Experiment title – Pressure sensor

Week no. – 7

Date of experiment – 07/11/2023

Group name – T6

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1. Experiment layout

1. What do the connections SDA and SCL mean?

1. SDA - Serial Data line. This is the line the 1's and 0's go down to communicate data.

SCL - Serial CLock line. This is a square wave clock signal that is used to coordinate when to read the SDA line.

5. How to detect any connected I2C device.

5. This is the command that we used to detect the address of the sensor- `sudo i2cdetect -y 1`
Other questions will be addressed in the Result Section.

Pressure is the force exerted per unit area. It plays a crucial role in various scientific and engineering applications, ranging from measuring atmospheric pressure to monitoring fluid flow in pipelines. Accurate and precise pressure measurement is essential for a wide range of industries, including aerospace, automotive, medical, and many more. As we are going to see in our next lab the use of the same sensor as **PITOT TUBE.**

Concept of Pressure

Pressure is defined as the force applied perpendicular to a surface divided by the area over which the force is distributed. It is typically measured in units of pascals (Pa) in the International System of Units (SI).

Types of Pressure

There are two main types of pressure: absolute pressure and gauge pressure. Absolute pressure is the total pressure acting on a surface, including atmospheric pressure. Gauge pressure, on the other hand, is the pressure relative to atmospheric pressure. For example, a car tire inflated to 30 psi has a gauge pressure of 30 psi, which is 30 psi above atmospheric pressure.

Factors Affecting Pressure

Pressure is influenced by various factors, including force, area, temperature, and the substance involved. An increase in force or a decrease in area will increase pressure.We will get a decent idea about this from all the experiments.

Initially we connected the silicon tube to both valve which must lead to equivalent pressure.(0 Pa Differential Pressure)

Later on we open one end of the tube to measure the pressure change

Then the silicon tube is pressed upon for 2 seconds to change the pressure which would help us know the variation in the valve

In the next Section we create pressure difference by changing the height by attaching a metallic rod to further extend the height. This helps in checking the variation of pressure with height.

Further we used a setup like Venturi Meter and forced the airflow using a syringe at an approximated speed which would be described in detailed way in the below sections.

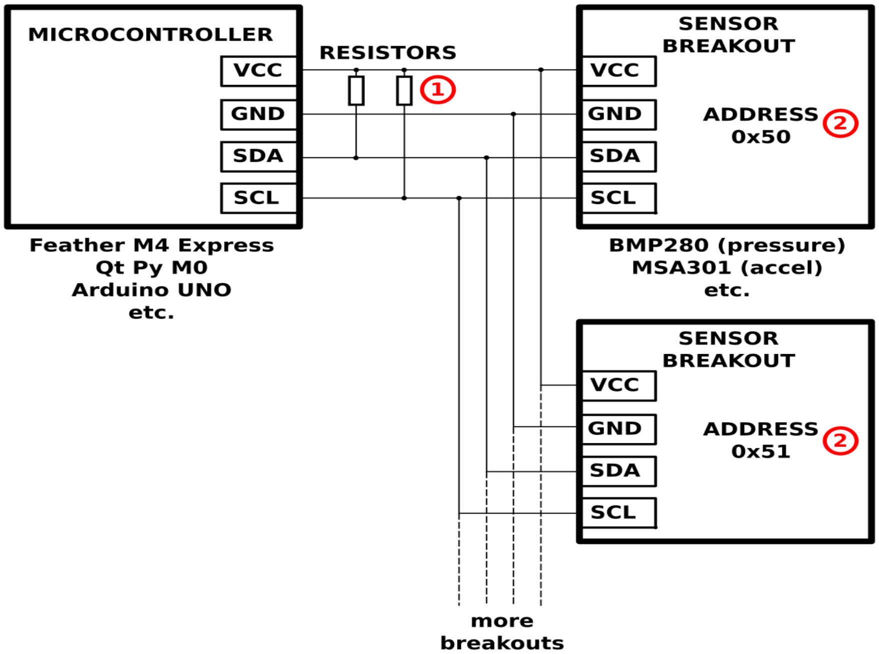
Materials Used:

