Final Project Report

ENGR 301
Section 1
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Objective:

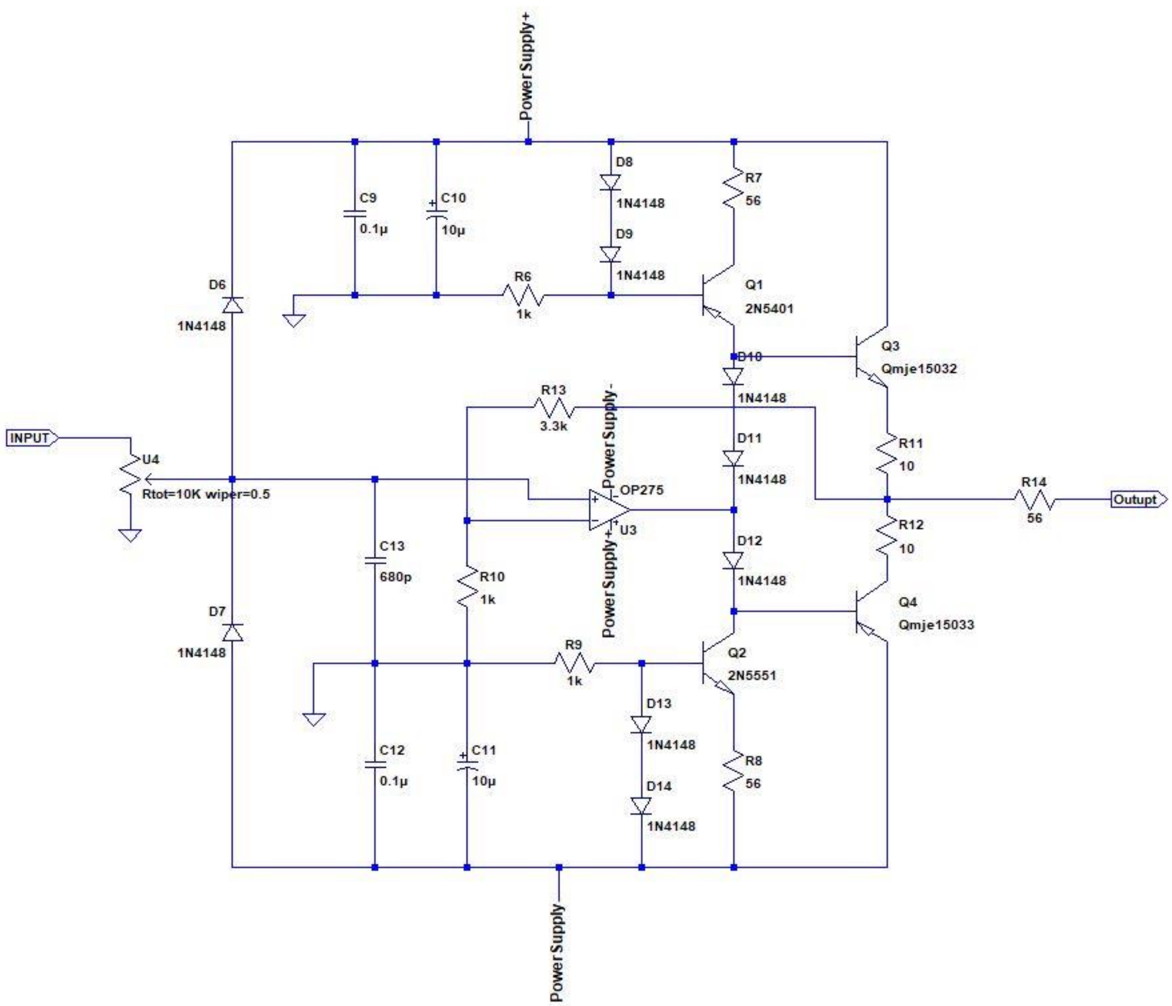
This report details the building process of our Engr 301 final project, a low-noise headphone amplifier. The objective of the project was to familiarize students with the process of designing and building a circuit, its board, component assembly, and testing/debugging our board

Components List:

Students were challenged to minimize the total price of components purchased. We were able to price the total price per board below ~$30 by buying in bulk as a group. Our Bill of Materials is listed in Appendix A at the end of this report.

