Deney 4 Basınç Sensörleri

Chapter 14

PRESSURE SENSOR

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14.1 OBJECTIVES

1. Understanding the construction of a pneumatic pressure sensor.
2. Study the operating principle of a pressure transducer.
3. Study the applications of a pressure transducer.

14.2 DISCUSSION OF FUNDAMENTALS

According to operating principles and constructions, pressure sensors (or transducers) can be classified into the following categories:

1. Resistive pressure transducers
   a. Diffused semiconductor pressure transducer
   b. Integrated semiconductor pressure transducer
   c. Metal-wire strain-gage pressure transducer

2. Capacitive pressure transducers
   a. Variable-gap pressure transducer
   b. Variable-area pressure transducer
   c. Variable dielectric coefficient pressure transducer

3. Inductive pressure transducers
   a. Variable-gap pressure transducer
   b. Variable-core pressure transducer
   c. Magnetostrictive pressure transducer

4. Self-generating pressure transducers
   Piezoelectric pressure transducer

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The most commonly used device for pressure measurements is the resistive strain sensor. It consists of a semiconductor or conductor with a small cross- section which is mounted to the measured surface so that it undergoes small elongations or constrictions due to tension or compression stresses applied to that surface, respectively. In Figure 14-1, when a mechanical stress is applied to the silicon crystal, the resistively of this crystal will be changed. As a result, the strain sensor undergoes a corresponding change in resistance due to stress. This effect is called the piezoresistive effect.

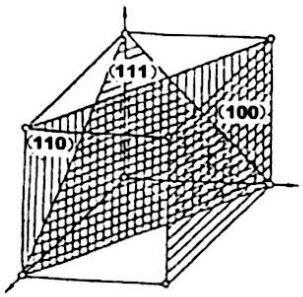


Figure 14-1 Piezoresistive-effect principle

The resistance change of a strain gage is given by:

$$R + \triangle R = (\rho + \Delta\rho)(L/A)$$

where R = original resistance, (Ω)

$\triangle R$ = change of resistance, (Ω)

ρ = original resistivity, (mΩ)

$\triangle\rho$ = change of resistivity, (mΩ)

L = length of strain gage, (mm)

A = cross-section area of strain gage, (mm^2)

The sensitivity of a strain gage is called the gage factor, the ratio of the unit change in resistance to the unit change in length.

$$K = \frac{\Delta R/R}{\varepsilon} = \frac{\Delta R/R}{\Delta L/L}$$

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where K = sensitivity (gage factor)

ε = $\triangle$L/L, strain

The resistance change of a strain gage is usually converted into a voltage change by connecting two or four matched gages as arms of a Wheatstone bridge. The relationship between output voltage and strain can be expressed by

$$Eout=(n/4)(K\varepsilon)(Ein)$$

or

$$Eout=(n/4)(K\varepsilon)(IinZ)$$

where n = constant determined by sensing elements and strain of bridge

Ein = constant voltage to bridge

Iin = constant current to bridge

Z = input impedance of bridge

The construction of integrated and diffused semiconductor strain gages is shown in Figures 14-2 and 14-3, respectively.

