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**SCHOOL OF APPLIED TECHNICAL SCIENCES**

**DEPARTMENT OF MECHATRONICS ENGINEERING**

**SENSORS AND ACTUATORS LAB -** **ME0355**

**SECONED SEMESTER 2023/2024**

**DISPLACEMENT & PROXIMITY SENSORS (A)**

**Section 1 Sun 2:00-4:00**

**PREPARED BY:**

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**Introduction**

**Objectives:**

Our goal for this experiment was to gain hands-on experience with various sensors used in measuring physical changes, including piezoelectric, pressure, and strain gauge sensors. We aimed to understand how these sensors respond to different stimuli and how they can be applied in practical scenarios.

**Test Equipment:**

* Mechatronic sensors board, we used these sensors: piezoelectric, pressure, and strain gauge.
* QNET Mechatronics Sensors Trainer which includes the LabVIEW software for every sensor.
* LabVIEW software for data acquisition and analysis which includes digital displays and Scope, and calibration tools.

**Procedure:**

**Piezoelectric Sensor:**

After we put the jumper in position J8 to enable the Piezo sensor on the mechatronics board, we ran the LabVIEW VI for the sensor (QNET\_MECHKIT\_Piezo.vi), we flicked the plastic band attached to the piezo sensor and observed the voltage response on the scope. Then we manually moved the band slowly up and down, noting the voltage changes, we observed that it depends on shock measurements, if we press it and hold it, the voltage doesn’t change. Finally, we ran the program again to measure the natural frequency which is 43.0769 Hz (the highest spike in the readings), by manually perturbed the piezo sensor, then analyzing the power spectrum response.

**Pressure Sensor:**

After we adjusted the jumper to position J9 to activate the pressure sensor.

We executed the LabVIEW VI for the sensor (QNET\_MECHKIT\_Pressure.vi). After that we started the plunger at the 1 ml mark and gradually reduce the volume while recording the voltage at each step down to 0 ml, we recorded our results into the table in the software which automatically plots the data against the calibrated curve.

**Strain Gauge:**

After we put the jumper to J7 for the strain gauge sensor. We executed the LabVIEW VI for the sensor (QNET\_MECHKIT\_Flexgage.vi). After that we applied different levels of bending to the strain gauge, which is the like the metal stick or ruler, the range of it was (-1- 1) cm, then we recorded the voltage output for each level we used the software to calculate and display the linear relationship between the force applied and the voltage output.

**Data and analysis:**

**Piezoelectric Sensor:**

The Natural Frequency = 43.0769 Hz (the highest peak of the signal), it’s derived directly from the software reading

\* No calculations were made, or data table collected, the purpose of the experiment was to observe the reading coming out of the sensor on the LABVIEW VI, only the natural frequency was documented.

**Pressure sensor:**

While moving the plunger from 1.0 ml to 0ml we documented the sensor voltage at each position in this table:

Table 1: Pressure Sensor Data

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Value** | **Units** |
| Sensor Measurement: at 1*.*0 ml | 8700 | mV |
| Sensor Measurement: at 0*.8* ml | 9600 | mV |
| Sensor Measurement: at 0*.6* ml | 2200 | mV |
| Sensor Measurement: at 0*.4* ml | 1400 | mV |
| Sensor Measurement: at 0.2 ml | 1680 | mV |
| Sensor Measurement: at 0 ml | 1950 | mV |

**Calibrating the sensor:**

These readings were inserted in the LABVIEW VI to find the (a, b, c) in this equation:

Where (x) is the sensor voltage and (y) is the output in milliliters.

And got these values:

a = 0.28 ml/V2, b = -1.67 ml/V2, c = 2.2 ml/V2

This equation was used to show the real position of the plunger on LABVIEW VI in (ml), which was achieved with 0.1 ml error.

**Strain Gauge:**

While moving the flexible link into various positions these reading was documented:

Table 2: Strain Gauge Data

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Value** | **Units** |
| Sensor Measurement: at 1.0 cm | -4000 | mV |
| Sensor Measurement: at 0.5 cm | -1700 | mV |
| Sensor Measurement: at 0 cm | 6600 | mV |
| Sensor Measurement: at 0.5 cm | 3100 | mV |
| Sensor Measurement: at 1.0 cm | 5000 | mV |

**Calibrating the sensor:**

These readings were inserted into the LABVIEW VI to find the Gain and Offset of this equation:

y = gain\*x + offset

where (y) is the output in centimeters and (x) is the sensor voltage.

Which was used to show the position of the flexible link in (cm), which was achieved with 0.1 cm error.

**Natural frequency:**

By using the Natural frequency tab on the LABVIEW VI and flicking the flexible link, we found that the natural frequency the link to be equal = 41.83Hz.

