BAŞKENT UNIVERSITY

DEPARTMENT OF

ELECTRICAL AND ELECTRONICS ENGINEERING

EEM 313 ELECTRONICS II

EXPERIMENT 10
Active Low Pass Filter Calculations

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Aim:

The aim of this laboratory experiment is to investigate the gain variation of an active low-pass filter as a function of load resistance, achieved by introducing a potentiometer into the circuit. Additionally, the experiment aims to analyze the impact of load resistance on the cutoff frequency and gain characteristics of the active low-pass filter.

Why Use a Low-Pass Filter:

A low-pass filter is a crucial electronic component designed to allow signals with frequencies lower than a certain cutoff frequency to pass through while attenuating higher-frequency components. In the context of this experiment, the low-pass filter is employed to selectively transmit signals below the cutoff frequency, demonstrating its application in audio and signal processing systems. The investigation into gain changes with a potentiometer connected to the load aims to provide insights into the adaptability of the filter to different load conditions.

Cut-off Frequency:

The cutoff frequency in a low-pass filter is a critical parameter that defines the point at which the filter begins attenuating or blocking higher-frequency components of a signal. In the context of a low-pass filter, the purpose is to allow signals with frequencies below the cutoff frequency to pass through relatively unaffected, while attenuating or reducing the amplitudes of signals with frequencies above this point. (Note that, the experimental and simulation calculations is going to exceed the ideal cut-off frequency. Because of that, you must consider 3dB point.)

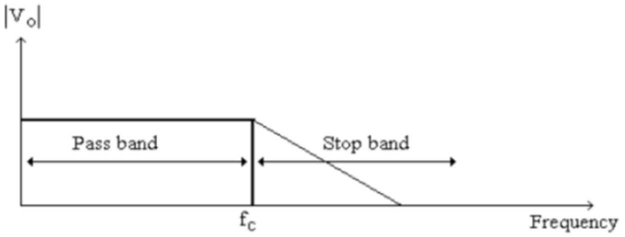


Fig 1.a. Frequency responses of low-pass filter

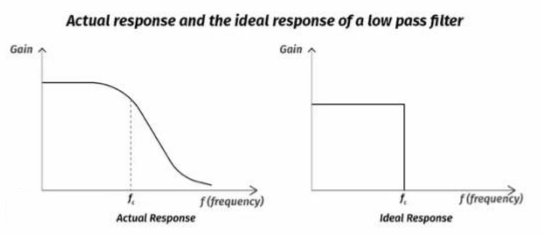


Fig 1.b. Actual and ideal response of low-pass filter

This experiment delves into the intricate interplay of load resistance, cutoff frequency, and gain in the realm of active low-pass filters. By dynamically adjusting the load resistance with a potentiometer, we aim to glean insights into the real-world implications and applications of low-pass filters within electronic circuits.

Low-pass Filter Representation and Calculations:

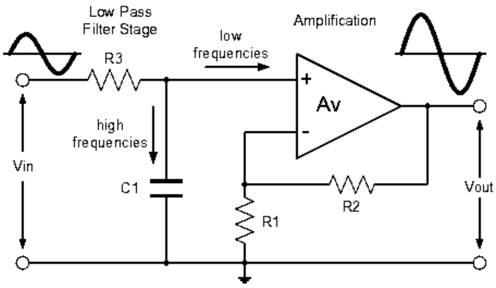


Fig 2. Active Low Pass Filter with Amplification

$$f_c = \frac{1}{2\pi RC} \; where,$$

$$C: capacitive\ reactance,$$
$$f_c:\ cut-off\ frequency\ of\ the\ input\ signal,$$
$$R: capacitance\ of\ the\ capacitor.$$

$$V_{out} = \frac{R_1 + R_2}{R_1} V_{in} = \ 1 + \frac{R_2}{R_1} V_{in}$$

$$DC\ Gain\ (the\ pass\ band\ gain\ of\ the\ filter) = \frac{V_{out}}{V_{in}} = \ 1 + \frac{R_2}{R_1}$$

