Instrumentation*

*Note: Instrumentation — Homework 2

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***Abstract*—The current document contains the solutions to the second assignment prepared for the class Instrumentation, 8106126-01 . Knowledge of Instrumentation is required for deep understanding of the materials presented in this report.**

***Index Terms*—Instrumentation,LS, RLS**

I. Introduction

A. List of Problems

1) Filter Design
2) Comparator vs. Schmitt Trigger
3) Biomedical Signal Processing with STM32
4) ....

II. Problem 1— Filter Designs

A. Part A — Low Pass Filter

1) - Determining R: : Since $f_c = 1k$ Hz , R is obtained from the equation below:

$$w_c = \frac{1}{RC}, \quad w_c = 2\pi f_c \tag{1}$$

consequently:

$$f_c = \frac{1}{2\pi RC} \tag{2}$$

and thus:

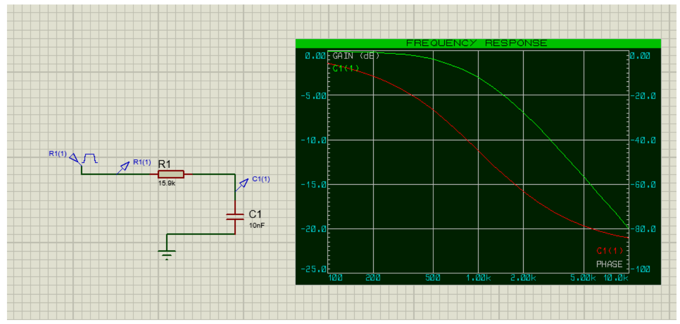
$$R = \frac{1}{2\pi f_c C} = 15.90\ k\ () \tag{3}$$

2) - Determining Transform Function:: Due to the structure of the Low pass filter circuit, the transfer function is obtained as below:

$$G(s) = \frac{V_{out}}{V_{in}} = \frac{\frac{1}{Cs}}{R + \frac{1}{Cs}} = \frac{1}{RCs + 1} \tag{4}$$

3) - Frequency Response Simulation in Proteus: : frequency response from 10 Hz to 100 kHz using Proteus : As expected, the cutoff frequency (3 dB) occurs at 1k Hz.

4) - Filter Response to Pulse: As it is evident in figure 3, the response is no longer square shaped since the filter changes the phase of different signals non-uniformly.



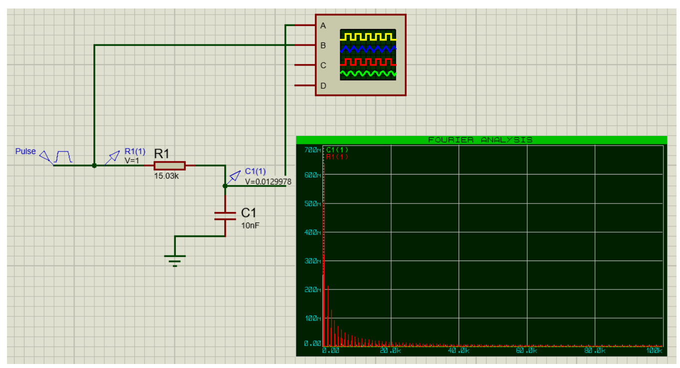


Fig. 2. Low pass filter circuit and fourier of pulse signal

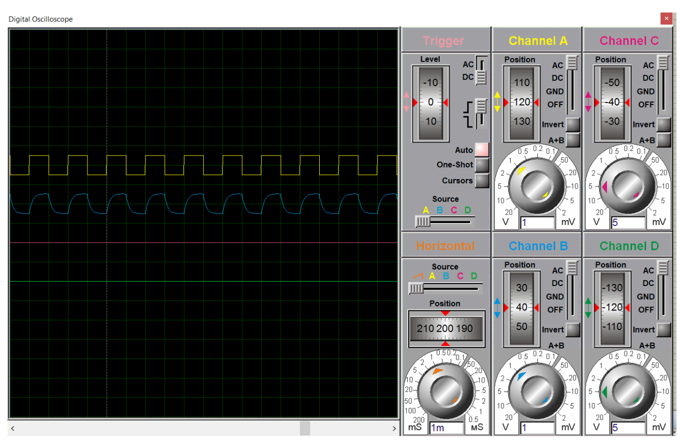


Fig. 3. Pulse frequency response

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B. Part B — RLC Band Pass Filter