Table 3: comparing the three sensors.

|  |  |  |  |
| --- | --- | --- | --- |
|  | Strain gauge | Pressure sensor | Piezoelectric sensor |
| Sensitivity | 5.27 per 1 cm |  | 0.5 per finger bounce |
| Range | -5.28 – 5.27 V | 0.5 – 2.5 | -1 – 1 V |
| Error | 0.1 | 0.1 |  |
| Accuracy | (0.9/1) \*100 = 90% |  |  |
| Relationship | linear | quadratic | linear |
| Input | Force | Force | Force |
| Output | Sensor voltage | Voltage | Voltage |

Figure 1: voltage and displacement relation Figure 2: voltage and displacement relation graph

graph for Strain Gauge for Pressure Sensor

**Discussion**

The results showed that each sensor type responded to its respective mechanical stimulus:

* Piezoelectric sensors exhibited an increase in electrical charge or voltage in response to applied pressure.
  + Pressure sensors displayed an increase in resistance with applied force or pressure.
  + Strain gauge displacement measurements showed changes in electrical resistance corresponding to the deformation of the object.

Trends observed included:

* Linear relationships between the applied force and the sensor output for the Strain Gauge and the Piezoelectric sensor within their operating ranges.
* Quadratic relationship between the input pressure and the output voltage.
* Factors such as temperature, mechanical loading, and electrical noise may have influenced the accuracy of the measurements.

Sources of errors for each sensor type include:

* + Temperature sensitivity: affecting piezoelectric sensors, pressure sensors, and strain gauges. Methods to avoid this include temperature compensation techniques and using temperature-controlled environments.
  + Mechanical loading: affecting piezoelectric sensors and strain gauges. Proper mounting techniques and ensuring uniform loading can minimize this error.
  + Zero drift and Span error: affecting pressure sensors. Recalibration and employing pressure-limiting devices can reduce these errors.
  + Electrical noise: affecting strain gauges. Shielding cables, using low-noise amplifiers, and filtering techniques can help avoid this error.
  + Observational errors**:** Humans, by nature, are prone to making subjective interpretations.

The results obtained were like the theoretical and accurate measurement, with a little error caused by the mentioned reasons of error.

**Real-life Applications:**

The knowledge obtained from the experiment has various real-life applications across industries such as:

* Structural health monitoring: Using strain gauges to monitor the structural integrity of bridges, buildings, and aircraft.
* Industrial process control: Employing pressure sensors to monitor and control pressure in manufacturing processes, oil and gas pipelines, and HVAC systems.
* Medical devices: Utilizing piezoelectric sensors for ultrasound imaging, pressure sensors in medical monitoring equipment, and strain gauges in prosthetics.

Strain gauges Real-life Applications

1. Bridges:

Strain gauges are frequently constructed at crucial sites on bridge structures, like joints, support points, and important structural elements. These gauges monitor the strain or deformation that the bridge experiences under various loads, such as traffic, wind, and temperature changes. Engineers may evaluate the success rate of maintenance and repair interventions, as well as the structural integrity of the bridge, by continuously monitoring strain levels and identifying any signs of fatigue, deformation, or damage. Early anomaly detection enables quick intervention, helping in the prevention of structural failures and assuring the bridge's longevity and safety.

1. Buildings:

Strain gauges can be used to monitor the foundation, beams, and columns in buildings. Through the measurement of strain or deformation caused by loads, settlement, or environmental factors, these gauges offer important information about the structural health and lifespan of the building. By discovering changes in stiffness, cracks, or other signs of deterioration, strain gauge-equipped structural health monitoring systems help building owners and managers to prioritize maintenance tasks, evaluate the effects of changes or renovations, and guarantee safety standards and regulations.

1. Aircraft:

Strain gauges are necessary to keep an eye on the structural integrity of the landing gear, wings, and fuselage of an aircraft. They evaluate the strain or deformation these parts undergo during takeoff, flight, and landing. Aircraft engineers can identify symptoms of weariness, corrosion, or structural deterioration brought on by working tensions, turbulence, or unfavorable weather conditions by monitoring strain levels in real time. To maintain the safety and dependability of a group of aircraft, airlines and maintenance teams use this information to schedule maintenance jobs, evaluate the aircraft's airworthiness, and make accurate choices on repairs, replacements, and fleet management strategies.

**Conclusion**

In the experiment we aimed to assess the performance of piezoelectric sensors, pressure sensors, and strain gauge displacement measurements under varying mechanical loads. We saw in the results that each sensor type exhibited varying responses to its respective load within its operating range. Piezoelectric sensors produced electrical charge or voltage in response to pressure, pressure sensors provided pressure readings correlating with applied force, and strain gauges displayed changes in electrical resistance corresponding to deformation. These findings underscore the reliability of these sensors in converting mechanical parameters into electrical signals, essential for applications like structural health monitoring, industrial process control, and medical devices.

**References**

* <https://blog.wika.us/knowhow/pressure-sensor-accuracy-3-errors/>
* <https://www.tutorchase.com/notes/ib/chemistry/11-1-1-types-of-errors-in-measurements>
* <https://strainblog.micro-measurements.com/>
* <https://www.intechopen.com/chapters/77225>
* Documents and files that are related to this experiment given on teams.