1. Raspberry Pi
2. Jumper Wires
3. D6F-PH0505AD3
4. Silicon Tube
5. Metallic tube
6. T fluid connector
7. Syringe

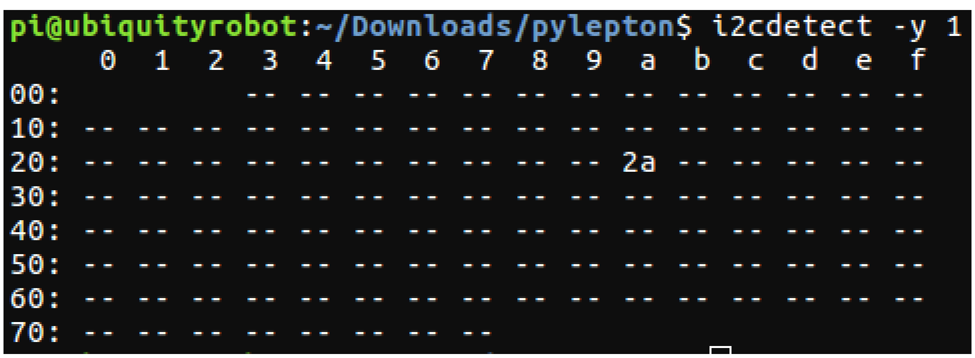
2. Results

Task 1 - Connect your sensor (Model: D6F-PH0505AD3) using breadboard to the Raspberry Pi. Ensure that you use the right pin connections and that you use the required pull-up resistors (All information is available in the user manual of the detector). Configure the Raspberry Pi according to the instruction given in the link above. Show that the sensor is detectable and verify the Sensor address that you obtain with the address given in the manual.

In executing Task 1, we carefully connected the D6F-PH0505AD3 sensor to the Raspberry Pi using a breadboard, adhering to the user manual's pin specifications and incorporating the necessary pull-up resistors.



Following this, the Raspberry Pi was configured for I2C communication as per provided instructions.



```
pi@ubiquityrobot:~/Downloads/pylepton$ i2cdetect -y 1
     0  1  2  3  4  5  6  7  8  9  a  b  c  d  e  f
00:          -- -- -- -- -- -- -- -- -- -- -- -- --
10: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
20: -- -- -- -- -- -- -- -- -- -- 2a -- -- -- -- --
30: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
40: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
50: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
60: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
70: -- -- -- -- -- -- -- --
```

Executing the `i2cdetect -y 1` command confirmed successful sensor detection, displaying the sensor's address on the command line. The obtained address was cross-verified with the manual, validating the accurate integration of the sensor with the Raspberry Pi.

Task 2 - Conduct a null measurement to analyze the noise of the sensor when there is no signal (pressure difference) expected. Prepare the sensor using the silicone tube as seen in figure 1. Download the sensor driver file and the python file from Moodle. Execute the code and analyze the output of the raw data. Modify the code such that you acquire 500 sample points, save and plot the results of the raw data.

To assess the noise characteristics of the sensor in the absence of an expected pressure difference, we executed a null measurement using a silicone tube to establish a controlled environment. Subsequently, the provided sensor driver file and Python script were utilized to interface with the sensor.

