press_out<15:8>								0x00

0xF6	DATA_MSB	R	Press_out<23:16>								0x00
0xF4	CONFIG_1	RW	OSR<1:0>								0xCE
0xF2	DAC_ctrl	RW								DAC_on	0x01
0xE0	Soft_reset	W	Softreset<7:0>								0x00
0x6B	Part ID	R	PartID<7:0>								0x42
0x30	CMD	RW	Sleep_time<3:0>				Sco	Measurement_ctrl<2:0>			0x00
0x00	SPI _Ctrl	RW	SDO_active	LSB_first					LSB_first	SDO_active	0x00

Reg 0xF9-0xFA

Temp_out: Temperature output with an LSB equals to (1/256) °C

Reg 0xF6–0xF8

Press_out: 24 bit pressure output data

Reg 0xF4

OSR<1:0>: 00:1024X, 01:2048X, 10:4096X, 11:8192X

Reg0xF2

DAC_on: 1, enable analog output

Reg 0xE0

Softreset : Write only register. If set to 0xB6, will perform a power on reset sequence. Auto returned to 0 after the soft reset completed.

Reg 0x6B

PartID: 8 bits Part ID, the default value is 0x42.

Reg 0x30

Sleep_time<3:0>: 0000:0ms, 0001:62.5ms, 0010:125ms... 1111: 937.5ms, only active during sleep mode conversion.

Measurement_control<2:0>: 010b: indicate a combined conversion (once temperature conversion immediately followed by once pressure signal conversion). 011b: indicate a sleep mode conversion (periodically perform once combined conversion with an interval time of 'sleep_time')

Sco: 1, Start of conversion, automatically come back to 0 after conversion ends (except sleep mode conversion).

Reg 0x00

SDO_active: 1: 4-wire SPI, 0: 3-wire SPI

LSB_first: 1: LSB first for SPI interface, 0: MSB first for SPI interface

Table 5.2 Summary of instructions

Instruction	Register address	Value
Set pressure conversion in OSR1024	0xF4	0x0E

Set pressure conversion in OSR2048	0xF4	0x4E
Set pressure conversion in OSR4096	0xF4	0x8E
Set pressure conversion in OSR8192	0xF4	0xCE
Single shot combined conversion	0x30	0x0A
(0ms)Sleep mode conversion	0x30	0x0B
(62.5ms)Sleep mode conversion	0x30	0x1B
(125ms)Sleep mode conversion	0x30	0x2B
(937.5ms)Sleep mode conversion	0x30	0xFB
Softreset	0xE0	0xB6
3-wire SPI, MSB first	0x00	0x00
4-wire SPI, MSB first	0x00	0x81

6 SPI Interface

FPS221 provides both SPI and I^2C interface for serial communication and 'CSB' pin is used to switch between these two protocols. Pulling 'CSB' pin low selects the SPI interface, leaving 'CSB' pin float or pulling it high selects the I^2C interface. The SPI interface is compatible with SPI mode 0 (CPOL=0, CPHA=0).

Table 6.1 SPI interface specifications

Symbol	Parameter	Condition	Min	Max	Unit
f_{sclk}	Clock frequency	Max load on SDIO or SDO = 25pF		10	MHz
t_{sclk_l}	SCLK low pulse		20		ns
t_{sclk_h}	SCLK high pulse		20		ns
T_{sdi_setup}	SDI setup time		20		ns
T_{sdi_hold}	SDI hold time		20		ns
T_{sdo_od}	SDO/SDI output delay	Load = 25pF		30	ns
		Load = 250pF		40	ns
T_{csb_setup}	CSB setup time		20		ns
T_{csb_hold}	CSB hold time		40		ns

