AN INTERNATIONAL AWARD-WINNING INSTITUTION FOR SUSTAINABILITY

KULLIYYAH OF ENGINEERING
DEPARTMENT OF MECHATRONICS ENGINEERING

EXPERIMENT WEEK 11

MCTA 3203
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Lecturer:
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1. Abstract

This report presents the implementation and demonstration of a low pass filter (LPF) using an Arduino microcontroller, with a potentiometer as the analog input source. The LPF is designed to smooth out high-frequency noise from the input signal, allowing only the lower frequency components to pass through. By utilizing a resistor and capacitor to form the LPF circuit, and incorporating the necessary Arduino code to read and filter the analog data, the experiment showcases the practical application of LPFs in real-time signal processing. The results are visualized through waveforms on the Arduino IDE's serial monitor, illustrating the filter's effect on the analog input signal. This experiment underscores the importance of LPFs in various applications, including audio processing and sensor data filtering, and provides a foundational understanding for further exploration of digital filtering techniques.

2. Introduction

In this lab, we aim to demonstrate the functionality of a low pass filter (LPF) using an Arduino microcontroller. A low pass filter is an electronic filter that passes signals with a frequency lower than a certain cutoff frequency and attenuates signals with frequencies higher than the cutoff frequency. The LPF is commonly used in various applications such as audio processing, signal conditioning, and data smoothing.

For this experiment, we will use a potentiometer as the analog input to the Arduino. The varying resistance of the potentiometer will provide a range of analog voltage values that the Arduino will read. The Arduino will then apply a low pass filter algorithm to these input values and output the filtered signal. We will observe the results in the form of waveforms displayed on the serial monitor of the Arduino IDE. This will help us understand how the LPF smooths out rapid changes in the input signal, allowing us to see its effect on the analog data in real-time.

3. Material and equipment

- Breadboard
- Arduino ide
- Arduino uno
- Jumper wire
- Potentiometer

4. Hardware setup

1) Connect the middle pin of the potentiometer to the Arduino analog input pin (e.g., A0).
2) Connect one of the outer pins of the potentiometer to the 5V pin on the Arduino.

3) Connect the other outer pin of the potentiometer to the GND pin on the Arduino.
4) Connect arduino to pc using usb cable

5. Procedure

1) Connect the Sensor: Interface the sensor to the analog input of the Arduino through the low pass filter (LPF) as depicted in Figure 2.
2) Determine Resistor and Capacitor Values: The resistor and capacitor form an LPF circuit that adheres to the cutoff frequency formula, fc=12πRCf_c = \frac{1}{2\pi RC}fc=2πRC1. Select the resistor and capacitor values based on the desired cutoff frequency.
3) Develop Arduino Code: Write the Arduino code to read analog data from the sensor and apply a low pass filter.
4) Upload the Code: Transfer the code to the Arduino board.
5) Monitor the Output: Use the serial monitor in the Arduino IDE to observe the output.
6) Observe LPF Functionality: Note how the LPF smooths the signal and mitigates high-frequency noise.
7) Discuss LPF Principles and Applications: Elaborate on the principles of low pass filters and their applications. Consider real-world uses of digital filtering in fields such as audio processing and sensor data filtering.