1) - Deriving R and C: : The bandwidth of a band-pass filter is defined as:

$$BW = \frac{R}{2\pi L} \tag{5}$$

Rearranging to fin R we get:

$$R = 2\pi BWL = 31.416 \tag{6}$$

The resonance frequency f_0 for a band-pass filter is given by:

$$f_0 = \frac{1}{2\pi\sqrt{LC}} \tag{7}$$

Solving for C we get:

$$C = \frac{1}{(2\pi f_0)^2 L} = \frac{1}{1580000} \tag{8}$$

2) - Deriving Q::

$$Q = \frac{f_0}{BW} = \frac{2000\ Hz}{500\ Hz} = 4 \tag{9}$$

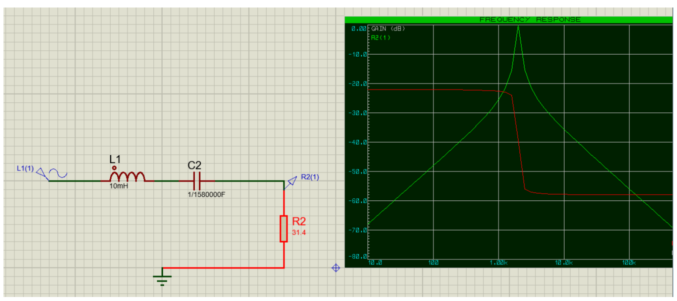

Fig. 4. Center frequency = 2k Hzand BW = 500 Hz as expected.

3) - Frequency Response Simulation: :

4) - R Effects on BW and Q Analysis: : Since Q is:

$$Q = \frac{\sqrt{L}}{RC} \tag{10}$$

It is clear that by increasing the value of R, Q decreases and as we know, the smaller the Q, the wider the BW and vice versa.

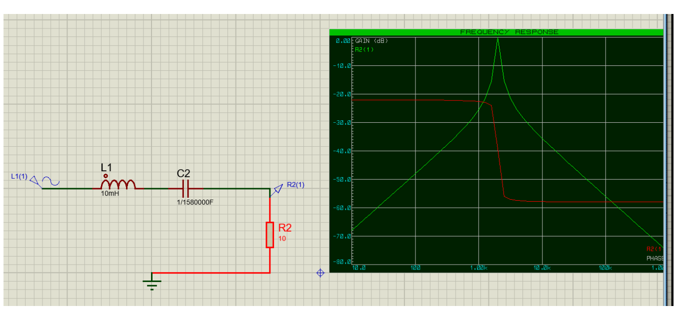

Fig. 5. Result for R = 10 , Q is greater and thus BW is narrower.

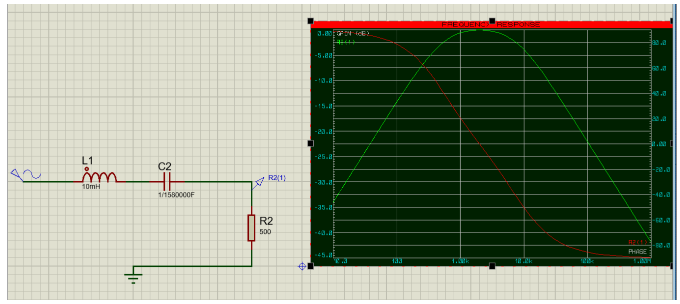

Fig. 6. Result for R = 500 , Q is smaller and consequently BW is wider.

