

Design an Optical Transducer for Pressure Measurement

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Abstract - This paper presents the optical transducer for pressure measurement . Where, there are many and different types of instruments to measure pressure, such as mechanical measuring instruments and electrical measuring instruments. Each one of them depend on a different working principle. This type of measuring instruments are highly used since this type is used in airplanes and other places, because it is easy to assemble and disassemble, easy to use, easy to repair, accurate in measuring values, high quality, Its working principle does not depend on few mechanical elements and sensitive to small changes of the pressure. the optical pressure transducer has been designed based on the principle work of the diaphragm and photoconductive circuits

are referred to as gauge pressure (psig) or positive pressure. Pressure below atmospheric are referred to as vacuum or negative pressure. A vacuum is merely a reduction from atmospheric pressure. A term often used in pressure measurement, particularly in low-pressure ranges near atmospheric, is hydrostatic head, or simply head. It represents the pressure at point below liquid surface due to the height of liquid above it. This head expressed in force per unit area is dependent on the specific gravity of the liquid exerting the hydrostatic head and on the pressure exerted by any gas or vapor above the liquid. There are many and different types of instruments to measure pressure, there are physical measuring instruments, mechanical measuring instruments and electrical measuring instruments. Each one of them depend on a different working principle, for example physical measuring instruments depend on measuring mercury, mechanical measuring instruments depend on the mechanical movement of the device, the electrical measuring instruments depend on the electrical elements used in the device. This paper focus on the optical transducer for pressure measurement.

Key Words: Pressure, Optical sensor, Bellows, Calibration, Circuit design

1.INTRODUCTION

Pressure may be defined as the action of a force against an opposing force. It has the nature of a thrust evenly distributed over a surface usually measured as a force per area . The most common units in the English system are the ounce, pound and ton. The practical unit in most cases in the processing industries is the pound, and the unit area is the square inch. Therefore, pressure is normally expressed in pound per square inch (psi). Other units used for expressing pressure include inches and feed of water and inches of mercury in the English system; grams or kilograms per square centimeter, centimeters of water or millimeters of mercury in the metric system; and in atmospheres. Two reference points for pressure measurement exist. The most logical one is absolute zero a condition existing only in a perfect vacuum. Pressure measured from this reference point are called absolute pressure (psia). The other reference point used is atmospheric pressure. The difficulty with this reference point is that it changes with altitude (referenced to sea level) and to some extent with either conditions. At or near sea level, this pressure is about 14.7 psia or 29.9 inches (760 mm) of mercury absolute. When using the later as the reference point, pressure above atmospheric

Pressure optical sensors can be used to measure the movement of a diaphragm due to pressure. An opaque vane is mounted to the diaphragm and moves in front of an infrared light beam. As the light is disturbed, the received light on the measuring diode indicates the position of the diaphragm. A reference diode is used to compensate for the ageing of the light source. Also, by using a reference diode, the temperature effects are nulled as they affect the sensing and reference diodes in the same way. The pressure optical sensor is shown in Fig-1.

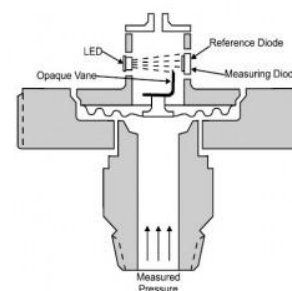


Fig -1: Pressure optical measurement

2. THE DESCRIPTION OF CIRCUIT DESIGN

This section will describe the configuration of the circuit design and its particular application for pressure measurement. Fig-2 shows the block diagram of the circuit. Although the block diagram does not entirely describe the detailed for all units, but it is sufficient to give the ground work for designing the transducer. The main principle idea of optical transducer depends on the transmitter light and receiver light

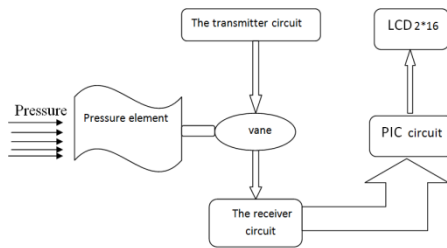


Fig -2: Block diagram of circuit design

In general, the circuit has been designed based on the following specification.

2.1 Bellows element

A bellows pressure element expands when pressure is applied to the inside, actuating an indicator, transmitter or controller. Bellows elements are generally used in pressure ranges from 0 to 10 inches H_2O and from 0 to 10 psig, and for vacuum ranges from 10 to 20 inches H_2O . In pneumatics instruments, bellows usually operate at approximately 3 to 15 psig, as shown the Fig-3



Fig -3: Bellows element

2.2 Photo resistor

As a photodiode, a photo resistor is a photoconductive device. The most common materials for its fabrication are cadmium sulfide¹ (CdS) and cadmium selenide (CdSe). The photo resistors are semiconductors whose resistances change upon light entering the surface. For its operation, a photo resistor requires a power source because it does not generate photocurrent; a photo effect is manifested in the change in the material's electrical resistance. Fig-4 shows a schematic diagram of a photo resistive cell.