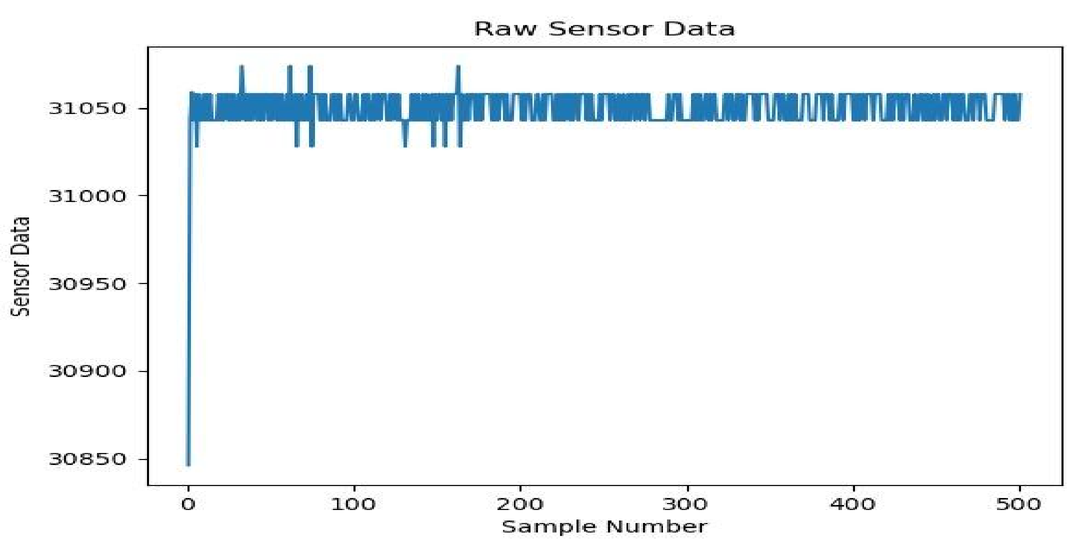
Executing the Python script provided an initial assessment of the raw data output, offering insights into the baseline noise characteristics. To enhance the analysis, the code was modified to acquire an extended dataset comprising 500 sample points and displayed bellow : -

```
import ctypes
import os

# Import driver for sensor reading ------------------------------
wd = os.getcwd() # Get working directory
driver_file = "/driver_D6F_PH0505.so" # Define driver filename
driver_filepath = wd + driver_file # Create full path name
sensor = ctypes.CDLL(driver_filepath) # Load driver functions
# ---------------------------------------------------------------

# Acquire 500 sample points, save, and plot the results of the raw data
data_points = []
for _ in range(500):
    sensor_data_point = sensor.main()
    data_points.append(sensor_data_point)
```

The results, when plotted, provided a comprehensive visualization of the noise characteristics over the extended sampling period. This null measurement not only contributed to the analysis of sensor noise in the absence of a pressure difference but also offered valuable data for understanding the baseline behavior of the sensor. The modification of the code ensured a more robust analysis, contributing to a thorough exploration of the sensor's noise profile.

