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2024-2025 Fall

EE-202 LAB 4 FINAL REPORT

1-Introduction

This lab explores the frequency response of RC and RL circuits. Key tasks include deriving transfer functions, analyzing responses using MATLAB, and validating them through LTSpice simulations. The study extends to higher-order filters by cascading RC stages and comparing theoretical, simulated, and measured results. Emphasizing gain and corner frequencies, the lab reinforces fundamental concepts in filter and circuit analysis within design constraints.

2-Analysis & Preliminary Work

A- First Order RC Circuit

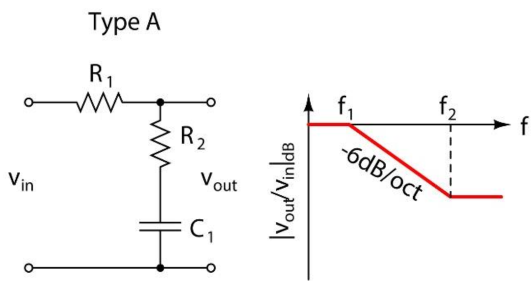

Figure.1: First Order RC Circuit

Given Values:

$ID: 22102104$

$f_1 = 5\ kHz, \quad f_2 = 120\ kHz$

Mathematical Derivations:

$$|\mathrm{H(w)}| = \sqrt{\frac{1 + (R_2 w C_1)^2}{1 + \left(w C_1 (R_1 + R_2)\right)^2}}$$

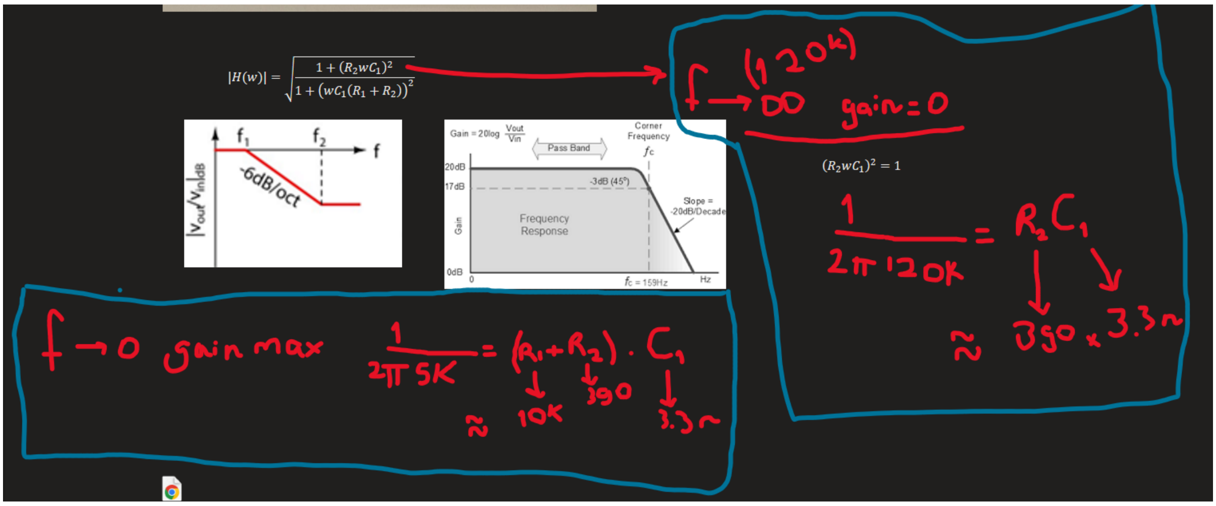

Figure.2: Mathematical Derivations

There are many problems in Preliminary Report so, new derivations were implemented.