Design:

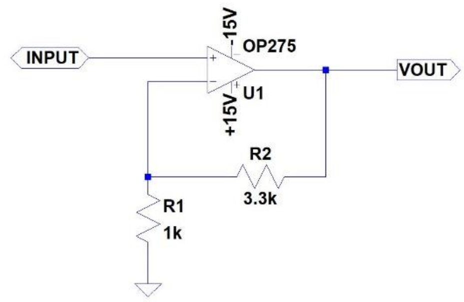
Amplifier: A low-noise amplifier or LNA is an electronic amplifier that amplifies a very low-power signal without significantly degrading its signal-to-noise ration and minimize any additional noise. Our design for the amplifier (show below) is composed of four primary parts.



Amplifier simulation recreated in LTSpice

1. **Non-Inverting Amplifier (OP275)**

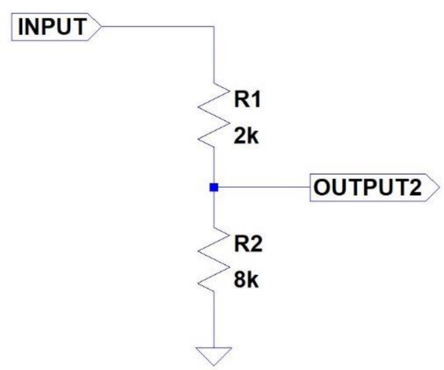
In the amplifier design, the non-inverting amplifier played a major role in keeping the distortion rate in the low range. It is known to be a highly valued op amp that can generally output linearly waveforms. Since non-inverting amplifiers are very sensitive compared to other op amps, they would be able to reproduce the most accurate waveforms. More importantly, it combines both bipolar and other transistors to help maintain the speed and sound quality, making it the perfect op amp to use for the amplifier design



$$\boxed{\frac{V_{out}}{V_{in}} = A_v = 1 + \frac{R2}{R1}}$$

2. **Voltage Divider (Potentiometer)**

The voltage divider is a common engineering tool generally used in a variety of industries. Used as a voltage divider for various circuits, it's main structure consists of three terminals total, where two of these terminals are connected to the ends of a resistive component. This type of resistive component is usually regarded as two resistors connected in series whereas the wiper determines the resistance ratio of the first resistor to the second resistor. Most importantly, it provides a changeable voltage as a control level in the amplifier circuit design in the final project.



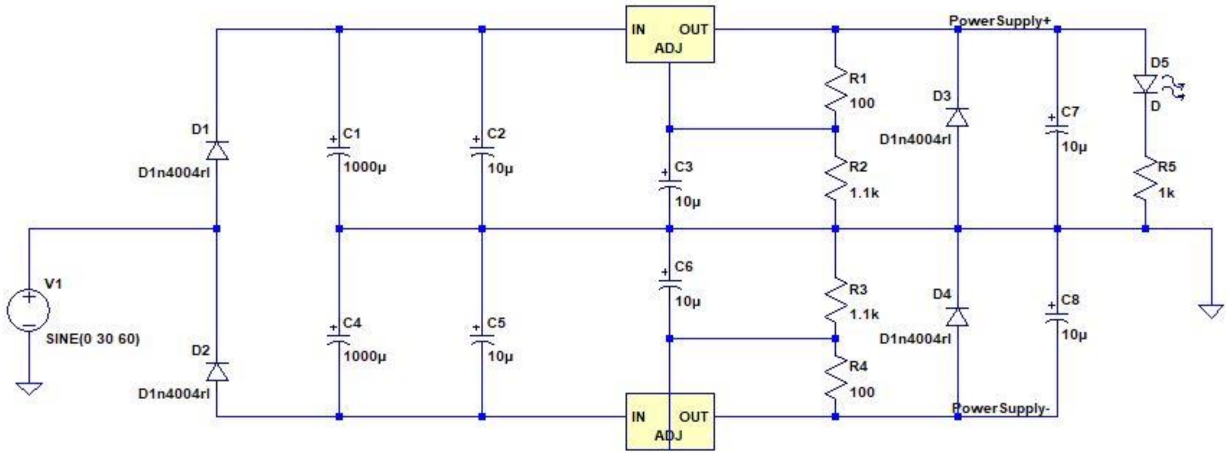
3. **Output Voltage Swing (Transistors)**

