Laboratory 3: Simple Filters

Lab Section AA

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EE233 Circuit Theory

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***Abstract* — In this lab the characteristics and usage of simple filters were explored through the construction of a preamplifier and a variation of the summing amplifier seen in previous labs. Further usage of lab equipment for testing/analyzing circuits was conducted. This lab effectively demonstrated the capabilities of filters for the overall project of making an audio mixer.**

I. INTRODUCTION

In this lab, students will explore integrating and differentiating circuits in their role for two circuits crucial for a sound equalizer. This serves as a vital step in the construction of the course's final project: an audio mixer. This lab's focus is on the preamplifier (using an integrator) and the summing amplifier (using a differentiating circuit). The preamplifier ensures a noise-tolerant output signal as low input signals pass in, while the summing amplifier combines multiple audio sources, enabling control of magnitude, frequency content, dynamics, and panoramic position. By

understanding the construction of an audio mixer in small "chunks," allows the student to engage with the individual components to better understand its role in the overall final project.

II. LAB PROCEDURE

The equipment to construct the different circuits for this lab included a breadboard, LM348N Operational-Amplifier, a 1kΩ resistor, a 47kΩ resistor, 50kΩ potentiometer, 100kΩ potentiometers, a 47pF capacitor, a 0.1μF capacitor, a 1μF capacitor, a microphone, a speaker, and jumper wires to connect the components.

The function generator was used to produce different sine waves throughout this lab. For the sine wave, the function generator was set to a sine wave with a range of frequencies: 300Hz, 1kHz, and 10Hz-1MHz (in 1-2-5 sweep order). The same applied to the amplitude where the range was: 200mV, 600mV, 1V, and 2V peak-to-peak.

The oscilloscope was used to measure output voltage of the whole circuit. The measurement functions of the oscilloscope were used to determine the amplitude of the output signals and the phase difference between input and output signals. Two main channels were used from the oscilloscope: Channel 1 and 2. Those channels were connected to the input signal voltages that were supplied by the waveform generator and the various output signal voltages measured across the different circuit components respectively.

III. EXPERIMENTAL PROCEDURE AND ANALYSIS

First the preamplifier circuit shown in Figure 1 was built, with power supplies V_{CC} = 12V, V_{EE} = -12V. R1 was set to 1kΩ and R2 was set to 47kΩ. The capacitor C was chosen to be 47pF. R3 was chosen to be a 50kΩ potentiometer and was set to zero.

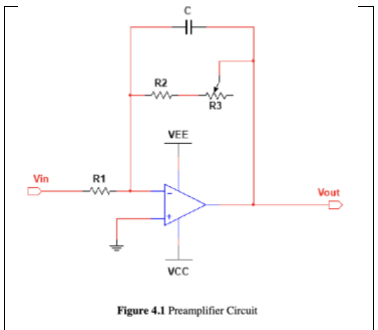

Figure 1 Preamplifier Circuit

The waveform generator was set to 200 mV peak to peak amplitude. The frequency was swept using the 1-2-5 sequence starting from 10 Hz up to 1 MHz. The amplitude and phase change of the output signal was recorded and is shown in Table 1.

Table 1: Amplitude and Phase change of Preamplifier Circuit with R3 set to 0Ω		
Frequency (Hz)	Amplitude Peak to Peak (V)	Phase Change (Degrees)
10	2.25V	-179
20	2.25V	-176
50	2.25V	-169.7
100	2.25V	-166.9
200	2.25V	-163.2
500	2.25V	-155.3
1000	2.25V	–146.7
2000	2.25V	-133.3
5000	2.25V	-104.8
10000	1.41V	-90.7
20000	710mV	-89.4
50000	281mV	-85
100000	139mV	-84.3
200000	70mV	-80
500000	28.3mV	-72.5
1000000 (1MHz)	15mV	-60.9

1. Comparing the bode plot in Figure 2 and 3, the experimental results yield similar trends to the bode plot that was simulated in 3.2 item 10 (integrator with shunt resistance). It is shown that as frequency increases the voltage begins to drop. This plot does differ from the one in 3.2 item 4 (the simple integrator) wherein the drop in voltage and phase starts immediately in the simple circuit compared to that of the experimental results.

