Lab 3 Report - Filters

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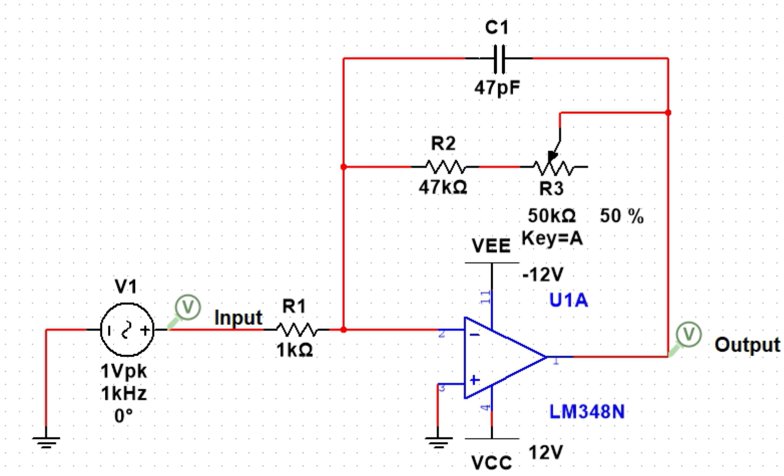
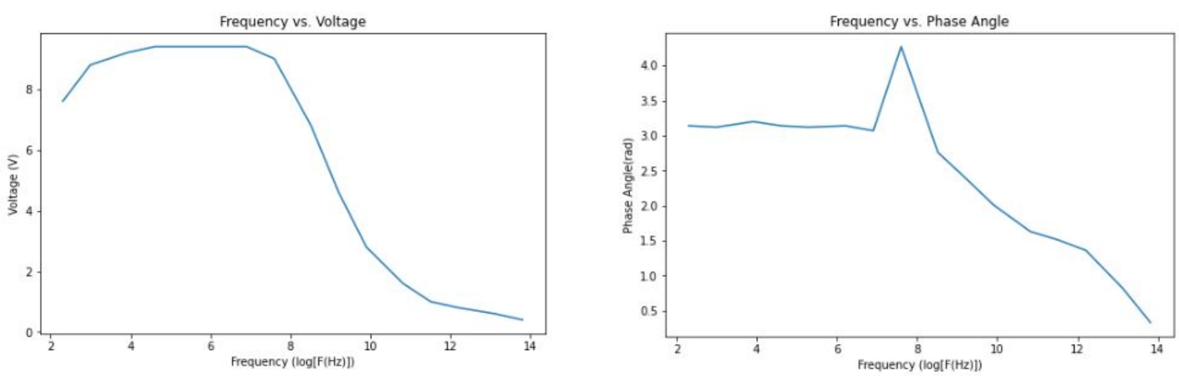
PROCEDURE 1

In this procedure, we constructed the preamplifier circuit as shown in figure 1.1, attaching the function generator in place of the sinusoidal source, connecting the oscilloscope across the input and to channel 1, and also connecting another set of probes across the output and connecting that to channel 2. Notably for this initial setup, we set the potentiometer to its lowest resistance across the terminals we were using (which was something around 20Ω). We then set the function generator to create a sine wave with amplitude 100mV and frequency 10Hz. We then varied the frequency of the input in a 1-2-5 configuration from 10Hz to 1MHz, measuring the amplitude and phase difference at each stage. The bode plot generated from this data shows largely expected behavior, as the circuit is an active low-pass filter, and we can see that for low frequencies, our amplitude is largely unaffected, but for high-frequencies the amplitude reduces dramatically. Comparing figures 1.2 and 1.3, the behavior seems largely consistent between ideal and real behavior (other than lower amplitudes at low frequencies, which we regularly observed). Then, we adjusted the potentiometer to 50kΩ and repeated the previous steps. The bode plot generated from the data after adjusting the potentiometer shows that adjusting the potentiometer adjusted the rejection range for the low-pass filter further than where it was for the previous part (see figure 1.4). Finally, we adjusted the input to a frequency of 300Hz and an amplitude of 300mV and printed the output, which can be seen in figure 1.5. From this graph, we can see that the circuit behaves as an integrator (notably, it hits saturation, so it does not work exactly like an integrator) as the output is 90 degrees out of phase with the input, as expected for the integral of a sinusoidal wave.

