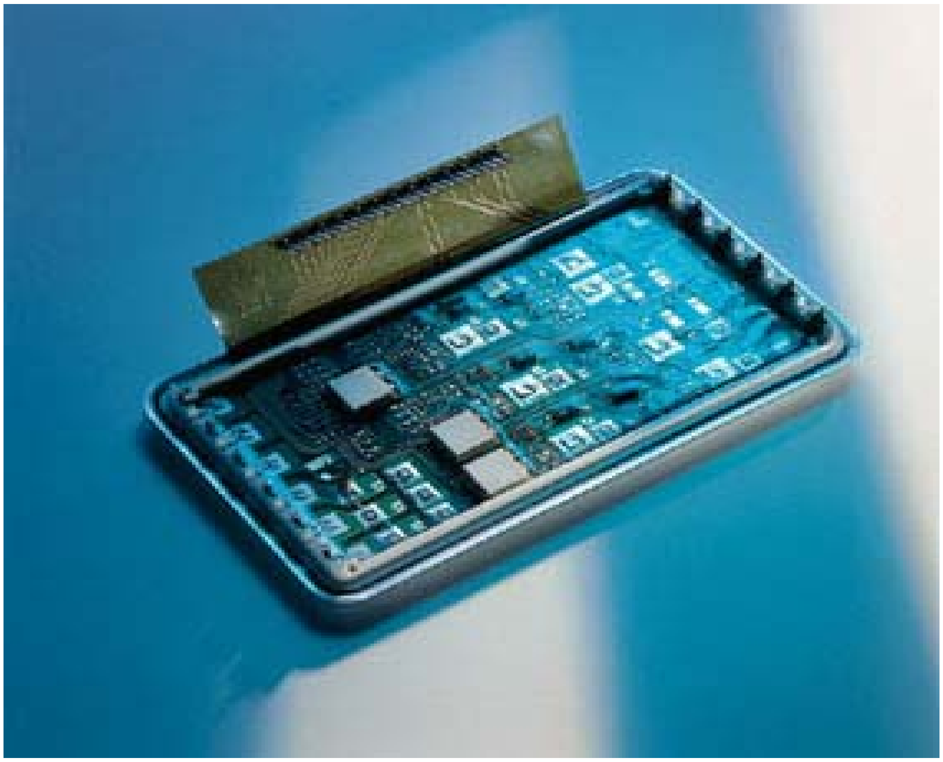

DESIGN AND BUILD YOUR OWN AUDIO AMPLIFIER

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Final Report
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Introduction

The purpose of this project was to design and build your own audio amplifier from scratch. Good audio amplifiers take a small input signal and magnify it several times, without distorting it, so that it can be heard at the speakers. In order to design our audio amplifier we used the scheme provided by professor Yang as a starting point, and made a few changes in order to meet the required specifications of high input impedance, low output impedance, and a gain of about 10.

The project was very instructive because it not only helped us solidify our theoretical knowledge acquired in Microelectronics classes, but it also gave us an insight into the procedures an engineer must take from a design on paper to a final working product. Another benefit of this project is the satisfaction that is gained after completing such a challenging task. Even though our design satisfies all requirements there are many other ways to design a good audio amplifier; either by using op-amps or JFET instead of the BJT used in our design.

The design of our audio amplifier was done on PSPICE, where we made sure that all requirements were met. After completing the design we built the circuit on the bread board and compared the observed DC voltages and currents with the ones obtained in PSPICE. We then designed a PCB layout on Microsoft Paint and built the PCB board. Few changes were made from the initial design in order to improve the performance of our circuit. This report contains all design schematics and measurements, as well as observed measurements done on the PCB board.

Circuit design

Our audio amplifier consists of two parts: a differential stage built using 2 BJTs and an emitter follower. The differential pair is used to amplify the input signal while the emitter follower is used as a power amp stage providing the necessary current to the load. Figure 1 below shows the circuit built in PSPICE.

