LABORATORY REPORT

LAB 11: Digital Signal Processing Interfacing

GROUP H

PROGRAMME: MECHATRONICS ENGINEERING

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ABSTRACT

This lab report details an experiment conducted to measure and analyze the output of a potentiometer using an Arduino-based data acquisition system. The primary objective was to implement a low-pass filter to smooth the raw analog readings obtained from the potentiometer. An Arduino microcontroller was programmed to read the potentiometer values through an analog input pin, process the data using a simple low-pass filter algorithm, and transmit both the raw and filtered values to a computer for visualization.

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INTRODUCTION

In signal processing, noise reduction and signal smoothing are critical for obtaining accurate and reliable data from sensors. This lab report presents an experiment designed to measure and analyze the output of a potentiometer using an Arduino microcontroller, with a focus on implementing a low-pass filter to enhance data quality.

A low-pass filter is a type of electronic filter that allows signals with a frequency lower than a certain cutoff frequency to pass through while attenuating signals with frequencies higher than the cutoff frequency. Essentially, it smooths the signal by filtering out rapid changes or high-frequency noise, thereby preserving the underlying trend of the data. The simple low-pass filter used in this experiment is implemented using an exponential moving average (EMA) formula, which combines a fraction of the current signal value with a fraction of the previous filtered value. The filter is defined mathematically as:

$$\text{filteredValue} = \alpha \times \text{sensorValue} + (1-\alpha) \times \text{filteredValue}$$

where:

- α is the filter coefficient, ranging between 0 and 1, that determines the filter's responsiveness. A smaller α yields smoother results by emphasizing past values more heavily, while a larger $\alpha\alpha$ responds more quickly to recent changes.

By understanding and applying low-pass filtering techniques, this experiment underscores the importance of signal conditioning in various applications, including data acquisition, instrumentation, and control systems. The filtered data not only provides a clearer insight into the potentiometer's behavior but also showcases the practical benefits of digital filtering in real-world scenarios.

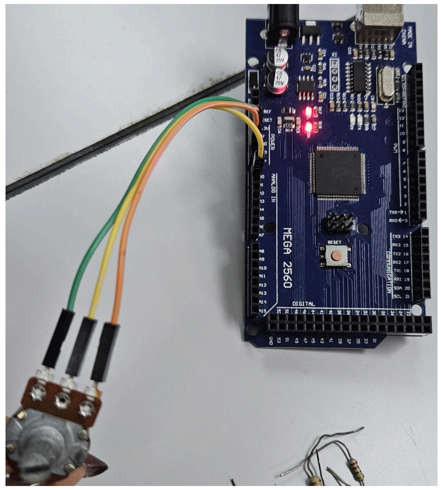
PROCEDURE

<u>Materials And Equipment:</u>

- Arduino board
- Potentiometer
- Jumper wires
- Breadboard
- Computer with Arduino IDE installed
- USB cable for Arduino
- Arduino board

<u>Experimental Setup:</u>

1. Connect the potentiometer to the Arduino mega middle pin→A0, left pin→5V and right pin→GND.
2. Connect Arduino to PC using USB cable.



Methodology:

$f_c = \frac{1}{2\pi RC}$ ……… (1)

f_c: $cutoff\ frequency$

R: $resistor$

C: $capacitor$

1. Write an Arduino sketch to show the potentiometers' original and filtered values in a graph.
2. Upload the code to the Arduino.
3. If cutoff frequency is 5kHz, find the value of the resistor and capacitor by using eq 1.

Arduino code:

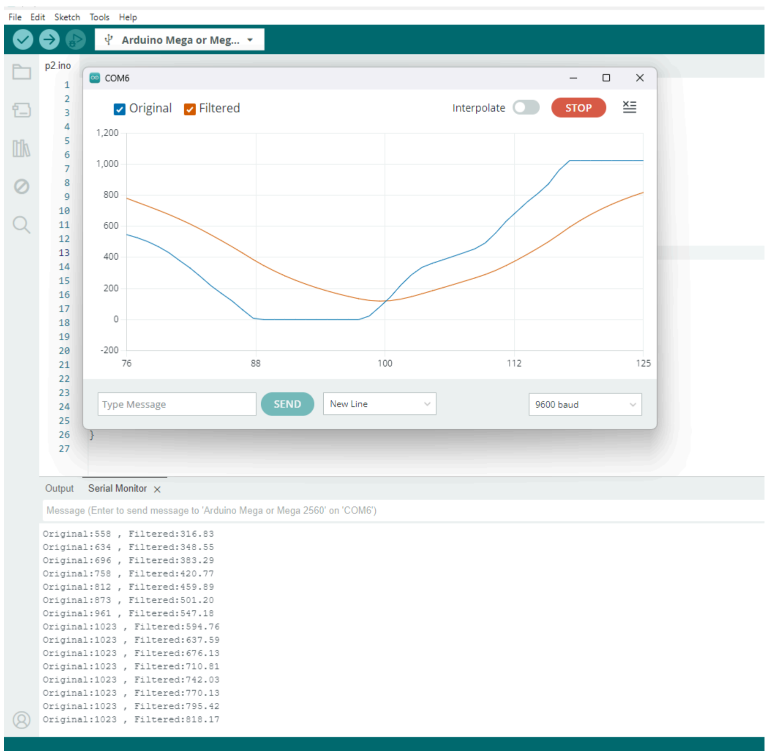
```
const int analogPin = A0;
int sensorValue;
float filteredValue = 0.0;
float alpha = 0.1; // Adjust this value for filter strength

void setup() {
  pinMode(analogPin, INPUT);
  Serial.begin(9600);
}

void loop() {
  sensorValue = analogRead(analogPin);
  // Apply low-pass filter
  filteredValue = alpha * sensorValue + (1 - alpha) * filteredValue;
  // Print the results
```

```
  Serial.print("Original:");
  Serial.print(sensorValue);
  Serial.print(" , ");
  Serial.print("Filtered:");
  Serial.println(filteredValue);
  delay(100);
}
```