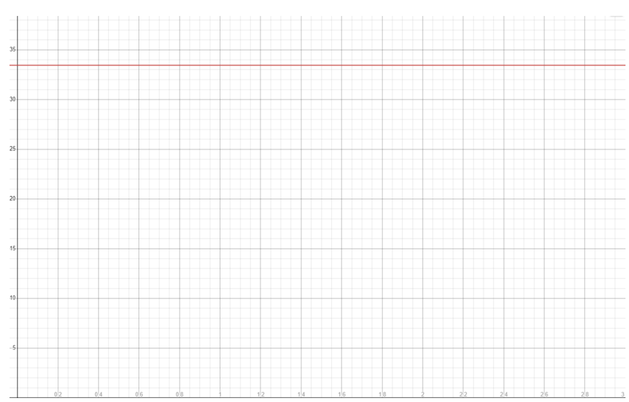
Overall, our preamplifier circuit behaved as we expected, removing high-frequency signals and maintaining low-frequency signals. There are, however, two notable deviations in our data from expectation: low-response at low frequencies and the unusual jump in phase angle in figure 1.2. The issue of low response at the start we attribute to the capacitive elements in the op-amp behaving partially as a high-pass filter, thus reducing the response at very low frequencies. The second issue we attribute to user error, as this was our first time collecting phase data on the oscilloscope. Looking at figures 1.2 and 1.4, the data is very uneven, so our collection procedures may not have been entirely consistent. Regardless, the actual behavior we observed was as expected.



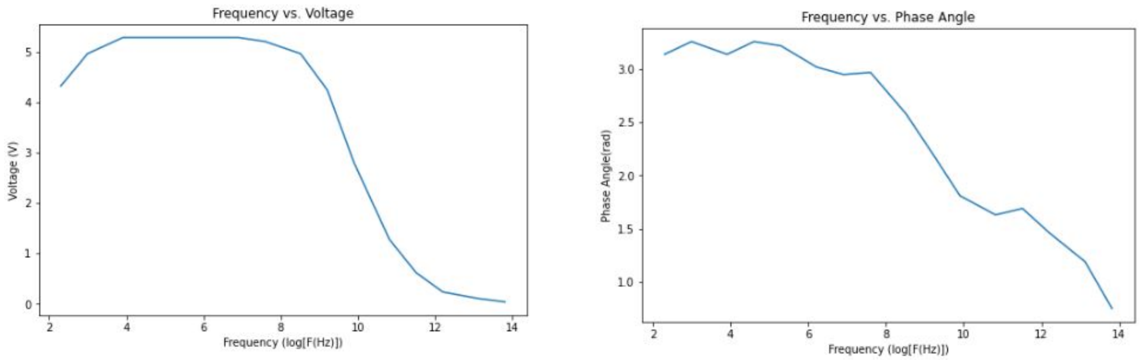
(Figure 1.1) Preamplifier circuit with test leads on input and output, stimulated by a sine wave input created in SPICE simulation.



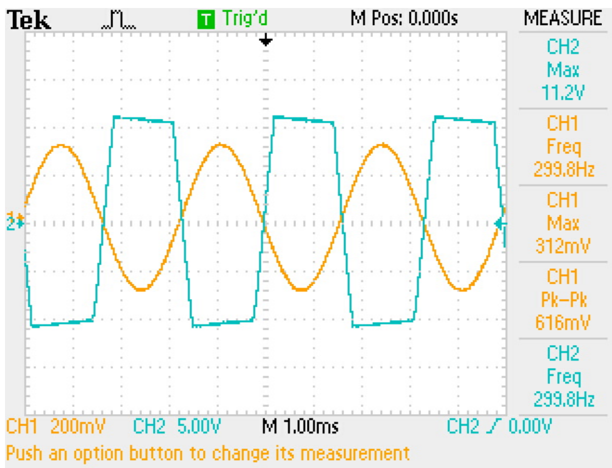
(Figure 1.2) Bode plots of amplitude and phase response to frequency change in preamplifier circuit (with potentiometer set to 0Ω) obtained from lab data



(Figure 1.3) Bode plot of amplitude of the preamplifier circuit as found from ideal components in prelab (shown from 20Hz to 20kHz)



(Figure 1.4) Bode plots of amplitude and phase response to frequency change in preamplifier circuit (with potentiometer set to 50kΩ) obtained from lab data