C. Part D — LC Notch

1) - Determine L given that $C = 1_F$ and $f_0 = 60\ Hz$::

$$Since\ f_0 = \frac{1}{2\pi\sqrt{LC}} \tag{11}$$

$$we\ get\ L = \frac{1}{(2\pi f_0)^2 C} = 7.006\ mH \tag{12}$$

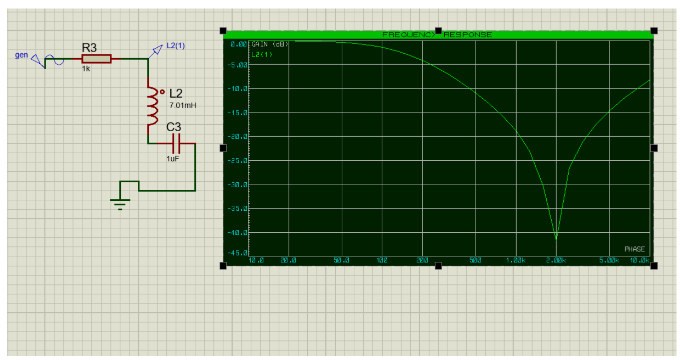

Fig. 7. notch filter simulation

2) - Frequency Response Simulation: :

3) - Suggestions: : To improve the performance of the notch filter, the following strategies can be used:

1) Adjust Damping: Adjust the value of the resistor R to fine-tune the quality factor Q. A higher R will allow for broader performance, while a lower R will create a sharper notch.
2) Use High-Q Components: Use inductors and capacitors with higher quality factors to lower losses at the target frequency.
3) Active Notch Filter: Consider designing an active notch filter using operational amplifiers to provide better control over gain and attenuation characteristics.
4) Tune Component Values: After initial testing, you may find that slight adjustments in component values can lead to better attenuation at the target frequency.
5) Simulation: Perform iterative simulations to observe how variations in L, C, and R affect the frequency response.
1) Adjust Damping: Adjust the value of the resistor RR to fine-tune the quality factor Q. A higher R will allow

for broader performance, while a lower R will create a sharper notch.
2) Use High-Q Components: Use inductors and capacitors with higher quality factors to lower losses at the target frequency.
3) Active Notch Filter: Consider designing an active notch filter using operational amplifiers to provide better control over gain and attenuation characteristics.
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III. Problem 2— Comparator vs. Schmitt Trigger

A. Part A and B

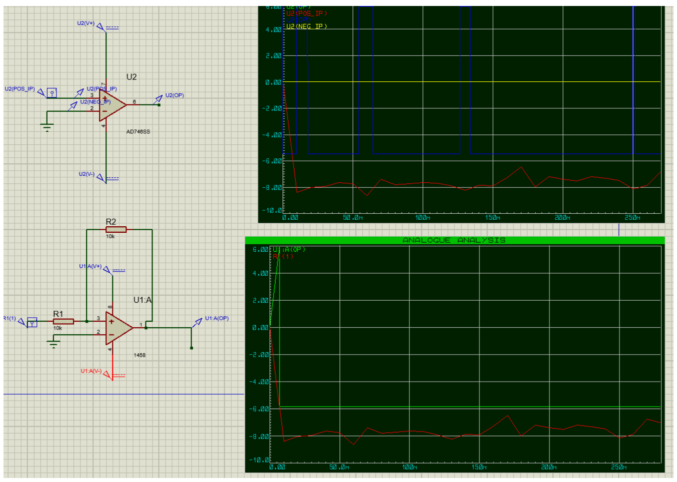


Fig. 8. comparator vs. Schmitt trigger with hysteresis

Calculating Resistor Values for Hysteresis (part B):

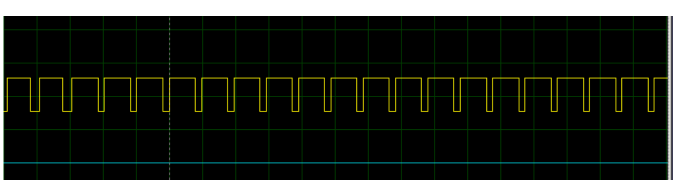
A common starting point is using $R1 = 10kt\ and\ R2 = 10k$This configuration will create two conditions for switching:

- – Upper Threshold: $V_{TH} = \frac{V_{out}}{R1/(R1+R2)}$
  – Lower Threshold: $V_{TL} = \frac{V_{out}}{R2/(R1+R2)}$

Both the comparator and Schmitt Trigger circuits will handle and analyze the noisy signals. The Schmitt Trigger, with hysteresis, is particularly effective at ensuring stable transitions in output, which improves performance in noisy environments.

