Brac University
Department of Electrical & Electronic Engineering
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Course Number EEE308L

Course Title Electronic Circuits II Laboratory

Section: 01

Open Ended Problem

Group Number: 02

Group members:

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Objective :

To design and implement a 3rd order active filter for a tweeter speaker in order to achieve the specified frequency response requirements. The goal is to reject all sounds with frequencies below a certain threshold, which is 12 kHZ in our case as our group number is 2.

Equipments :

- DC source (+15V and -15V)
- AC source
- Resistors
- Capacitors(10nF)
- Op-Amp (741)
- Breadboard
- jumper Wires
- Multimeter
- 5k Ohm Potentiometer

Methodology

Our design methodology entails the strategic arrangement of cascaded Sallen and Key high-pass filters, characterized by their second-order response, followed by the integration of their collective output with a first-order high-pass filter. This deliberate configuration aims to achieve a precise and efficient frequency response tailored to our specific signal processing objectives. The Sallen and Key filter, a cornerstone of active filter design, presents a second-order transfer function that enables effective frequency selectivity. We cascade one 2nd order high-pass filter, we integrate their output with a 1st order high-pass filter. This final stage serves to further refine the frequency response to conform precisely to our desired specifications. The 1st order filter contributes an additional degree of control over the transition band, allowing for meticulous tuning of the roll-off slope and attenuation. The rationale behind this design methodology is rooted in the advantages of combining various order filters. The 2nd order Sallen and Key filters offer a balance between complexity and performance, providing satisfactory frequency discrimination while avoiding excessive circuitry. Moreover, the cascade configuration empowers us to sculpt the response according to the intricacies of the application at hand, optimizing the filter's behavior to seamlessly align with our requirements. In summary, our arrangement of cascaded 2nd order Sallen and Key high-pass filters, supplemented by a subsequent 1st order high-pass filter, embodies a methodical approach to achieving an intricate 3rd order high-pass response. This methodology capitalizes on the strengths of each filter stage, permitting us to realize a tailored frequency response that effectively discriminates against lower frequencies while permitting desired higher frequencies to pass through. By fusing theory and engineering acumen, this design not only realizes technical precision but also encapsulates the synergy between theoretical foundations and practical implementation.

calculation:

Filter-1 $a_1 = 0.9996$ $b_1 = 0.4772$

Filter-2 $a_2 = 0.756$ $b_2 = 0$

assume, $C = 10nF$

$f_c = 12KHz$

Second order HPF,

$$R_1 = \frac{1}{2\pi f_c a_1 C_1} = \frac{1}{2\pi(12\times10^3)(10\times10^{-9})(0.756)}$$

$$= 3.5086\,k\Omega$$

$$R_2 = \frac{a_2}{4\pi f_c C_1 b_2} = \frac{0.9996}{4\pi(12\times10^3)\cancel{(\times10^{-9})}(10\times10^{-9})(0.4772)}$$

$$= 1.3891\,k\Omega$$

First order HPF,

$$R_3 = \frac{1}{2\pi f_c a_1 C_1} = \frac{1}{2\pi(12\times10^3)(0.756)\times(10\times10^{-9})}$$

$$= 1.7543\,k\Omega$$

Here $C_1 = C_2 = C_3 = 10nF$

Detection of experimental errors and troubleshooting :