Components were selected as,

$C_1 = 3.3\text{nF}\ R_1 = 10k\ R_2 = 390$

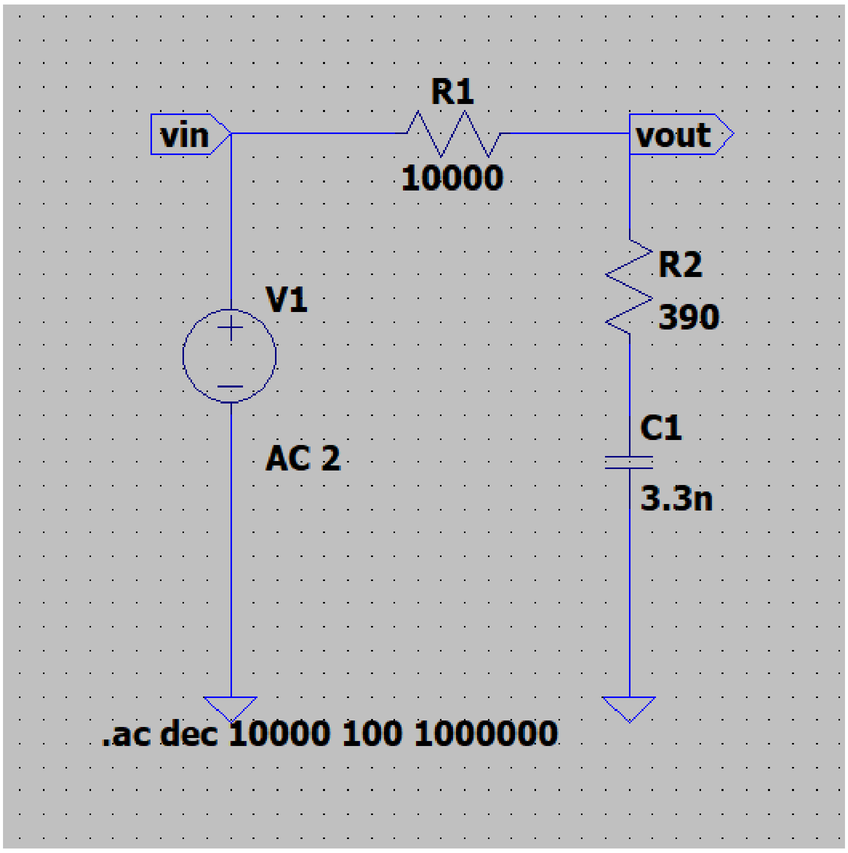

Figure.3: LTspice schematics for RC circuit.