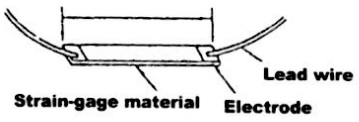


Figure 14-2 Integrated semiconductor strain gage

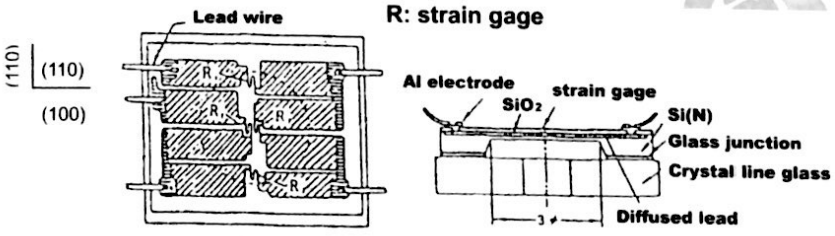


Figure 14-3 Diffused semiconductor strain gage

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The sensitivities of semiconductor strain gages are between 50 and 200 and are typically around 125, whereas the sensitivities of metal strain gages are no greater than 5 and are typically around 2. Because of their feature to provide relatively large output voltages in response to small strains (see Figure 14-4), however, semiconductor strain gages have found quite a few applications, especially in force and pressure transducers. In these applications, they offer the very significant advantage of requiring much lower sensing-element (e.g., diaphragm) deflections than metal strain gages. This permits the use of stiffer and more stable sensing elements, and stiffer sensing elements also provide a far higher frequency response. Figure 14-5 shows the examples of pressure transducer applications.

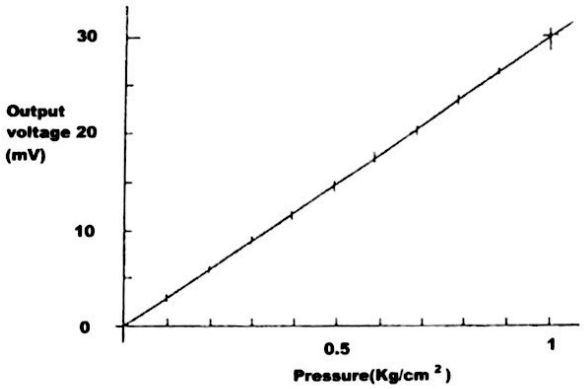


Figure 14-4 Output characteristic of integrated semiconductor pressure transducer

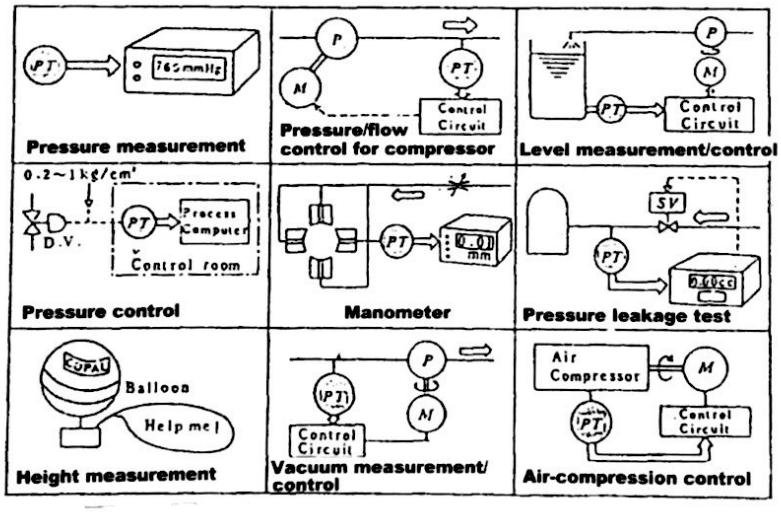


Figure 14-5 Examples of pressure transducer applications

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As mentioned above, a semiconductor manometer or pneumatic pressure sensor is based on the piezoresistive effect. The sensor undergoes a corresponding change in resistance due to pneumatic pressure. When a constant-current source is applied to the bridge, as shown in Figure 14-6, the change in resistance will be converted into the change in voltage. The output characteristic is shown in Figure 14-7. In order to eliminate thermal effects, temperature compensation is provide by temperature-sensitive resistive elements, as illustrated in Figure 14-8.