Trial and error using Pspice and troubleshooting

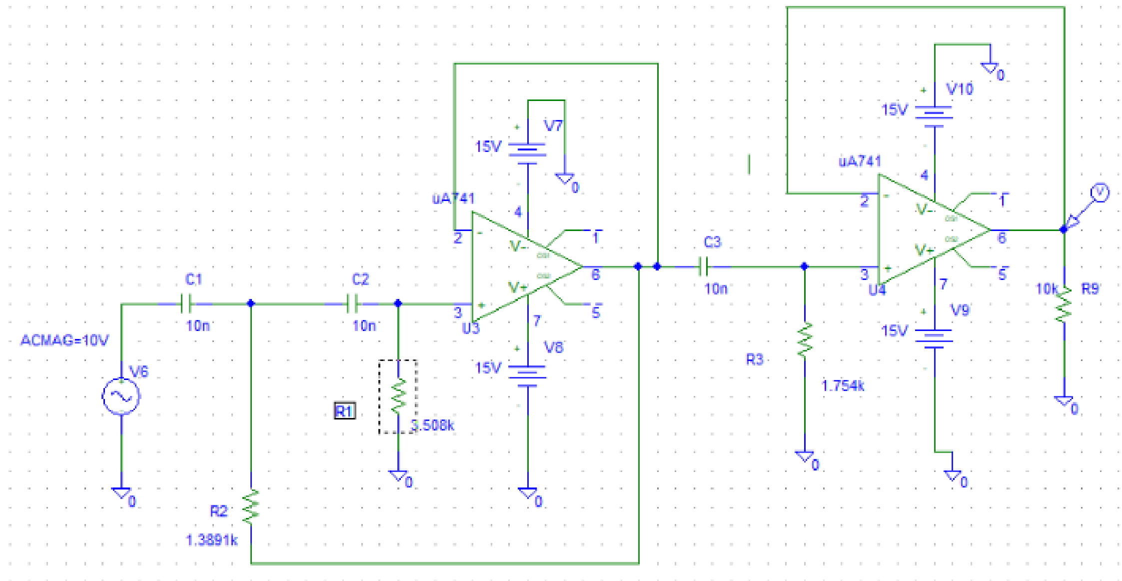
While doing the experiment we didn't face that much of trial and error as we used the supplement circuit to calculate the value. And after stimulation we got the cut off frequency. The Desired was 12K and we got 13K.

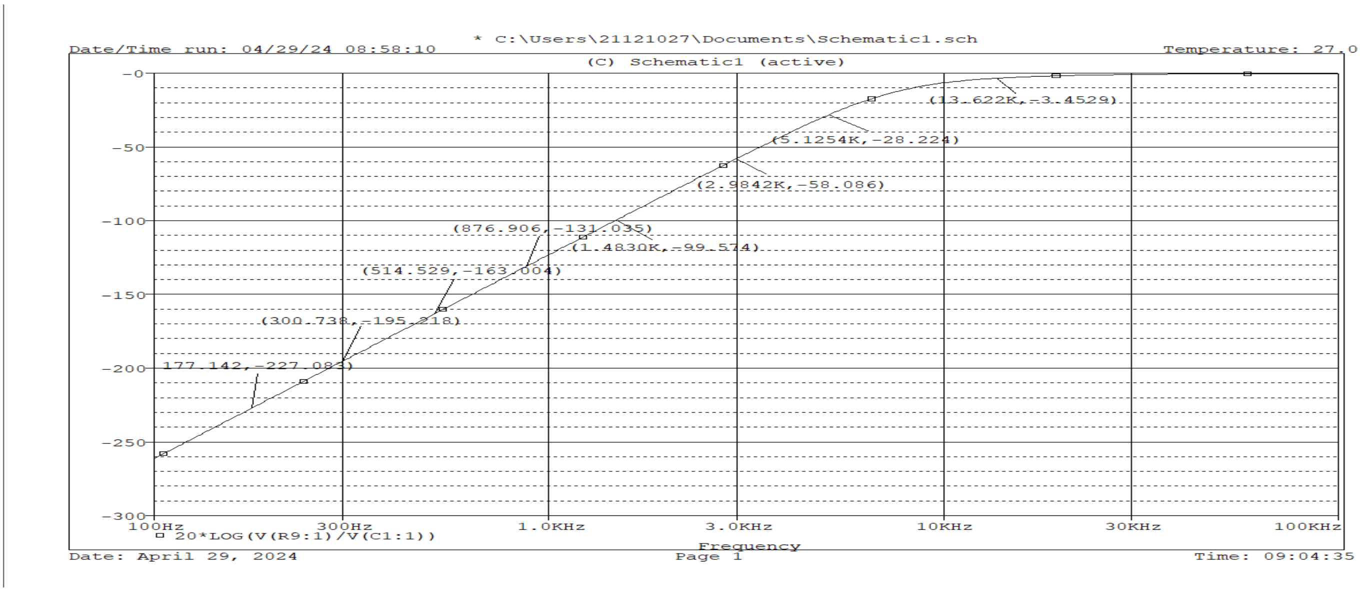
Hardware implementation issues and troubleshooting