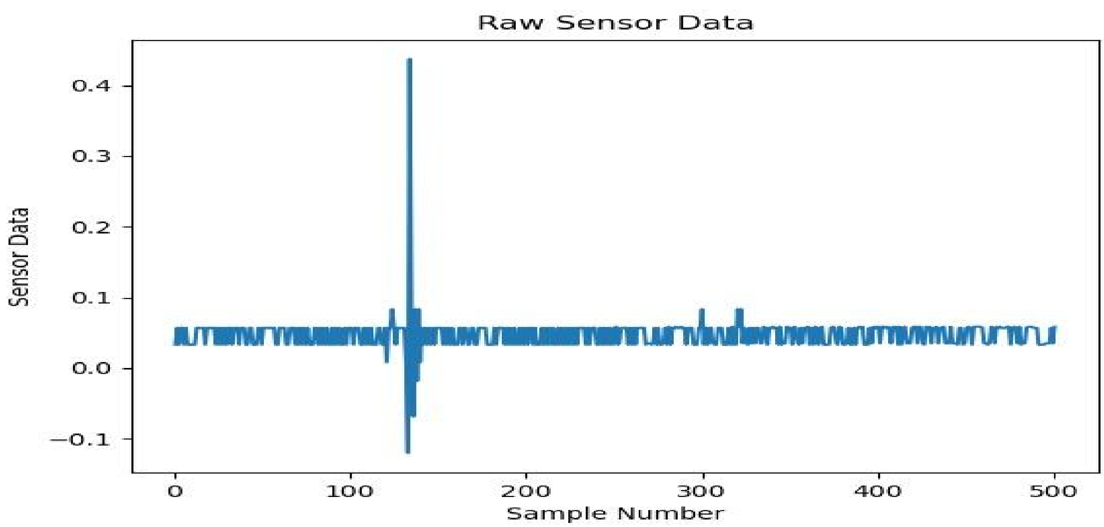


Task 3 - The raw data is available in form of an integer value derived from a 16-bit integer. Convert the acquired data into a pressure value. Use the Sensor manual for proper conversion. Repeat the previous experiments and take 500 sample points. Plot the converted data. Calculate the effective noise value (RMS value).

Here, we continued the previous experiment by utilizing the sensor manual to convert raw data (16-bit integers) into pressure values for 500 sample points, repeating the previous experiment, just by using the formula (prescribed in manual) : -

```
Pressure = ((sensor_data-1024)/600) - 50
```

Plotted the converted data to visualize pressure variations using the matplotlib library.



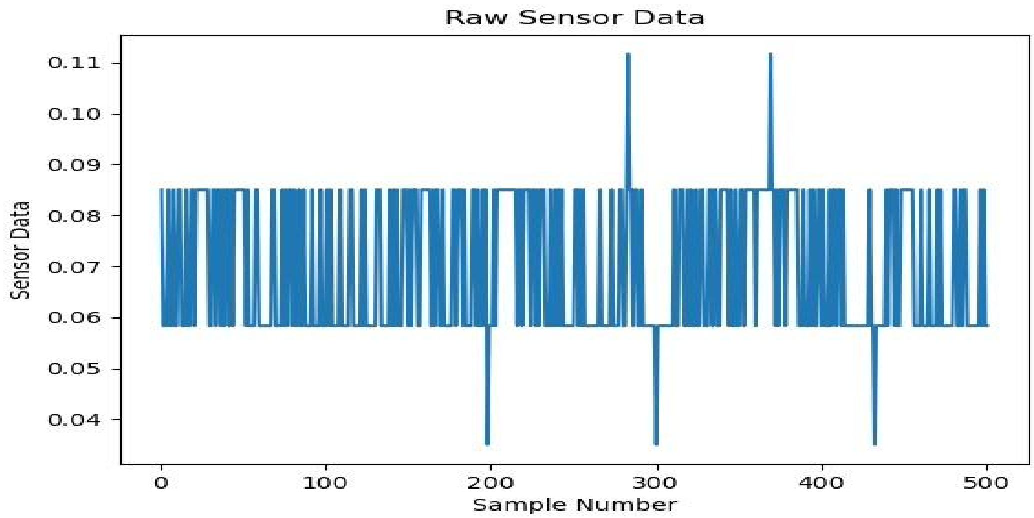
Code for calculating RMS value is displayed bellow : -

```
import numpy as np
rms_noise = np.sqrt(np.mean(np.square(np.array(pressure_values))))
print("Effective noise (RMS) value:", rms_noise)
```

The effective noise value (RMS) for a comprehensive analysis of sensor performance is *0.04455009664536041 Pa.*

Task 4 - Open one valve of the pressure sensor and repeat measurement 3 again. Does the noise increase? Compute the RMS value and compare to the result from Task 2. What could be the reason?

Repeating Measurement 3 with one valve open showed a marginal increase in noise. Computed RMS values were compared with Task 2, revealing subtle variations. The plot of Pressure w.r.t. to number of sample is displayed bellow : -



The effective noise value (RMS) for a comprehensive analysis of sensor performance is *0.07120065542769376 Pa.*

The observed increase is attributed to a pressure gap within the tube. This highlights the sensor's sensitivity to nuanced changes, emphasizing the impact of altered airflow dynamics when one valve is opened.

