Class:	EE 320L - Engineering Electronics I Lab		Semester:	Summer 2017
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		Document topic:	**Final Project Report – Mho Loud**	
Instructor's comments:				

Goal

The goal of this project is to implement our idea of a headphone amplifier circuit. We wanted to capture the range of human hearing—20 Hz to 20 kHz—and magnify those ranges via the amplifier. We used the LM 741 operational amplifier chip, 2N2904 NPN BJT, 2N2906 PNP BJT, and two 1N4001 diodes for this circuit. With the knowledge from previous laboratories, we created a two-stage amplifier to capture this hearing range as well as amplify these sounds to about four times. These components along with resistors and capacitors are all connected in a small breadboard. With this, we better organized our circuit and ensured proper operation.

Background Theory

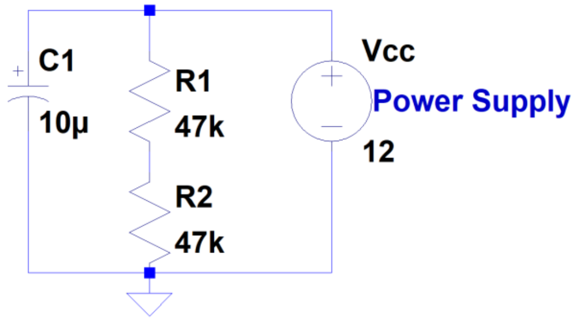
From previous laboratory experiments, one of the main focuses of this class was amplification through different electronic components, such as operational amplifiers and bipolar junction transistors. For the volume control, we used a variable resistor connected from the input to control the incoming voltage to the amplifiers. The first stage of the amplifier uses the op-amp to filter a certain bandwidth and passes it on to the transistor stage. This is an example of an active first-order band pass filter using operational amplifier. The feedback to the inverting amplifier comes from the final output to the speakers. Unlike previous laboratory experiments, we did not use a differential voltage supply for the operational amplifier to simplify the circuit even more, especially for the op-amp's power supply inputs. The second stage of the amplifier consists of a NPN and a PNP bipolar junction transistors to clamp down the amplified output from op-amp to a DC offset of close to zero volts. This is called a class AB power amplifier. To achieve a clear and constant voltage input to the entire circuit, a simple low pass filter was used to clean the signal from the DC power supply. With these parts, we can amplify an input voltage from a sound source up to four times when the potentiometer is close to zero resistance, and mute the input when the potentiometer is close to its maximum resistance value.

Group Member Roles

We shared similar roles throughout the entire process of creating, testing, debugging the circuit. We both brainstormed and researched for many ideas until we settled for this project idea. Since Reiner built the schematic, and tested it through simulation, Angel wired most of the circuit onto the small breadboard. Reiner also checked the circuitry and rewired when necessary. With these roles during circuit design, we effectively implement our circuit with as little problem as possible since one person focused on the circuit at a time. In terms of project write up and presentation, Reiner wrote the final project report while Angel created the final project presentation, while we checked each for spelling and grammar.