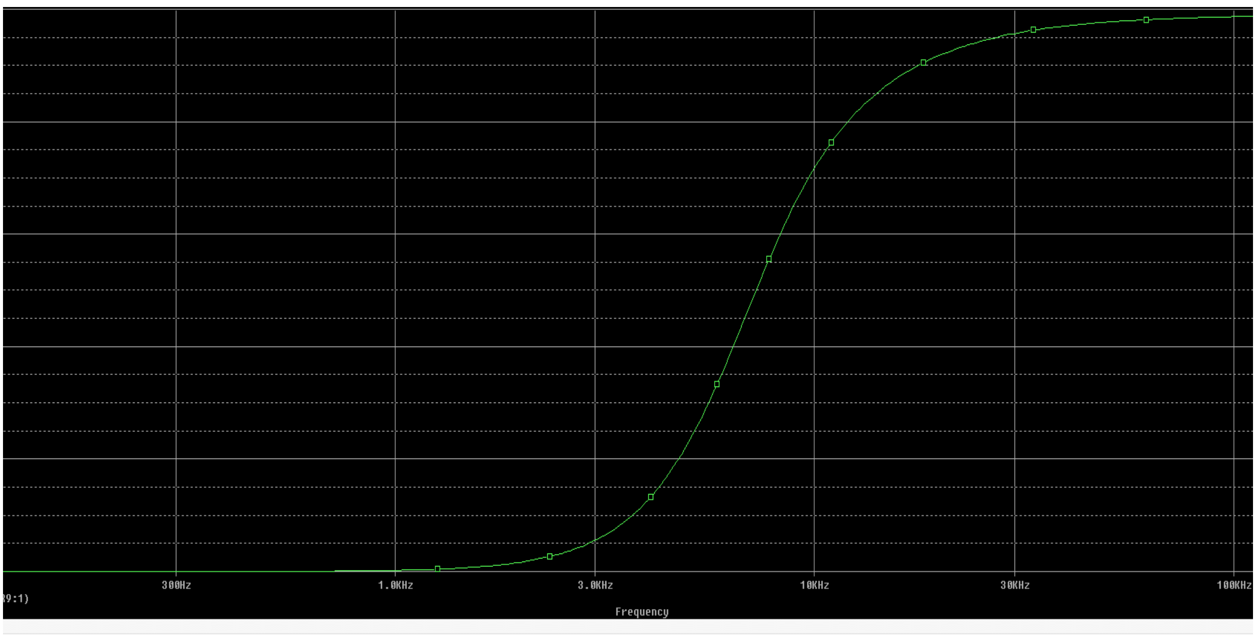
Unfortunately we could not find exact values of resistors, so we rounded up the resistor and made a series combination of some resistors using appropriate practical values close to it. Sometimes the biasing DC voltage fluctuates so we had to fix it with a multimeter. Also the labeled resistor values itself were not 100% accurate. Some wires and resistors were loosely connected so we carefully figured it out and fixed it. In the oscilloscope, sometimes there was a thin noise curve which we also compensated by adjusting the time/division. Also the oscilloscope showed fluctuation.

Experiments and measurements :