The figure below shows the definition of the SPI timing given in table 6.1

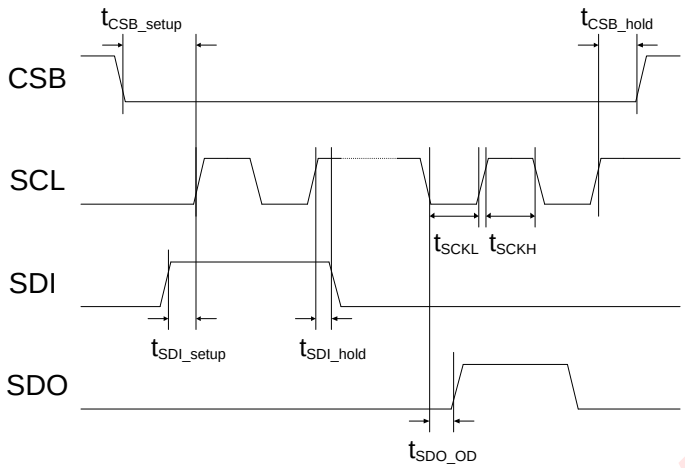


Figure 6.1 SPI timing diagram

The falling edge of CSB, in conjunction with the rising edge of SCLK, determines the start of framing. Once the beginning of the frame has been determined, timing is straightforward. The first phase of the transfer is the instruction phase, which consists of 16 bits followed by data that can be of variable lengths in multiples of 8 bits. If the device is configured with CSB tied low, framing begins with the first rising edge of SCLK.

The instruction phase is the first 16 bits transmitted. As shown in Figure 6.2, the instruction phase is divided into a number of bit fields.

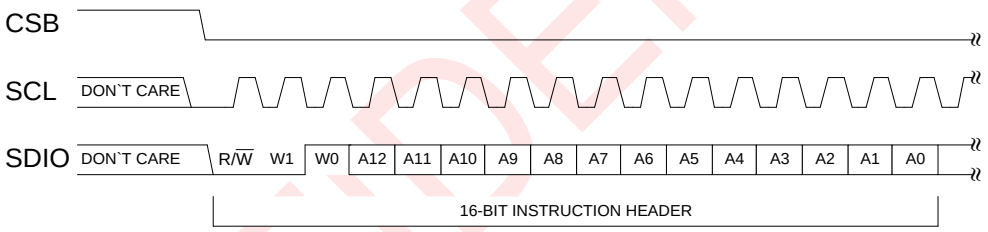


Figure 5.2 Instruction Phase Bit Field

The first bit in the stream is the read/write indicator bit (R/W). When this bit is high, a read is being requested, otherwise indicates it is a write operation.

W1 and W0 represent the number of data bytes to transfer for either read or write (Table 5.2). If the number of bytes to transfer is three or less (00, 01, or 10), CSB can stall high on byte boundaries. Stalling on a nonbyte boundary terminates the communications cycle. If these bits are 11, data can be transferred until CSB transitions high. CSB is not allowed to stall during the streaming process.

The remaining 13 bits represent the starting address of the data sent. If more than one word is being sent, sequential addressing is used, starting with the one specified, and it either increments (LSB first) or decrements (MSB first) based on the mode setting.

Table6.2. W1 and W0 settings

W1:W0	Action	CSB stalling
00	1 byte of data can be transferred.	Optional
01	2 bytes of data can be transferred.	Optional
10	3 bytes of data can be transferred.	Optional
11	4 or more bytes of data can be transferred. CSB must be held low for entire sequence; otherwise, the cycle is terminated.	No

Data follows the instruction phase. The amount of data sent is determined by the word length (Bit W0 and Bit W1). This can be one or more bytes of data. All data is composed of 8-bit words.

Data can be sent in either MSB-first mode or LSB-first mode (by setting 'LSB_first' bit). On power up, MSB-first mode is the default. This can be changed by programming the configuration register. In MSB-first mode, the serial exchange starts with the highest-order bit and ends with the LSB. In LSB-first mode, the order is reversed. (Figure 6.3)