DATA COLLECTION



DATA ANALYSIS

cutoff frequency is 5kHz and assuming resistance to be 1kΩ;

$$5k = \frac{1}{2\pi(1k)C}$$

$$C = \frac{1}{2\pi(1k)(5k)}$$

$$C = 0.0318\ \mu F \approx 0.032\ \mu F$$

RESULTS

The experiment successfully captured and processed the potentiometer values using the Arduino microcontroller. Both the raw and filtered data were collected and visualized over a period to analyze the performance of the low-pass filter. The raw data obtained directly from the potentiometer exhibited significant fluctuations, indicative of high-frequency noise typical in analog sensor readings. The rapid variations in the signal were pronounced, especially when the potentiometer was adjusted quickly. On the other hand, for the filtered data the low-pass filter was applied to the raw data using the exponential moving average formula. The filtered data showed a marked reduction in noise, resulting in a much smoother signal.

The calculation provided is for determining the capacitance required in a low-pass RC filter to achieve a desired cutoff frequency of 5 Hz with a resistance of 1 kΩ. The capacitance C calculated is approximately 0.0318 μF, which is reasonably approximated to 0.032 μF.

DISCUSSION

The fluctuations in the raw data can obscure the true signal, making it challenging to interpret the potentiometer's position accurately. However, using the exponential moving average formula the high-frequency variations were effectively attenuated, allowing the underlying trend of the potentiometer's position to emerge more clearly. The low-pass filter effectively smoothed out the rapid, minor fluctuations, highlighting the essential changes in the potentiometer's position. Moreover, it reduced the raw signal when it seemed to be rising in value. Additionally, The graphical representation of both raw and filtered data underscored the filter's effectiveness. The raw data graph displayed erratic peaks and troughs, while the filtered data graph showed a smoother, more consistent trend line. This visual contrast reinforced the importance of filtering in achieving a more interpretable signal.

The resistance was assumed to be 1kΩ because it is one of the most common values found for a resistor. After calculating the capacitance it was rounded up to the nearest available value found in the market. This process aligns with the standard method for designing RC filters, ensuring that the components chosen will yield the specified cutoff frequency.

CONCLUSION

This experiment successfully demonstrated the application and effectiveness of a low-pass filter in processing analog sensor data obtained from a potentiometer using an Arduino microcontroller. By comparing the raw and filtered data, the results clearly showed that the low-pass filter significantly reduced high-frequency noise, providing a much smoother and more reliable signal. In conclusion, the experiment highlights the practical benefits of digital filtering techniques in enhancing the quality of sensor data. The successful reduction of noise and the resultant clearer signal provide a compelling case for the use of low-pass filters in various real-world scenarios. This experiment underscores the importance of signal conditioning in achieving accurate and reliable measurements, which is fundamental to many technological and engineering applications.

RECOMMENDATIONS

experimenting with different values is of the filter coefficient recommended to find the optimal balance between noise reduction and responsiveness. In applications where rapid response is critical, a higher αα may be necessary, whereas in applications requiring smooth data, a lower αα may be preferable.

REFERENCES

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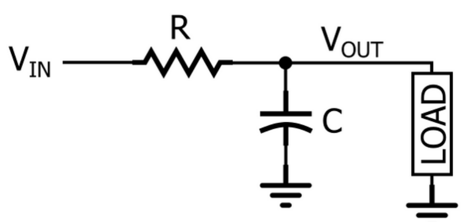
APPENDICES



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STUDENT'S DECLARATION

This is to certify that we are responsible for the work submitted in this report, that the original work is our own except as specified in the references and acknowledgement, and that the original work contained herein have not been untaken or done by unspecified sources or persons.

We hereby certify that this report has not been done by only one individual and all of us have contributed to the report. The length of contribution to the reports by each individual is noted within this certificate.

We also hereby certify that we have read and understand the content of the total report and no further improvement on the reports is needed from any of the individual's contributors to the report.

We, therefore, agreed unanimously that this report shall be submitted for marking and this final printed report has been verified by us.

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