$$At\ very\ low\ frequencies, f < fc \ \rightarrow \ \frac{V_{out}}{V_{in}} = \ 1 + \frac{R_2}{R_1}$$

$$At\ the\ cut-off\ frequency, f = fc \rightarrow \ \frac{\frac{V_{out}}{V_{in}}}{\sqrt{2}} = \ (.707) 1 + \frac{R_2}{R_1}$$

$$At\ very\ high\ frequencies, f > fc \ \rightarrow \ \frac{V_{out}}{V_{in}} < \ 1 + \frac{R_2}{R_1}$$

$$Av\ (in\ dB) = 20 \log \frac{Vout}{Vin}\ and\ 20 \log\left(\frac{Vout}{Vin} * .707\right) = -3dB\ (f = fc)$$

Experiment:

Set up a low pass circuit with following conditions and do calculations:

- f_c = 159 Hz. (Use RC filter)
- Calculate DC gain for 1kHZ sinusoidal wave peak voltage = 5V
  - Initially set V_{out} up for unity – gain ($V_{in} = V_{out}$)
  - $A_v = 2$
  - $A_v = 6$

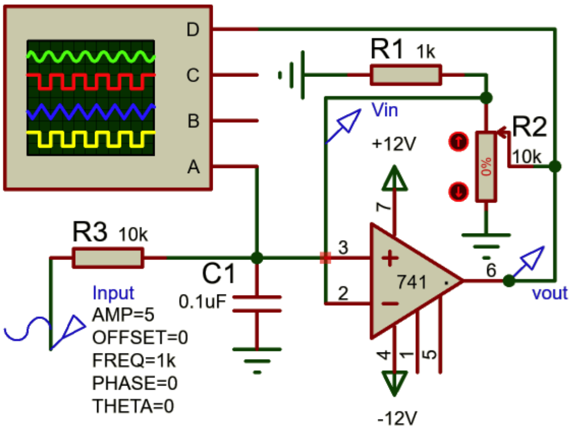
Preliminary Work:

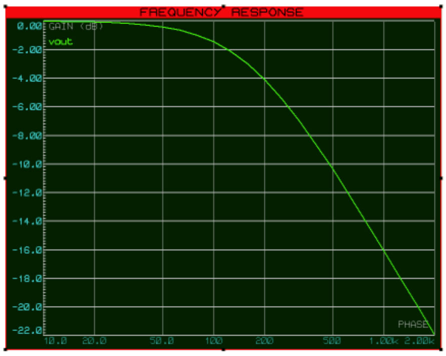
- Calculate required resistance for 159Hz and 0.1uF capacitor.
- Simulate experiment on Proteus.

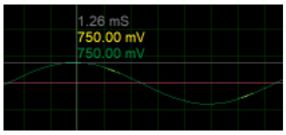
$$f_c = \frac{1}{2\pi RC} = 159Hz.$$

For 0.1uF capacitor: $R = \frac{1}{2\pi(159Hz)(0.1uF)} = 10009\Omega \cong 10k\Omega$

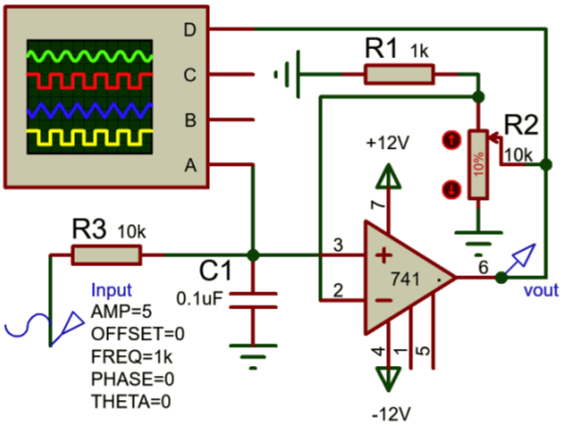
1. Unity – gain $A_v = (1 + R_2 / R_1) = 1$ > $R_2 = 0$. > $\textit{Gain in dB} \rightarrow 20\log\frac{Vout}{Vin} = 20log1 = 0.$