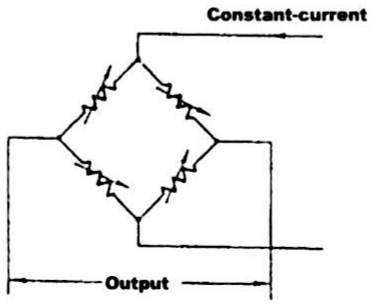


Figure 14-6 Equivalent circuit of pneumatic pressure sensor

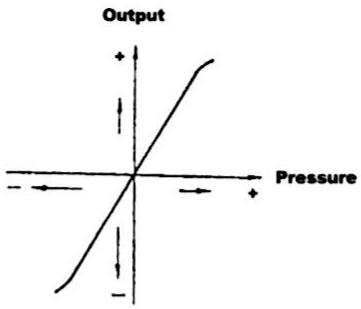


Figure 14-7 Output characteristic of pneumatic pressure sensor

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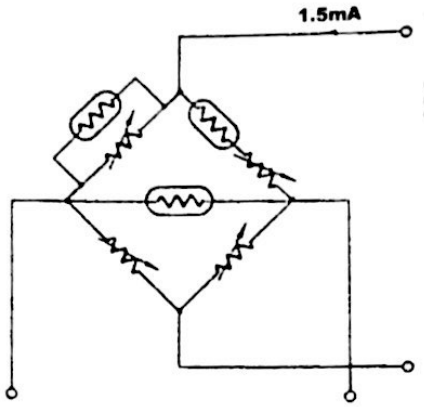


Figure 14-8 Typical temperature compensation

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14.3 DESCRIPTION OF EXPERIMENTAL CIRCUITS

Pressure is a multidirectional uniform type of stress, a force applying on a unit area; it is measured as force per unit area exerted at a given point.

Vacuum -- is the complete absence of any matter in a volume or a region of space.

Absolute pressure -- is measured relative to zero pressure (a perfect vacuum). The most commonly used unit is the psia (pound force per square inch for absolute).

Differential pressure -- is the pressure difference between two points of measurement, measured relative to a reference pressure or a range of reference pressures. The most commonly used unit is the psid (pound force per square inch for differential).

1 kpa (kilopascal) = 0.145 psi

Figure 14-9 shows an integrally diffused semiconductor strain-gage transducer, type SPX 50D. The unit consists of the basic four-arm-bridge sensor encapsulated in a glass-filled nylon package. The sectional view and physical construction are shown in Figure 14-10. The SPX 50D has a very fast response speed. In differential pressure applications, the terminal P1 is a port for high pressure input and P2 is for low pressure input. In pressure measurements, the measured pressure must be applied to the port P1.

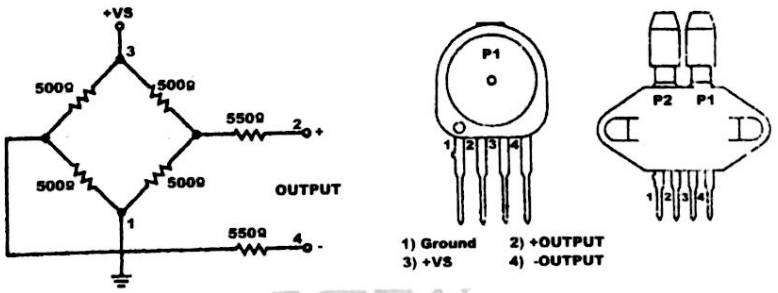
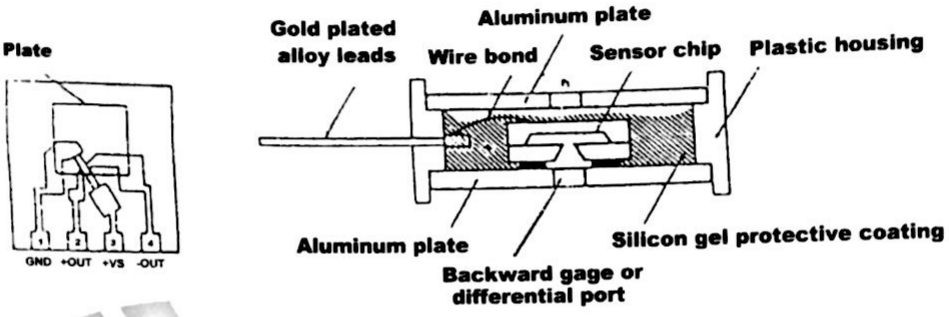


Figure 14-9 Equivalent circuit and packages of SPX 50D

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(a) (b)

Figure 14-10 (a) sectional view; (b) physical construction

In practice, a suitable device of temperature compensation is need for the SPX transducer. We will introduce some commonly used types:

1. Diode compensation

Figure 14-11 shows a diode compensating circuit. When the power voltage Vs=5V or 6V, low-cost diodes (e.g., 1N914, 1N4148, etc.) can be used for this purpose.