Schematic/Diagrams

Simple Low-Pass Filter

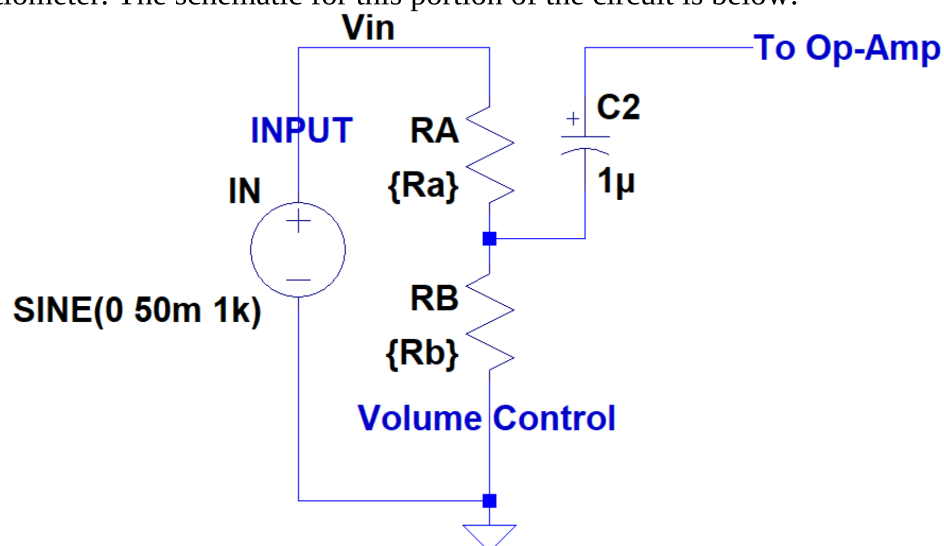


To achieve low signal amplification, we need to eliminate the noise from the DC power supply. For this purpose, we implemented a simple low pass filter which filters out frequencies higher than 0.169 Hz. We placed a 10u farad capacitor with two 47k ohm resistors in parallel to the DC power supply. We chose these values since filters out noise of at most 1 Hz to realize a clean DC signal.

$$f_c = \frac{1}{2\pi RC} = \frac{1}{2\pi(94000\Omega)(10^{-5}\text{F})} = \boxed{0.169\text{Hz}}$$

Volume Control

Any good headphone amplifier allows the user to control the volume to a suitable level for enjoyable experience. For our circuit, we used a 25k ohm potentiometer that was connected in parallel with the input sound source. The output through the variable resistor is fed into the two stage amplifier. Accordingly, the two ends of the potentiometer are connected to the power supply and to ground. In LTSpice, we used two resistors in series that was parameterized to model a potentiometer. The schematic for this portion of the circuit is below:

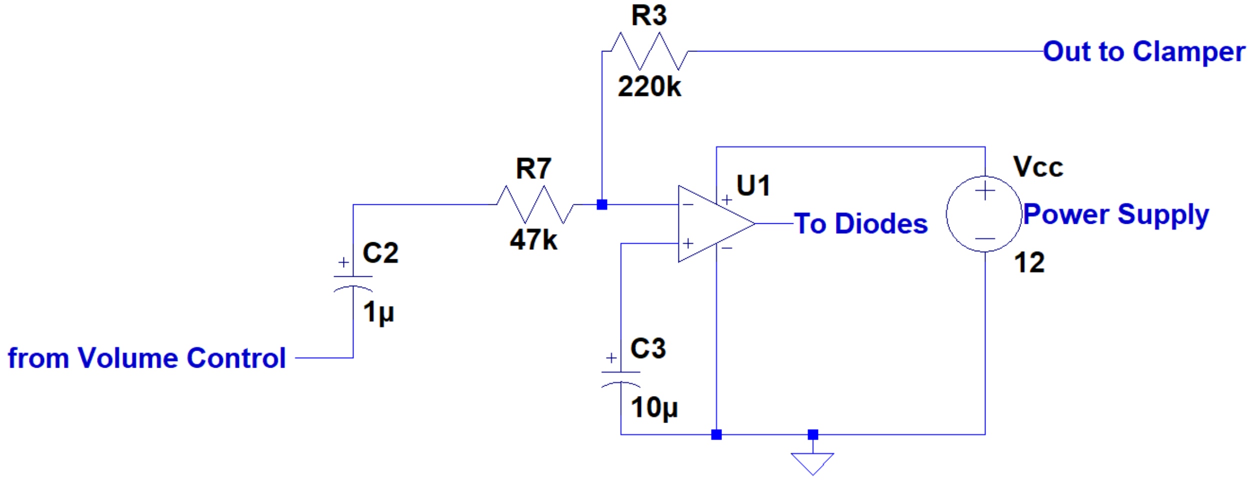


Active Band Pass Op-Amp Filter

For the first stage of the amplifier, we chose a first order active band pass filter to capture the human hearing range. We used a LM741 operational amplifier for this part of the circuit. At the inverting input, we connected the output from the potentiometer in series with a 1u capacitor and 47k ohm resistor. The feedback from the final output to the speaker is fed back onto the inverting input of the op-amp. We measured a parasitic capacitance of the breadboard of 0.425 pF. With this configuration, this filters out anything lower than 3 Hz and higher than 1.70MHz. The calculation and the schematic for this portion of the circuit are below:

$$f_{lower} = \frac{1}{2\pi RC} = \frac{1}{2\pi\left(27000\Omega\right)\left(10^{-6}\,\mathrm{F}\right)} = \boxed{3.39\mathrm{Hz}}$$