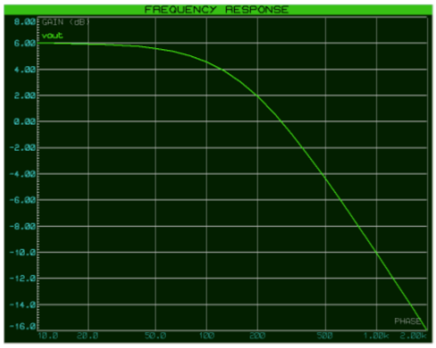


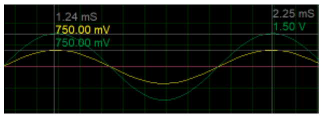




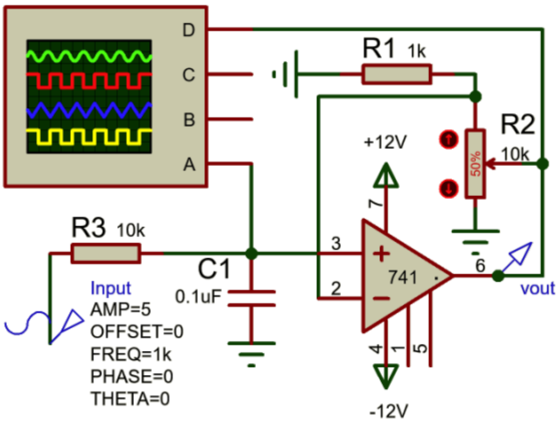
1. $A_v = (1 + R_2 / R_1) = 2$ > $R_2 = R_1$. > $\textit{Gain in dB} \rightarrow 20\log\frac{Vout}{Vin} = 20log2 = 6.02\ dB.$

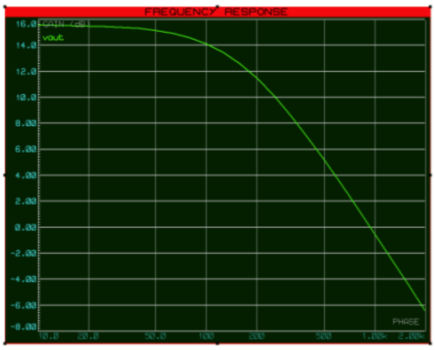


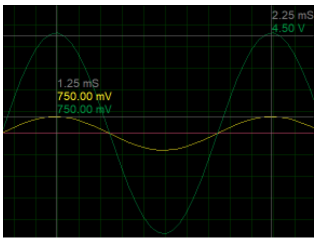




2. $A_v = (1 + R_2 / R_1) = 6$ > $R_2 = 5R_1$. > $\textit{Gain in dB} \rightarrow 20\log\frac{Vout}{Vin} = 20log5 = 15.56\ dB.$







Experimental Setup: Low-Pass RC Filter Circuit

Components Needed:

1. Resistor (R)
2. Capacitor (C)
3. Operational Amplifier (Op-Amp)
4. Signal Generator
5. Oscilloscope
6. Connecting wires
7. Breadboard

Circuit Configuration:

1. Connect the non-inverting input (+) of the operational amplifier to the signal source (Vin).
2. Connect the inverting input (-) of the operational amplifier to the junction of the resistor (R) and capacitor (C).
3. Connect the other end of the resistor to the output (Vout) of the operational amplifier.
4. Connect the other end of the capacitor to the ground.
5. Connect the output (Vout) to the oscilloscope for observation.