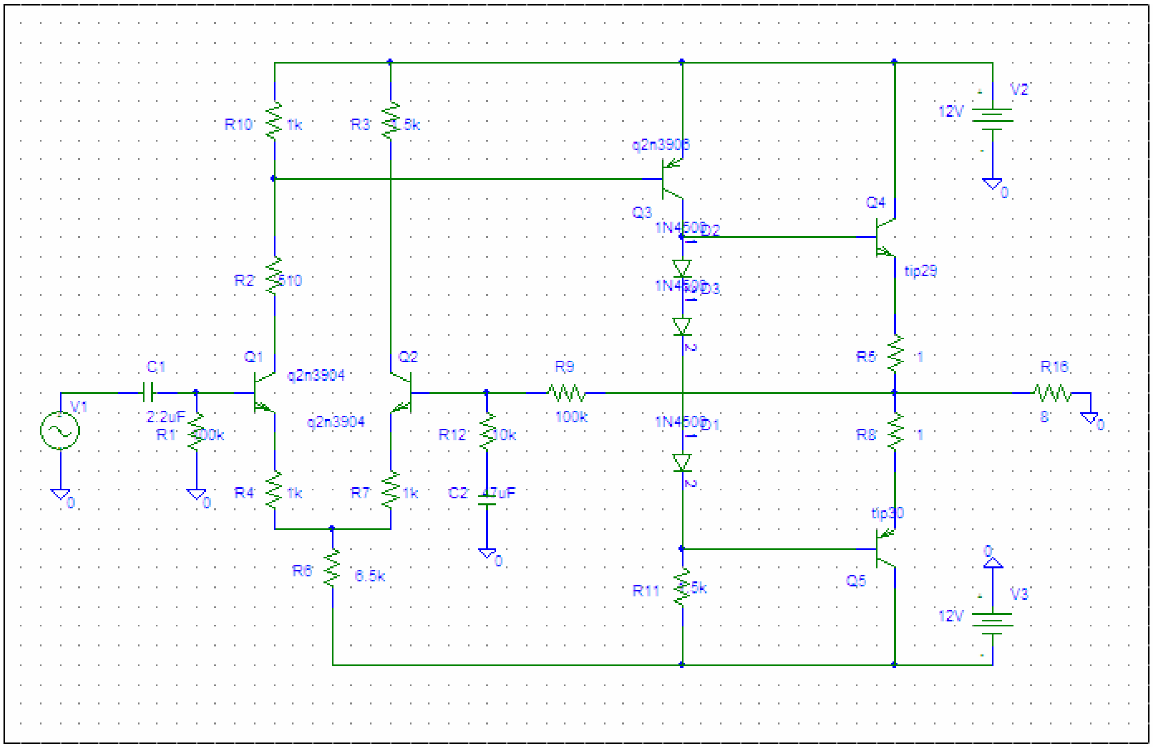


Figure 1: Final Audio Amplifier Schematic

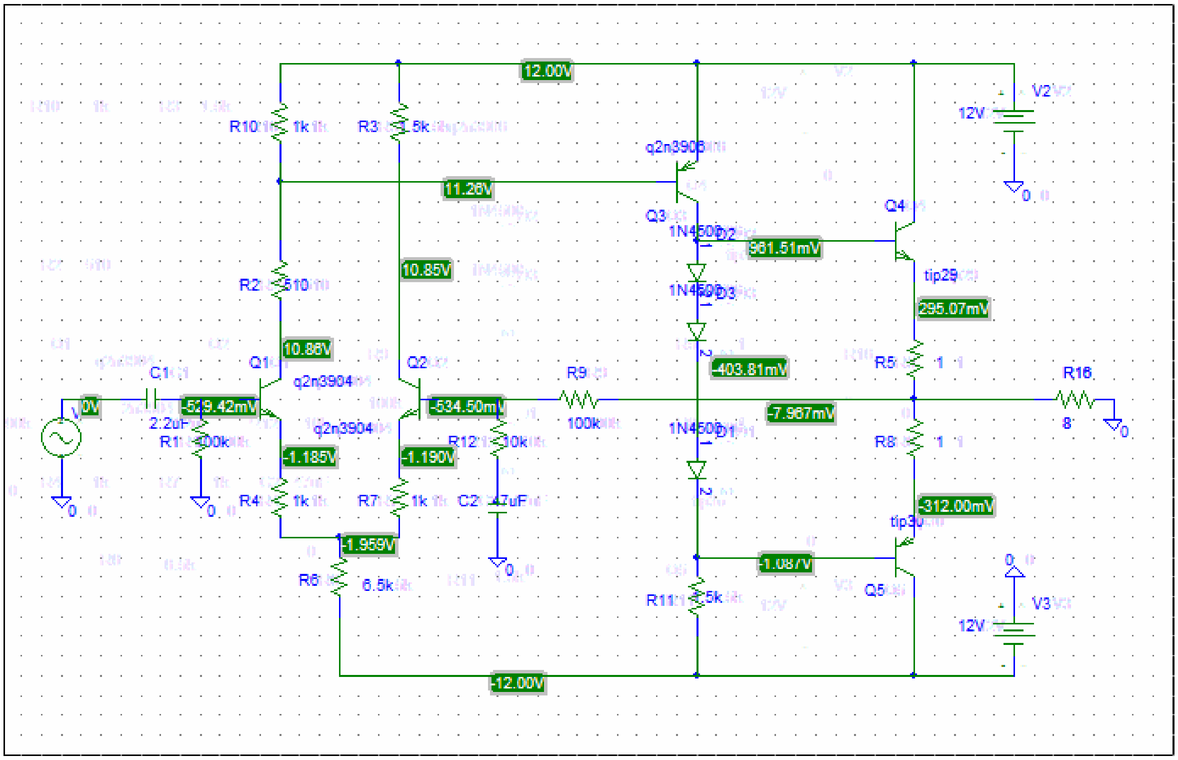


Figure 2: DC Voltages in PSPICE

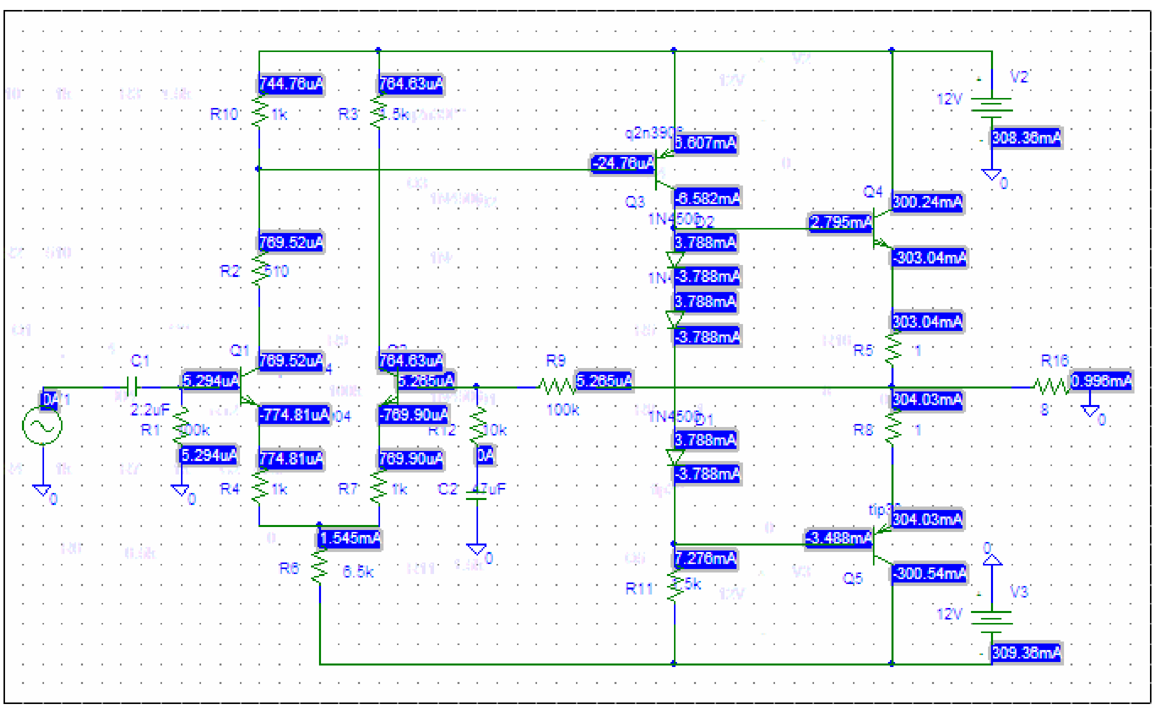


Figure 3: DC Currents in PSPICE.

Figure 2 and 3 above, show the various DC voltages and currents that were obtained in PSPICE.

Figure 4 below shows the voltage gain as a function of frequency. From the figure we can see that the gain is approximately 10 across the audio range (from 10 Hz to 20 KHz).