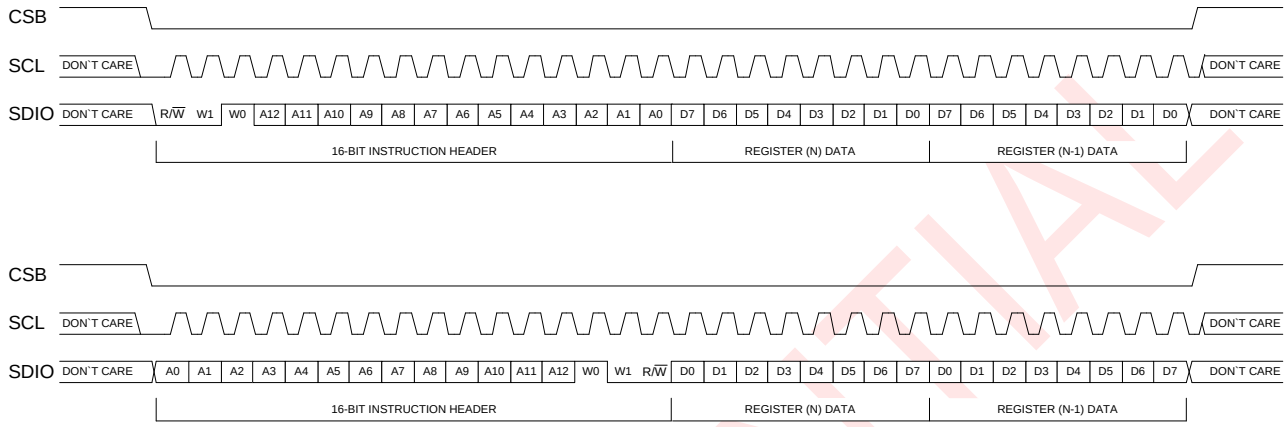


Figure5.3: MSB First and LSB First Instruction and Data Phases

Register bit 'SDO_active' is responsible for activating SDO on devices. If this bit is cleared, then SDO is inactive and read data is routed to the SDIO pin. If this bit is set, read data is placed on the SDO pin. The instruction and data phase is as shown in figure 6.4. The default for this bit is low, making SDO inactive.

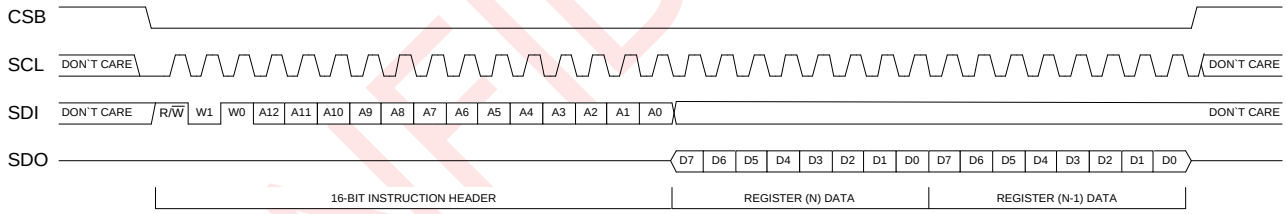


Figure 6.4 MSB First Instruction and Data Phases for 4-wires SPI Mode

7 I²C Interface

I²C bus uses SCL and SDA as signal lines. Both lines are connected to VDDIO externally via pull-up resistors so that they are pulled high when the bus is free. The I²C device address of FPS221 is shown below. The LSB bit of the 7bits device address is configured via SDO/ADDR pin. If the SDO/ADDR pin was left not connected or pulled high, the A1 bit is "1". And the device address is "1101101". For I²C bus application,' CSB' pin have to be left float or pulled high.

Table 7.1 I²C Address.

A7	A6	A5	A4	A3	A2	A1	W/R
1	1	0	1	1	0	SDO/ADDR	0/1

Table 7.2 Electrical specification of the I²C interface pins

Symbol	Parameter	Condition	Min	Max	Unit
f_{scl}	Clock frequency			400	kHz
t_{LOW}	SCL low pulse		1.3		us
t_{HIGH}	SCL high pulse		0.6		us
t_{SUDAT}	SDA setup time		0.1		us
t_{HDDAT}	SDA hold time		0.0		us
t_{SUSTA}	Setup Time for a repeated start condition		0.6		us
t_{HDSTA}	Hold time for a start condition		0.6		us
t_{SUSTO}	Setup Time for a stop condition		0.6		us
t_{BUF}	Time before a new transmission can start		1.3		us

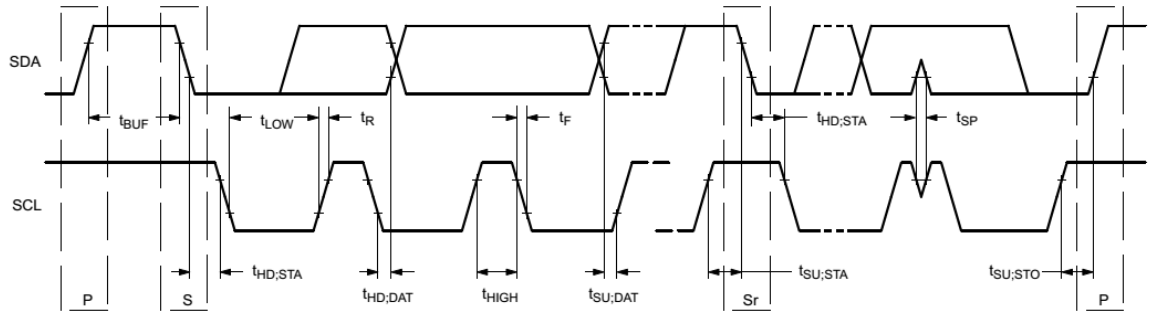


Figure 7.1 I²C Timing Diagram

The I²C interface protocol has special bus signal conditions. Start (S), stop (P) and binary data conditions are shown below. At start condition, SCL is high and SDA has a falling edge. Then the slave address is sent. After the 7 address bits, the direction control bit R/W selects the read or write operation. When a slave device recognizes that it is being addressed, it should acknowledge by pulling SDA low in the ninth SCL (ACK) cycle.