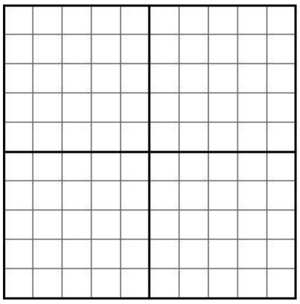
Steps:

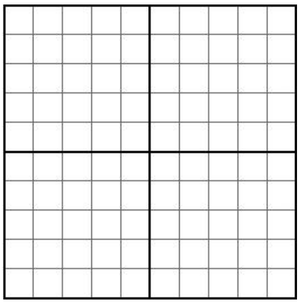
1. Set up the Initial Conditions:

- Connect the circuit components according to the configuration.
- Use a signal generator to input a sinusoidal wave with a frequency of 159 Hz (cutoff frequency) and peak voltage of 5V.
- Initially, set the gain (Av) of the operational amplifier such that Vin = Vout, achieving unity gain.

2. Calculate DC Gain for Unity Gain (Av = 1):

- Measure the output voltage (Vout) using an oscilloscope.
- Calculate the DC gain
- Record the DC and dB gain for unity gain.

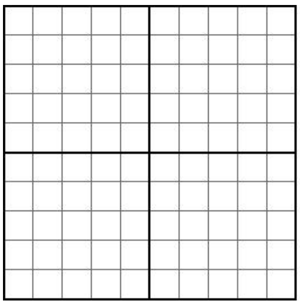


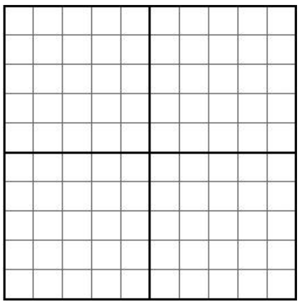


V / Div	
Sec / Div	
R_1	
R_2	
V_{in}	
V_{out}	
A_v	
A_v (dB)	

3. Adjust Amplification (Av = 2):

- Adjust the gain (Av) of the operational amplifier to 2.
- Measure the output voltage (Vout) and calculate the DC gain.
- Record the DC and dB gain for Av = 2.

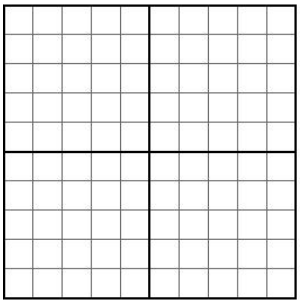


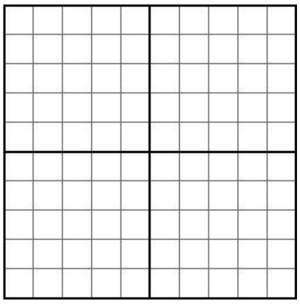


V / Div	
Sec / Div	
R_1	
R_2	
V_{in}	
V_{out}	
A_v	
A_v (dB)	

4. Adjust Amplification (Av = 6):

- Adjust the gain (Av) of the operational amplifier to 6.
- Measure the output voltage (Vout) and calculate the DC gain.
- Record the DC and dB gain for Av = 6.





V / Div	
Sec / Div	
R_1	
R_2	
V_{in}	
V_{out}	
A_v	
A_v (dB)	

5. Analysis:

- Compare the calculated gains for different amplification settings.
- Ensure that the circuit behaves as a low-pass filter by observing the attenuation of higher frequencies.

Note:

- Ensure that the resistor and capacitor values are selected to achieve the desired cutoff frequency (fc = 159 Hz) according to the formula above.
- Use appropriate precautions to prevent damage to the components and ensure safe experimentation.

References:

1. https://www.ee.hacettepe.edu.tr/~hakan/labs/ELE313/exp_pre6.pdf Access Date: Dec 9, 23.

2. https://www.electronics-tutorials.ws/filter/filter_5.html Access Date: Dec 9, 23.

3. Alexander, C. K., & Sadiku, M. N. O. (2017).
Fundamentals of Electric Circuits (6th ed.). McGraw-Hill Education.

Analysis of Experimental Results: