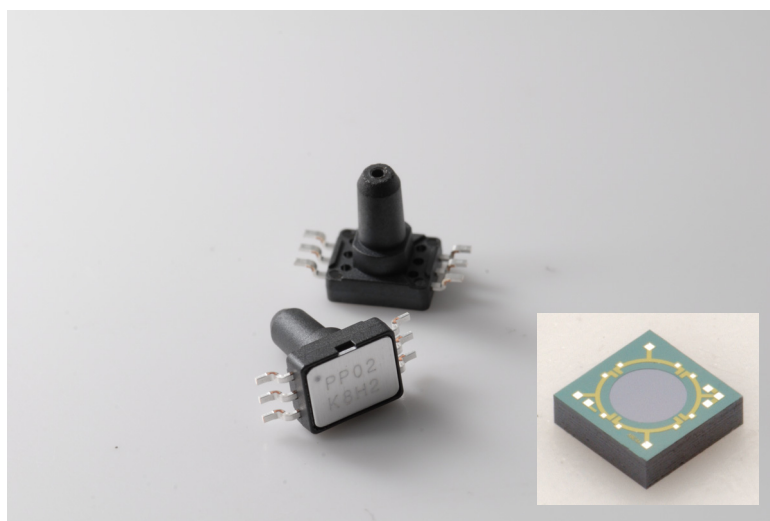


## *Application Note 01*

### **Usage of Pressure Sensor 2SMPP-02**



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INDEX

1	OUTLINE .....	3
2	STRUCTURE OF PRESSURE SENSOR .....	3
3	DIMENSIONS .....	4
4	PRINCIPAL OF PRESSURE DETECTION.....	5
5	SPECIFICATIONS OF 2SMPP-02.....	7
6	FEATURES OF PRODUCT .....	7
7	USAGE .....	8
7.1	CONNECTION METHOD .....	8
7.2	EXAMPLE OF RECOMMENDED CIRCUIT .....	10
7.3	OUTPUT CHARACTERISTICS 1: BASIC OUTPUT CHARACTERISTICS OF 2SMPP-02 ELEMENTARY SUBSTANCE .....	11
7.4	OUTPUT CHARACTERISTICS 2: BASIC OUTPUT CHARACTERISTICS BY USING RECOMMENDED CIRCUIT .....	11
8	GLOSSARY .....	12
9	WARRANTY AND LIMITED LIABILITY .....	13
10	CONTACT .....	15
11	HISTORY .....	15

## 1 Outline

This document shows an overview of plus an example of a circuit and the recommended connection method to use with the Omron Gauge type pressure sensor (2SMPP-02).

## 2 Structure of Pressure Sensor

Fig. 1 shows the structure of 2SMPP-02. Each unit is [mm].