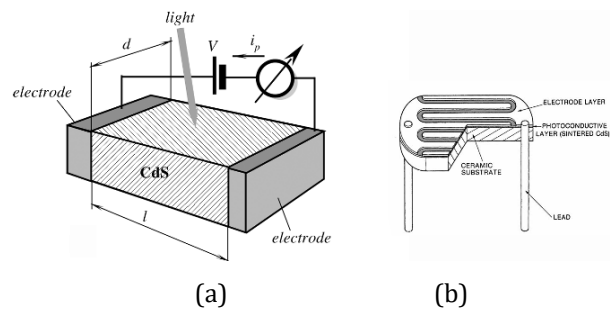


Fig -4: (a) Structure of a photo resistor (b) plastic-coated photo resistor having a serpentine shape

2.3 Vane

The vane or object can be installed on the top of the bellows and can be moved upward when the pressure increase inside the bellows. The movement of the vane will prevent the part of light to reach the photo resistor, so that changing the voltage in the receiver circuit. Therefore, when the pressure increase, the light emitting decrease. The structure of vane element is shown in Fig-5.



Fig -5: vane element

2.4 The transmitter circuit

The LED diode is used for the drive of the optical sensor. The six LED diode are connected in parallel. Fig-6 shows the circuit of the transmitter when the power supply voltage of this drive circuit is +9V. It is converting voltage with the transistor to make control at the operating voltage of +5 to match the specification of PIC-18F452.

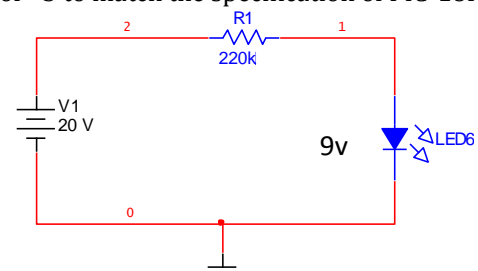


Fig -6: Circuit of transmitter part

2.5 The receiver circuit

The work idea of this circuit depends on receiving the light at the receiver when the photo resistor is used. The output of the circuit is a voltage that changes proportionally with the quantity of the light as shown in Fig-7.

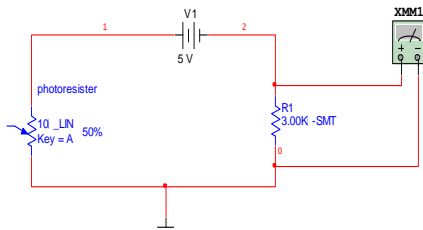


Fig -7: Circuit of receiver part

3. CALIBRATIONS

The prototype system of optical pressure transducer to measure the pressure as shown in the Fig-8. In order to obtain accurate results all experiments have been performed under normal condition such as ambient temperature and humidity. The obtained results of this survey lead to evaluate the efficiency of the system through several calibrations such as accuracy, repeatability, hysteresis and linearity.

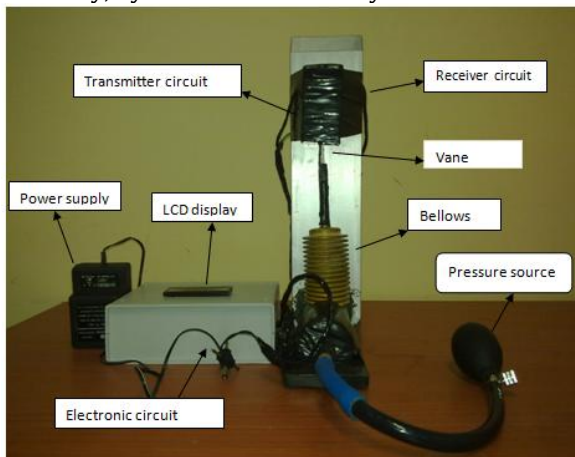


Fig -8: prototype system

The results have been evaluated according to the following static specification. The test has been done by applying the pressure to the transducer and corresponding output readings are recorded.

3.1 Accuracy

The most widely used and misused of static specification. Actually, accuracy is specified in terms of the percent error. Error is the difference between the true (correct) output from the source pressure and the actual output. But accuracy is expressed in percent error. Fig-9 shows the difference between the true output and actual output.