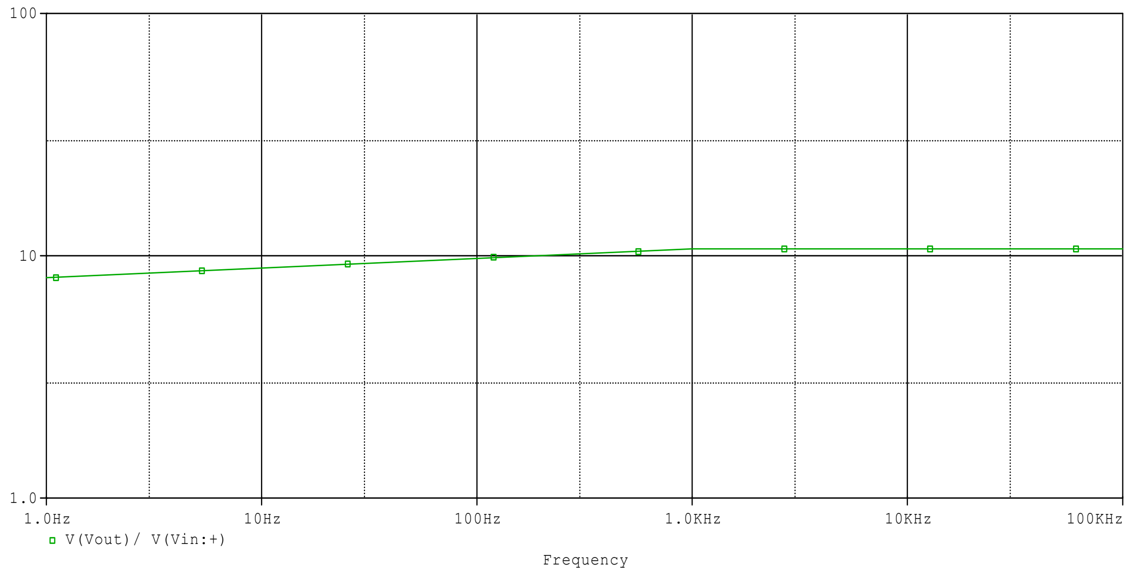


Figure 4: Voltage Gain as a function of Frequency

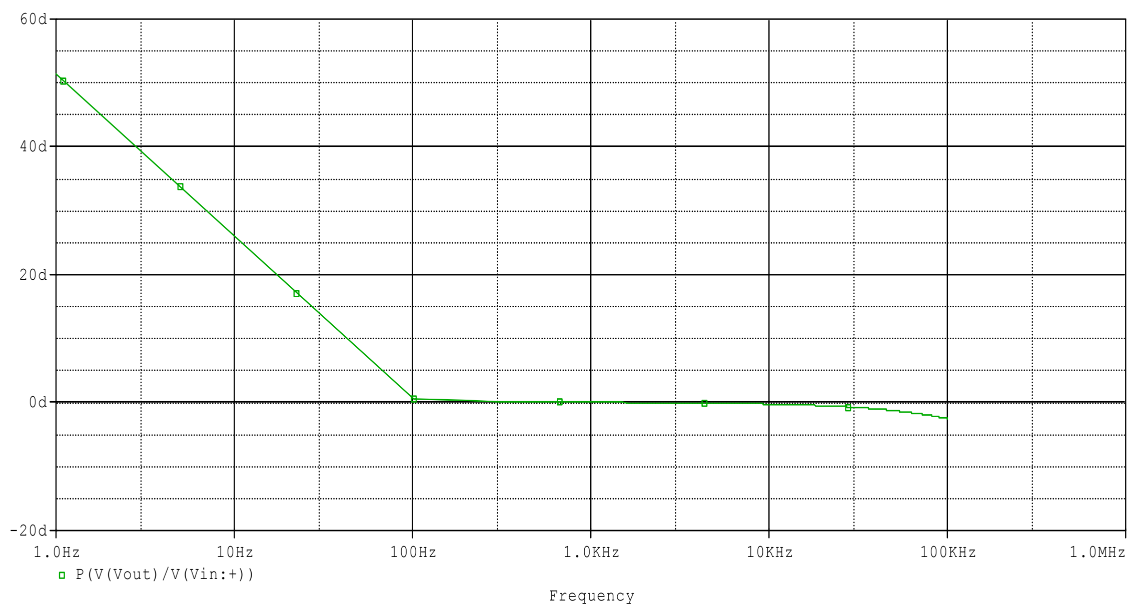


Figure 5: Phase as a function of Frequency

As it can be seen from Figure 6 below the input impedance in the audible frequency range is approximately 100KΩ. In the ideal case the input impedance would be infinite, but since our circuit is far from being ideal 100KΩ is an acceptable value.

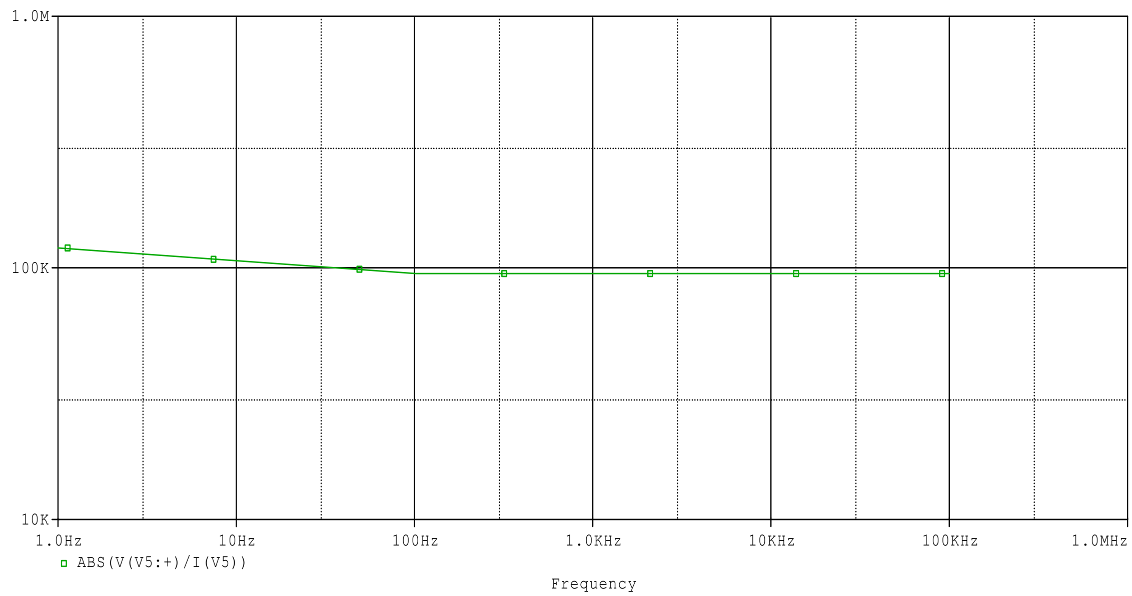


Figure 6: Input Impedance vs. Frequency (Amplitude)