The output voltage swings are a set of transistors, which are defined as how close the op-amp output is under specified conditions. The main goal of these transistors is to determine the amount of current of the op-amp and its capability of the op-amp is largely dependent on the op-amp's output along with the load current. The transistors played a critical role to the amplifier circuit design as they tell you whether the circuit works as planned.

4. **Filter Capacitors**

The filter capacitors play a role of filtering out a certain range of different frequencies in a circuit board. Acting as a low-pass filter, these capacitors are in charge of passing through low frequency signals and blocking the high frequency signals. Their purpose is not to filter noise that's coming in, but to prevent any device from injecting noise into the main section.

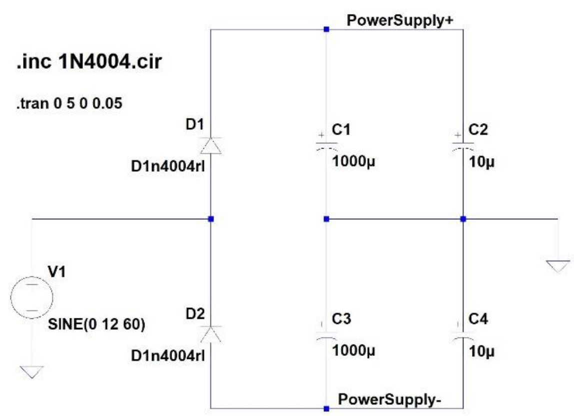
Power supply: Our power supply is composed of a rectifier circuit that acts as a AC to DC converter, and we regulate the output voltage to +15 and -15V. The PSU, pictured below, is composed of 4 main sections.



PSU in LTSpice Simulation

1. **Rectifier (Diode)**

In the power supply design, the rectifier is an electrical device that converts alternating current(AC) to direct current(DC). It is composed of one or more diodes and it can take the shape of various forms. Most importantly, the rectifier can be performed in a variety of such as a source of power used in laptops, televisions, and video games. Based on the power supply design, we needed a rectifier to get DC current to operate the circuit.



2. **Positive and Negative Voltage Regulators (±15V)**

The voltage regulators on the power supply design serves to generate a fixed output voltage of a preset magnitude that remains constant regardless of the changes to the input voltage. This regulation of the output voltage level is usually handled by various feedback techniques such as the Zener diode for example. For the power supply design, we used both positive and negative voltage regulators to operate the circuit.