Circuit and Output gain shape

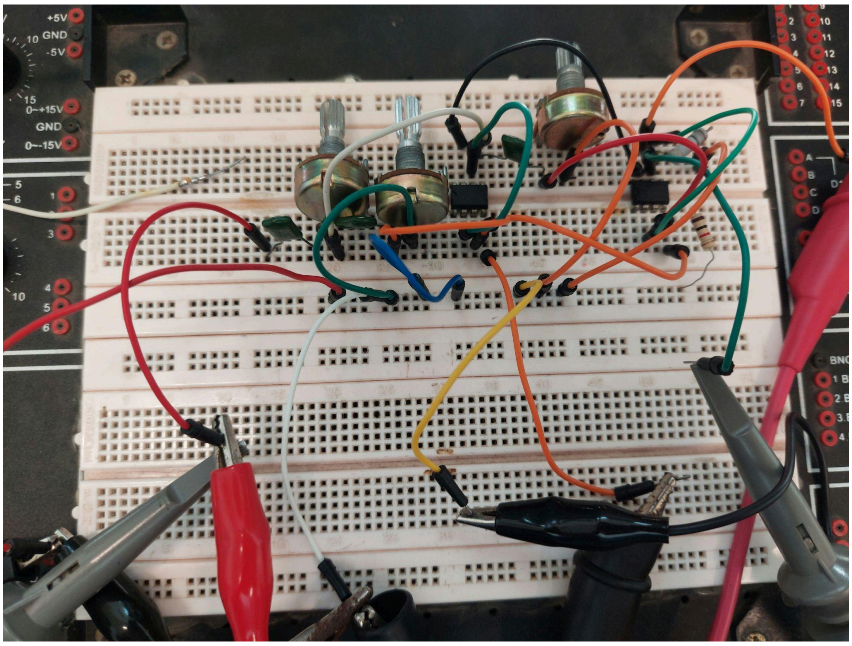






Hardware (Practical Verification):

Hardware setup:

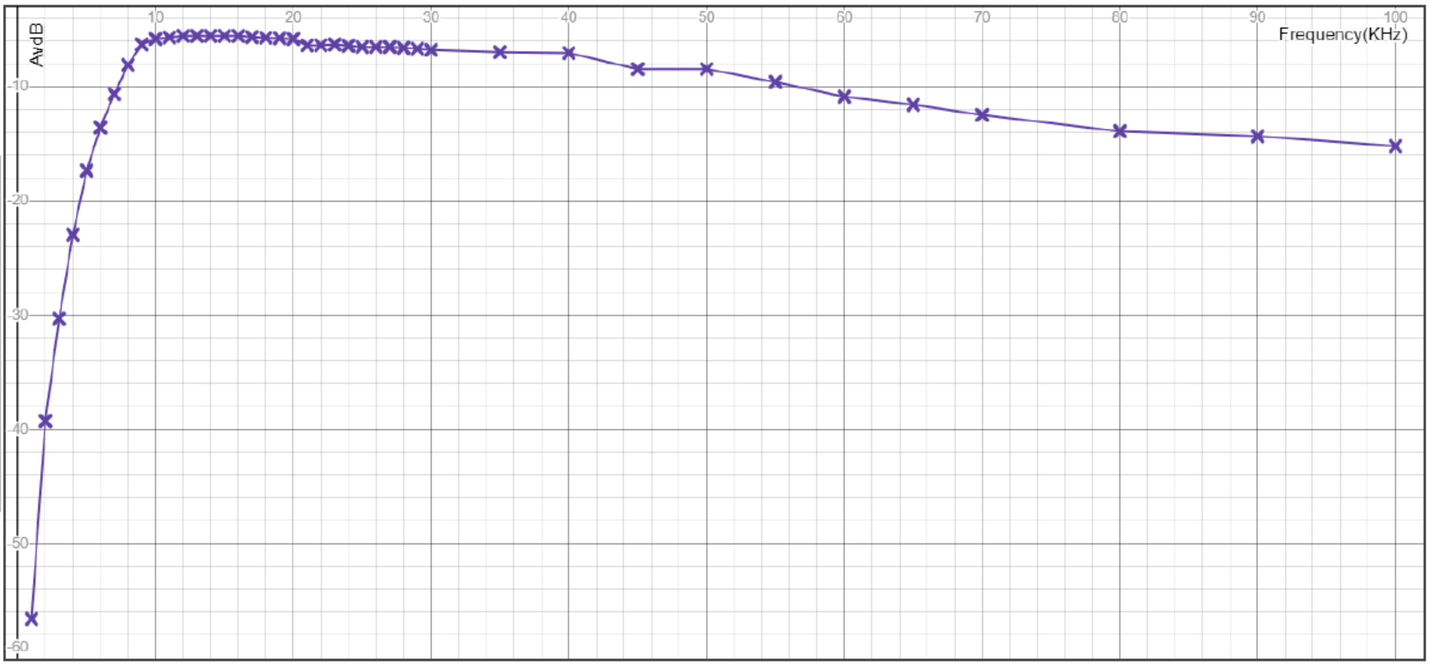


Data Table of hardware :