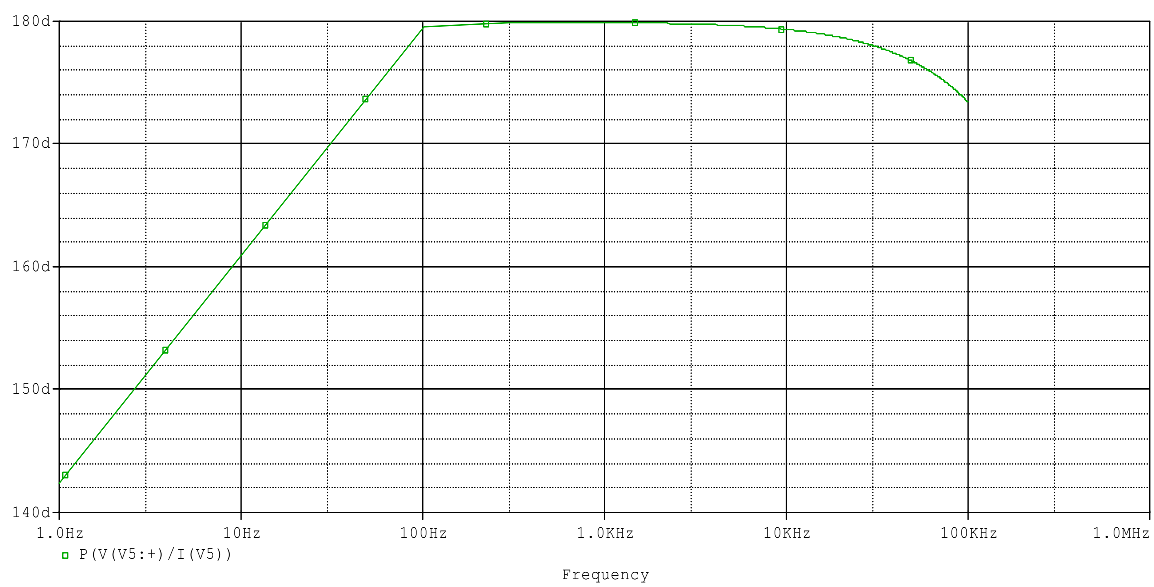


Figure 7: Input Impedance vs. Frequency (Phase)

As it can be seen from the figure below the output impedance is approximately zero, which is the desired value.

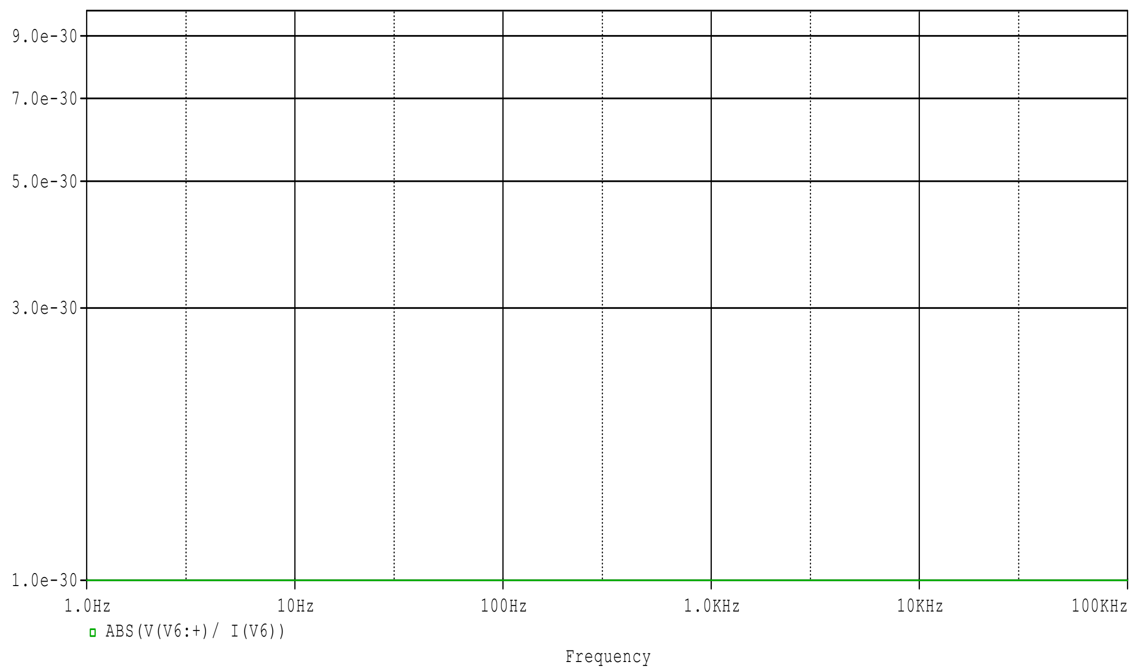


Figure 8: Output impedance vs. Frequency (Amplitude)

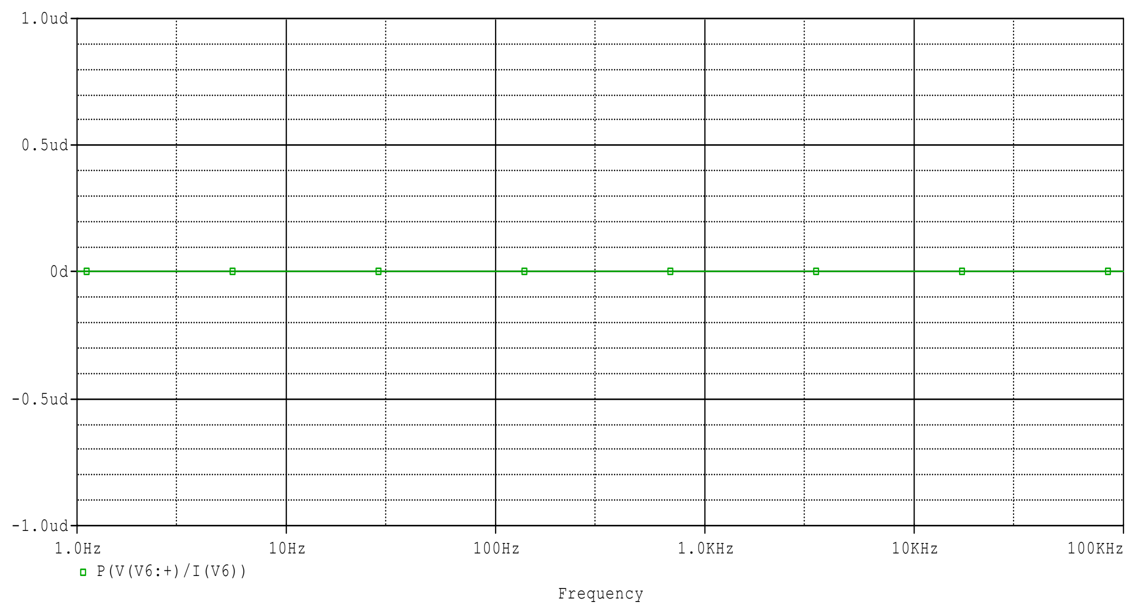


Figure 9: Output impedance vs. Frequency (Phase)

Figure 10 shows the input vs. the output as simulated in PSPICE.