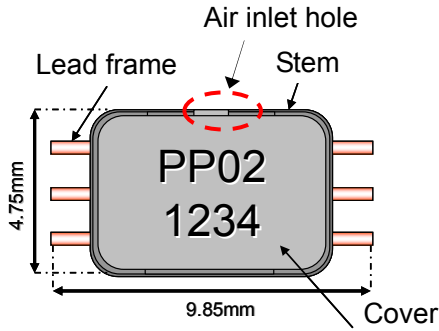


Fig. a TOP View

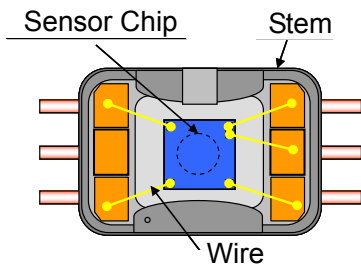


Fig. b Inside TOP View

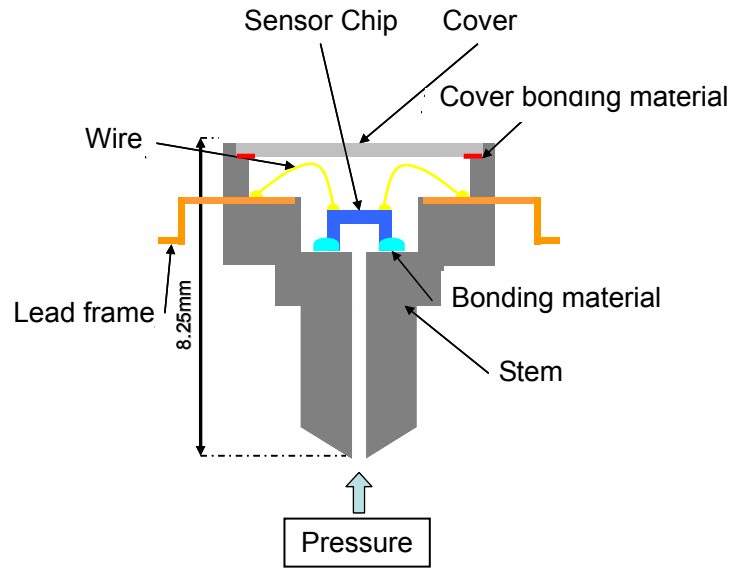
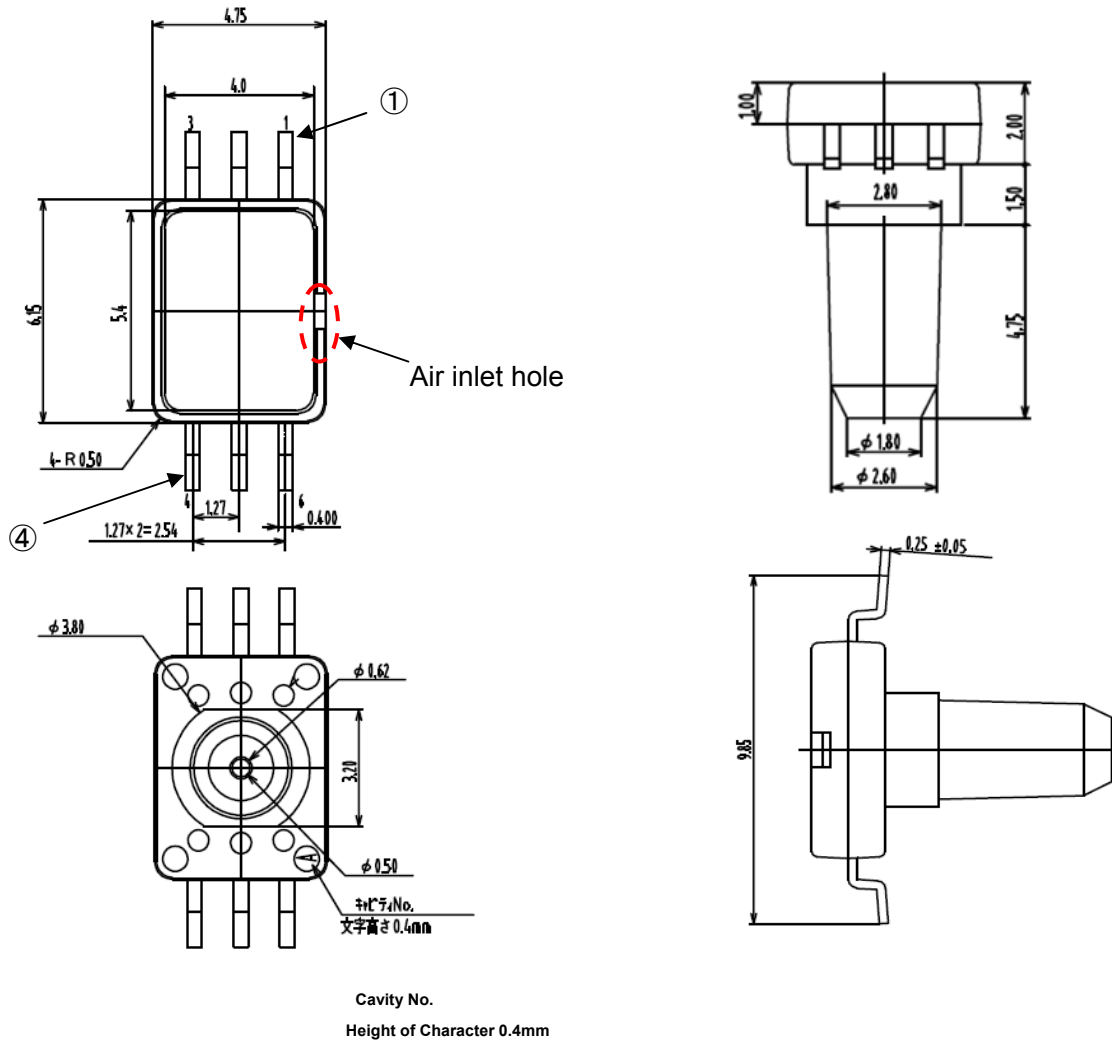


Fig. c CROSS Section

Fig. 1 The structure and parts name of 2SMPP-02

### 3 Dimensions

Fig. 2 shows the outline dimension of 2SMPP-02. Each unit is [mm].



The recommended tube inside diameter is 2 mm.

Fig. 2 Outline dimension of 2SMPP-02

**4 Principal of Pressure detection**

Omron's 2SMPP series pressure sensors utilize a piezo-resistive type sensing element.