3. **Bypass Capacitors**

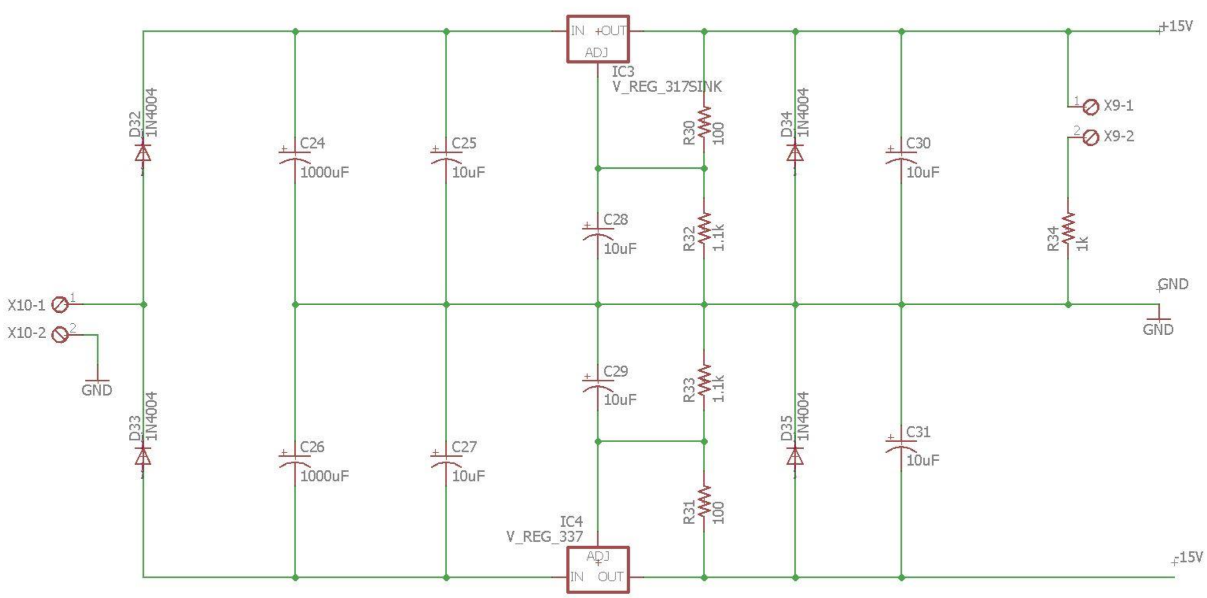
The bypass capacitors are in charge of shorting out the AC signals to ground so that any of the AC noise is removed. So basically, this capacitor type will bypass all the AC noise lingering on a DC signal and filter it out to make sure that there's AC ripple going through the DC signal. These AC ripples are most likely going to show up, especially at very high frequencies. We wanted to make the DC signal stay as clean as possible and we don't want any AC ripples, so we used some of these bypass capacitors in our circuit.

4. **Terminal Blocks (Usage)**

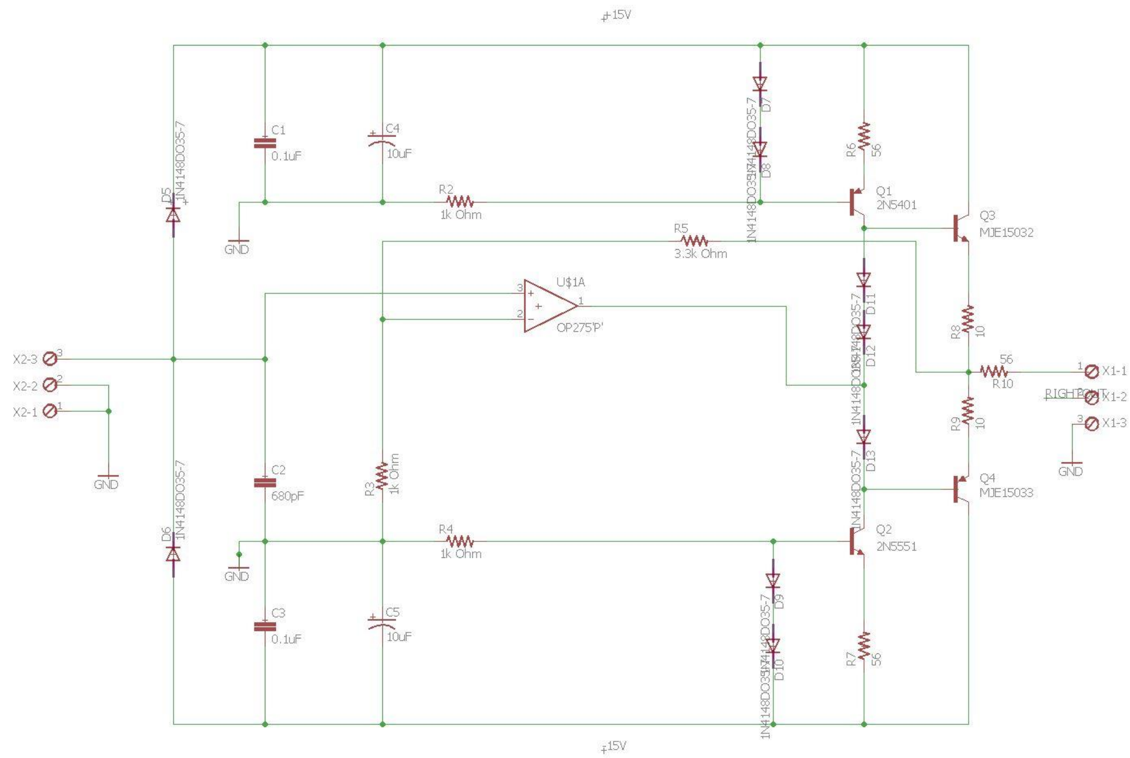
The terminal blocks serve as a connector, which basically allows more than one circuit to connect to another circuit. Known as connection terminals, they are used to secure and terminate wires. Most people use these terminal blocks for connecting the wires to ground and connecting the electrical switches and outlets to the main section. Their main purpose is to reduces corrosion caused by the action between two different types of metals.