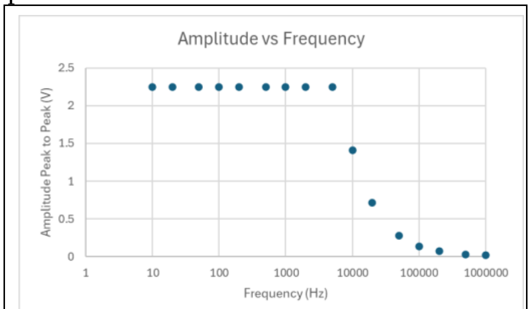

Figure 2. Bode plot amplitude when R3 set to 0kΩ from 10 Hz to 10kHz.

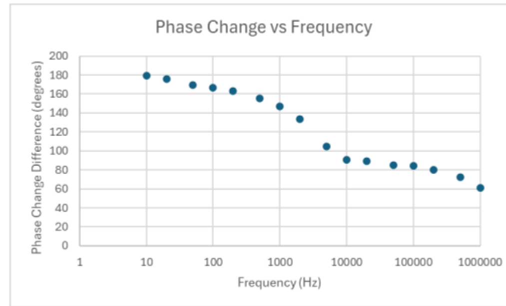

Figure 3. Bode plot phase when R3 set to 0kΩ from 10 Hz to 10kHz.

Next the waveform generator was set to a sine wave input signal with an amplitude of 600 mV peak to peak amplitude and a frequency of 300 Hz. This was connected to V_{in} of the preamplifier circuit that was built. The oscilloscope was used to show the input signal on Channel 1 and output signal on Channel 2.

2.

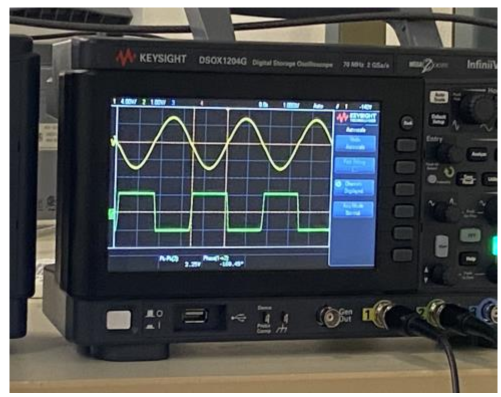

Figure 4. Input signal corresponding to sine wave with amplitude of 600mV peak to peak amplitude on Channel 1. Output signal connected to V_{out} of preamplifier circuit on Channel 2.

The potentiometer was set to 50kΩ, and the frequency was swept using the 1-2-5 sequence starting from 10 Hz up to 1 MHz. The amplitude and phase change of the output signal was recorded and is shown in Table 2.

Table 2: Amplitude and Phase change of Preamplifier Circuit with R3 set to 50kΩ		
Frequency (Hz)	Amplitude Peak to Peak (V)	Phase Change (Degrees)
10	2.25V	-176.0
20	2.25V	-178.5

50	2.25V	-176.55
100	2.25V	-177
200	2.25V	-177
500	2.25V	-173.7
1000	2.25V	-170
2000	2.25V	-162
5000	2.25V	-141.6
10000	2.21V	-107.9
20000	1.14V	-96
50000	470mV	-90.1
100000	229mv	-87.6
200000	115mV	-81.6
500000	46mV	-68
1000000 (1MHz)	22.5mV	-50.4

3. Upon looking over the bode plots in Figure 5 and 6, the voltage amplitude trend is the same as that compared to 4.1 item 1. However, the phase difference while having a similar trend of decreasing differs in when that decrease starts. When the potentiometer increases to 50kΩ, the phase difference does not start to really decrease immediately compared to that of 4.1 item 1.

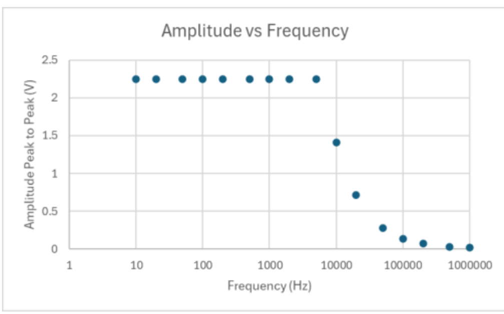

Figure 5. Bode plot amplitude when R3 set to 50kΩ from 10 Hz to 10kHz.

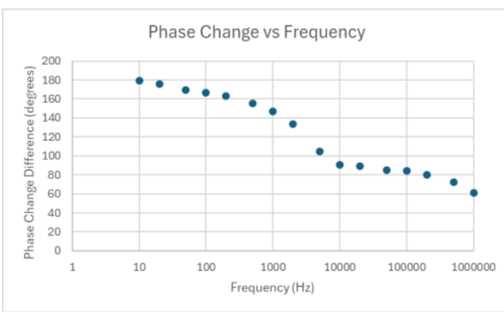

Figure 6. Bode plot phase when R3 set to 50kΩ from 10 Hz to 10kHz.