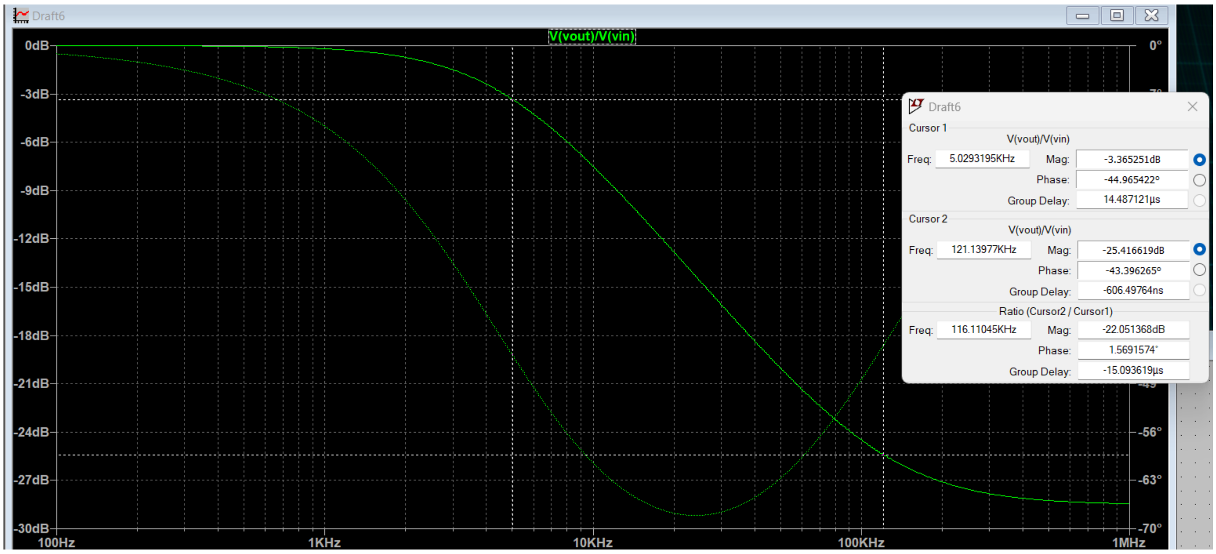

Figure.4: LTspice simulation for RC circuit

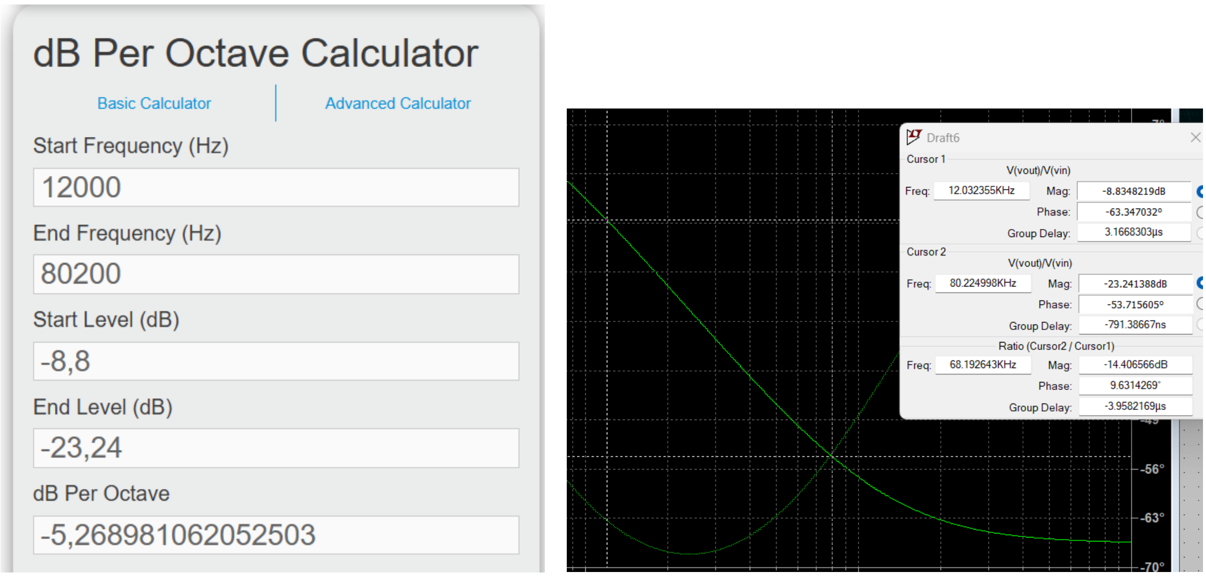

Figure.5: Appx. 6dB stop band

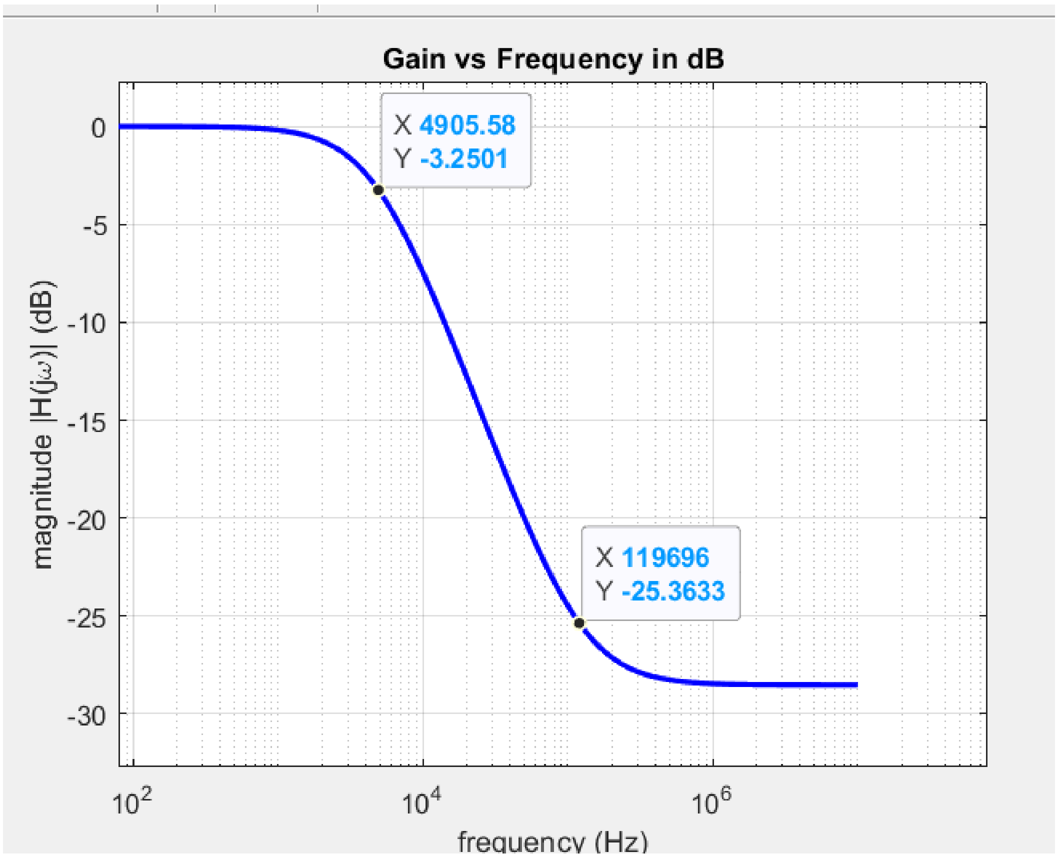

Figure4: MATLAB simulation for RC circuit

```
f = logspace(1, 7, 1000); % from 10 Hz to 10^7 Hz
omega = 2 * pi * f;

% Transfer function components
numerator = sqrt(1 + (R2 * omega * C1).^2);
denominator = sqrt(1 + (omega * C1 * (R1 + R2)).^2);
H_magnitude = numerator ./ denominator;

% Convert transfer function to dB scale
H_dB = 20 * log10(H_magnitude);

% Plot
figure;
semilogx(f, H_dB, 'b', 'LineWidth', 2); % Blue line for your transfer function
grid on;
xlabel('frequency (Hz)');
ylabel('magnitude |H(j\omega)| (dB)');
title('Gain vs Frequency in dB');
```