Using Eagle

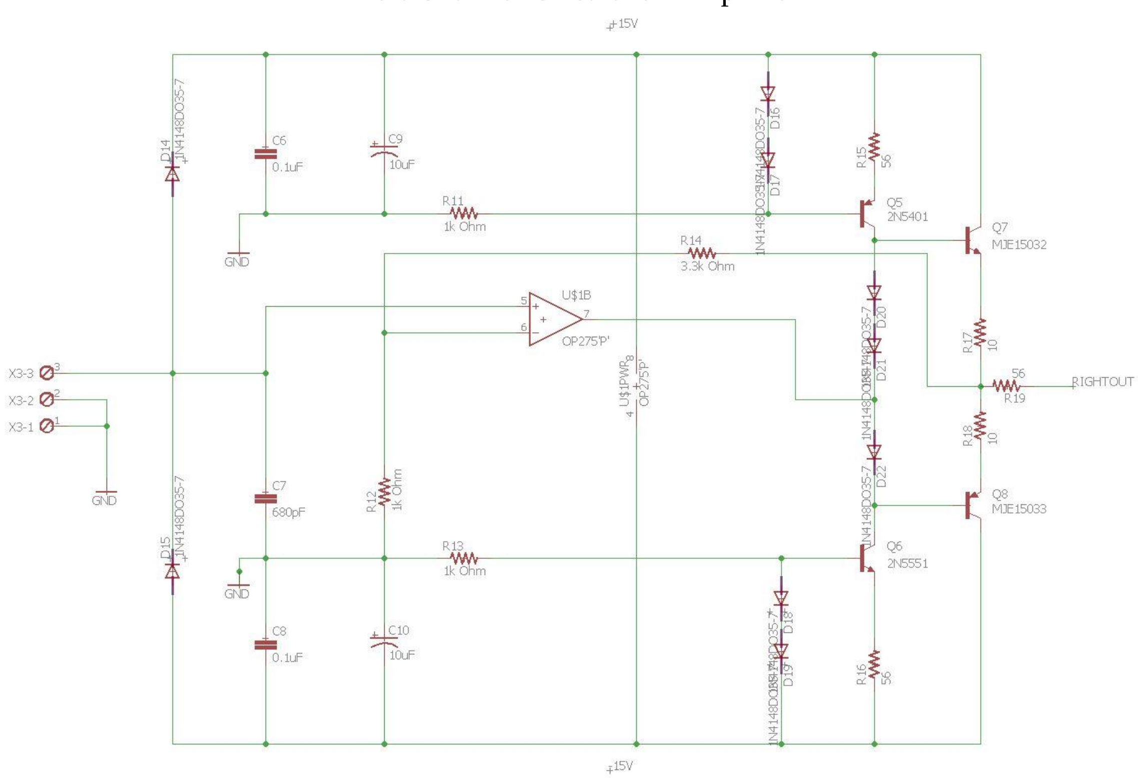
Using Eagle, we reconstructed the schematics given to us (in pdf) during the first weeks in class for both the PSU and left/right amplifiers, all in one sheet. We were provided the additional components that were not in Eagle's standard library. We placed each component, picking out the ones of the smallest size due to our board-size constraint of 3x3in. With in a couple of weeks, we came up the following:



Power Supply Schematic in EAGLE



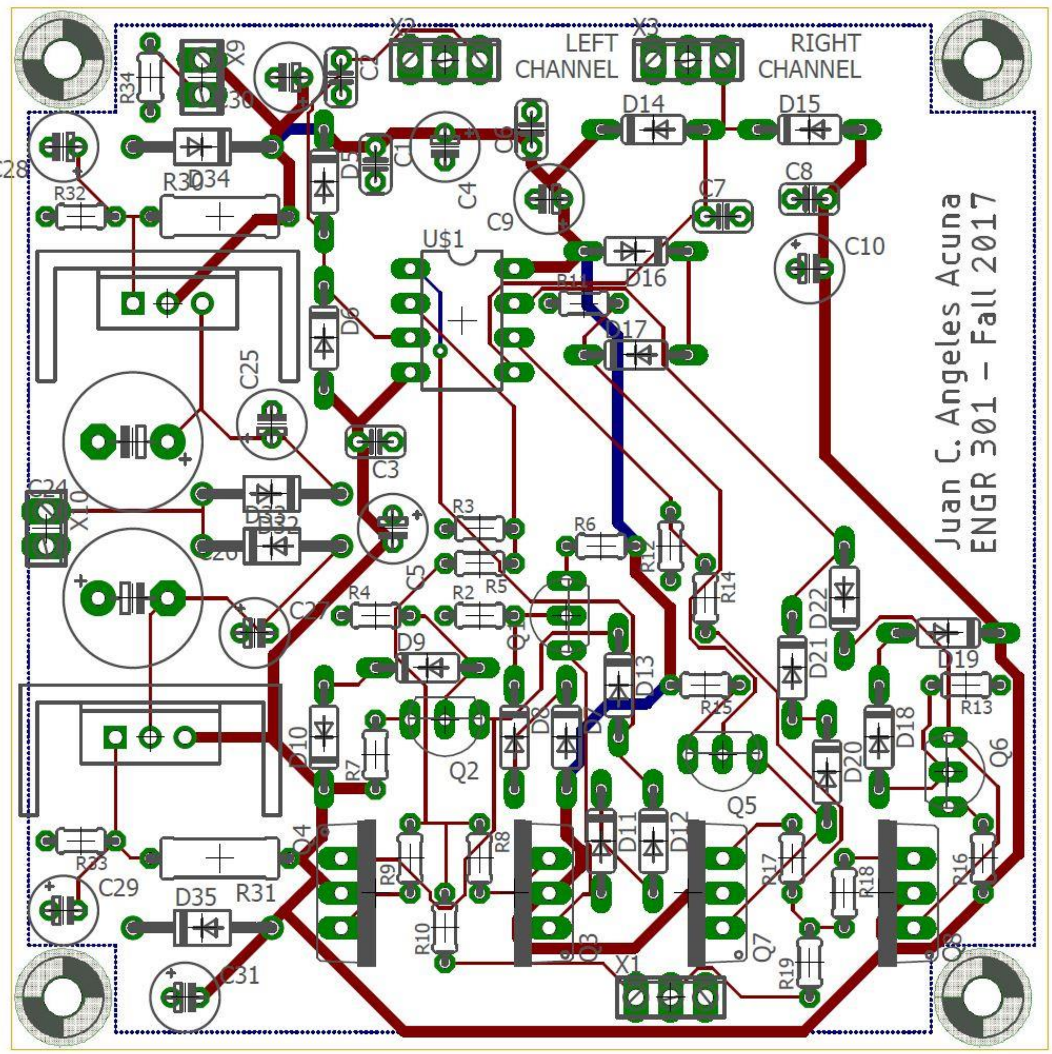
Left Channel Circuit for Amplifier



Right Channel Circuit for Amplifier

When we finished placing all the necessary components on our schematics, including the connectors to the components that are not in the board, our next step is to design the board itself. From EAGLE itself, we generated a 3x3in board and placed the components one by one. In the figure below, we see the placement of all the components in addition to some notes:

- We tried to placement as to no have any vias and most importantly, have a clean trace to reduce noise generated by other parts of the circuit.
- To the left, we see the components of the PSU, while on the right we have the power lines going from top to bottom across the amplifiers.
- In addition, we labeled the left/right channel input (top) and output (bottom)and placed our name, class, and semester.
- We placed a board-wide ground pour.
- We placed mounting holes on each corner to mount on an enclosure.
- We made our power lines wider.



EAGLE generated board

Once all the components were placed, we were confident our build was successful (no errors in all the tests provided in EAGLE), they were ready to be shipped to the PCB manufacturer. From EAGLE CAM, we generated GERBER files (which consisted of Component side, solder side, silk screen CMP, solder stop mask CMP, and solder stop mask SOL, etc), which are the files needed to build the board.

Purchasing

While waiting for the manufacturer, students oversaw purchasing the components (listed in Appendix A). We got all our stuff from Digikey, and purchased in bulk for two people. The specs for each part were obtained from EAGLE schematics. For every component, we needed the specific value and size as we needed to fit them all in one board.

Soldering/Building

Soldering was a relatively easy process, having experience in the field and the ability to learn fast. Our group finished soldered with little to now problem. We started with smaller components, such as resistors and caps, and worked our way up in terms of size.