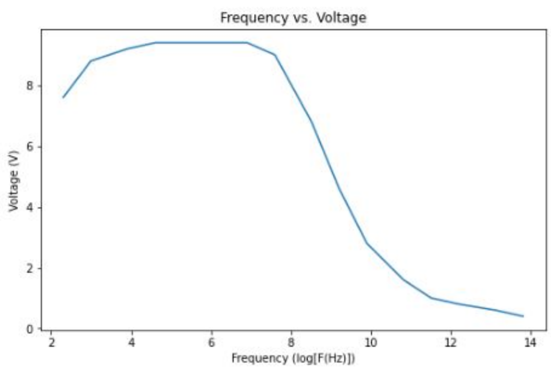


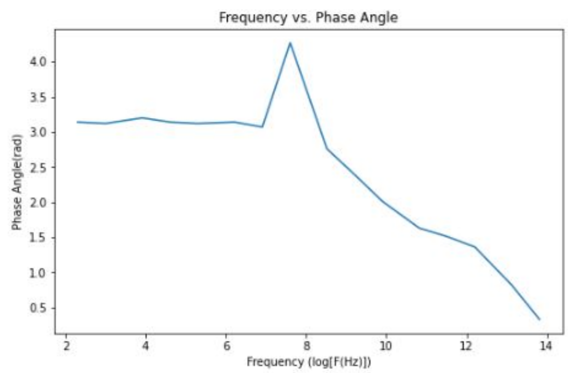
(Figure 1.5) Response of the preamplifier circuit to a sinusoidal stimulus of frequency 300Hz and amplitude 300mV obtained from oscilloscope in lab

ANALYSIS 1

1.1

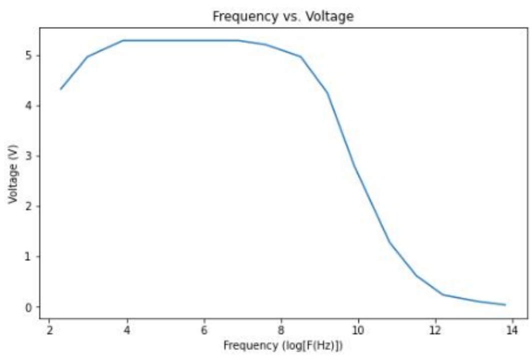
Frequency	***10 Hz***	***20 Hz***	***50 Hz***	***100 Hz***	***200 Hz***	***500 Hz***	***1 kHz***	***2 kHz***	***5 kHz***
Output	4.32 V	4.96 V	5.28 V	5.28 V	5.28 V	5.28 V	5.28 V	5.2 V	4.96 V
Time Shift	50 ms	25.2 ms	10.2 ms	5 ms	2.52 ms	1 ms	490 µs	340 µs	88 µs
Phase Angle	3.14	3.12	3.20	3.14	3.12	3.14	3.07	4.27	2.76
Frequency	***10 kHz***	***20 kHz***	***50 kHz***	***100 kHz***	***200 kHz***	***500 kHz***	***1 Mhz***		
Output	4.24 V	2.8 V	1.28 V	620 mV	238 mV	108 mV	41.6 mV		
Time shift	38 µs	16 µs	5.2 µs	2.4 µs	1.08 µs	260 ns	52 ns		
Phase Angle	2.39	2.01	1.63	1.51	1.36	0.82	0.33		