Figure.5: MATLAB code for LPF

B- Adding another RC circuit

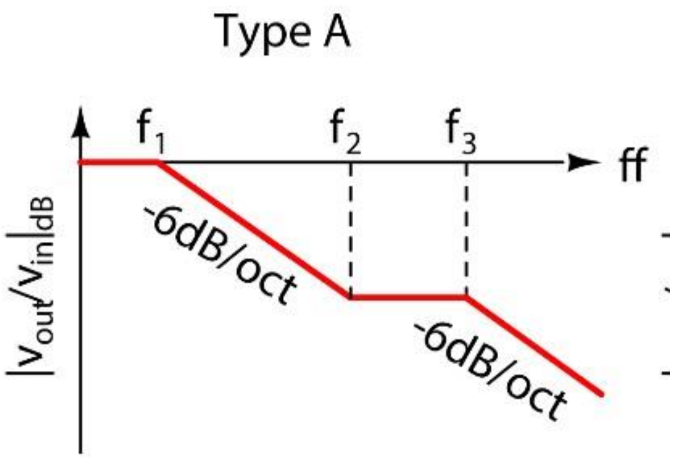

Figure.6: Final RC circuit

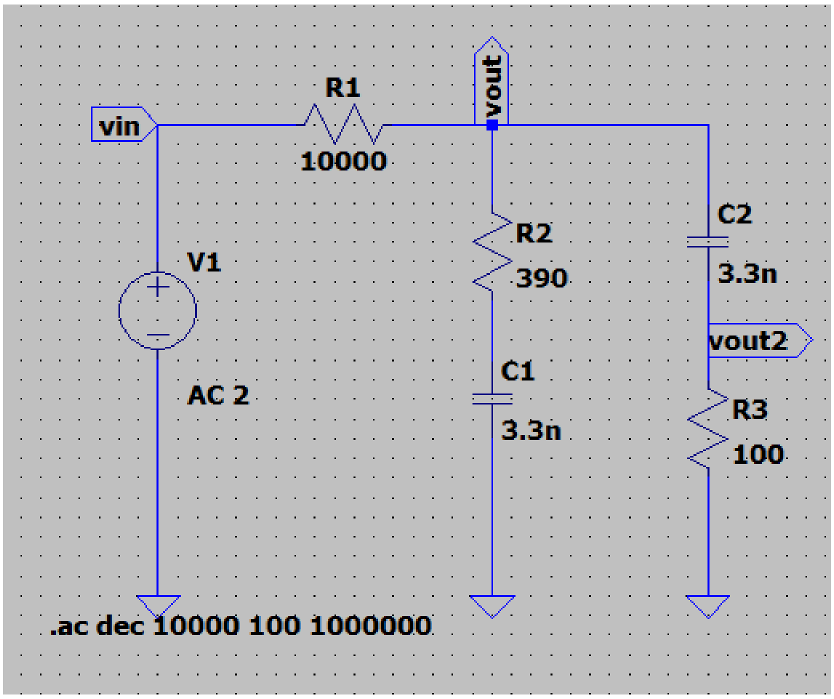

Figure.7: Final RC circuit, LTspice schematics

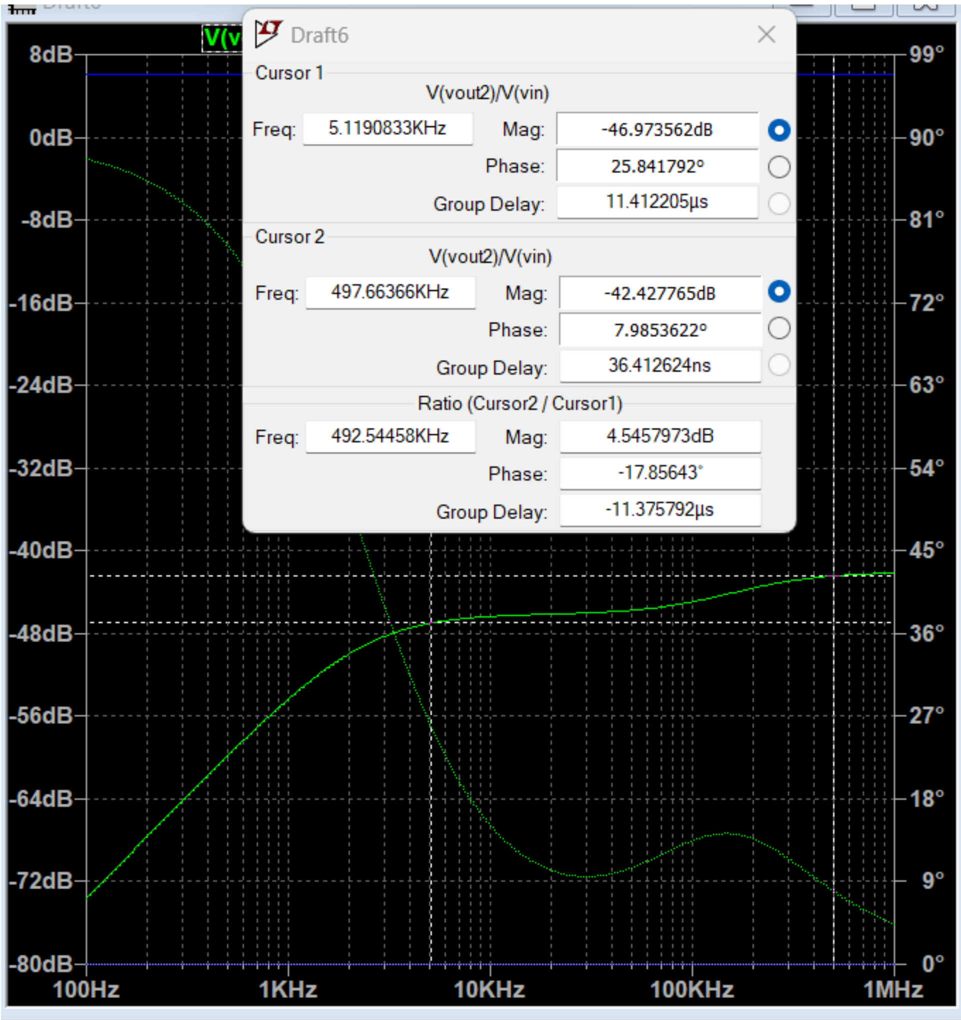

Figure.8: Final RC circuit, LTspice simulation

5-Hardware Implementation and Results

Component Selection: The component values for the circuit were determined using a Python program. The code was manually adjusted iteratively to refine the values until the desired conditions were met. The final component values obtained from this process functioned successfully in the circuit.

Further Optimization: The second stage of the experiment involved a more complex approach. In addition to analyzing mathematical calculations and Python-generated results, a trial-and-error method was employed to select the most suitable values. This iterative process helped finalize the component values, which were then implemented in the circuit.

