Lab Report 7: RC Filter Analysis

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1 Low-Pass Filter and Frequency Response

1.1 The Circuit

We constructed the following circuit:

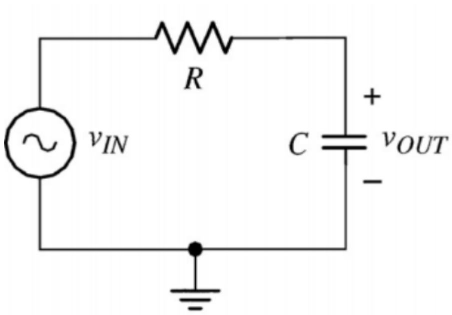


Figure 1: Circuit Diagram

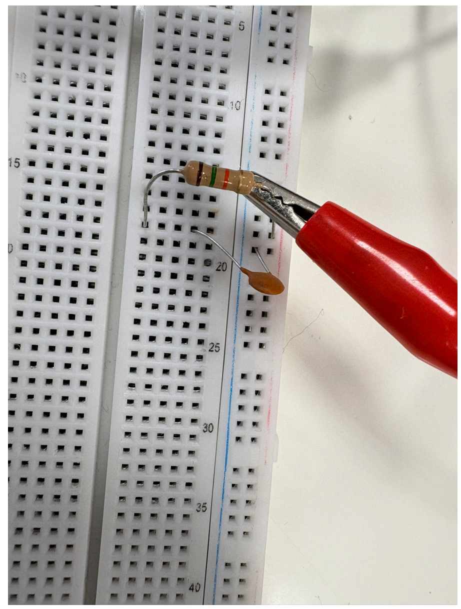


Figure 2: The circuit (red probe is the input)

1.2 Frequency Variations

We compared the output signal (yellow) with the input signal (blue) at various frequencies. We used a sinusoidal signal with 2V amplitude.

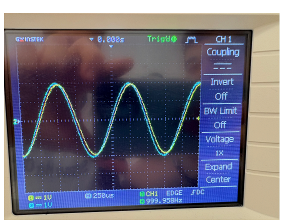


Figure 3: $f = 1\,kHz$

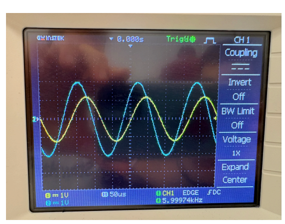


Figure 4: $f = 6\,kHz$

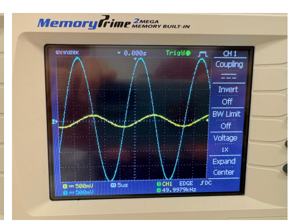


Figure 5: $f = 50\,kHz$

Observation

As frequency increases, the phase difference increases and the output amplitude decreases.

1.3 Theoretical and Experimental Cutoff Frequency

The theoretical value is $f_c = \frac{1}{2\pi RC} = 4822.877063\,Hz$. Starting from this value, we obtained $G = \frac{A_{out}}{A_{in}} = \frac{1.40\,V}{2\,V} = 0.7$. On the oscilloscope, with small frequency adjustments, we measured $A_{out} = 1.43\,V$ and $G = 0.715$. We kept the theoretical cutoff frequency value since the gain is closer to 0.707, which we were trying to achieve.

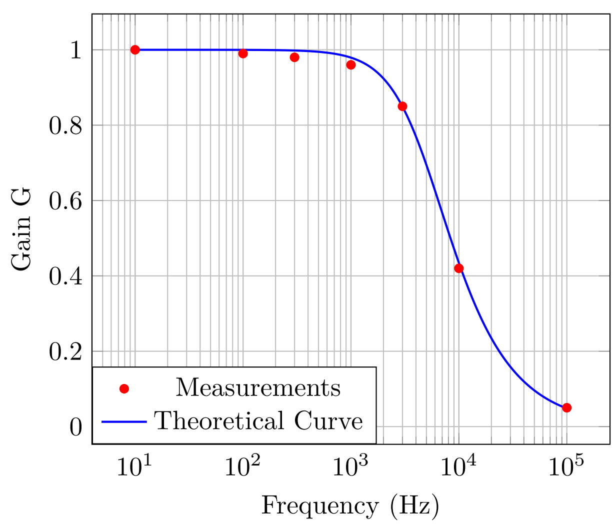
In conclusion, any deviations were too small to have a noticeable effect on the circuit.