Conclusion

This semester-long project gave us key knowledge on the process of designing and building a circuit board. Through EAGLE, we learn how to design and build a schematic, generate an efficient board layout, and GERBER files. We also learned how to choose and shop for electronic components, within a given set of constraints, size and money. Finally, we learned the process of soldering, desoldering, testing and debugging our built board. As of the time this writing, one of our fully built board work flawlessly, and we expect the other to do as well. All this gain knowledge will be crucial for our senior project, and our future jobs. As a side note, in the process of writing this report to created simulations which were not required but are shown in the figures throughout the report. (see picture below)

Final board (working w/ extra credit) =)

Appendix A

Low-noise Headphone Amplifier -- Bill of Materials

POWER SUPPLY

Description	Reference Designator	Qty	Unit Price	Total Price	Vendor	Vendor P/N	Manufacturer	Manufacturer P/N
CAP 1000 UF 20% 16 V	C24, C26	2	0.41000	$0.82	Digikey	732-8609-1-ND	Wurth Electronics Inc.	860010375017
CAP 10 UF 20% 16 V	c25, C27-31	6	0.10000	$0.60	Digikey	732-8593-1-ND	Wurth Electronics Inc.	860010372001
DIODE GEN PURP 400V 1A DO41	D32-35	4	0.10400	$0.42	Digikey	1N4004-TPMSCT-ND	Micro Commercial Co	1N4004-TP
RES 100 OHM 1W 5% AXIAL	R30, R31	2	0.24000	$0.48	Digikey	RSMF1JT100RCT-ND	Stackpole Electronics Inc.	RSMF1JT100R
RES 1.1K OHM 1/2W 1% AXIAL	R32, R33	2	0.20000	$0.40	Digikey	PPC1.10KXCT-ND	Vishay BC Components	SFR16S0001101FR500
RES 1K OHM 1/2W 1% AXIAL	R34	1	0.20000	$0.20	Digikey	PPC1.00KXCT-ND	Vishay BC Components	SFR16S0001001FR500
IC REG LIN POS ADJ 1.5A TO220AB	IC3	1	0.58000	$0.58	Digikey	LM317TG	ON Semiconductor	LM317TG
IC REG LIN NEG ADJ 1.5A TO220AB	IC4	1	0.76000	$0.76	Digikey	LM337TGOS-ND	ON Semiconductor	LM337TGOS-ND
IC OPAMP AUDIO 9MHZ 8DIP	U$1	1	3.43000	$3.43	Digikey	OP275GPZ-ND	Analog Devices Inc.	OP275GPZ

