Technical Explanation for Pressure Sensors

CSM_Pressure_TG_E_2_2

Introduction

What Is a Pressure Sensor?

A pressure sensor is a device equipped with a pressure-sensitive element that measures the pressure of a gas or a liquid against a diagram made of stainless steel, silicon, etc., and converts the measured value into an electrical signal as an output.
(The E8☐ Pressure Sensors use a silicon diaphragm.)

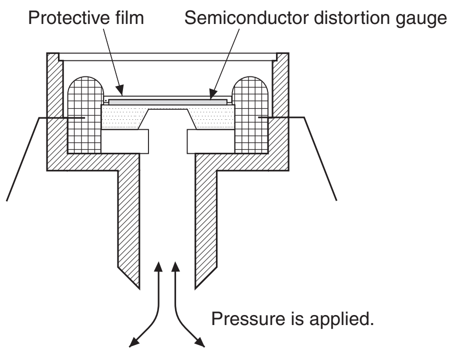
Features

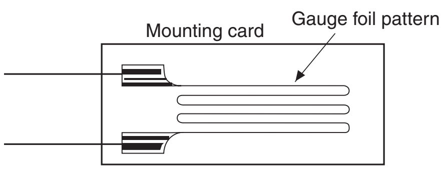
1. Different sensors are used for different measurement targets, such as liquids, gases, flammable substances, and corrosive substances.
   (The E8☐ Sensors are used to measure the pressure of non-flammable and non-corrosive gases.)
2. There are sensors that measure the absolute pressure and those that measure the pressure relative to atmospheric pressure or a specified pressure. For sensors that use atmospheric pressure as a reference, there are sensors that measure negative pressures and positive pressures. (The E8Y is a differential pressure sensor. The E8F2 is a gauge pressure sensor that uses atmospheric pressure as the reference.)

Operating Principles

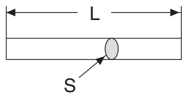
- A semiconductor piezo-resistance dispersion pressure sensor has a semiconductor distortion gauge formed on the surface of the diaphragm, and it converts changes in electrical resistance into an electrical signal by means of the piezo-resistance effect that occurs when the diaphragm is distorted due to an external force (pressure).
  Typical model: E8F2
- A static capacitance pressure sensor has a capacitor that is formed by a static glass electrode and an opposing movable silicon electrode, and it converts changes in static capacitance that occur when the movable electrode is distorted due to an external force (pressure) into an electrical signal.
  Typical model: E8Y

Semiconductor Distortion Gauge Construction



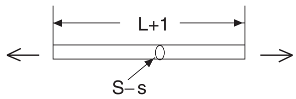


Piezo-resistance Effect



The electrical resistance of the above conductor is expressed by the following formula:
$R = \rho \times L/S$.
(ρ: Electrical resistivity
L: Conductor length
S: Conductor cross-sectional area)

When this conductor is pulled to the right or left as shown below, the length increases and the cross-sectional area decreases.



The electrical resistance of the above conductor is expressed by the following formula:
$R' = \rho \times (L+1)/(S-s)$.

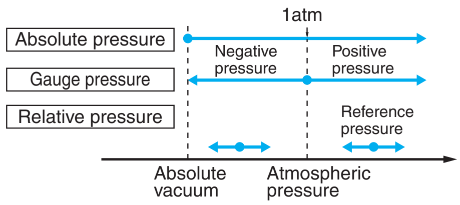
Accordingly,
$R' > R$.
This shows how the application of a mechanical force changes the electrical resistance.

Explanation of Terms

Gauge Pressure
The amount of pressure is expressed in terms of atmospheric pressure. It is referred to as "positive pressure" when it is greater than one atmosphere, and "negative pressure" when it is less than one atmosphere.

Absolute Pressure
This is the amount of pressure expressed in relation to an absolute vacuum.

Pressure Difference (Relative Pressure)
This is the amount of pressure compared to any particular pressure (the reference pressure).



Atmospheric pressure
The pressure of the atmosphere. The standard atmospheric pressure (1 atm) is equal to the pressure of a column of mercury with a height of 760 mm.

Vacuum
A pressure less than one atmosphere.

Pressure Detection Range
The range of pressure that can be detected by the Sensor.

Withstand Pressure
The pressure that must be withstood without degraded performance
after returning to the pressure detection range.

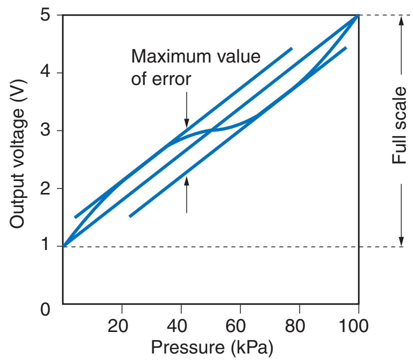
Repeat Accuracy (ON/OFF Output)
Repeat accuracy refers to the deviation in the operating point when the output inverts while pressure is increased or decreased at a temperature of 23°C, divided by the full scale of the pressure detection range.

Repeat accuracy

$$= \frac{\text{Maximum operating point - Minimum operating point}}{\text{Rated output}} \times 100\% \text{ F.S.}$$

Accuracy (linear)
This is the deviation from the rated output current (4 mA, 20 mA) when zero pressure and the rated output are applied at a temperature of 23°C, divided by the full-scale value.
It is expressed in units of %F.S.