6. Calculation

Define value of capacitor and resistor to produce 5khz of cut off frequency

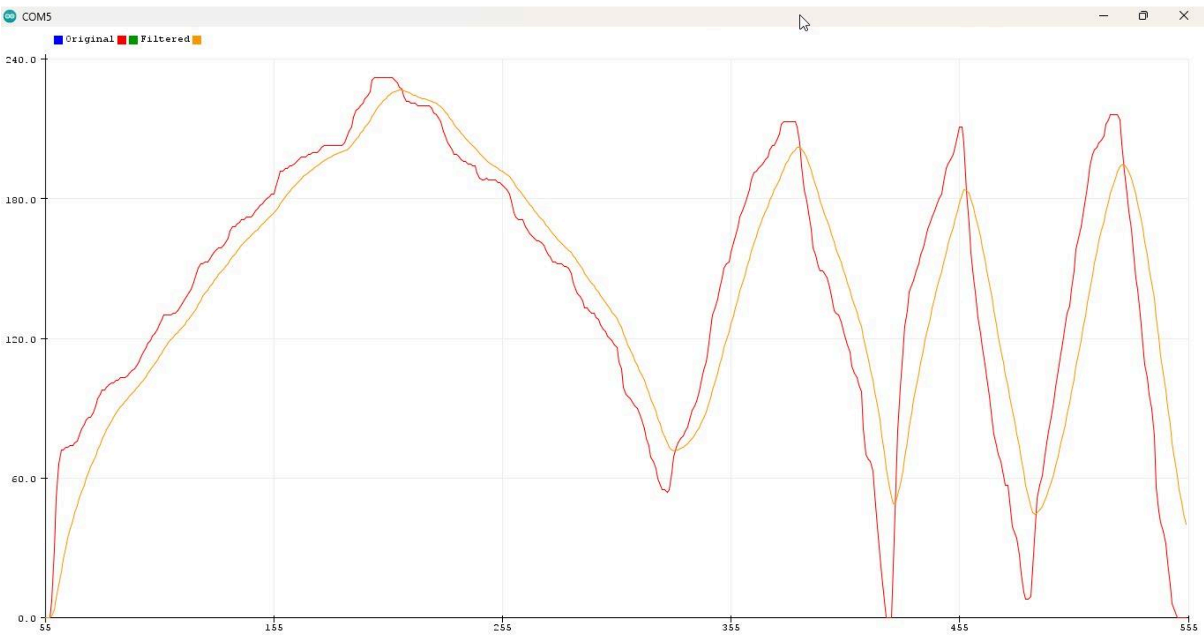
$$f_c = \frac{1}{2\pi RC} = 5\ KHz$$

$$RC = 3{\cdot}183 \times 10^{-5}$$

$$R = 10K\Omega$$

$$C = 3{\cdot}183\ \mu F$$

7. Result



8. Discussion

Discuss the principle of low-pass filter and its application. Consider real-world applications of digital filtering in areas like audio processing or sensor data filtering.

A low pass filter (LPF) allows low-frequency signals to pass through while reducing the amplitude of high-frequency signals. It is commonly made with a resistor and a capacitor. The cutoff frequency (fcf_cfc) determines which frequencies are filtered out and is calculated using fc=12πRCf_c = \frac{1}{2\pi RC}fc=2πRC1. In the time domain, an LPF smooths out rapid changes in the input signal, reducing noise and stabilizing the output.

LPFs are widely used in various applications due to their ability to remove unwanted high-frequency noise and retain useful low-frequency information. In audio processing, LPFs reduce noise and enhance bass sounds, improving sound quality in music production and broadcasting. In sensor applications, LPFs smooth out noisy sensor readings, providing more accurate data, which is crucial for temperature monitoring and accelerometer data processing. Communication systems use LPFs to condition signals before transmission, ensuring the integrity of the transmitted signal and preventing aliasing during digital conversion.

Additionally, LPFs are employed in digital image processing to reduce noise and smooth images, enhancing preprocessing for tasks like edge detection. In medical devices, LPFs clean up signals from electrocardiograms (ECG) and improve the quality of medical images. Overall, the LPF's ability to smooth signals and reduce noise makes it essential in audio processing, sensor data filtering, communication systems, and medical devices, enhancing the performance and reliability of these systems.

9. Recommendation

To enhance the effectiveness and depth of this experiment, several improvements and extensions can be recommended. Firstly, using a higher-order low pass filter instead of a first-order one could provide sharper cutoff frequencies and better noise attenuation, allowing for a more precise analysis of signal smoothing. Secondly, integrating dynamic adjustment of the filter coefficient (α) based on the rate of change of the input signal could make the filter more adaptable to varying signal conditions, offering both smoother outputs when the input is stable and quicker responses to rapid changes. Additionally, exploring digital signal processing (DSP) techniques, such as implementing Fast Fourier Transform (FFT) for frequency analysis, could provide deeper insights into the characteristics of the input signal and enhance the filtering process. For practical applications, testing the LPF with different types of sensors and in various real-world scenarios, such as environmental monitoring or wearable health devices, would demonstrate its versatility and robustness. Finally, comparing the performance of software-implemented LPFs with hardware LPFs could offer valuable insights into their relative advantages and limitations, guiding future implementations in different contexts.

10. Conclusion

In this lab, we successfully demonstrated the implementation of a low pass filter using an Arduino. By utilizing a potentiometer as the analog input, we were able to observe how the low pass filter smooths out rapid changes in the input signal. The waveforms displayed on the serial monitor clearly showed the attenuation of high-frequency noise and the retention of the lower frequency components of the signal. This experiment highlights the practical application of low pass filters in various electronic and signal processing scenarios. Understanding how to implement and visualize the effects of an LPF using an Arduino provides a solid foundation for further exploration into more complex filtering techniques and their applications in real-world systems.

Student’s declaration

Certificate of Originality and Authenticity
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 acknowledgment, and that the original work contained herein has 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 contributor 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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