Results

A- First Order RC Circuit

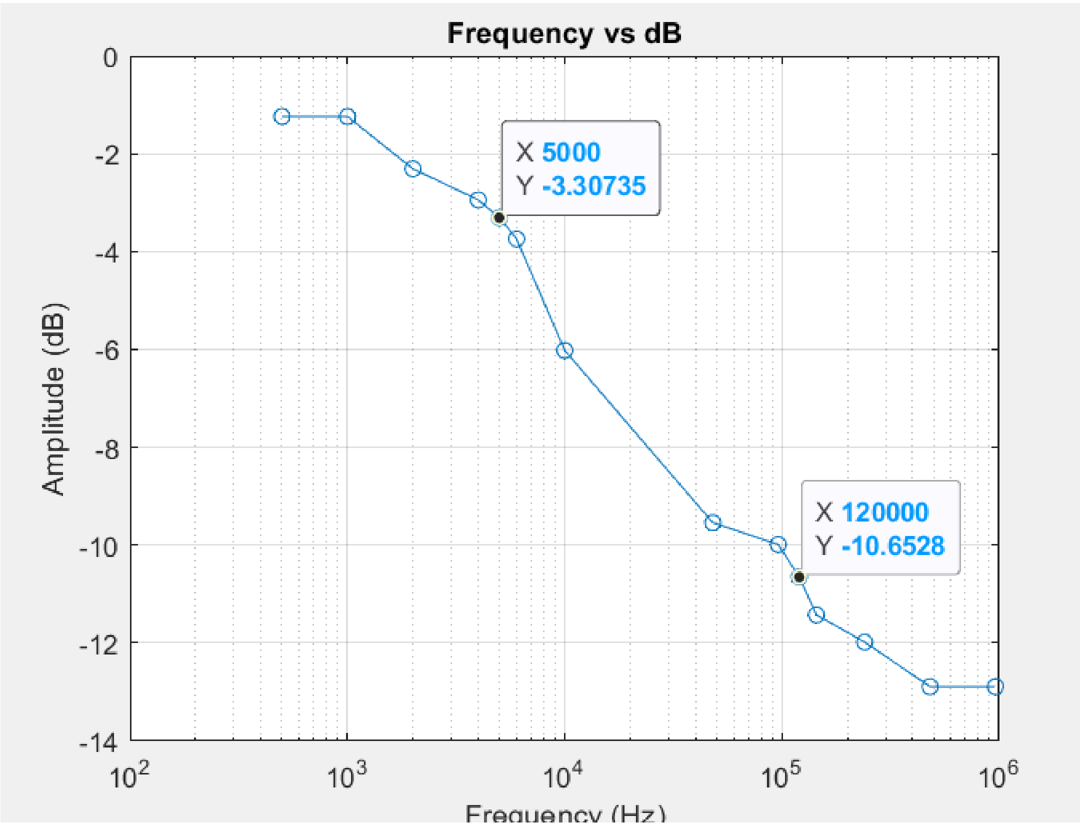

Figure.9: First part, MATLAB plot

There is -5.7dB/octave slope.

	Frequency (Hz)	Vin	V_ratio	dB
1	500	10400	0.8666666666666667	-1.2429581349768892
2	1000	10400	0.8666666666666667	-1.2429581349768892
3	2000	9200	0.7666666666666667	-2.3078683740413903
4	4000	8550	0.7125	-2.9443026263890437
5	5000	8200	0.6833333333333333	-3.3073478732781627
6	6000	7800	0.65	-3.7417328671428884
7	10000	6000	0.5	-6.020599913279624
8	48000	4000	0.3333333333333333	-9.54242509439325
9	96000	3800	0.31666666666666665	-9.987952988616293
10	120000	3520	0.29333333333333333	-10.652771651389877
11	144000	3220	0.2683333333333333	-11.42650748703588
12	240000	3020	0.25166666666666665	-11.983486061809485
13	480000	2720	0.22666666666666666	-12.892246840268522
14	960000	2720	0.22666666666666666	-12.892246840268522

Figure.10: First part Vout values

```
freq = [500, 1000, 2000, 4000, 5000, 6000, 10000, 48000, 96000, 120000, 144000, 240000, 480000,
960000];
Vin = [10400, 10400, 9200, 8550, 8200, 7800, 6000, 4000, 3800, 3520, 3220, 3020, 2720, 2720];
V_ratio = Vin / 12000;
dB = 20 * log10(V_ratio);
figure;
semilogx(freq, dB, '-o');
xlabel('Frequency (Hz)');
ylabel('Amplitude (dB)');
title('Frequency vs dB');
grid on;
```