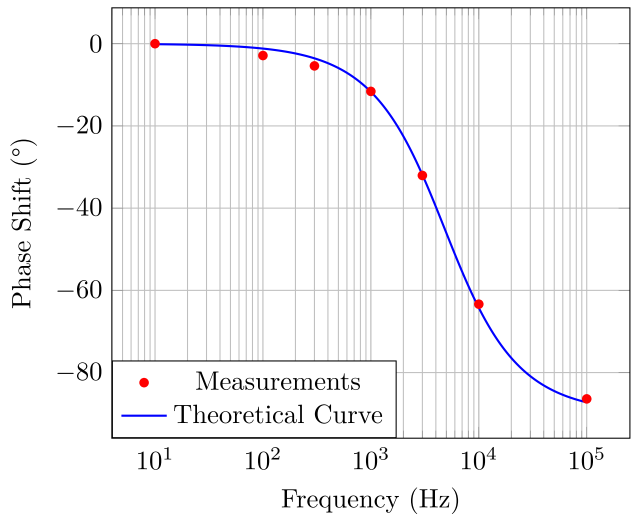
1.4 Amplitude and Phase Measurements

1.4.1 Measurements

Frequency (kHz)	A_{in} **(V)**	A_{out} **(V)**	**Gain G**	**Phase Shift (°)**
0.01	2.03	2.03	1.00	0.00
0.1	2.03	2.00	0.99	-2.88
0.3	2.07	2.03	0.98	-5.40
1	2.00	1.91	0.96	-11.6
3	2.00	1.70	0.85	-32.05
10	2.00	0.840	0.42	-63.36
100	2.00	0.096	0.05	-86.4

1.4.2 Gain vs Frequency (Bode Plot)





2 High-Pass Filter and Frequency Response

2.1 The Circuit

Using the same circuit, we swapped the positions of the resistor and capacitor:

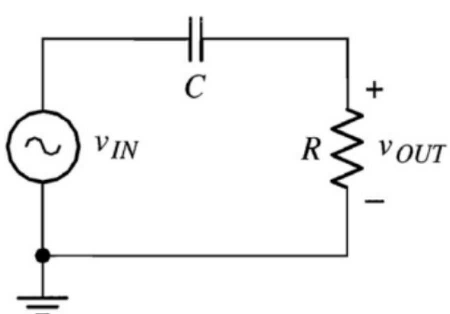


Figure 6: Circuit Diagram

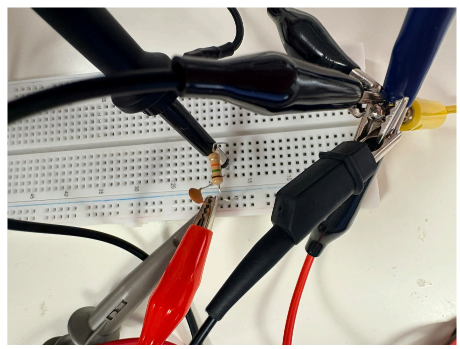


Figure 7: The circuit with oscilloscope probes for input and output (red probe is the input)

2.2 Frequency Variations

We compared the output signal (yellow) with the input signal (blue) at various frequencies. We used a sinusoidal signal with 2V amplitude.