In the next part of the lab the Summing Amplifier circuit was built shown in Figure 7 with power supplies V_{CC} = 12V, V_{EE} = -12V. The capacitor C was set to 0.1 µF and R1, R2, R3, and Rf were set to 100kΩ potentiometers.

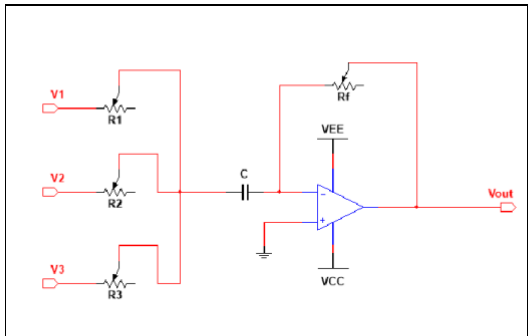

Figure 7 Summing Amplifier Circuit

The waveform generator was set to a sine wave with 500 mV peak to peak amplitude. The frequency was swept using the 1-2-5 sequence starting from 10 Hz up to 1 MHz. The amplitude and phase change of the output signal was recorded and is shown in Table 3.

Table 3: Amplitude and Phase change of Summing Amplifier Circuit		
Frequency (Hz)	Amplitude Peak to Peak (V)	Phase Change (Degrees)
10	39.4mV	116.5
20	64mV	132
50	90mV	157
100	100mV	168
200	103mV	174
500	105mV	178
1000	105mV	180
2000	105mV	181
5000	105mV	183
10000	105mV	-180
20000	105mV	-172
50000	105mV	-165
100000	107mV	-149
200000	90mV	-103
500000	28mV	-64
1000000 (1MHz)	12mV	-53

4. Upon analyzing the bode plots shown in Figure 8 and 9, for the output summing amplifier, the voltage and phase difference trends yield that this is a band-pass filter. At lower frequencies,

nothing is present but slowly increases to a steady amplitude before decreasing as frequency gets higher and higher.

R1 was set to 0Ω and Rf was set to 50kΩ. The waveform generator was set to a sine wave with 600 mV peak to peak amplitude with frequency of 300 Hz. The oscilloscope was used to show the input signal on Channel 1 and output signal on Channel 2.

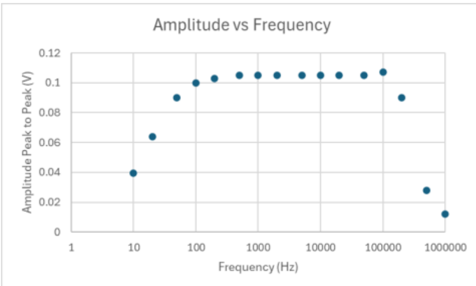

Figure 8. Bode plot amplitude of summing amplifier circuit.

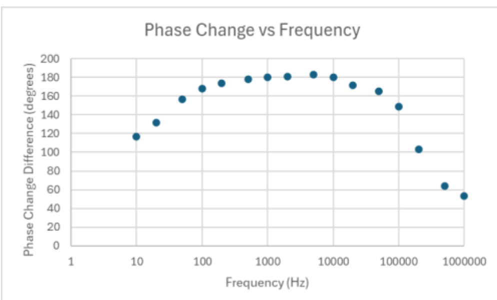

Figure 9. Bode plot phase of summing amplifier circuit.

5.

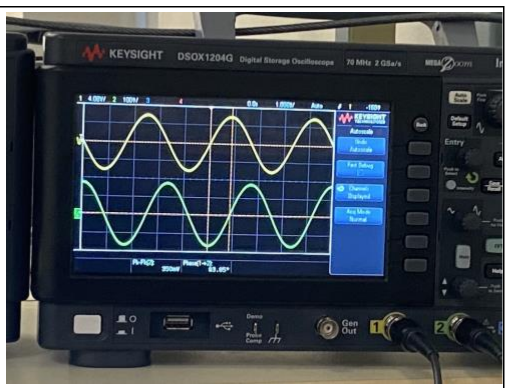

Figure 10. Input signal and output signal shown on oscilloscope showing that it is a differentiator.

The waveform generator was set to 2V peak to peak amplitude and a frequency of 1 kHz. The output signal was displayed on the oscilloscope. R1 was set to 1kΩ and Rf was increased until the output waveform became distorted.