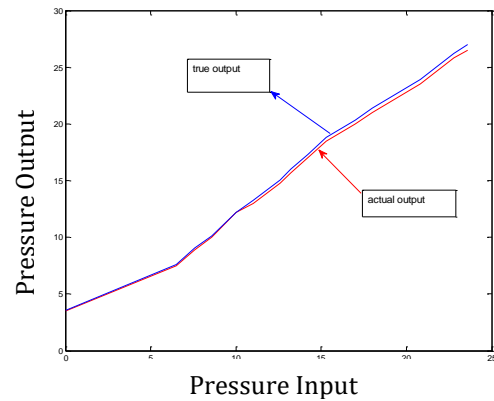


Fig-9: The relation between actual and true pressure output

3.2 Repeatability

Repeatability is measured of how well the output returns to a given value when the same precise input is applied several times. Be careful, not to confuse repeatability with accuracy. The repeatability pressure measurement is shown in Table -1.

Table -1: Repeatability of pressure measurement

Trial No.	Reading for (17.7 psi)	Trial No.	Reading for (17.7 psi)
1	17.8	7	18
2	17.8	8	17.7
3	17.7	9	17.6
4	17.8	10	17.8
5	17.8	11	18
6	18	12	18

$$\text{Repeatability} = \frac{\text{maximum} - \text{minimum}}{\text{full scale}} \times 100\%$$

$$\text{Repeatability} = \frac{18 - 17.6}{26 (\text{psi})} \times 100\%$$

$$\text{Repeatability} = 1.53\%$$

3.3 Hysteresis

Hysteresis is also an indication of the reproducibility of the transducer's output. A given input value when reached by increasing the input may produce an output that is different when reached by decreasing the input. This is the reason for two calibration runs, one increasing and one decreasing. To calculate the hysteresis, you take the difference between the output on the decreasing run and the output on the increasing run at each point in the calibration record. Fig-10 show the hysteresis for increasing and decreasing of pressure measurement.

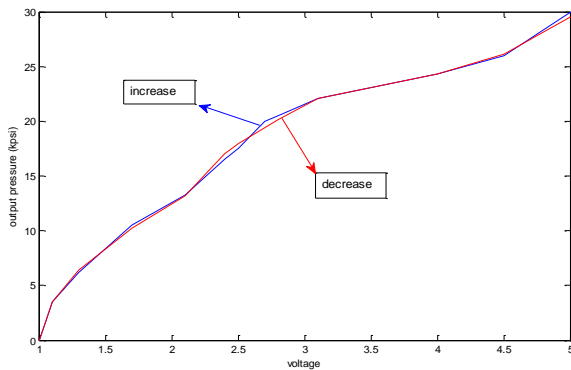


Fig-10: Hysteresis for increasing and decreasing of pressure measurement

$$\text{Hysteresis} = \frac{\text{dec. reading} - \text{inc. reading}}{\text{full scale}} \times 100$$

$$\text{Hysteresis} = \frac{0.5}{26 \text{ (psi)}} \times 100$$

$$\text{Hysteresis} = 1.92\%$$

4.4 linearity

There are several different ways to determine the linearity, the least-squares (also called best-fit or linear regression) linearity is one of these ways which can be used. This technique is measured from a statistically derived straight line "this is the straight line which the sum of the squared distances (error) is the least or at a minimum ". Given a set of x, y pairs, which is the calibration data (input value on the x axis, output on the y) we can calculate the equation of the straight line that yields minimum error. Fig-11 illustrates the output readout pressure meter before and after linearization. The output YL was determined using the straight line equation $Y_L = mx + b$. The calculation of the slope and the intercept of this technique straight line can get a bit tedious. Many calculators have many routines built in, or can be programmed to calculate m and b after you enter all the data points.

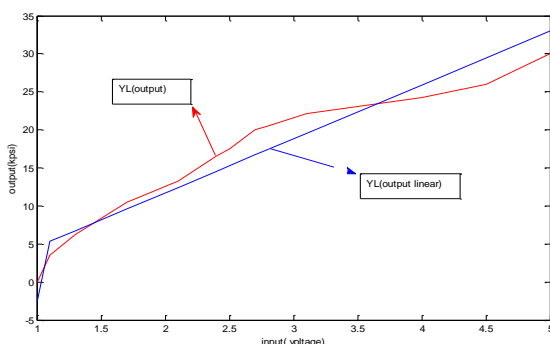


Fig-11: The difference between linear and nonlinear output.

4. CONCLUSION

The optical transducer system had successfully been designed and developed. The optical pressure transducer has been designed based on the principle work of the bellows and photoresistor circuits. Four different calibrations which are accuracy, repeatability, hysteresis and linearity have been done experimentally in order to evaluate the performance of the transducer. According to the calibration, good results have been obtained when the accuracy and hysteresis do not exceed 2 and 1.92, respectively. Unfortunately, the linearity of this transducer is not good as expected due to the lack of adjustment for zero and span of the circuit.

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BIOGRAPHIES



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