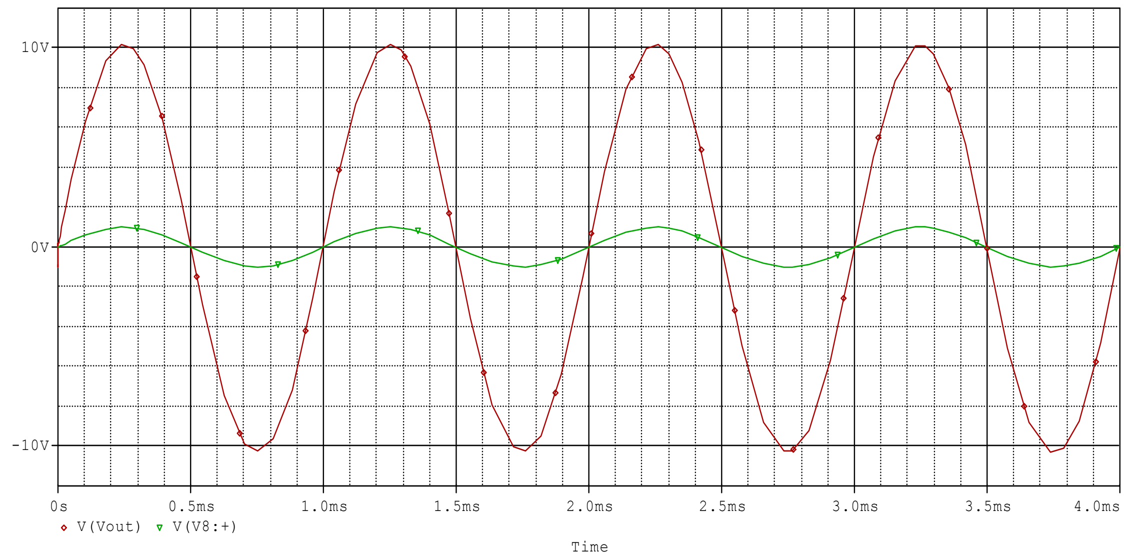


Figure 10: Input vs. Output

Figure 11 below shows the PCB layout for our circuit.

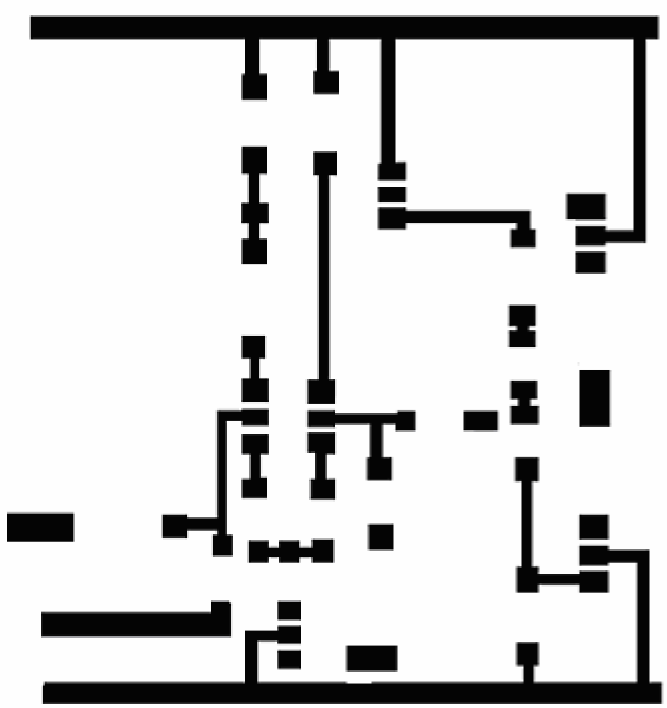


Figure 11: PCB layout

Although we came up with a scheme for the Tuner we were not able to test it or build it due time restrictions. The figure below shows the schematic for the Tuner.