LEFT/RIGHT CHANNEL

Value	Reference Designator	Qty		Total Price	Vendor	Vendor P/N	Manufacturer	Manufacturer P/N
DIODE GEN PURP 100V 200MA DO35	D5-22	18	0.06300	$1.13	Digikey	1N4148FS-ND	ON Semiconductor	1N4148
CAP CER 0.1UF 50V Y5V RADIAL	C1, C3, C6, C8	4	0.12700	$0.51	Digikey	BC1160CT-ND	Vishay BC Components	K104Z15Y5VF5TL2
CAP CER 680PF 50V C0G/NP0 RADIAL	C2, C7	2	0.31000	$0.62	Digikey	BC1023CT-ND	Vishay BC Components	K681J15C0GF5TL2
CAP 10 UF 20% 16 V	C4, C5, C9, C10	4	0.10000	$0.40	Digikey	732-8593-1-ND	Wurth Electronics Inc.	860010372001
RES 1K OHM 1/2W 1% AXIAL	R2, R3, R4, R11, R12, R13	6	0.17300	$1.04	Digikey	PPC1.00KXCT-ND	Vishay BC Components	SFR16S0001001FR500
RES 3.3K OHM 0.4W 1% AXIAL	R5, R14	2	0.24000	$0.48	Digikey	BC3270CT-ND	Vishay BC Components	MBA02040C3301FCT00
RES 56 OHM 0.4W 1% AXIAL	R6, R7, R15, R16, R10, R19	6	0.19700	$1.18	Digikey	BC3946CT-ND	Vishay BC Components	MRS16000C5609FCT00
RES 10 OHM 0.4W 1% AXIAL	R8, R9, R17, R18	4	0.19700	$0.79	Digikey	BC3924CT-ND	Vishay BC Components	MRS16000C1009FCT00
TRANS PNP 150V 0.6A TO-92 -2N5401	Q1, Q5	2	0.49000	$0.98	Digikey	2N5401CS-ND	Central Semiconductor Corp	2N5401
TRANS NPN 160V 0.6A TO-92 -2N5551	Q2, Q6	2	0.24000	$0.48	Digikey	2N5551TFCT-ND	ON Semiconductor	2N5551TF
TRANS NPN 250V 8A TO220AB - MJE15032	Q3, Q7	2	1.58000	$3.16	Digikey	MJE15032GOS-ND	ON Semiconductor	MJE15032G
TRANS PNP 250V 8A TO220AB - MJE15033	Q4, Q8	2	1.58000	$3.16	Digikey	MJE15033GOS-ND	ON Semiconductor	MJE15033G
CONN TERM BLOCK 2.54MM 2POS PCB	X9, X10	2	0.91000	$1.82	Digikey	ED10561-ND	On Shore Technology Inc.	OSTVN02A150
TERM BLOCK 3POS SIDE ENT 2.54MM	X1, X2, X3	3	1.98000	$5.94	Digikey	A98334-ND	TE Connectivity AMP Connectors	282834-3

TOTAL: $29.38