Fig. 3 shows image of overview of Piezo-resistive pressure sensor chip. The diaphragm (blue circle of a Fig. a) is a thin disc, formed on a silicon wafer and deformed by pressure difference between upper and lower. Piezoresistors (green part of Fig. b & Fig. c) are arranged on four points of this thin diaphragm.

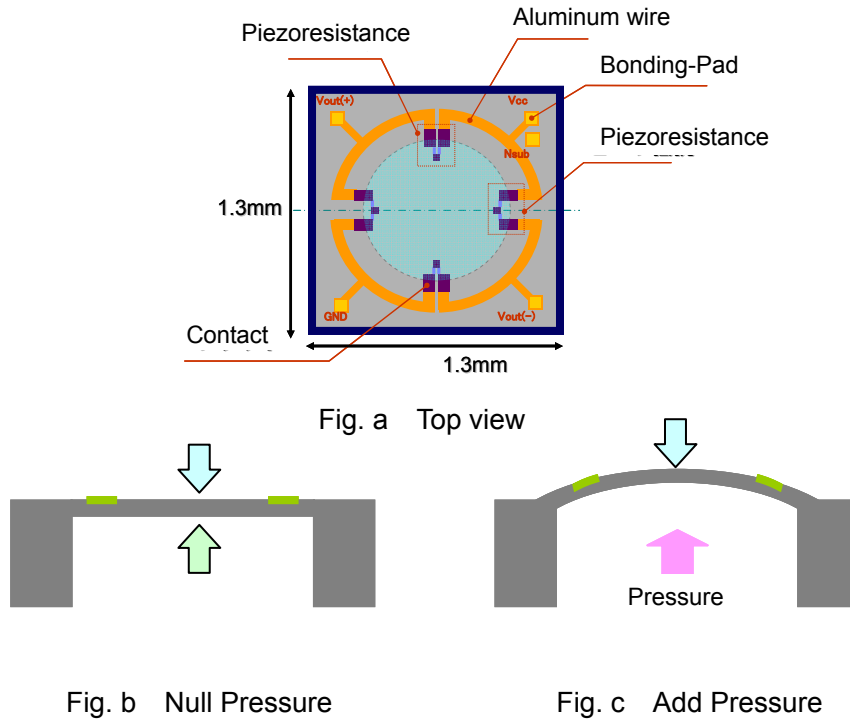


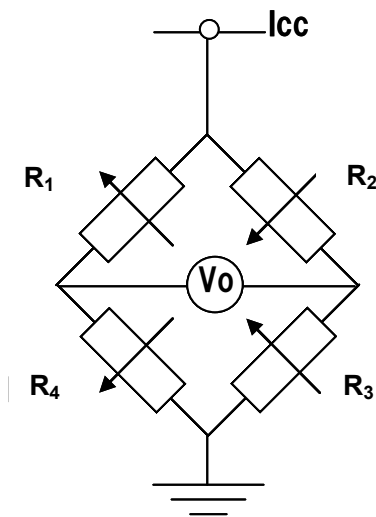
Fig. 3 Piezoresistive pressure sensor image and state of change diaphragm

Atmospheric pressure (Light blue arrow) pushes down on the diaphragm, and the pressure to be measured (Pink arrow in Fig. c) pushes up from the bottom of the diaphragm. In Fig. b, the target pressure (green arrow) is equal to atmospheric pressure, so it is a condition that does not bend the diaphragm. In Fig. c, the target pressure (Pink arrow) is bigger than atmospheric pressure (Light blue arrow), so the diaphragm is pushed up. Under this condition, the deflection of the diaphragm changes the piezoresistance's value on the upper surface of diaphragm.

Fig. 4 shows how to convert from piezoresistance value change to output voltage change. If the pressure applied to the upper and lower diaphragms are balanced, the bridge output voltage  $V_0$  is represented by formula 1.1. In theory  $V_0$  is zero if  $R_1=R_2=R_3=R_4$ , as the voltage is generated by a slight variation in manufacturing, and is defined as  $V_{offset}$ .

Upon deflection of the diaphragm, pressure equilibrium is broken and each of the resistances of the piezoresistive are changed from  $R$  to  $R \pm \Delta R$ . Piezoresistive change in the resistance value which is arranged diagonally as shown by the arrows in the figure has the same tendency (increase or decrease). In case of the condition  $R=R_1=R_2=R_3=R_4$  formula 1.1 applies, however when the piezoresistive value has changed from  $R$  to  $R \pm \Delta R$  formula 1.2 applies. This voltage is called the span voltage, by supplying a constant current  $I$ , the amount of change can be detected as a voltage  $V_0$  resistance value change amount ( $\Delta R$ ).