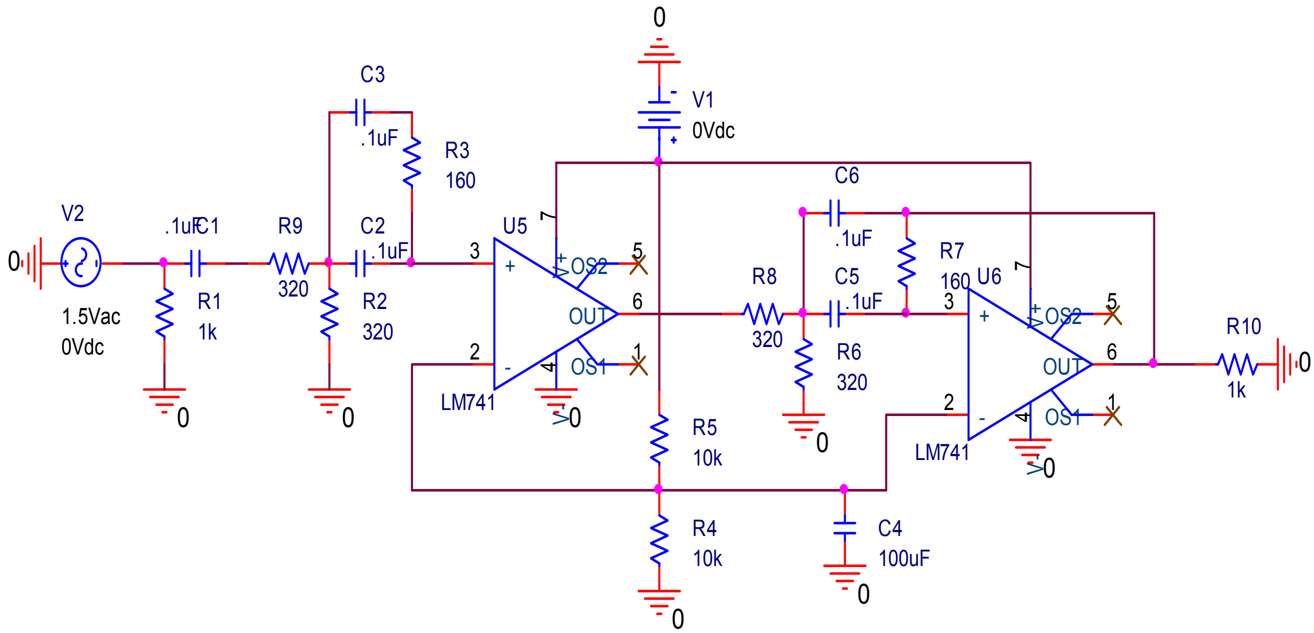


Figure 12: Tuner Schematic

Experiment

The actual built circuit is shown in Figure 13. As it can be seen almost all voltages are close to the ones simulated in PSPICE. The output voltage is -4.2 mV; ideally this would be equal to zero but -4.2 mV is small enough not to burn the speaker. There were several problems associated with the original circuit so we had to change the biasing resistors in order to achieve the desired output. After obtaining a good result on the bread board we built our circuit on the PCB board. The most challenging part of our project was probably troubleshooting the PCB board. We had to build the circuit twice and make sure that we did not have a cold solder anywhere. In fact after rebuilding the circuit the second time the circuit was not working because one side of the 47uF capacitor was not soldered correctly. One of our recommendations for future student is that they should make sure that every single item is properly soldered.

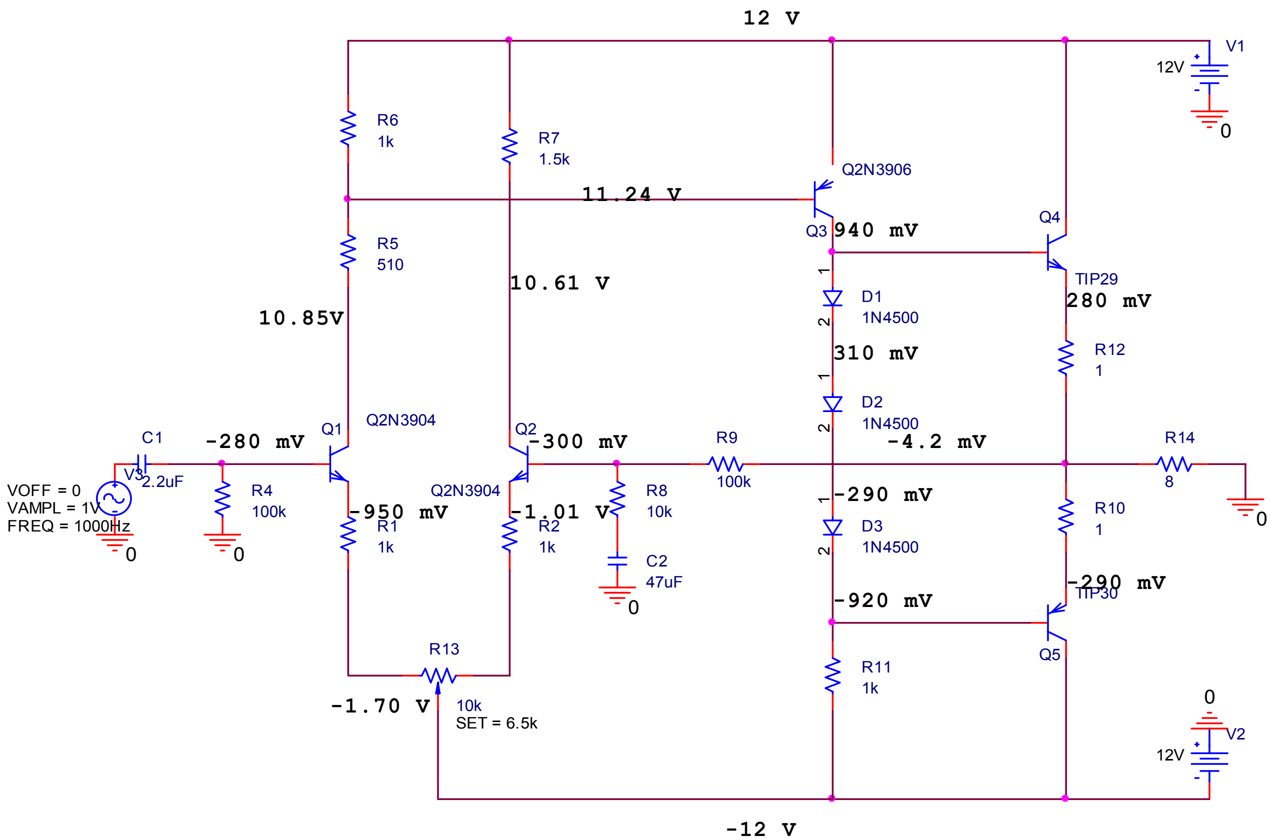


Figure 13: Actual DC Voltages.