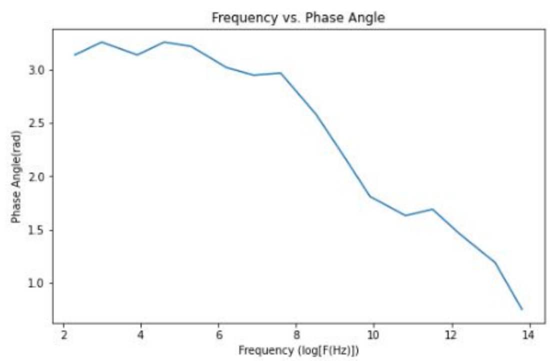




1.2

Frequency	***10 Hz***	***20 Hz***	***50 Hz***	***100 Hz***	***200 Hz***	***500 Hz***	***1 kHz***	***2 kHz***	***5kHz***
Output	7.6 V	8.8 V	9.2 V	9.4 V	9.4 V	9.4 V	9.4 V	9 V	6.8 V
Time Shift	50 ms	26 ms	10 ms	5.2 ms	2.56 ms	960 µs	470 µs	236 µs	82 µs
Phase Angle	3.14	3.26	3.14	3.26	3.22	3.02	2.95	2.97	2.58
Frequency	***10 kHz***	***20 kHz***	***50 kHz***	***100 kHz***	***200 kHz***	***500 kHz***	***1 Mhz***		
Output	4.6 V	2.8 V	1.6 V	1.0 V	800 mV	600 mV	400 mV		
Time shift	35 µs	14.4 µs	5.2 µs	2.7 µs	1.16 µs	380 ns	120 ns		
Phase Angle	2.20	1.81	1.63	1.69	1.46	1.19	0.75		