Since there are manufacturing variations in the piezoresistive  $R_1/R_2/R_3/R_4$  as described above, the approximate expression of the span voltage is found in formula 1.3.



Bridge output voltage ( $V_0$ )

$$V_0 = \left( \frac{R_1 \cdot R_3 - R_2 \cdot R_4}{R_1 + R_2 + R_3 + R_4} \right) \cdot I \quad \dots \text{Eq 1.1}$$

Span Voltage ( $V_0$ )

$$V_0 = \left( \frac{(R + \Delta R) \cdot (R + \Delta R) - (R - \Delta R) \cdot (R - \Delta R)}{(R + \Delta R) + (R - \Delta R) + (R + \Delta R) + (R - \Delta R)} \right) \cdot I$$

$$= \Delta R \cdot I \quad \dots \text{Eq 1.2}$$

Span Voltage ( $V_0$ )

$$V_0 = \Delta R \cdot I + V_{offset} \quad \dots \text{Eq 1.3}$$

Fig. 4 Theoretical formula and the electrical equivalent circuit of Piezo-resistive pressure sensor

## 5 Specifications of 2SMPP-02

Table 1 shows the main specifications of 2SMPP-02.

Table 1 Specifications of 2SMPP-02

Item	Description				
Pressure Type	Gauge Pressure (Note 1) (Note 3)				
Applicable gases	Air (Note 2)				
Driven method	Constant Current Supply				
Item	Min	Typ	Max	Unit	Note
Pressure Range	0	-	37	kPa	
Withstand Pressure	0	-	53	kPa	
Supply Current	-	100	-	uADC	
Max Supply Current	-	-	130	uADC	
Ambient Operating Temp	0	-	50	°C	
Ambient Storage Temp	-30	-	85	°C	
Ambient Operating Humidity	15	-	90	%RH	
Ambient Storage Humidity	10	-	95	%RH	
Electrical Characteristic (Temperature: 23[°C], Drive current: 100[uA] Constant current)					
Item	Min	Typ	Max	Unit	Note
Bridge Resistance	18	20	22	kΩ	
Offset Voltage (Note 3)	-6.5	-2.5	1.5	mV	
Span Voltage (Note 3)	27.9	31.0	34.1	mV	at 37[kPa] pressure
Non-Linearity (Note 3)	-0.8	-	0.8	%FS (Note 3)	0~37[kPa]
Hysteresis (Note 3)	-0.5	-	0.5	%FS (Note 3)	0~37[kPa]
Temp influence of Span	-0.5	0.5	1.5	%FS (Note 3)	0[°C]
	-0.7	0.3	1.3		50[°C]
Temp influence of Offset	-3.0	-	3.0	%FS (Note 3)	0~25[°C]/0~50[°C]

(Note 1) : Standard product is not calibrated for negative pressures.

(Note 2) : Please use dry gases, and avoid dust or corrosive gases.

(Note 3) : For the meaning of the unit, characteristics, refer to Chapter 8.

## 6 Features of Product

As discussed in the section on the principle of pressure sensing, piezoresistive type sensors to minimize the variation in piezoresistive leads to minimization of measurement error. By using CMOS technology which is applied to the production of highly integrated semiconductor, our gauge pressure sensor is able to achieve a good offset voltage, span voltage and temperature variation characteristics.

## 7 Usage

### 7.1 Connection method

As shown in Fig. 5, when a constant current of 100uA is provided to the Piezoresistor between terminals 6 and 3. the output voltage, depending on the pressure change, will be output between terminal 1 and 4. Short-circuit terminals 5 and 6 in use and solder terminal 2 to the board, but leave open connection. Refer to the 100uA constant current circuit (Chapter 8.2) before use.