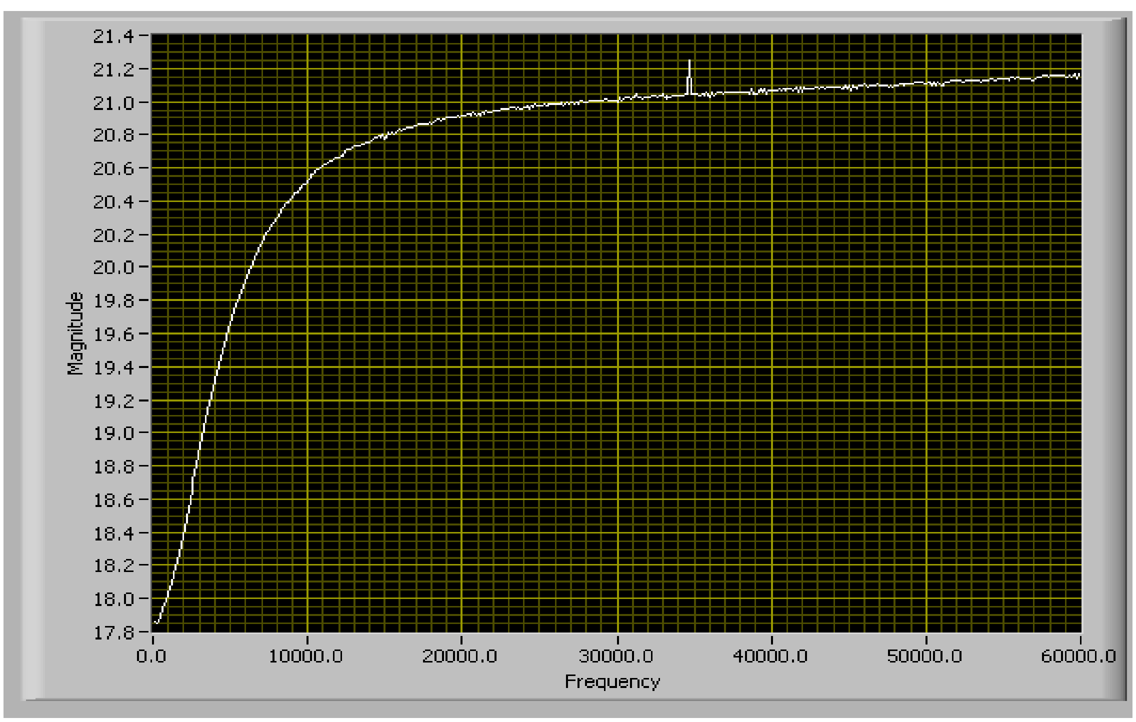


Figure 14: Gain Amplitude vs. Frequency.

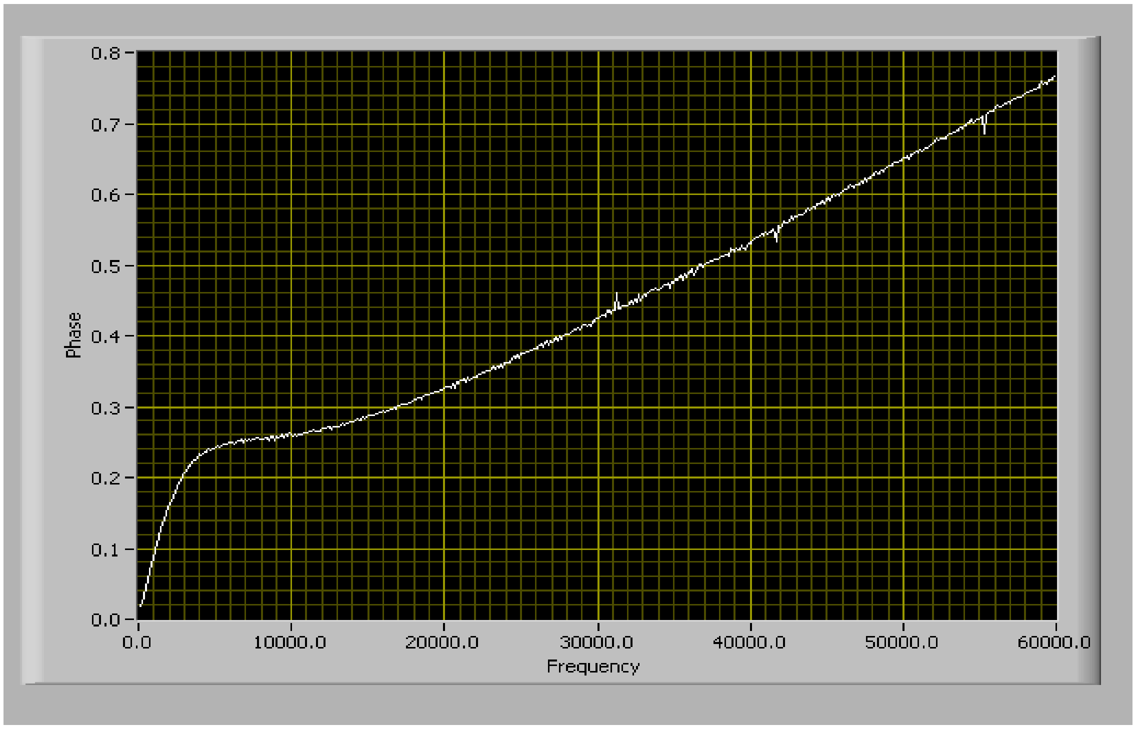
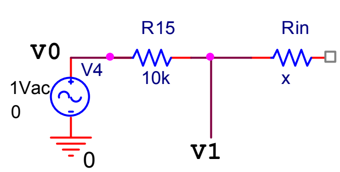


Figure 15: Gain Phase vs. Frequency

Figure 14 and 15 represent the Amplitude and Phase of the Gain plotted against the Frequency. The plots were done using LabView and as it can be seen the log-log plot of the Amplitude increases smoothly and settles around 21; while the linear-log plot of the phase has a steep slope, but since the circuit is far from being ideal this is an acceptable result.

Input and Output Impedance

In order to measure the input impedance we used Kirchoff's current law after inserting a 10K resistor at the input. The picture shown below shows the scheme that was used:



The procedure we followed was to measure the V0 and V1 shown in the picture and use the following equation to solve for Rin:

(V0 – V1) / 10K = V0 / Rin

Rin = (V0*10K) / (V0 – V1)

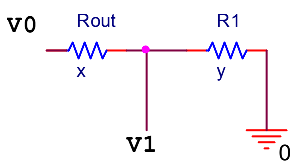
For input amplitude of 200mV and frequency of 1000 Hz the input impedance we obtained was**: Rin = (580 mV * 10K) / (630 mV – 580 mV) = 116 KΩ.** This value is very close to the one obtained using PSPICE which was 100KΩ.

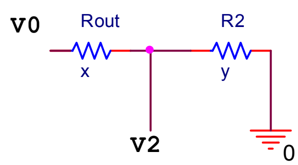
The following table list input impedances measured at different frequencies.

Frequency (Hz)	Input Impedance (KΩ)
15	109
200	112
5400	115
10256	115
40000	116

Table 1: Input Impedance as a function of Frequency

The Output Impedance was measured using a similar scheme as the one used to measure the input impedance. The pictures shown below show the scheme that was used:





By measuring V1 and V2 and using known resistor values R1 and R2, we plugged the values in the following equations and solved them for Rout:

1. (V0 – V1) / Rout = V1 / R1 **2. (V0 – V2) / Rout = V2 / R2**

After equating equation 1 and 2, we solved them for Rout. The result we obtained is the following:

Rout = (V1- V2) / [(V2/R2) – (V1/R1)]

Table 2 shows the Output Impedance for several values of input Frequency:

Freq (KHz)	**R1(Ω)**	**V1(mV)**	**R2(Ω)**	**V2(mV)**	**Rout(Ω)**
1.040	13.6	59.9	5.6	57.8	0.355
5.295	13.6	56.9	5.6	54.9	0.356
9.927	13.6	58.3	5.6	56.2	0.365
18.684	13.6	58.8	5.6	57.5	0.219

Table 2: Output Impedance as a function of Frequency

As it can be seen from the table above all Output Impedance values are very close to zero as desired.