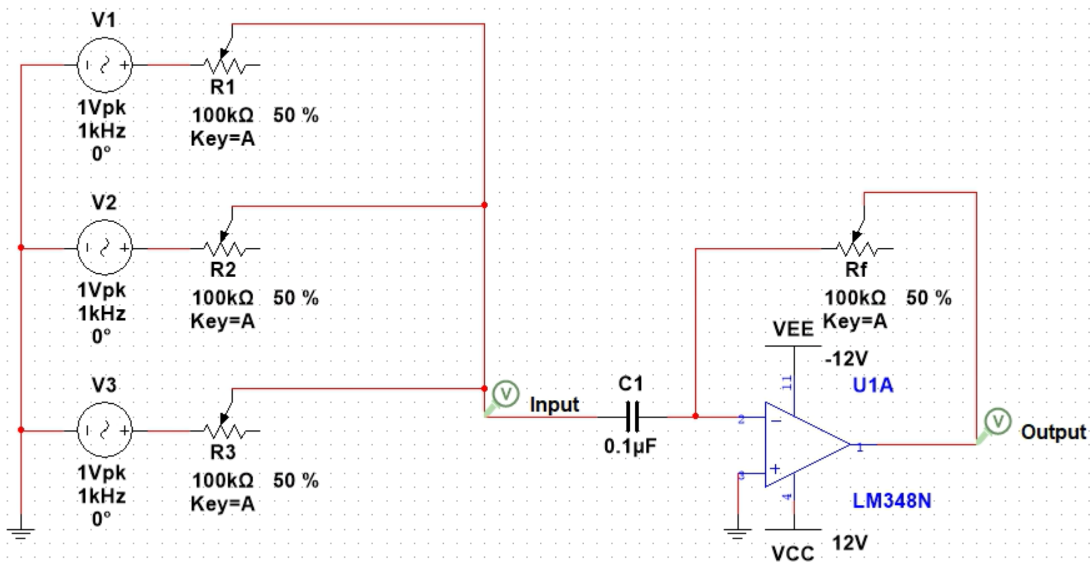
1.3

See figure 1.5

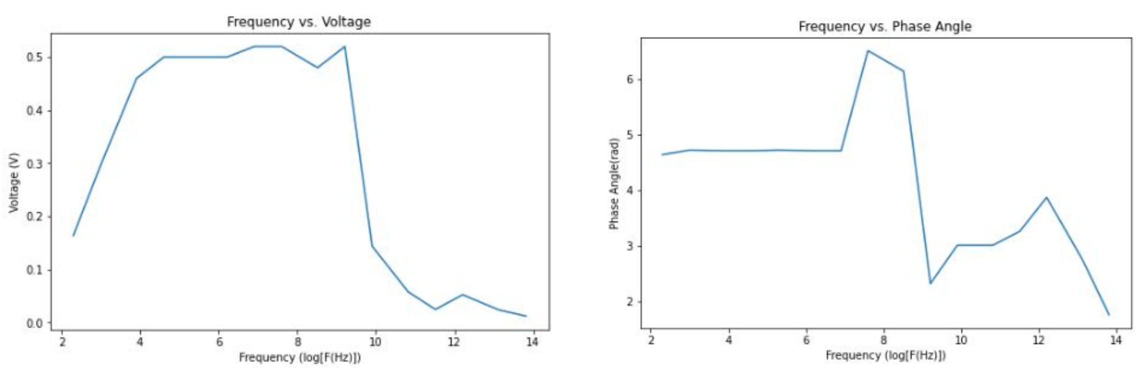
PROCEDURE 2

In this procedure, we constructed the summing amplifier circuit as shown in figure 2.1, but with V2 and V3 disconnected. We set all of the potentiometers to 100kΩ and applied an input sine wave from the function generator with an amplitude of 500mV and a frequency of 10Hz. We then connected channel 1 of the oscilloscope across the input, and channel 2 across the output. With everything set, we began to vary the frequency of the input signal from 10Hz to 1MHz in a 1-2-5 configuration, collecting amplitude and phase information at each step. From the Bode plot we made from this data (figure 2.2), we can see that the circuit severely reduces both low-frequency and high-frequency signals, which makes sense, since this circuit is intended to filter out unwanted noise which would typically be in very low or very high ranges. We then adjusted R1 to 0Ω and Rf to 50kΩ and applied an input sine wave with amplitude 300mV and frequency 300Hz. Taking a screenshot of these waveforms, we found figure 2.3, which shows behavior largely expected of a differentiator (though the phase is not 90 degrees, just a little bit off). We then set the input to an amplitude of 1V and a frequency of 1kHz, also setting R1 to 1kΩ. With this, we varied the resistance of Rf until the waveform became distorted. This distortion occurred around the saturation limit of the op-amp with the power voltages we provided, so the waveform is no longer sinusoidal if the amplifier amplifies too far. Finally, we tested low-frequency sine-waves on the circuit and listened to how they sounded with and without the input capacitor. From what we heard, we believe that the purpose of the capacitor is to remove noise from the input signal before amplification so the noise does not get amplified with the rest of the signal.

Overall, our circuit behaved as expected, with exception of the low-frequency gain and the phase-shifting we found. The low-frequency gain was not expected, as we only anticipated the capacitor to be resistant to high-frequency voltage change, but this was not the case in actual behavior (though the outcome is welcomed for very low frequency noise). The other notable issue is in our phase plot for our frequency response. We recorded a few very sharp changes, which we believe were likely due to a change in which signal was leading or lagging that we could not accurately observe on the oscilloscope by our method of phase data collection. Regardless, our data largely indicates that our summing amplifier behaved properly as a differentiator and summing amplifier.



(Figure 2.1) Summing amplifier circuit with test leads on input and output, stimulated by three sine wave inputs created in SPICE simulation.



(Figure 2.2) Bode plots of amplitude and phase response to frequency change in summing amplifier circuit obtained from lab data (potentiometers all set to 100kΩ)

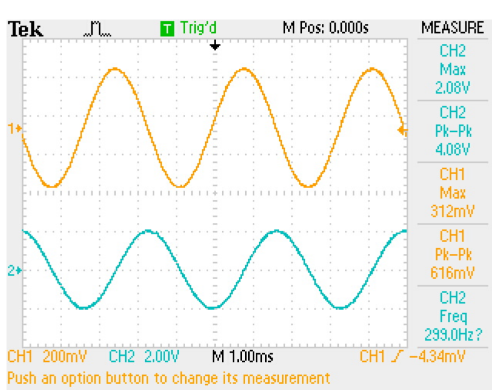
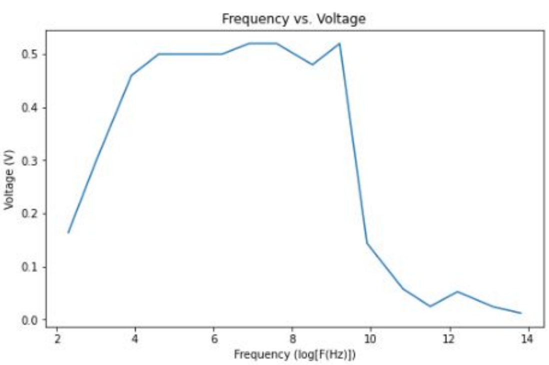


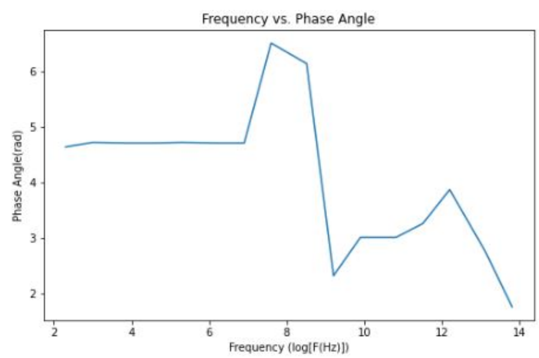
Figure 2.3) Response of the summing amplifier circuit to a sinusoidal stimulus of frequency 300Hz and amplitude 300mV obtained from oscilloscope in lab