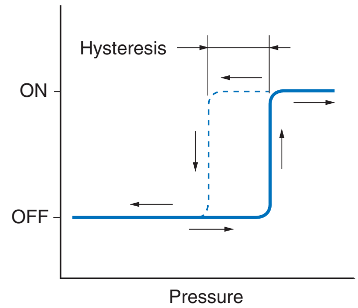
Linearity
The analog output changes in an approximately linear fashion with respect to the detected pressure. The change, however, deviates slightly from an ideal straight line. This deviation is expressed as a percentage of the full scale.



Linear Hysteresis
An ideal straight line is drawn between the output current (or voltage) at zero pressure and the rated current (or voltage), and the difference between the measured current (or voltage) and the ideal current (voltage) is obtained as an error. The error as the pressure rises and the error as the pressure falls are obtained, and the maximum value of the absolute value of the difference between the rising error and falling error is divided by the full scale current (or voltage). This is the linear hysteresis, and it is expressed in units of %FS.

Hysteresis (ON/OFF Output)
The difference between the output ON pressure and OFF pressure is divided by the full pressure scale.

$$\text{Hysteresis} = \frac{\text{ON pressure} - \text{OFF pressure}}{\text{Rated output}} \times 100\%\text{FS}$$



Non-corrosive Gas
Substances contained in the air (nitrogen, carbon dioxide, etc.) and inert gases (argon, neon, etc.).

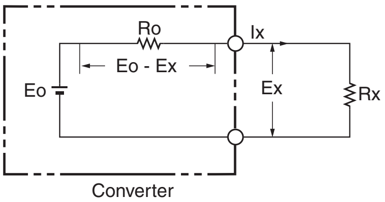
Pressure Unit Conversion Table

	kgf/cm^2	mmHg	mmH_2O	Pa
$1kgf/cm^2$	1	735.559	1.000028×10^4	0.0980665M
1mmHg	1.3595×10^{-3}	1	1.3595×10	0.133322k
$1mmH_2O$	0.99997×10^{-4}	7.356×10^{-2}	1	0.00980665k
$1Pa(N/m^2)$	1.0197×10^{-5}	7.5006×10^{-3}	0.10197	1

Output Impedance

1. Measuring the Output Impedance of Voltage Output Models

Figure 1



Ro: Output impedance [Ω]
Rx: Load resistance [Ω]
Eo: Output voltage (terminals open) [V]
Ex: Output voltage (with load Rx connected) [V]
Ix: Load current (with load Rx connected) [A]

In Figure 1, the current (Ix) that flows when the load resistance (Rx) is connected is calculated as follows:

$$Ix = \frac{Ex}{Rx} = \frac{Eo - Ex}{R0} \quad ......(1)$$

The output impedance (Ro) in Equation (1) is calculated as follows:

$$Ro = Rx\left(\frac{Eo - Ex}{Ex}\right) ......(2)$$

The voltage (Eo) is measured when the output is open, followed by the voltage (Ex) when a load resistance (for example, the minimum value of the permitted load resistance of a transducer) is connected. The measured values Eo and Ex and the connected load resistance (Rx) are inserted into Equation (2) to calculate the output impedance (Ro) of the transducer.

2. Measuring the Output Impedance of Current Output Models

In Figure 2, the voltage (Ex) of the output terminals when the load resistance (Rx) is connected is calculated as follows:

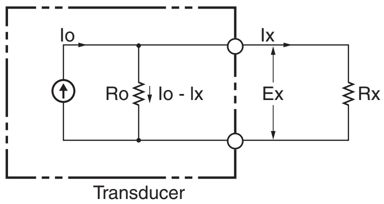
$$Ex = IxRx = (Io - Ix)\ Ro \quad ......(3)$$

The output impedance in Equation (3) is calculated as follows:

$$Ro = Rx\left(\frac{Ix}{Io - Ix}\right) ......(4)$$

Here, the current (Io) is measured with the output short-circuited.

Figure 2



Ro: Output impedance [Ω]
Rx: Load resistance [Ω]
Io: Output current (output terminal short-circuited) [A]
Ix: Output current (with load Rx connected) [A]
Ex: Output voltage (with load Rx connected) [V]

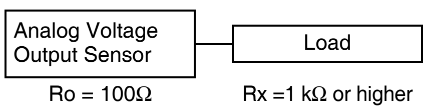
Next, the output current (Ix) is measured when a load resistance (for example, the maximum value of the permitted load resistance of a transducer) is connected. The measured values Io and Ix and the value of the connected load resistance (Rx) are inserted into Equation (4), and the output impedance (Ro) of the transducer is calculated. The output impedance of the transducer introduced here is the value for normal operation.

3. Desirable Output Impedance

In general, it is best to make the output impedance of a voltage output transducer as small as possible, i.e., as close to 0 W as possible, to minimize the effects of load fluctuations on the transducer.
For a current output transducer, the opposite is true: the higher the impedance (the closer to infinite impedance), the better.

4. Example of Calculation Using Impedance

$$\text{Error in analog voltage output} = \left(1 - \frac{Rx}{Ro + Rx}\right) \times 100\%$$



Rx	Error
1kΩ	Approximately 10%
10Ω	Approximately 1%