IV. Problem 3— Biomedical Signal Processing with STM32

A. Part A



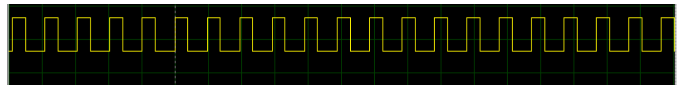


Fig. 9. The noisy output PWB signal.

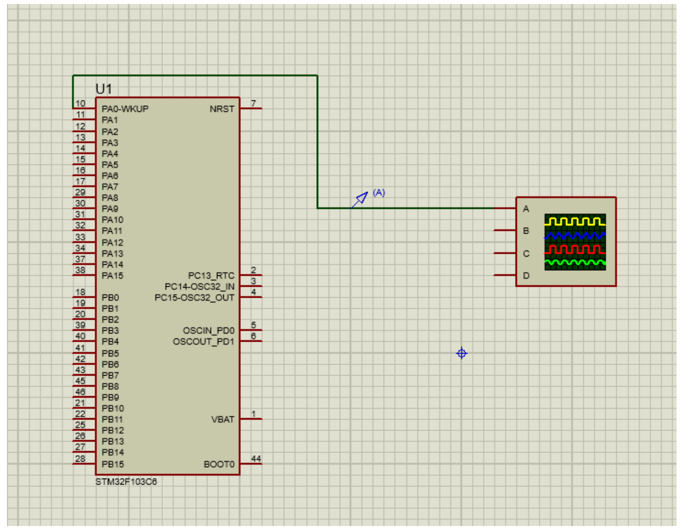


Fig. 10. Simulation in Proteus

B. Part B

To filter the noise, I designed a RC Low Pass filter since body's signals are low in frequency. Since EMG signals

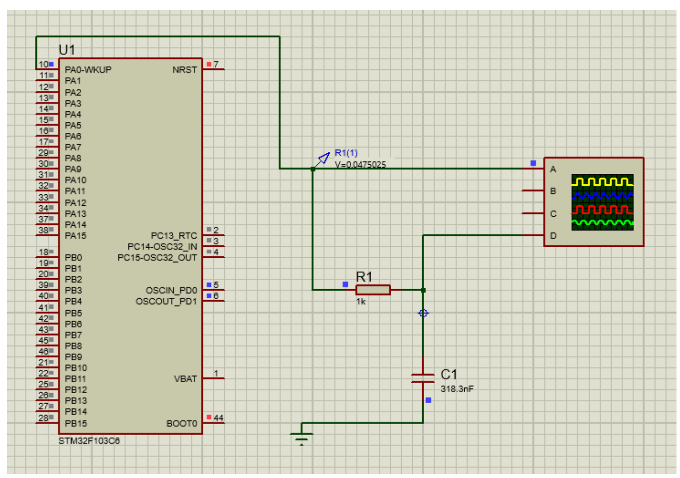


Fig. 11. RC Low pass filter in Proteus

typically have frequencies up to 500 Hz, a cutoff frequency around 500 Hz will help filter out unwanted high-frequency noise. The formula for the cutoff frequency f_c an RC filter is given by:

$$f_c = \frac{1}{2\pi RC} \tag{13}$$

- Resistor $R = 1k$
- Capacitor $C318.3nF$.

- This would result in a cutoff frequency of roughly 500 Hz.