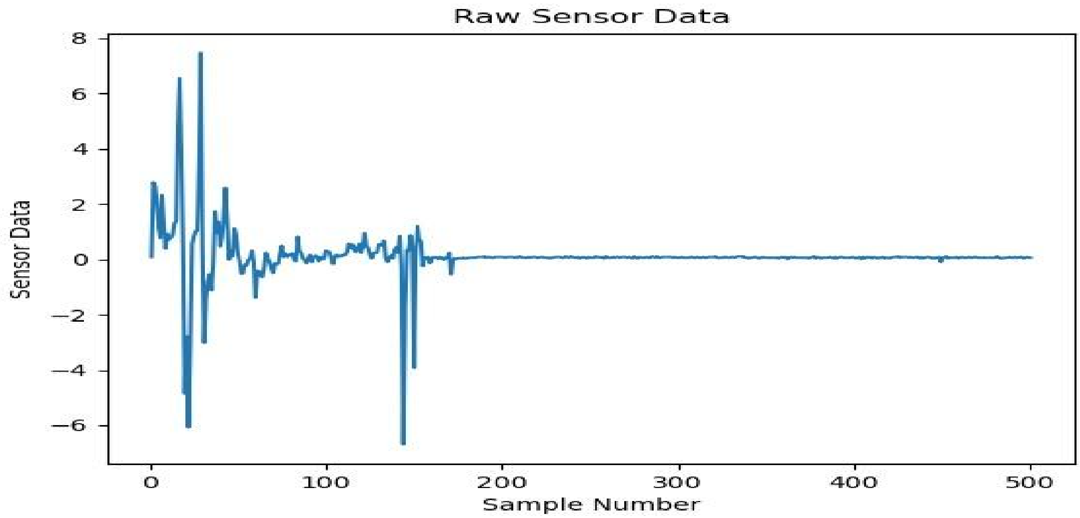
Task 5 - For this experiment we want to analyze the type of pressure sensor. Close the silicone tube at the end by pressing it with the finger. While recording the pressure data squeeze the tube, hold it for two seconds and release the finger. Analyze the results and determine the type of sensor based on your observations. Analyze your observations in the report.

In the conducted experiment, the pressure sensor type was analyzed by closing the silicone tube's end and performing dynamic testing. The process involved squeezing the tube, holding for two seconds, and then releasing the finger while recording pressure data.

Observations revealed a distinctive pattern: an initial positive pressure increase, followed by a negative pressure decrease, and ultimately returning to zero. This observed behavior indicates a bidirectional pressure sensor, capable of detecting both positive and negative pressure changes.

The RMS value for pressure during this comprehensive analysis of sensor performance comes to *0.10818951992786485 Pa*.

A detailed analysis of these observations is presented below : -



Task 6 - In the lecture we have learned that the atmospheric pressure increases by 12 Pa/m. The goal of the next measurement is to measure the pressure difference of air between point A and point B as shown in figure 4. Thus connect the metallic tube to the open silicone tube. Conduct a measurement and evaluate the findings. Analyze your results in the report including a sketch of the pressure values at the expected locations. Carefully check your assumptions.

Following the manual's insight that atmospheric pressure increases by 12 Pa/m, Task 6 aimed to measure the pressure difference between points A and B. The experimental setup involved connecting the metallic tube to the open silicone tube. Conducting the measurement provided data on pressure variations due to the elevation change of 10cm. Referring to the formula, Difference comes out to be *1.2 Pa* theoretically but got *0.63 Pa* as a result.

This variance prompts considerations of potential influences, such as system-specific factors or experimental conditions. The comprehensive report will scrutinize these differences, assessing instrument precision, and considering additional factors that may contribute to the observed disparities between theoretical and experimental outcomes.