At stop condition, SCL is also high, but SDA has a rising edge. Data must be held stable at SDA when SCL is high. Data can change value at SDA only when SCL is low.

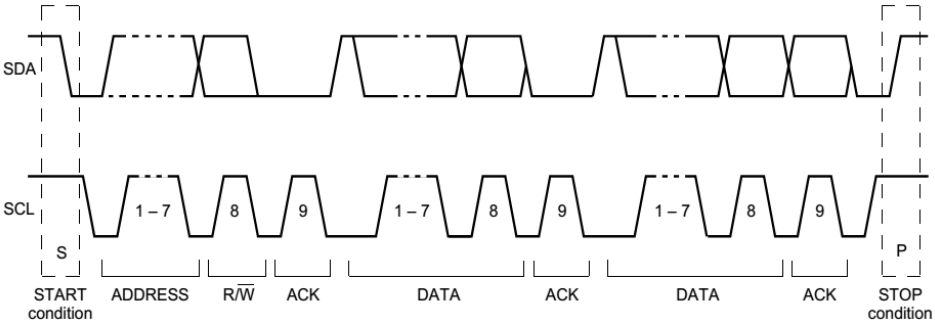


Figure 7.2 I²C Protocol

8 Digital output

In digital output mode, FPS521 could convert input pressure to digital value. The digital value could be accessed through either I²C or SPI interface. The calibrated pressure value could be accessed through register 0xF6, 0xF7 and 0xF8. The calibrated temperature value could be accessed through register 0xF9 and 0xFA. So there is a simple transfer function between input pressure and digital value. The transfer function is as following:

The temperature and pressure output are singed integer value stored in 2`s complement. The features of output data, like range, width and LSB, are listed in the following table.

Table 8.1 The features of output data

Item	Description	Min.	Typ.	Max.	Width(bit)	LSB
temp_out	Temperature output	-128		127	16	1/256
press_out	Normalized pressure output	-1		1	24	$1/2^{23}$

$$\text{Temperature}(℃) = \text{temp\_out} \times \left(\frac{1}{256}\right)$$

$$\text{P} = \left(\frac{\text{press\_out} \times \left(\frac{1}{2^{23}}\right) - 0.1}{0.8}\right) \times \text{FS}$$

P: the real pressure value measured by pressure sensor

FS: full scale of pressure range

For example: part no. FPS221-D20H5T, its full scale of pressure range is 2 kPa.

9 Analog output

In analog output mode, FPS221 could convert input pressure to voltage output. The output voltage is ratiometric to supply voltage. So there is a simple transfer function between input pressure and output voltage. The transfer function is as following:

P= ((Vout-0.5)/4)*FS

P: the real pressure value measured by pressure sensor

Vout: voltage output of pressure sensor

FS: full scale of pressure range

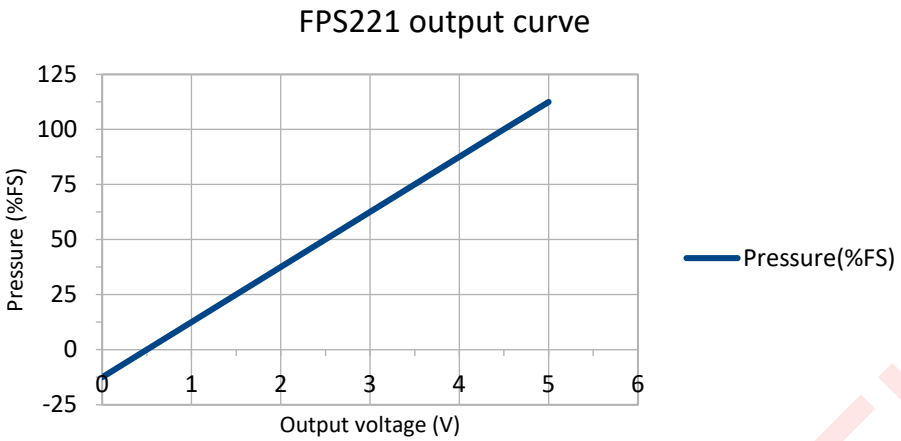
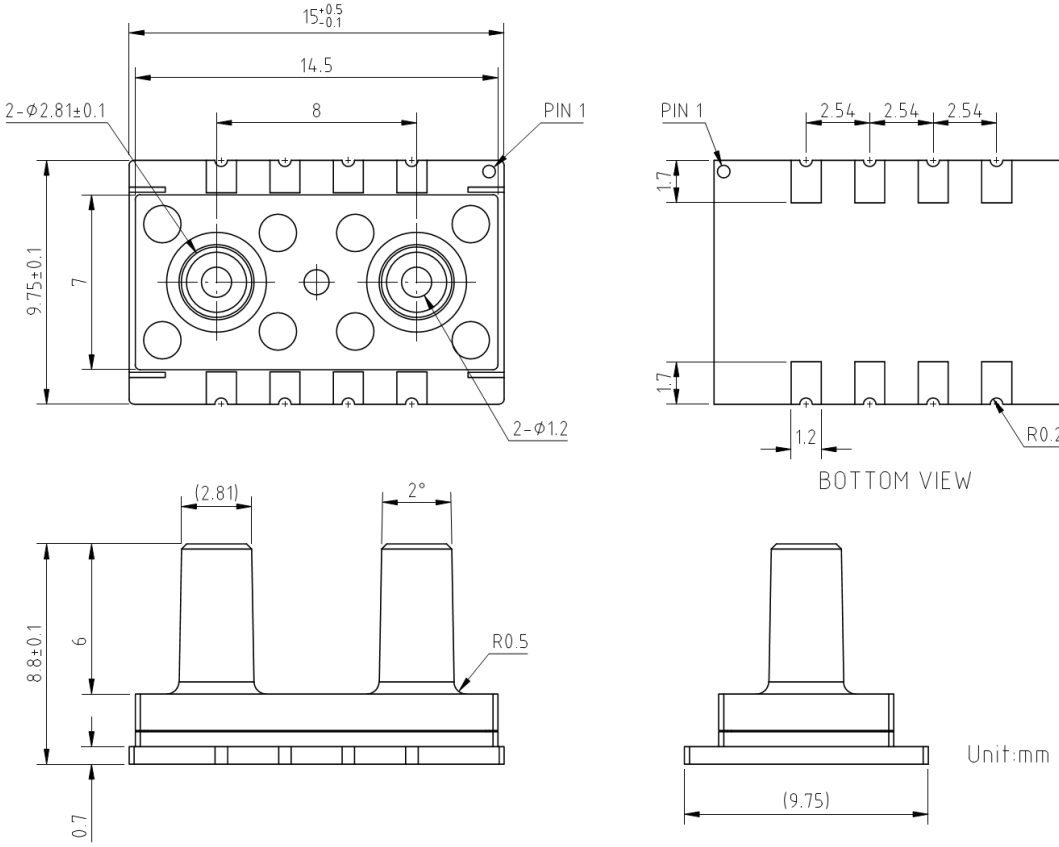


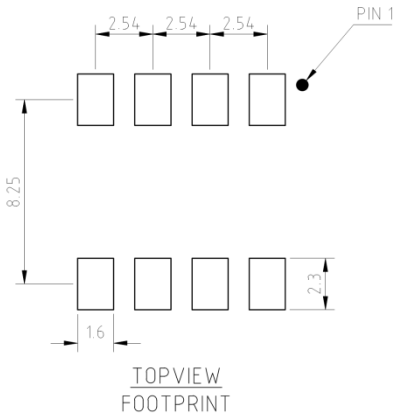
Figure 9.1 FPS221 output curve

10 Package Information

10.1 Outline dimensions



10.2 Recommended footprint



11 Document history and modification

Rev.	Description	Date
0.1	First edition (Preliminary)	2017/3/16
0.2	Modified: 5.Control register. Page 6,7,8 8.Analog output --> 9.Analog output, page12,13 Added: 8. Digital output, page12	2017/5/9
0.3	Modified: Maximum Overpressure, page 5	2020/2/20
0.4	Modified: For example: part no. FPS221-D20H5T, its full scale of pressure range is 2 kPa., page 12	2020/3/6
0.5	Added: A new part no. FPS221-E20H5T was added., page 1, 4	2020/3/18