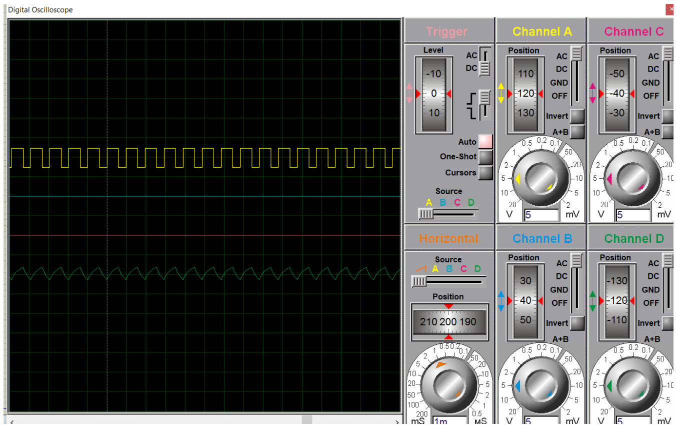


Fig. 12. Green represents the filtered signal.

The filtered signal is no longer square shape, since certain frequencies required for that shape are filtered, also nonuniform phase shift along different frequencies has led to this shape.

The DAC is missing in the above pictures, but it does exist in the file and was accounted for in the simulation:)

C. Part C—Amplify the signal

— To achieve a gain of 5:

$$Gain = 1 + \frac{R_f}{R_{in}} \tag{14}$$

- $Rf = 4.0k$
- $Rin = 1.0k$

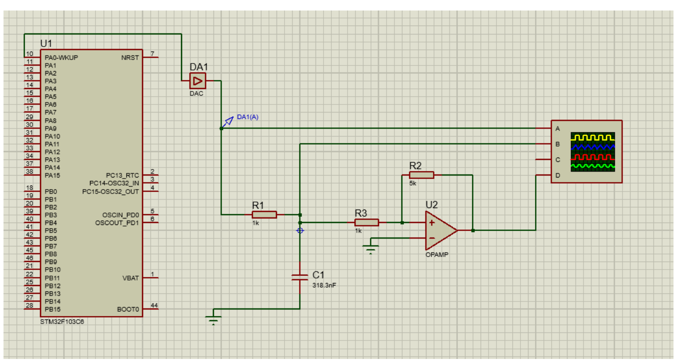


Fig. 13. The required circuit in Proteus

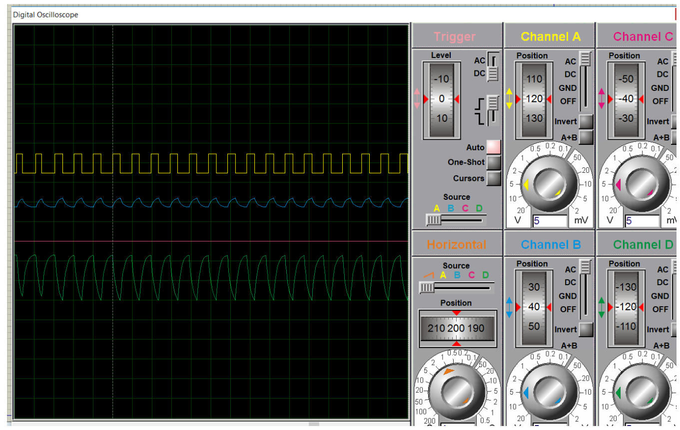


Fig. 14. Green represents the amplified output signal.

D. Problem 4

— Digital Controllers It is worth mentioning that the below controller doesn't work (same goes for my brain).

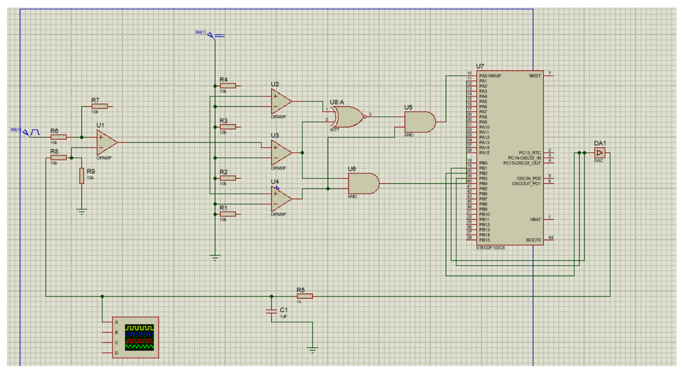


Fig. 15. How I wired up the controller