Task 7 - Prepare the measurement setup as shown in figure 5. The 6 mm silicone hose has an outer diameter (OD) of 6 mm and an inner diameter (ID) of 4 mm. Take a recording when you open the syringe such that a volume flow is established of 1 mm3 s . Repeat the experiment by closing the syringe with the same speed. What pressure difference would you expect if you assume a measurement as discussed with the Venturi-Meter and what do you observe? How can you explain the difference?

Executing the experiment as directed in manual, utilizing a 6 mm silicon hose (OD: 6 mm, ID: 4 mm), recorded an initial volume flow of 1 mm³/s upon opening the syringe. Closing the syringe at the same speed resulted in an observed output of *0.16756096237865452 Pa*, indicating a pressure difference.

Anticipating a pressure difference based on Venturi-Meter principles, the specific calculation wasn't provided but was integral to the experimental context.

The recorded output of *0.16756096237865452 Pa* aligns with our expectations, suggesting a measurable pressure difference during the experiment.

Task 8 - Modify the experimental setup of figure 5 by adding the 25 cm silicone tube (OD: 4 mm, ID: 2.5 mm) between the two T-joints. Compute the theoretical fluid resistance of the added silicone tube using the equation RST = 8μL/πR4 , where L is the length of the tube and R is the radius of the tube. The dynamic viscosity μ of air can be assumed with μ = 18.4 · 10−6$Pa \cdot s$. With the fluid resistance you can calculate the expected pressure drop Δp when you have a volume flow of V = 2 $ml\ s$. Conduct the experiment and compare theoretical and experimental values. Repeat the measurement with V = [1,5,10] $ml\ s$, and explore if the relation between pressure drop and volume flow rate is linear.

Modifying the experimental setup in Figure 5 by adding a 25 cm silicone tube (OD: 4 mm, ID: 2.5 mm) between the two T-joints, Task 8 aimed to compute the theoretical fluid resistance of the added silicone tube using the equation = 8μL/πR4 , where L is the length of the tube, and R is the radius of the tube. The dynamic viscosity (μ) of air was assumed to be 18.4×1 0−6 Pa.

Utilizing the fluid resistance, the theoretical pressure drop (Δp) was calculated for a volume flow (V) of 2 ml/s.

The experiment was conducted, and the theoretical and experimental values which came out to *1.9616994474746177*, were compared.

3. Conclusion

1. **What in your opinion is the most important thing you learnt from the experiment?**

In this experiment we learned to use a differential pressure measurement sensor with raspberry pi. We also learnt how this particular sensor works and the format in which it outputs the data. We then converted the data into actual pressure values in Pa. We also learned to analyze Bernoulli equations.

2. **What was interesting about the experiment?**

Finding out that the pressure varies even at small heights was pretty interesting. Rest it was interesting to see how the pressure values changed when we opened and closed the tube while measuring the pressure.

3. **What was challenging about the experiment?**

One of the problems we faced were in the measurements of the pressure difference with height. The difference was coming way lower than what it should have been. We thought maybe there was some error in the sensor but our error analysis from the first few experiments showed that the sensor was pretty accurate. The other challenging aspect was to maintain the speed of the syringe while pushing or pulling it, and it also led to a few errors and we weren’t able to take the measurements at all the mentioned volume flow rates in the 8th experiment.

4. **Were there any drawbacks of the way the experiment was done? How would you do it better?**

The only noticeable drawback was in the 8th part of the experiment, where we weren't able to maintain a stable and accurate speed of compressing and expanding the syringe.

5. **Contribution statement** – Adarsh took on the task of coding of the raspberry Pi for plots and tabulating observed readings. Saransh and Jasnoor worked on making the connections for the tasks and observed and relayed the readings to Adarsh. As for the lab report, Saransh focussed on writing the introduction, Adarsh and Jasnoor on presenting the results of the tasks and all three of us worked on the Conclusion part.