6. With the constructed output summing amplifier, there is a near hard cap for the output voltage to be, and as the frequency increases passes a certain point, that amplitude voltage will end up never exceeding that point, causing the flat tops and bottoms displayed on the oscilloscope. This behavior is saturation and is the most likely reason for the distortion. To avoid it from happening, the op-amp requires enough headroom (voltage margin that the input signal can be accommodated for) to avoid more distortion. One solution is using the preamplifier circuit constructed earlier in this lab to scale down the input signal.

A low frequency sine wave was used as an input signal to V_1 and V_{out} was connected to a speaker. A sound was played with the capacitor in and when it was removed.

7. With the capacitor, it allows for the circuit to behave like a band pass filter. Without it, the behavior is that of a normal summing amplifier. The amplitude voltage remains at a steady state until very high frequencies (near 1 MHz). The capacitor is crucial for limiting the type of frequencies that are wanted by the circuit.

In the next part we used the summing amplifier and connected the output terminal to the speaker. We then used our laptops headphone jacks as input signals to the circuit. Different audios were played from the laptops and mixed which was heard as the output from the speaker. When the potentiometer of the individual input signals was changed the volume for that input signal increased or decreased due to the change in resistance. When the potentiometer Rf was changed it resulted in an overall volume increase or decrease due to the change in resistance which can be correlated to the overall gain of the circuit.

As an extra-credit assignment, a microphone circuit was constructed and tested on the breadboard. The circuit was built from Figure 10 and was connected to the preamplifier circuit constructed earlier in the lab, which connected to the speaker. However, due to a potential breadboard issue, the microphone circuit was connected to the summing amplifier circuit constructed as well in this lab. To test the functionality of the microphone, a sound was played from one of the student's phones, as well as talking into the microphone.

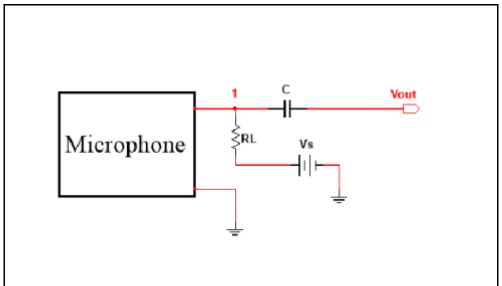

Figure 10. Input signal and output signal shown on oscilloscope showing that it is a differentiator.

Question-E: When the microphone circuit was constructed and connected to the summing amplifier (there was a potential breadboard issue so the preamplifier could not be used) there was sound coming out of the speaker. The noise comes from the microphone, however there is a loud noise that comes out from the speaker. To combat this, a capacitor is put between the microphone and the output to limit the frequency in which that loud noise is produced. The capacitor is playing the same role as that from the output summing amplifier constructed in Figure 7, a band pass filter.

IV. Conclusions

This laboratory demonstrated the practical application and effectiveness of simple filters in audio signal processing, specifically within the context of building an audio mixer. The experiments allowed for a deepened understanding of how integrating and differentiating circuits can be applied to crucial components like preamplifiers and summing amplifiers to manage audio signals effectively. Key findings from the lab include: The preamplifier circuit, even at its basic configuration with R3 set to 0Ω, showed significant amplitude and phase changes across a wide range of frequencies, confirming the theoretical predictions about integrator behavior.

Adjusting the potentiometer R3 to 50kΩ in the preamplifier modified the phase response, illustrating the tunability of circuit properties through simple adjustments. The summing amplifier circuit functioned as expected, exhibiting characteristics of a band-pass filter. This was evident from its response to varying frequencies and the steady state amplitude maintained until reaching very high frequencies.

Through these experiments, we were able to observe the behavior of filters in electronic circuits, providing them with valuable insights for future projects involving more complex systems such as a complete audio mixer.

Team Roles

Activity	Student(s) Name
Prelab: Circuit Analysis	Ethan, Juhan, Travis
Prelab: Simulations and Graphs	Ethan, Juhan, Travis
Prelab: Questions	Ethan, Juhan, Travis
Lab: Circuit Construction	Ethan, Juhan, Travis
Lab: Data Collection	Ethan, Juhan, Travis
Lab: Data Analysis	Ethan, Juhan, Travis
Report: Procedure	Ethan, Juhan, Travis
Report: Analysis and Graphs	Ethan, Juhan, Travis
Report: Questions	Ethan, Juhan, Travis