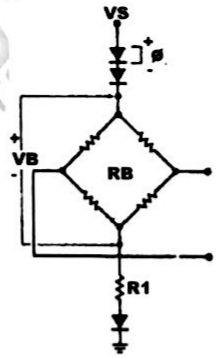


Figure 14-11 Diode compensating circuit

2. Transistor compensation

Figure 14-12 shows a transistor compensating circuit. When Vs=5V, the resistors should be R1=402Ω and R2=150Ω. Another combination is Vs=6V, R1=429Ω, and R2=133Ω. Each combination can provide a excellent compensation in temperature range from 0 to 100℃.

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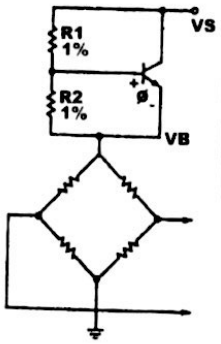


Figure 14-12 Transistor compensating circuit

3. Constant-current compensation

Figure 14-13 shows a constant-current compensating circuit. The constant-current source IC LM334 has a good temperature coefficient of 3300 ppm / ℃.

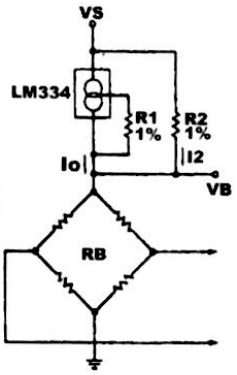


Figure 14-13 Constant-current compensating circuit

The circuit of Figure 14-14 is a suggested amplifier for the SPX transducers. The operational amplifiers should be precision and wide-temperature range amplifiers, such as LT1014, LT1002, OP07, etc. The voltage gain Av is calculated by

$$Av = (R4 / R3) [1 + 1 / 2 (R2 / R1+R3 / R4) + (R2+R3) / R5]$$

If R1=R2 and R3=R4, then

$$Av = 2 + (R2+R3) / R5$$

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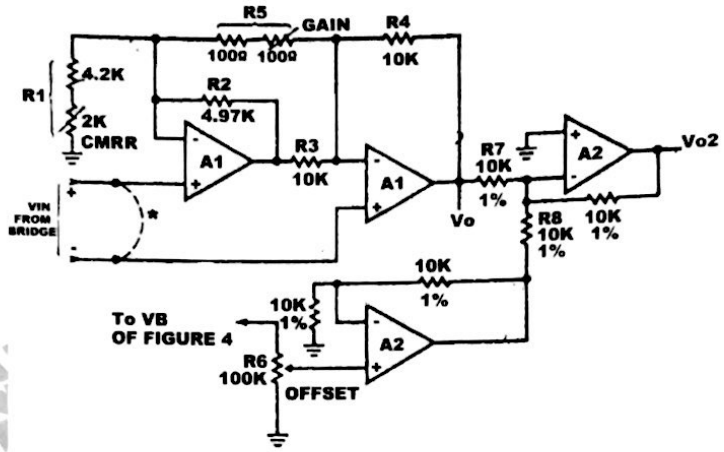


Figure 14-14 Amplifier

The circuit of Figure 14-15 is pressure sensor signal conditioner circuit.