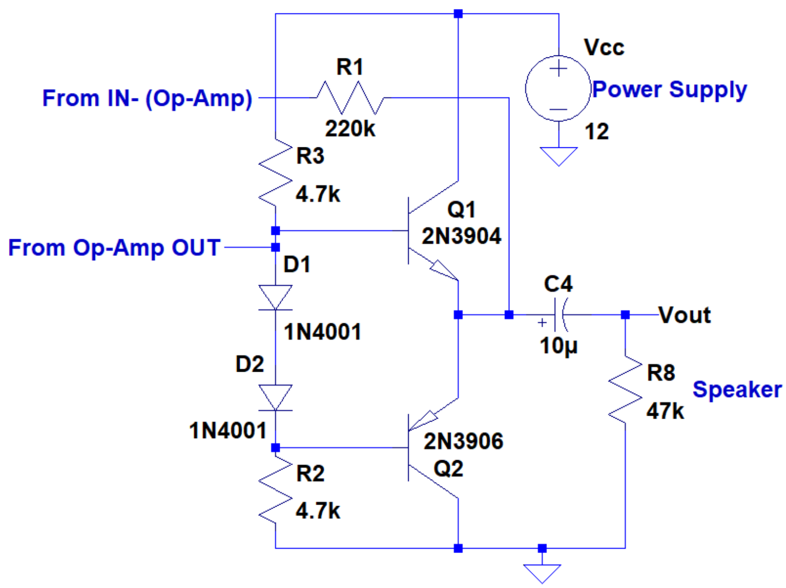
$$f_{upper} = \frac{1}{2\pi RC} = \frac{1}{2\pi\left(220000\Omega\right)\left(4.25\cdot 10^{-13}\,\mathrm{F}\right)} = \boxed{1.70\,\mathrm{MHz}}$$



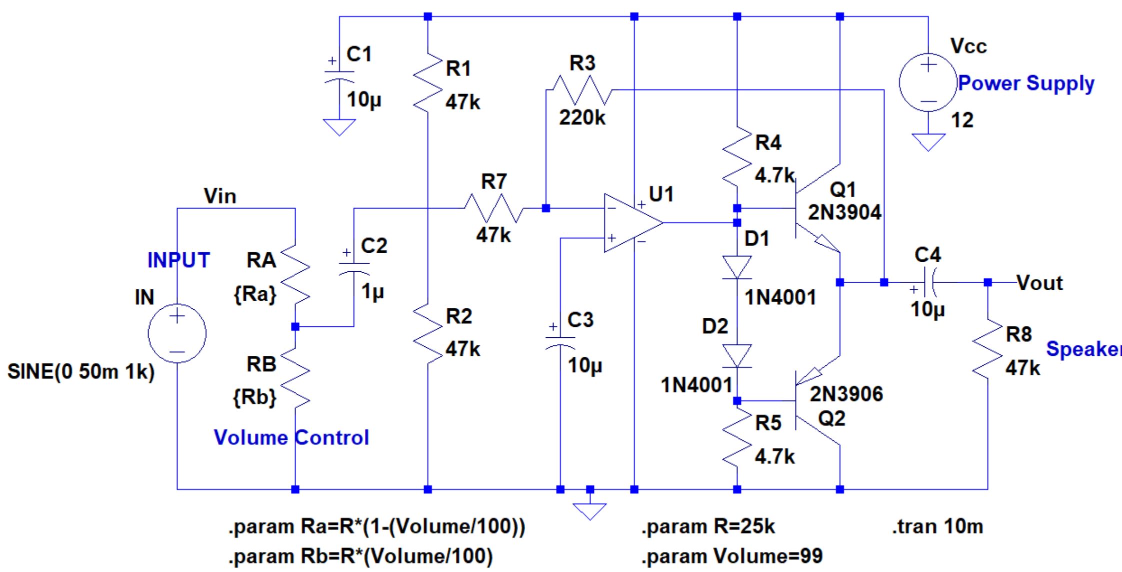
Class AB Power Amplifier

For this second stage of the amplifier, we implemented a Class AB power amplifier using bipolar junction transistors. With these transistors, we configured them as emitter follower amplifiers circuit which means there is no voltage amplification. These amplifiers are for power amplification enough to drive speakers or headphones. Based on our textbook, one way to bias this amplifier was using diodes and resistors. We chose this amplifier over simply choosing Class A or Class B since it eliminates crossover distortion caused when one of the transistor is off during switching between positive and negative voltages. This amplifier allows both transistors to be on for that switching period. We got these resistor values by using the equation below. From the output of the op-amp, the max current is 1.2 mA. Along with this hand calculation, the schematic for this portion are below:

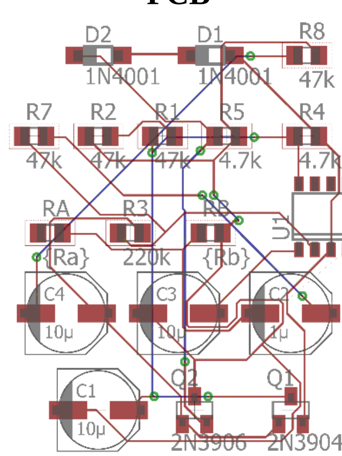
$$R = \frac{V_{CC} - 0.7}{2I_Q} = \frac{12\,\mathrm{V} - 0.7\,\mathrm{V}}{2\cdot 1.2\,\mathrm{mA}} = \boxed{4.7\,\mathrm{k}\Omega}$$



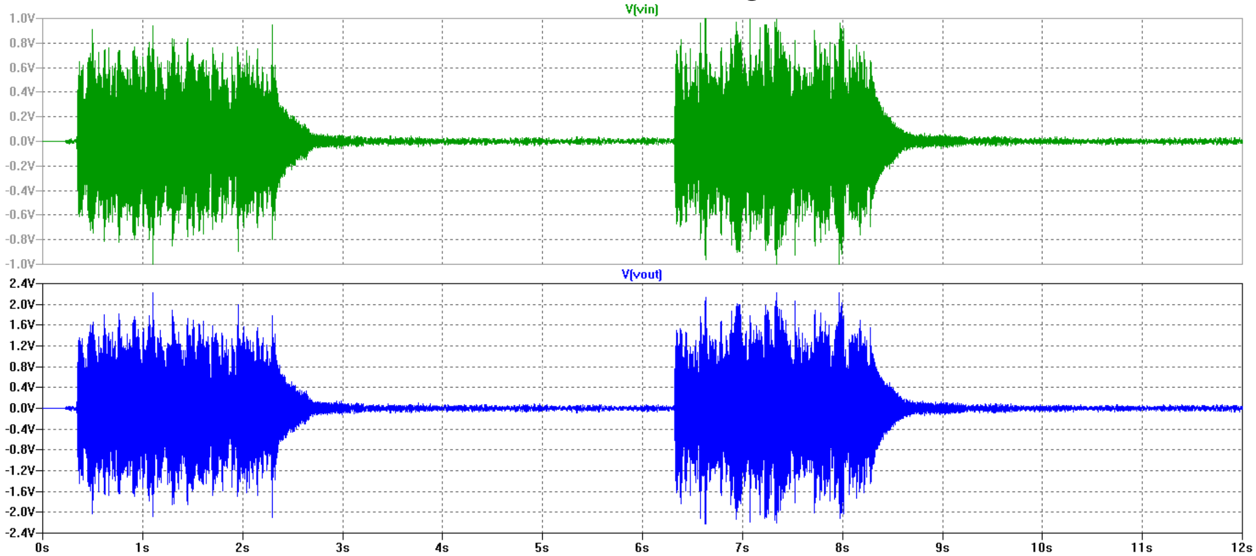
Overall Schematic



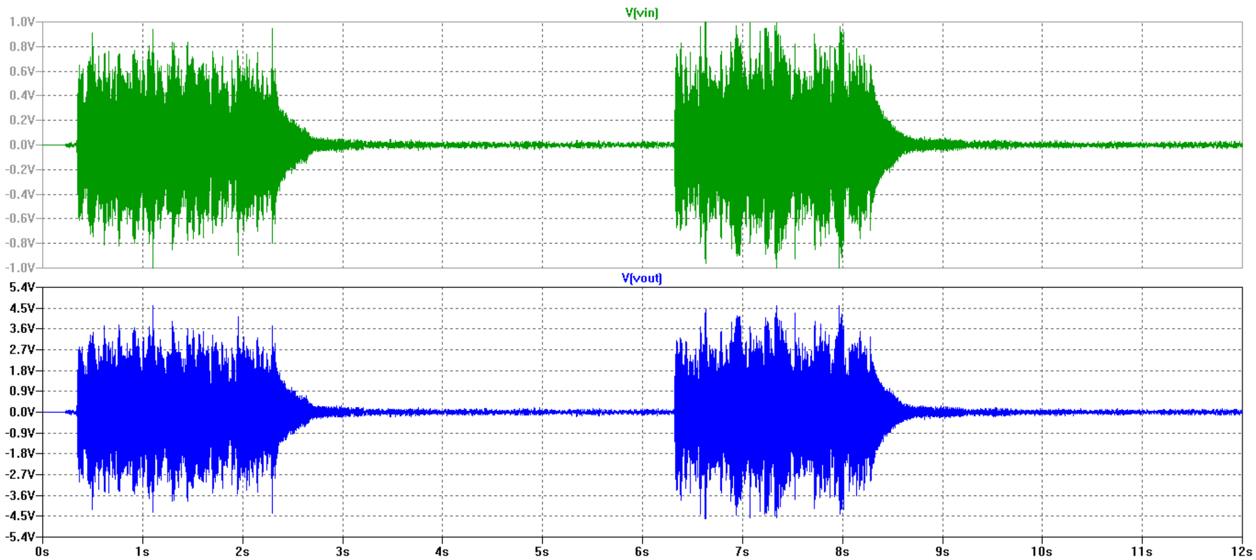
PCB



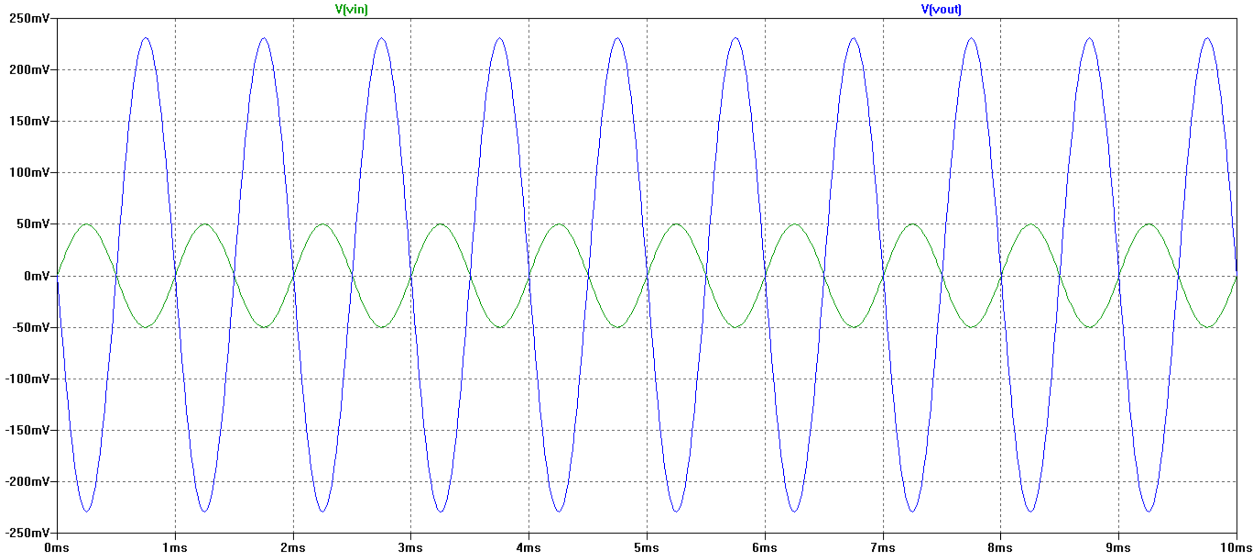
Here are the simulation waveforms with a sound signal source with a volume of 50:



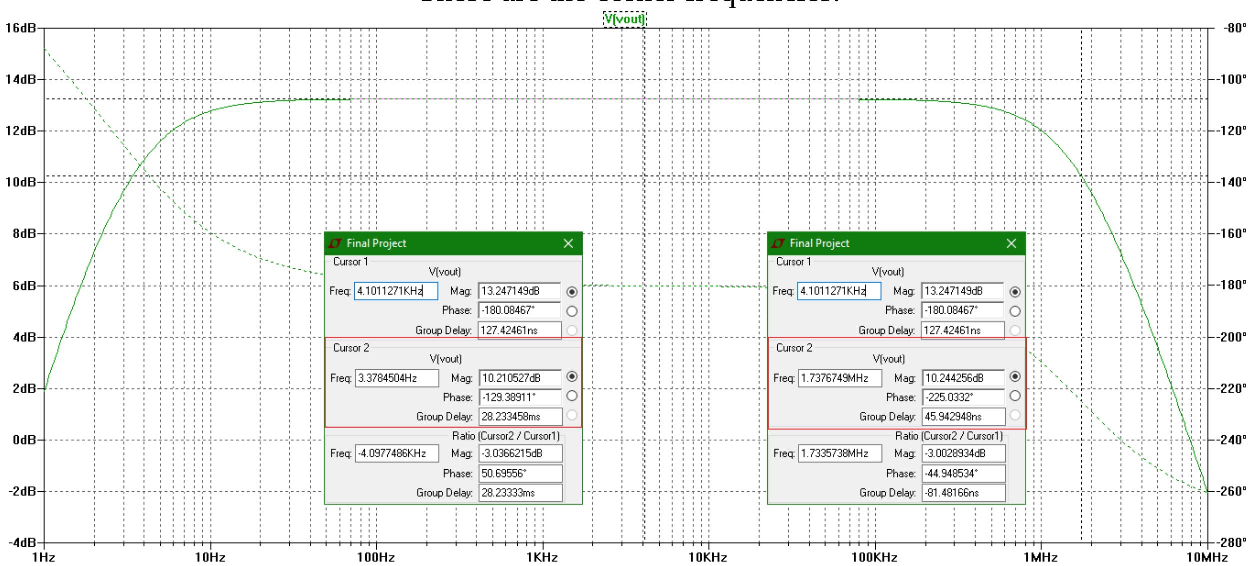
volume of 99:



This is the transient analysis with 50mVpp, 1kHz sine signal:

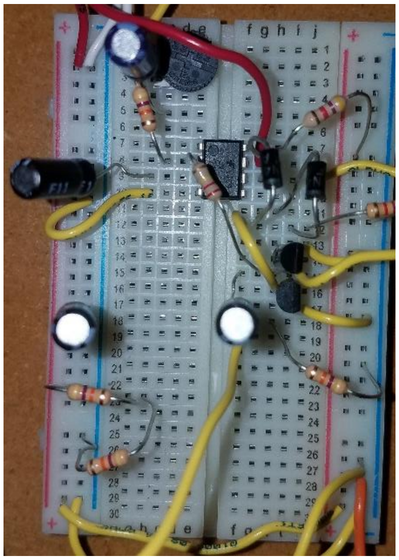


These are the corner frequencies:

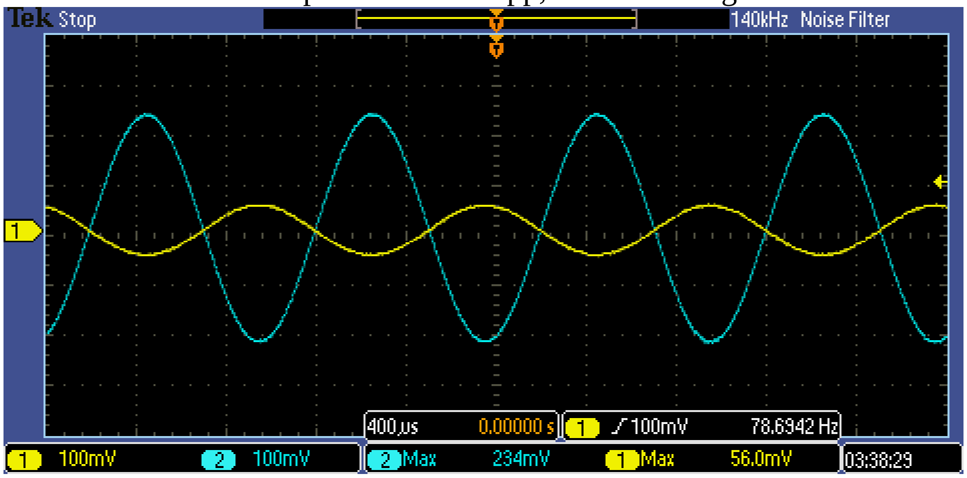


Circuit Operations

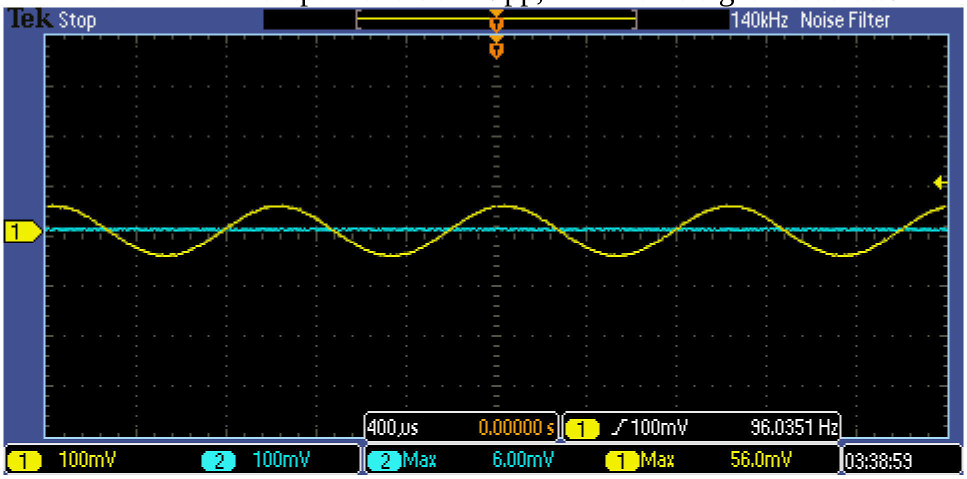
The main operation of this circuit is to take in a weak signal from a sound source and amplifies that signal with enough power to drive the speaker or headphone at the output. For our circuit, we stripped two 3.5mm female headphone wire to provide accessibility for headphone and sound source. At the input, we connected a female headphone wire at the potentiometer. Moreover, we connected the other one in parallel with the 47k ohm resistor by where Vout is in the schematic. The breadboard circuit and scope images are in the next pages.



The maximum output for a 50 mVpp, 1 kHz sine signal is below:

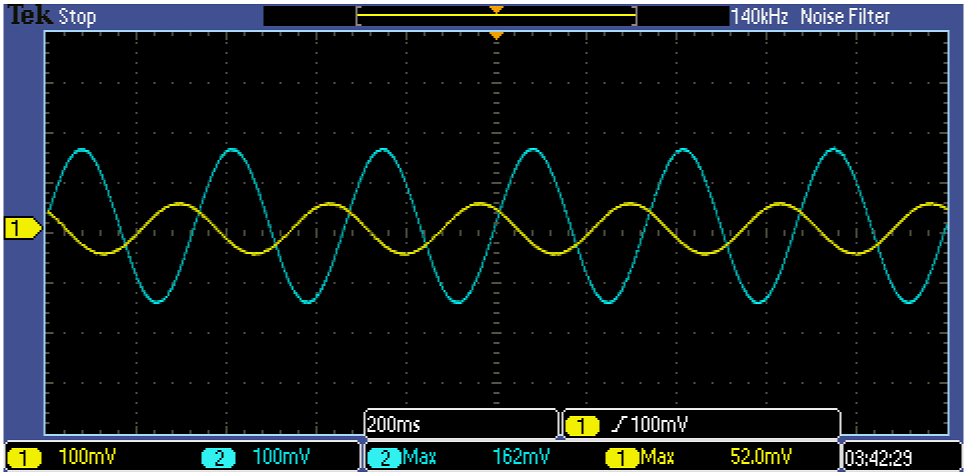


The minimum output for a 50 mVpp, 1 kHz sine signal is below:

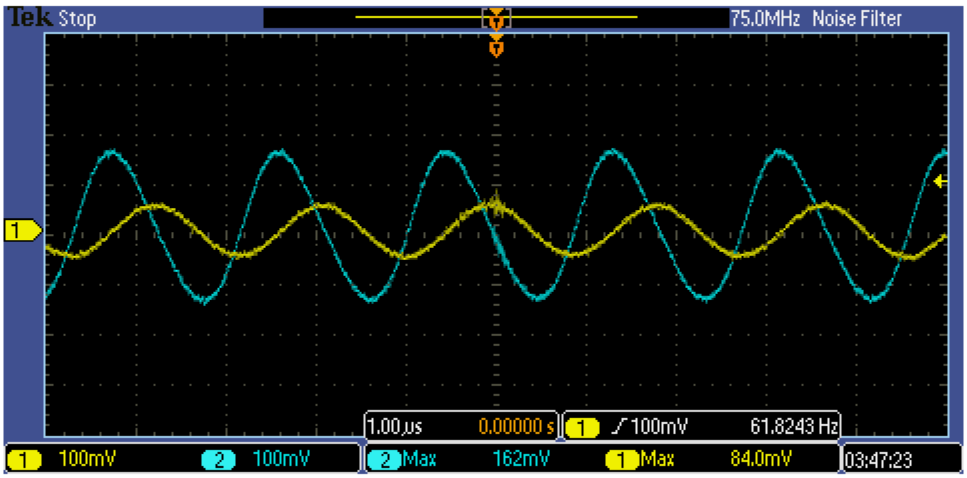


The lower and upper corner frequencies are below:

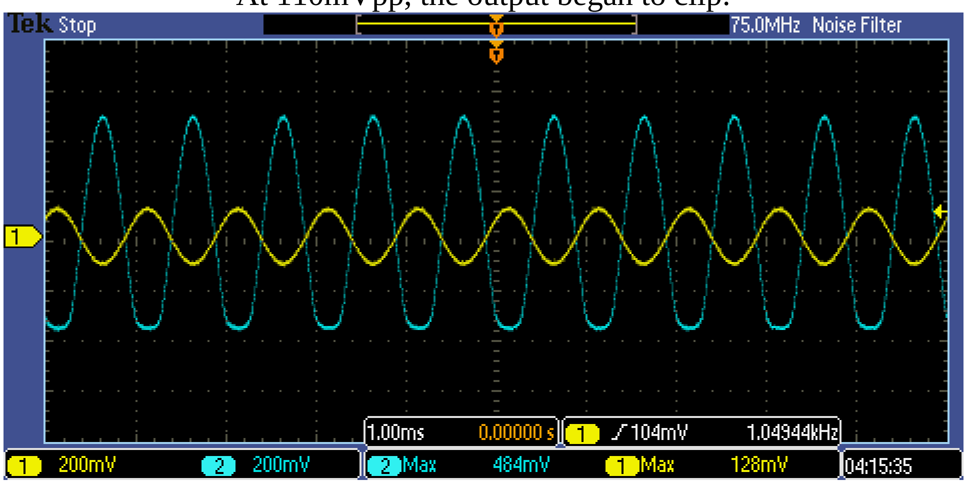
3 Hz



540 kHz



At 110mVpp, the output began to clip:



Here is the summary of all our measurements:

	Input	Max	F_{lower}	F_{lower}, BW	Gain	Distortion
Ideal	50 mV	230 mV	3 Hz	1.7 MHz	13.26 dB	1.2 V
Experimental	50 mV	234 mV	3 Hz	540 kHz	13.40 dB	110 mV

*Some of the experimental values may be greater than the ideal values due to the averaging capabilities of the oscilloscope which may alter these results.

Encountered Problems

During our final project, we encountered a few problems. The first problem we encountered is that our upper corner frequency is much lower than the LTSpice simulation. This is probably due to the simulation using an ideal op-amp as there is no lm741 in LTSpice. The second problem encountered was that our gain was higher than the simulation. This is most likely due to the oscilloscope averaging out values as the voltage was fluctuating. Our third issue was the clipping audio; this is caused by the speakers not being intended for volumes above a certain range or frequencies. This can also be caused by giving an input voltage higher than 100mV. The distortion mentioned earlier when a higher voltage is input is caused again by the simulation being technically inaccurate because it did not have the LM741. Because the simulation had an ideal op-amp the simulation had infinite gain possibilities whereas our circuit does not.

Conclusions

After finishing this final project for this laboratory class, we now have a better understanding about the inner workings of a headphone amplifier. The two stages of this amplifier are called preamplifier and the power amplifier. In our circuit, the active band pass operational amplifier circuit is the preamplifier, which takes in the weak signal from the sound source and amplifies the voltage. Moreover, the power amplifier is the Class AB amplifier which consists of two common collector BJT amplifiers, which takes the amplified input signal and output it with enough power to the headphone or speaker. With these two amplifiers combined, we can take a wide range of inputs from most sound source and amplify these sounds to most headphones and certain speakers.