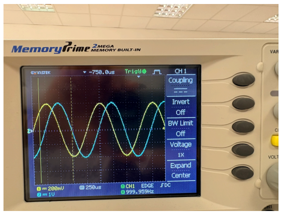


Figure 8: $f = 1\,kHz$

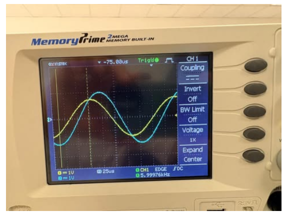


Figure 9: $f = 6\,kHz$

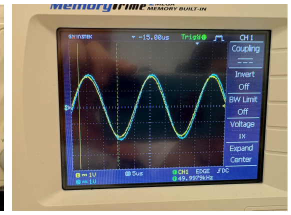


Figure 10: $f = 50\,kHz$

Observation

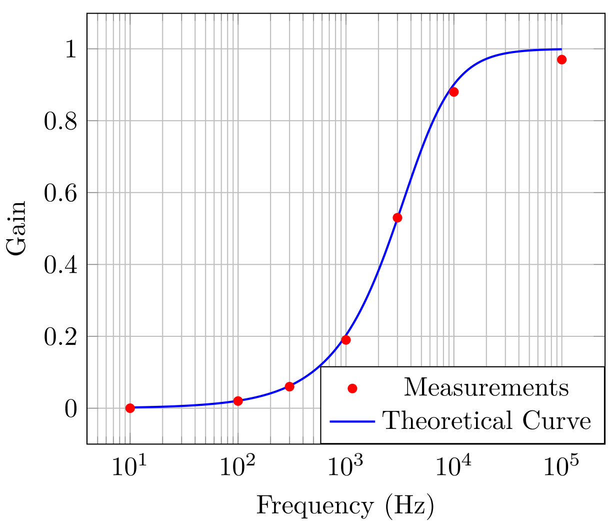
As frequency increases, the phase difference decreases and the output amplitude approaches the input amplitude.

2.3 Amplitude and Phase Measurements

2.3.1 Measurements

Frequency (kHz)	A_{in} **(V)**	A_{out} **(V)**	**Gain**
0.01	2.03	0.00	0.00
0.1	2.03	0.048	0.02
0.3	2.07	0.128	0.06
1	2.00	0.38	0.19
3	2.00	1.05	0.53
10	1.96	1.72	0.88
100	2.00	1.93	0.97

2.3.2 Gain vs Frequency (Bode Plot)



2.4 Theoretical and Experimental Cutoff Frequency

The theoretical value is $f_c = \frac{1}{2\pi RC} = 4822.877063\, Hz$. Starting from this value, we obtained $G = \frac{A_{out}}{A_{in}} = \frac{1.40\, V}{2\, V} = 0.7$. On the oscilloscope, with small frequency adjustments, we measured $A_{out} = 1.38\, V$ and $G = 0.69$. We kept the theoretical cutoff frequency value since the gain is closer to 0.707, which we were trying to achieve.

In conclusion, any deviations were too small to have a noticeable effect on the circuit.

3 Tone Control

3.1 The Circuit

We constructed the following:

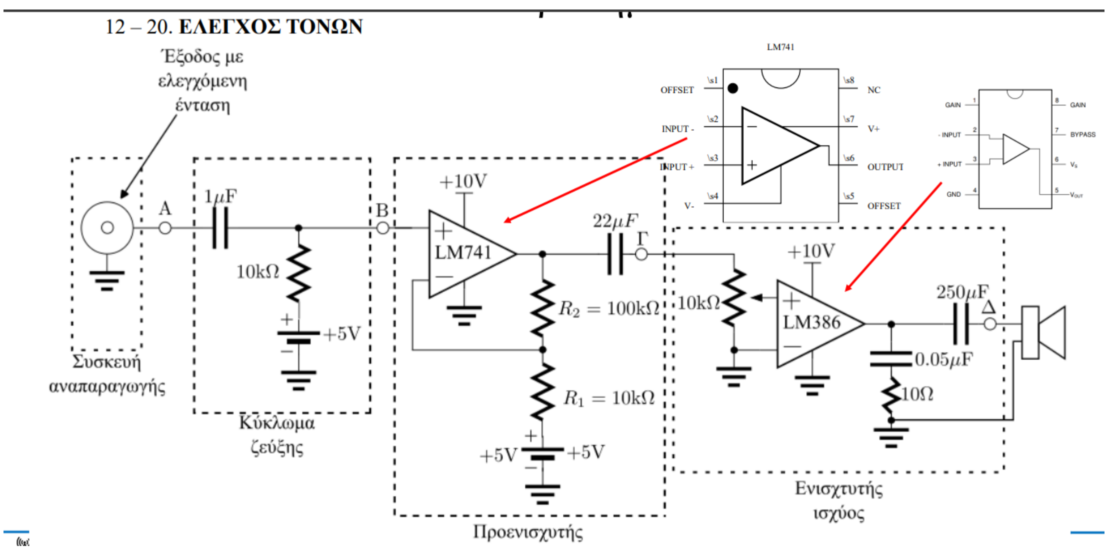


Figure 11: Circuit Diagram

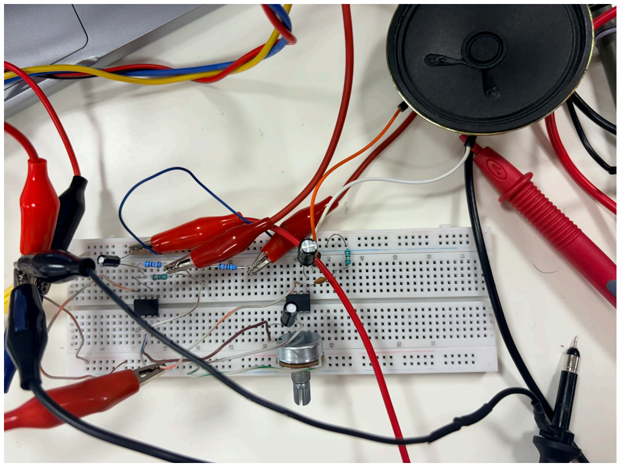


Figure 12: The Circuit

Note that the 22 F, 0.05 F, and 250 F capacitors were replaced with 15 F, 47nF, and 220 F respectively. The circuit functioned normally.

3.2 Test at Point B

We heard a loud click when the source was connected, but no sound afterward.

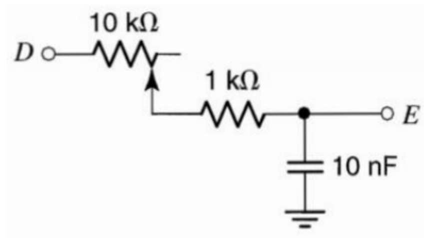
3.3 Tests at Other Frequencies

For frequencies between 20Hz and 20000Hz, we heard sound normally except near the extremes of the range.

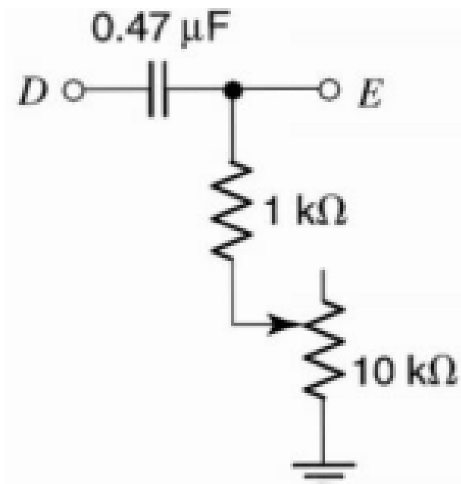
3.4 Filters

Applying the formula $f_c = \frac{1}{2\pi RC}$:

- $1k\Omega \leq R_{total} \leq 11k\Omega$
  $15.915\,kHz \geq f_c \geq 1.446\,kHz$



- $1k\Omega \leq R_{total} \leq 11k\Omega$
  $338.63\,Hz \geq f_c \geq 30.78\,Hz$



Conclusion

In the low-pass filter, increasing resistance cuts off progressively lower frequencies.

In the high-pass filter, increasing resistance allows progressively lower frequencies to pass through.