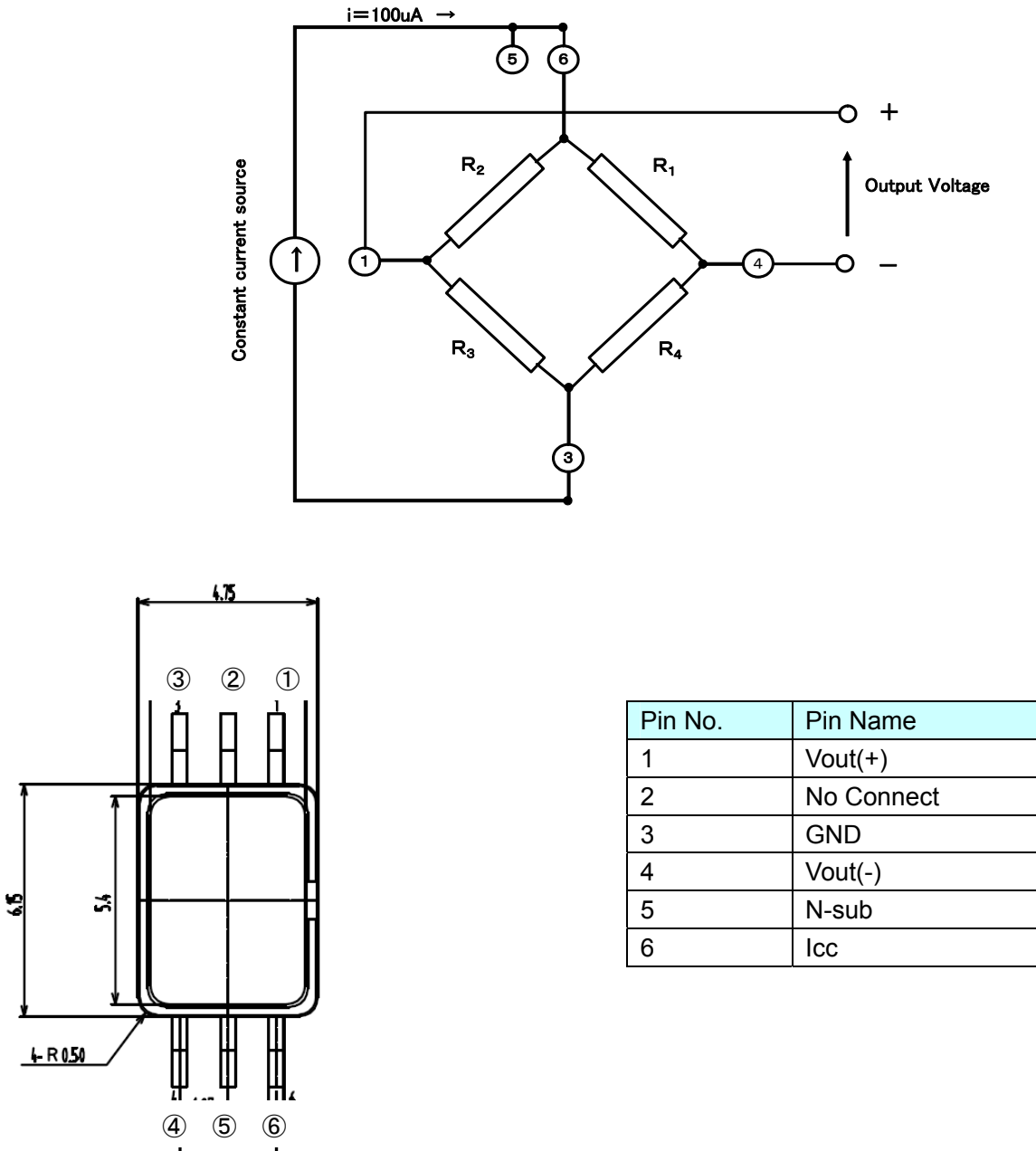


Fig.5 Equivalent Circuit and Connection Diagram of 2SMPP-02

Be sure to check that there is no leak path between each terminal by solder paste before actual use. The desired characteristic may not be achieved if there is the influence of a leak path.



Fig. 6 shows the recommended mounting pad layout of 2SMPP-02. In order to penetrate the pressure port through the mounting board, through-hole of  $\Phi 4.0$  mm needs to be made on a mounting board.