The following are pictures of the PCB circuit that we built.

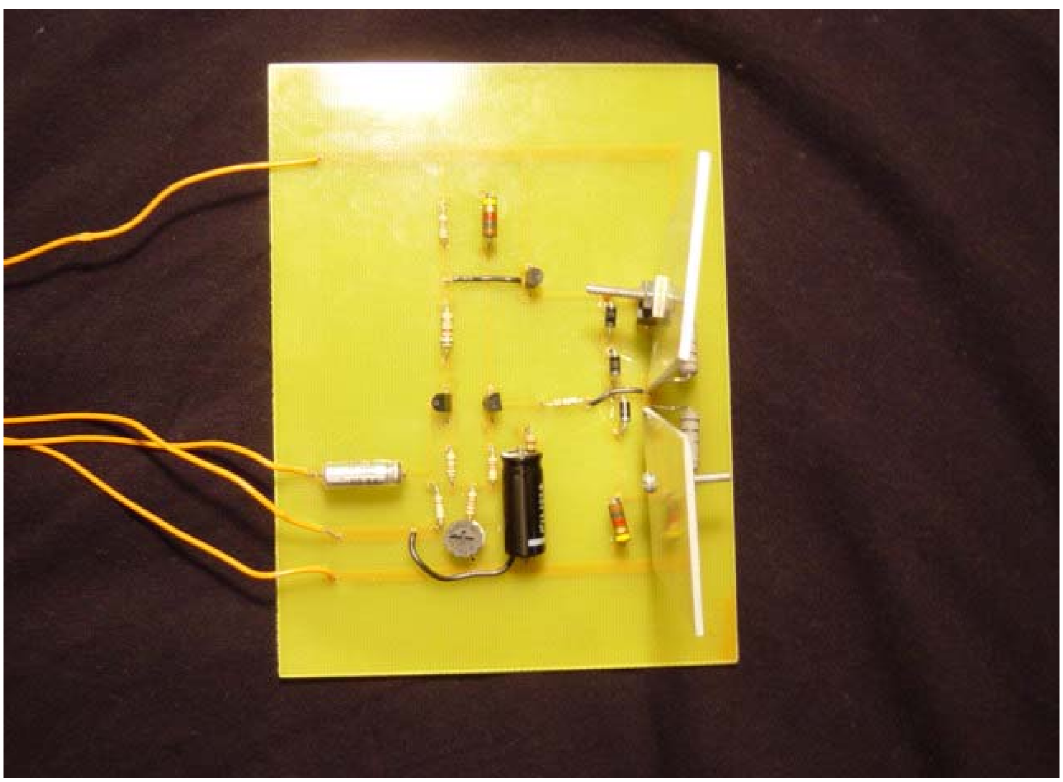


Figure 16: Actual Audio Amplifier (top view)

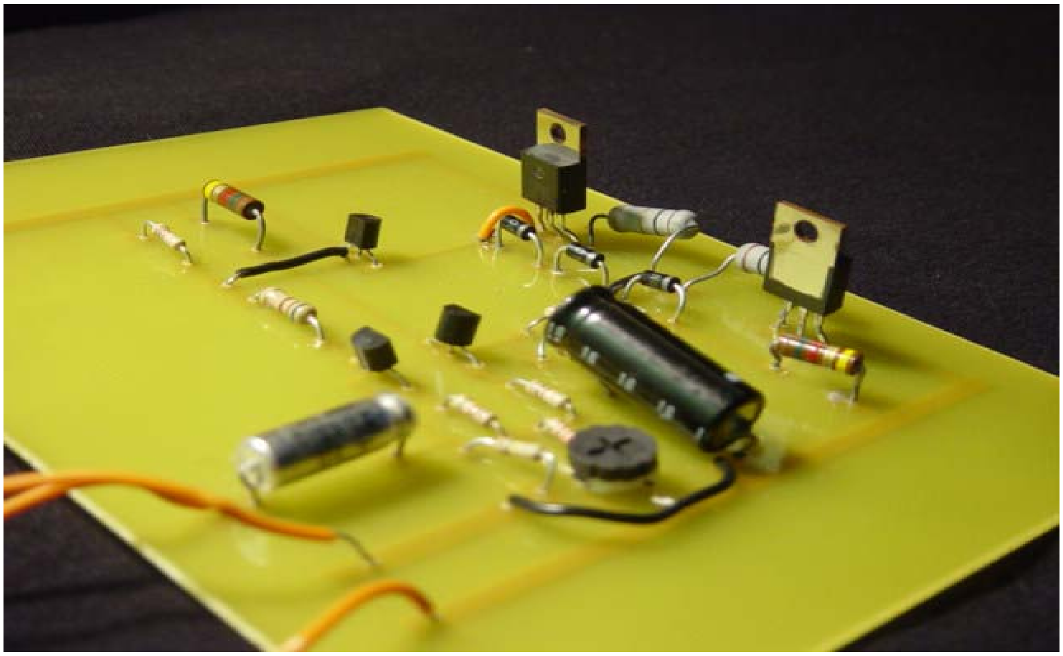


Figure 17: Actual Audio Amplifier (side view)

Discussions

The main obstacle that we encountered with our circuit was not with the design but with its real world application. We found that PSPICE can really only be a guide or reference tool used to give the general expected results. When the design gives the desired results in PSPICE, the challenge is achieving those results on the breadboard.

Once we built our circuit on the breadboard we spent a considerable amount of time tweaking our design to get the desired gain at the output. Most of our problems rooted in voltage and current biasing problems. We went through a series of labs testing a seemingly infinite amount of resistor value configurations until we achieved a functional output. The only remaining problem lied in an output voltage that was too large. We remedied this problem by placing a potentiometer before the emitters in our differential amp stage which made the granular adjustment needed to correct our circuits biasing currents.

With pleasing breadboard results, we moved on to building our PC board. After constructing a malfunctioning channel in route to our final working board, the main thing we learned was that the physical quality of the board is what characterizes your results. It is of optimal concern to draw a layout that allows clean copper paths followed by solid solder connections in order to attain the breadboard results.

Overall, this lab gave us a real opportunity to experience what it is like to design and build a real world circuit. It gave us the necessary benefit of realizing the circuits we have been studying only in textbooks in previous classes at the University. Future projects may have involved building amplifiers of different classes or selective tuners like those used in AM/FM radios.