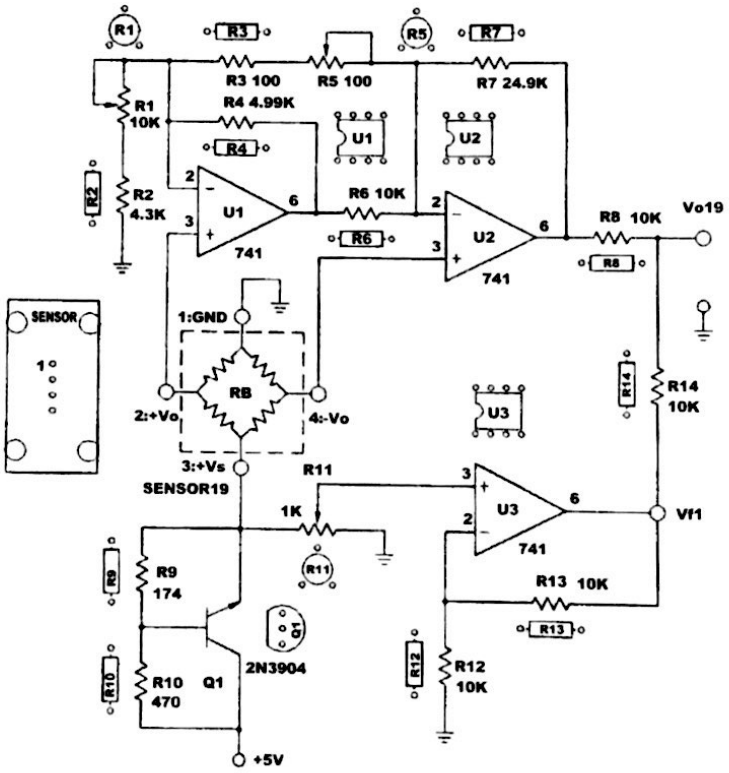


Figure 14-15 Pressure sensor module

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14.4 EQUIPMENT REQUIRED

1 - DMM
2 - Module KL-64007
3 - KL-61001A Trainer

14.5 EXPERIMENTS AND RECORDS

14.5.1 Zero-pressure calibration

1. Set the Pressure Sensor Module KL-64007 (see Figure 14-15) on the Trainer KL-61001A and supply the power.
2. Connect 2:+Vo to 4: -Vo.
3. Adjust the R1(CMRR Adj.) to obtain the voltage at U2pin6 for Vu2pin6=0.0V.
4. Adjust the R11(OFFSET Adj.) to obtain the voltage at Vo19 for Vo19=0.0V.

14.5.2 Computer control

1. Complete the following connections:

SECTION	AREA	SIGNAL	TO SECTION	AREA	SIGNAL
SINGLE CHIP	OUT CONTROL	1	→ AMPLIFIER	ALARM AMPLIFIER	SIN IN
KL-64007	PRESSURE SENSOR	Vo19	→ A/D CONVERTER	CONTROL	A/D IN
KL-64007	PRESSURE SENSOR	GND	→ A/D CONVERTE R	CONTROL	GND

2. Set the Pressure Sensor Module KL-64007 on the Trainer KL-61001A. Supply the power.
3. Repeat Step in experiment 14.5.1.
4. Supply the powers of the KL-61001A.
5. Set the THUMBWHELL SW. at "1000".
6. Increase pressure of P1 till the alarm buzzer turned on. Observe the value from the STATUS DISPLAY.

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7. The value of display should be over "1221" when the alarm buzzer turned on. The procedures that we display the pressure value by the pressure sensor circuit. Send out the alarm signal to buzzer if the pressure overload. (1221=Preset Value X 5000/4095)
8. Refer to Table 14-1. Turn the value of thumbwheel switch in order and then complete the table by repeat step 6. Discuss it if you can not complete the table.

Table 14-1

THUMBWHEEL SW.	0819	1638	2457	3276	4095
KL-61001A readout					
KL-64007 Vo19 voltage					

9. For observe data from PC, connect the SINGLE CHIP, OUT CONTROL, CTRL to the GND. Refer Chapter 2-7 for more connection details.
10. Set the THUMBWHELL SW. at "1000". Execute KL-600 Series to start the program.
11. Set "500" into Delay(ms), "3600" into Acqu num. It's able to record 30 minutes.
12. Set Higher of Level at "1.22" from the control panel of KL-600 Series. Click Acquire button. The program is start to record data from KL-61001A.When the Pressure of P1 overload, the alarm buzzer turned on. The display of KL-600 Series will change the background color to red at the same time.
13. Press Power button of KL-600 Series to exit.

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