Figure.11: MATLAB code for first part

B- Adding another RC circuit

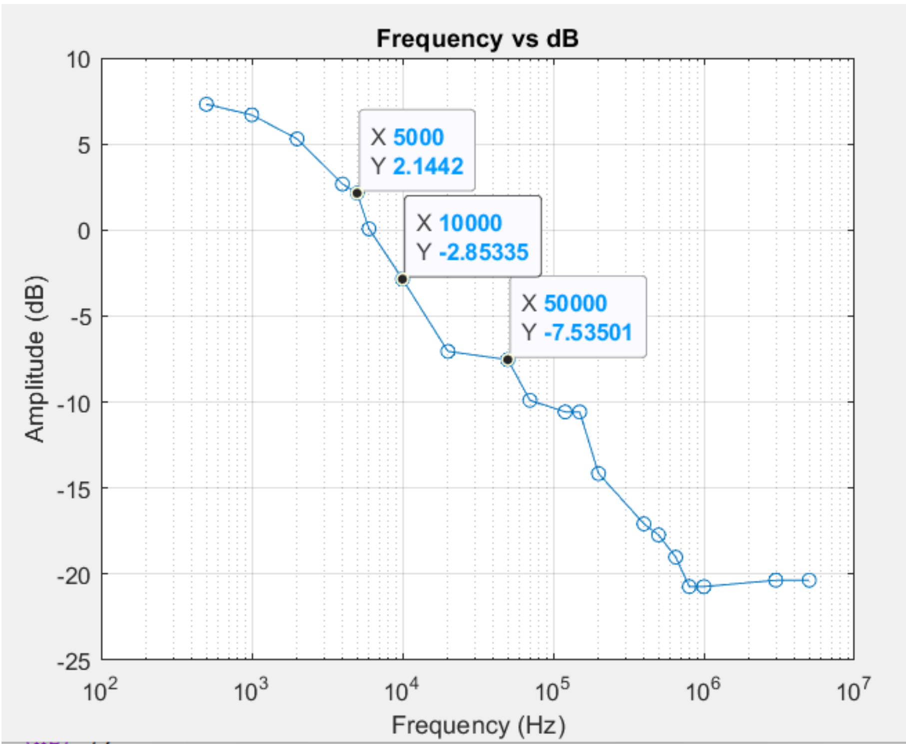

Figure.12: Second part, MATLAB plot

	Frequency (Hz)	Vin	Vout	dB
1	500	5000	11600	7.309759697817992
2	1000	5000	10800	6.689075023018618
3	2000	5000	9200	5.296356460190729
4	4000	5000	6800	2.6707781674043507
5	5000	5000	6400	2.1441993929573675
6	6000	5000	5040	0.06921064219012979
7	10000	5000	3600	-2.8533500713746314
8	20000	5000	2220	-7.0523405977076035
9	50000	5000	2100	-7.5350141920419915
10	70000	5000	1600	-9.89700043360188
11	120000	5000	1480	-10.574165778821229
12	150000	5000	1480	-10.574165778821229
13	200000	5000	980	-14.15487857287048
14	400000	5000	700	-17.07743928643524
15	500000	5000	650	-17.721132953863265
16	650000	5000	560	-19.01563954659637
17	800000	5000	460	-20.724243453088896
18	1000000	5000	460	-20.724243453088896
19	3000000	5000	480	-20.35457533920863
20	5000000	5000	480	-20.35457533920863

Figure.13: Second part, Vout values

```
freq = [500, 1000, 2000, 4000, 5000, 6000, 10000, 20000, 50000, 70000, 120000, 150000, 200000,
400000, 500000, 650000, 800000, 1000000, 3000000, 5000000];
Vin = [11600, 10800, 9200, 6800, 6400, 5040, 3600, 2220, 2100, 1600, 1480, 1480, 980, 700, 650,
560, 460, 460, 480, 480];
V_ratio = Vin / 5000;
dB = 20 * log10(V_ratio);
figure;
semilogx(freq, dB, '-o');
xlabel('Frequency (Hz)');
ylabel('Amplitude (dB)');
title('Frequency vs dB');
grid on;
```

Figure.14: MATLAB code for second part

6-Conclusion

Conclusion

The experiment successfully met its primary objective of designing and analyzing filters with specific slope characteristics. In the first phase of the experiment, the results were highly positive. The achieved slope of 5.7 dB/octave aligns closely with the theoretical expectations, confirming the validity of the design and component choices.

In the second phase, while the circuit demonstrated overall functionality, certain challenges were observed. These issues, likely due to experimental limitations or minor inaccuracies in setup, suggest that additional trials and refinements could further enhance performance. Despite these hurdles, the circuit operated within acceptable parameters, providing valuable insights for future iterations.

Overall, the experiment highlights the importance of precise measurements and iterative testing to optimize filter performance, particularly in circuits requiring critical frequency-dependent characteristics.