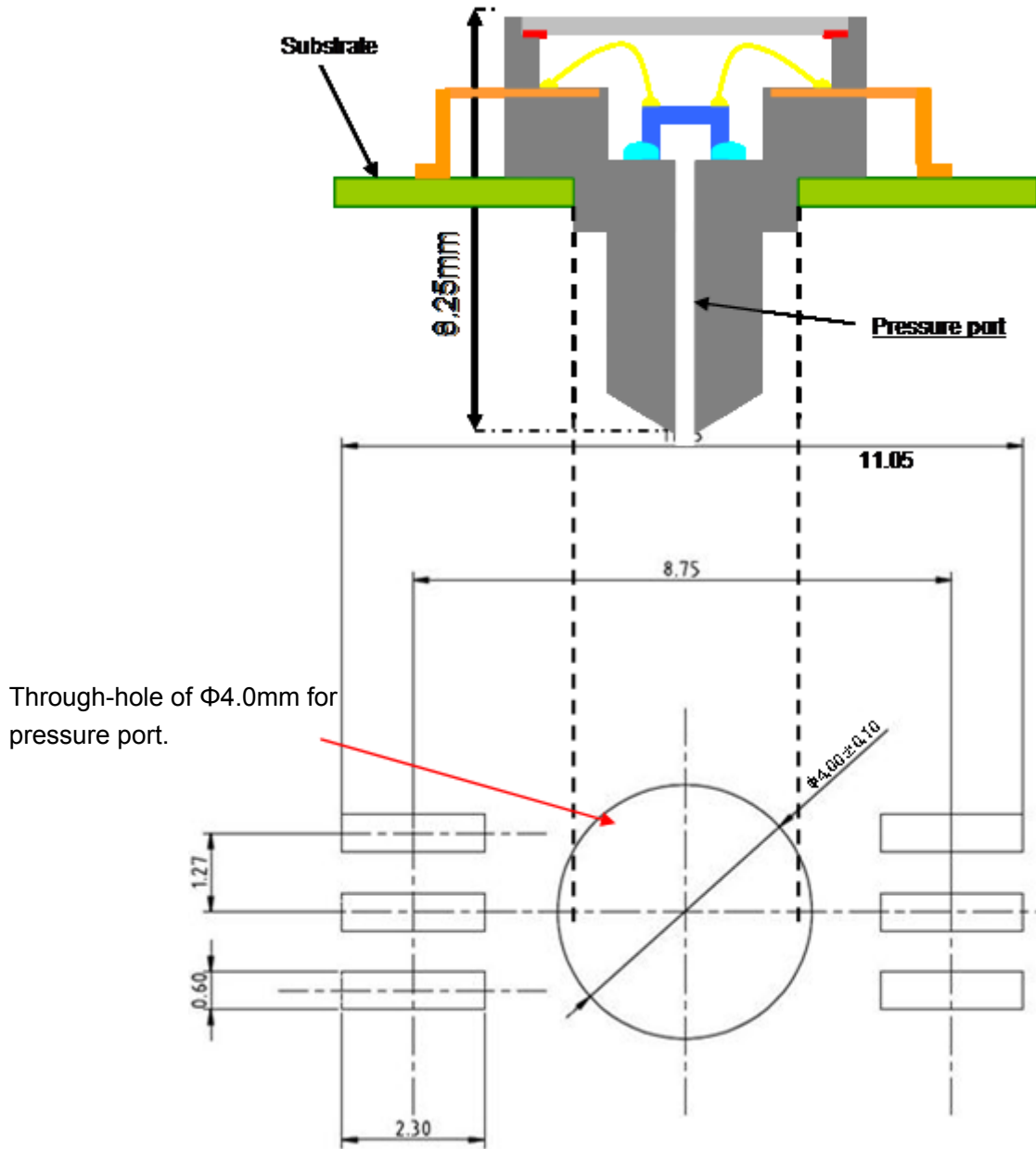


Fig. 6 Recommended Mounting PAD Layout of 2SMPP-02

## 7.2 Example of recommended circuit

An example of a recommended circuit is shown in Fig. 7. A constant current circuit and an instrumentation amplifier are used with an example of Gain=21. Herein, a power supply voltage is 5 [V].

- Calculation of constant current ( R1=40[kΩ] , R2=10[kΩ] )

$$I_{cc} = \frac{V_{DD} \cdot \left(\frac{R2}{R1 + R2}\right)}{R3} \Rightarrow I_{cc} = \frac{5[V] \cdot \left(\frac{10[k\Omega]}{40[k\Omega] + 10[k\Omega]}\right)}{10[k\Omega]} = 100[\mu A]$$

- Calculation of Gain ( R4~R5 , R7~R10=10[kΩ] , R6=1[kΩ] )

$$Gain = 1 + \left(\frac{2 \cdot R5}{R6}\right) \cdot \left(\frac{R9}{R4}\right) \Rightarrow Gain = 1 + \left(\frac{2 \cdot 10[k\Omega]}{1[k\Omega]}\right) \cdot \left(\frac{10[k\Omega]}{10[k\Omega]}\right) = 21[ratio]$$

Herein, R4=R8, R5=R7, R9=R10

Then, final output voltage of Vout is defined as Vout = Gain · Vs. ( Vs is sensor output voltage )