frequency(KHz)	Vout	Vin	AvdB=20log(Vout/Vin)
1	7.4mV	5V	-56.59
2	54.5mV	5V	-39.25
3	0.153V	5V	-30.29
4	0.356V	5V	-22.95
5	0.68V	5V	-17.33
6	1.05V	5V	-13.56
7	1.47V	5V	-10.63
8	1.97V	5V	-8.09
9	2.42V	5V	-6.30
10	2.56V	5V	-5.81
11	2.6V	5V	-5.68
12	2.64V	5V	-5.55
13	2.64V	5V	-5.55
14	2.64V	5V	-5.55
15	2.64V	5V	-5.55
16	2.64V	5V	-5.55
17	2.61V	5V	-5.65
18	2.59V	5V	-5.71
19	2.58V	5V	-5.75

20	2.56V	5V	-5.81
21	2.4V	5V	-6.38
22	2.4V	5V	-6.38
23	2.42V	5V	-6.30
24	2.39V	5V	-6.41
25	2.36V	5V	-6.52
26	2.36V	5V	-6.52
27	2.36V	5V	-6.52
28	2.34V	5V	-6.60
29	2.32V	5V	-6.67
30	2.29V	5V	-6.78
35	2.24V	5V	-6.97
40	2.22V	5V	-7.05
45	1.89V	5V	-8.45
50	1.89V	5V	-8.45
55	1.66V	5V	-9.58
60	1.43V	5V	-10.87
65	1.32V	5V	-11.57
70	1.19V	5V	-12.47
80	1.01V	5V	-13.89
90	0.96V	5V	-14.33
100	0.87V	5V	-15.19

Desmos graph :



Comments

Since we have rounded up resistor values closest to the practical values in hardware implementation, there was a slight shift of cut-off frequency which is what we expected while manipulating in the Pspice software. Other than that this was our closest possible outcome.

summary of the outcome :

Frequency Response Analysis

1. **Low-Frequency Attenuation**:

   - At frequencies well below the cutoff (1 kHz to 10 kHz), the filter shows significant attenuation of the output voltage (Vout) compared to the input voltage (Vin). The attenuation decreases as the frequency approaches the cutoff point.
   - At 1 kHz, the attenuation is at its highest with Vout at 7.4 mV from an input of 5 V, corresponding to an attenuation of about -56.59 dB.
   - The attenuation gradually lessens as the frequency increases, indicating the filter's effectiveness in suppressing lower frequencies.

2. **Near Cutoff Frequency:**
   - At around the cutoff frequency (12 kHz), the filter's output voltage begins to stabilize, indicating that frequencies at and above 12 kHz are passing through with minimal attenuation. This is evidenced by the output voltage Vout stabilizing around 2.64 V at frequencies from 12 kHz to 15 kHz, which corresponds to an attenuation of approximately -5.55 dB.

3. **High-Frequency Performance:**

   - Beyond the cutoff, from 16 kHz to 30 kHz, the output voltage slightly declines but remains relatively stable, indicating a good high-pass characteristic. This suggests that the filter allows high frequencies to pass with consistent minimal attenuation.

- At 30 kHz, Vout is 2.29 V, translating to an attenuation of -6.78 dB.

4. **Further Attenuation at Very High Frequencies:**
    - As the frequency increases further (35 kHz to 100 kHz), there is a noticeable gradual decrease in Vout, indicating additional attenuation at very high frequencies. This could be due to the inherent properties of the components used (e.g., capacitors, resistors) or the design of the filter itself.
    - At the highest tested frequency of 100 kHz, Vout is reduced to 0.87 V, corresponding to -15.19 dB attenuation.

Summary:

- The filter effectively attenuates frequencies below 12 kHz, demonstrating a sharp cutoff around the desired threshold, which supports its intended design as a high-pass filter.
- At and above the cutoff frequency, the filter maintains a relatively stable output with minimal attenuation, which is crucial for maintaining the integrity of the higher frequencies desirable for tweeter applications.
- The observed additional attenuation at very high frequencies (above 30 kHz) may require further investigation to ensure it does not impact the intended audio quality or could be considered an acceptable characteristic depending on the specific audio application.

This analysis suggests that the filter design meets the goal of rejecting frequencies below 12 kHz while allowing higher frequencies to pass with reasonable consistency and minimal loss, which is suitable for tweeter speakers in high-fidelity audio applications.