ANALYSIS 2

2.1

Frequency	***10 Hz***	***20 Hz***	***50 Hz***	***100 Hz***	***200 Hz***	***500 Hz***	***1 kHz***	***2 kHz***	***5 kHz***
Output	164 mV	296 mV	460 mV	500 mV	500 mV	500 mV	520 mV	520 mV	480 mV
Time Shift	74 ms	37.6 ms	15 ms	7.5 ms	3.76 ms	1.5 ms	750 µs	280 µs	100 µs
Phase Angle	4.64	4.72	4.71	4.71	4.72	4.71	4.71	3.51	3.14
Frequency	***10 kHz***	***20 kHz***	***50 kHz***	***100 kHz***	***200 kHz***	***500 kHz***	***1 Mhz***		
Output	520 mV	144 mV	58 mV	24.8 mV	25.6 mV	24 mV	12.4 mV		
Time shift	37 µs	24 µs	9.6 µs	5.2 µs	3.08 µs	880 ns	280 ns		
Phase Angle	2.32	3.01	3.01	3.26	3.87	2.76	1.76		





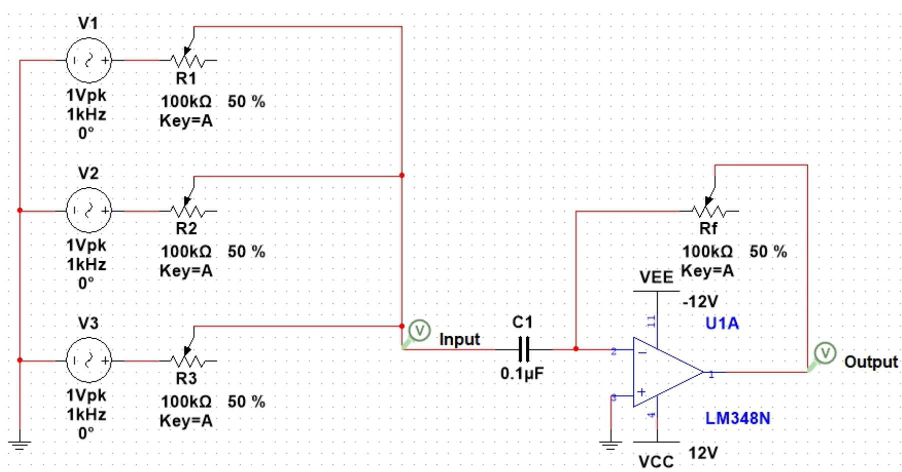
2.2
See figure 2.3

2.3
We varied the resistance of Rf until the waveform became distorted. This distortion occurred around the saturation limit of the op-amp with the power voltages we provided, so the waveform is no longer sinusoidal if the amplifier amplifies too far.

2.4
The capacitor is there to filter out unwanted noise from the input sources in the circuit.

PROCEDURE 3

In this procedure, we used the circuit as seen in figure 3.1, but with each of the input voltage sources replaced with an audio jack which we connected to our phones, laptops, etc. Upon listening, we found that all three sounds were audible once we adjusted the potentiometers until we could hear a mix of all three. Notably, as we adjusted the volume higher with the potentiometers, we found that the sound became very distorted and, as we described it "crunchy". We believe we can attribute this behavior to the distortions we found with the saturation voltage earlier in the lab. Initially, we noticed a significant amount of noise in our outputs that weren't over-amplified, but upon reseating all of our components, we found the noise went away (presumably the poor contact resulted in external noise being introduced). We did not build the microphone circuit, but if we were to guess, we would expect that DC noise from the microphone's active power would be mitigated by adding a capacitor to remove low-frequency noise.



(Figure 3.1) Summing amplifier circuit with test leads on input and output, stimulated by three sine wave inputs created in SPICE simulation.

ANALYSIS 3

3.1

Initially, we noticed a significant amount of noise in our outputs that weren't over-amplified, but upon reseating all of our components, we found the noise went away (presumably the poor contact resulted in external noise being introduced). We did not build the microphone circuit, but if we were to guess, we would expect that DC noise from the microphone's active power would be mitigated by adding a capacitor to remove low-frequency noise.