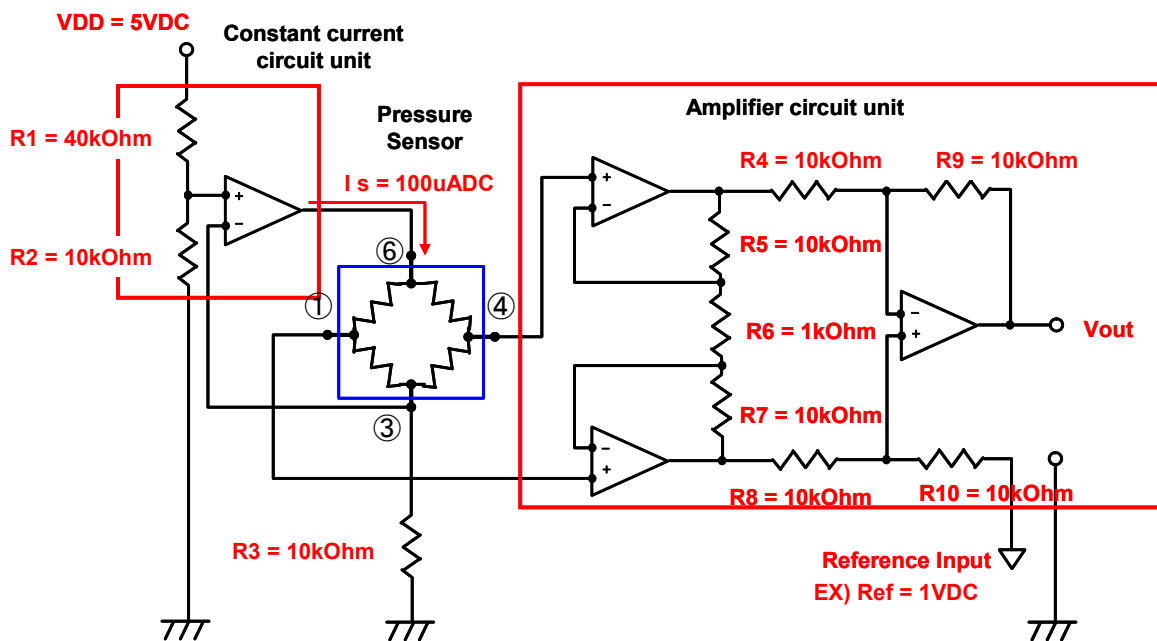


Fig. 7 Example of Recommended Circuit Diagram for 2SMPP-02

In such recommended circuit diagram, instrumentation amplifier such as Texas Instruments LMV324 with four operational amplifiers can be used for gain adjustment. A metal film resistor with good temperature characteristics should be used for R3. In addition, it is necessary to adjust the Ref voltage value connected to R10 according to the gain to be used. For example, if Gain = 21 then Ref = 1.0 [V], if Gain=201 then Ref = 1.5 [V] would be needed.

7.3 Output Characteristics 1: Basic output characteristics of 2SMPP-02 elementary substance  
 Fig.8 shows the output characteristics at room temperature (25deg-C) when applying the pressure from -10 [kPa] to 50 [kPa] at the condition of the constant current 100 uA. Note that the guaranteed measurement range of 2SMPP-02 is 0 [kPa] to 37 [kPa] that is shown by a break line in red. Span voltage at 0 [kPa] to 37 [kPa] is typically 31 [mV].

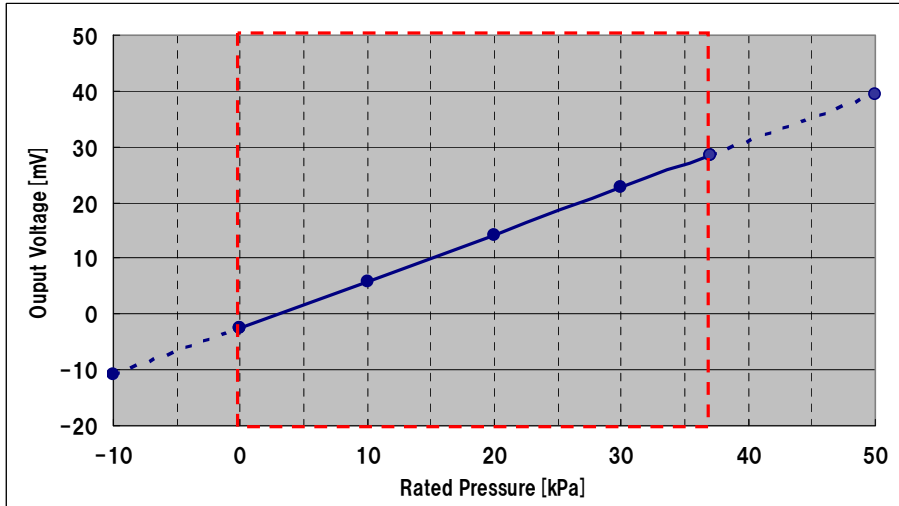


Fig. 8 Output Characteristic of 2SMPP-02 (raw output voltage between Terminal 1 and 4)

7.4 Output Characteristics 2: Basic output characteristics by using recommended circuit  
 When using the circuit configuration at the condition of Gain =21 as described in Fig. 7, the output characteristics for low pressure range between 0 [kPa] and 7 [kPa] is shown in Fig.9. In this case, Ref voltage is connected to 1.0 [V]. This is a result of monitoring the output Vout shown in Fig. 7.

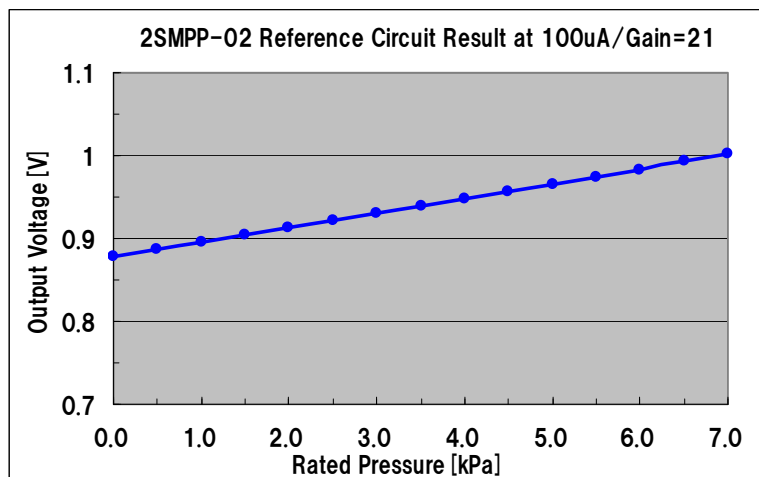


Fig.9 Output characteristic of 2SMPP-02 after Gain=21 times

In this result, it has only 0.3% of an error, even if it compares with the ideal Span voltage. The ideal Span voltage is 123mV [=7kPa / 37kPa x 31mV x 21] and actual Span voltage is 122.6mV at the condition of 0kPa to 7kPa. This means our recommended circuit can be used for even low pressure range.

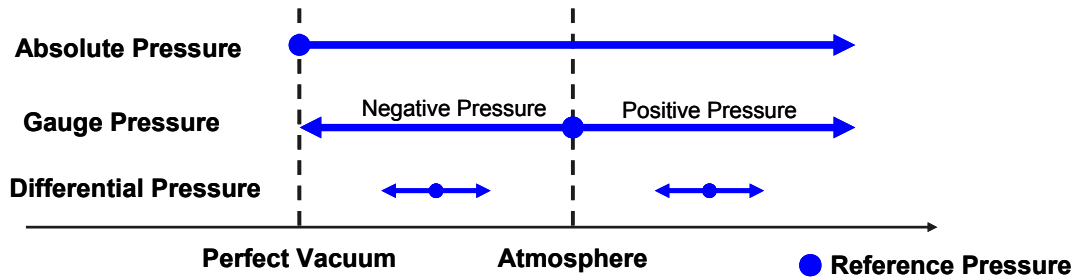
## 8 Glossary

- **Various pressure and pressure reference name**

A gauge pressure is a pressure relative to the atmospheric pressure.

A gauge pressure which is greater than atmospheric pressure, is called positive pressure.

And a gauge pressure which is smaller than atmospheric pressure, is called negative pressure.



- **Offset Voltage**

The output voltage at Null pressure. ( 0[kPa] ).

- **Span Voltage**

It is calculated by subtracting the output voltage at Null pressure ( 0 [kPa] ) from the output voltage at Maximum rating pressure ( 37 [kPa] ).

- **Non-Linearity**

The amount of gap from an ideal output straight line and the output voltage at any pressure within the specified range which makes the deviation maximum. An ideal output line is drawn by connecting the points of output voltage at Null pressure ( 0 [kPa] ) and at Maximum rating pressure ( 37 [kPa] ). %FS notation that is normalized on the Span voltage at the time of 25 deg-C can be used.

- **Hysteresis**

The maximum output voltage deviation at any pressure within the specified range when a pressure is repeatedly applied from Null pressure ( 0 [kPa] ) to Maximum rating pressure ( 37 [kPa] ). %FS notation that is normalized on the Span voltage at the time of 25 deg-C can be used.

- **%FS**

"Percent Full Scale". Target item and amount of change are normalized on the Span voltage at the time of 25 deg-C. The percentage notation can be used.

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## 11 History

Revision	DATE	Note
Rev 1.0	Oct01,2013	New Released