PHYSICS 406 - CMOY OPAMP TESTS

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PHYSICS 406

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INTRODUCTION/MOTIVATION

Going into this project, I had the goal in mind to create something that I would physically be able to take away from the class and use frequently enough to know that it was not a waste. At the same time, I wanted to learn how to do something that I had never done before, to be able to take away some intangible benefits from the course as well. I am also something of a fundamentalist in that I like to make things "from scratch." The full reconciliation of these manifested through the CMOY headphone amplifier.

The CMOY headphone amp is an extremely simple circuit (Figures 1, 2) designed to amplify a small signal like headphone music (thus, on the order of mW in terms of power). The simplicity is an important deciding factor, as I have never built a circuit before and to create as little room for human error in the process of building the circuit.

The job of amplification and coloring of sound rests on the opamp in the circuit. The simplicity of the circuit almost guarantees that switching the opamp for various tests will expose the differences between each opamp's characteristics. Having also just taken ECE 210 and learned some introductory knowledge of opamp behavior in circuits, it seemed like good timing and a good opportunity for me to simply learn more about commonly used opamps.

THE SCHEMATIC

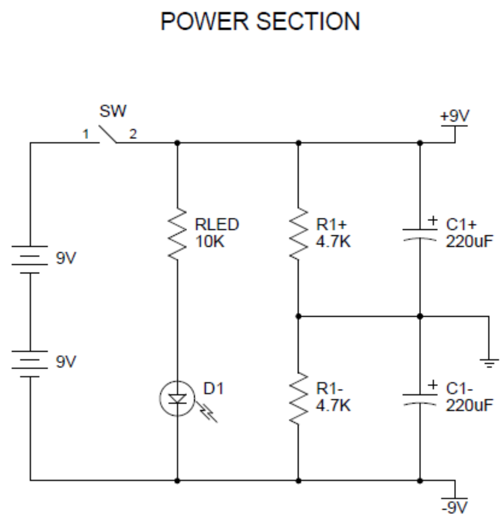

FIGURE 1: POWER SECTION SCHEMATIC FROM

HTTP://TANGENTSOFT.NET/AUDIO/CMOY-TUTORIAL/MISC/CMOY-TANGENT-SCH.PDF

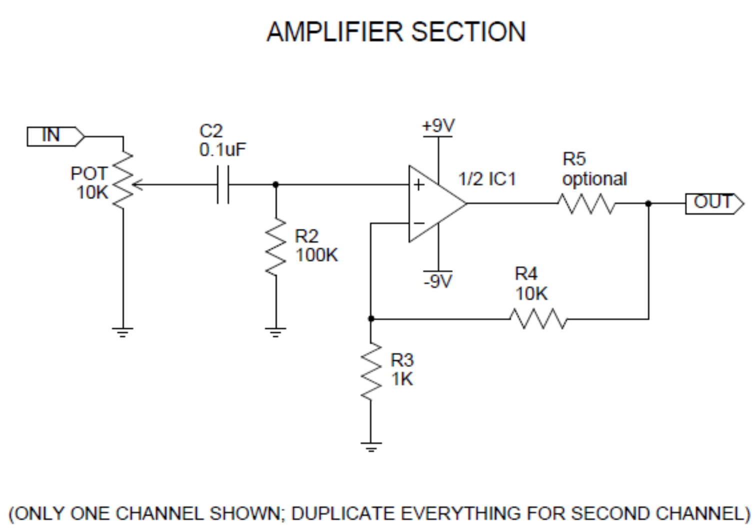

FIGURE 2: AMPLIFIER SECTION SCHEMATIC FROM

HTTP://TANGENTSOFT.NET/AUDIO/CMOY-TUTORIAL/MISC/CMOY-TANGENT-SCH.PDF

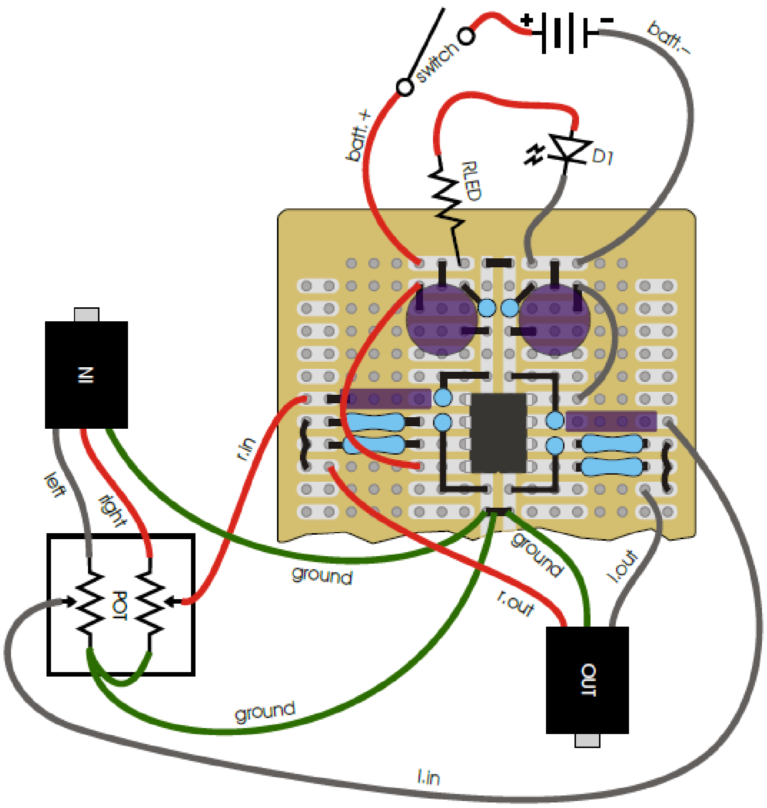

FIGURE 3: CMOY PCBOARD LAYOUT FROM TANGENTSOFT.NET

BUILDING PROCESS

Building the CMOY headphone amplifier was a slightly more complicated task than I had originally planned for. The first difficulty in building this circuit was finding and purchasing parts for it about which I had no knowledge of. Many of the parts for this project were purchased on blind faith from the parts list provided on the tangentsoft.net website. After acquiring the parts, I was baffled as to how to assemble them, as my only prior experience with circuits was using breadboards. With the assistance of Darby Hewitt, the TA of my lab section, I was able to learn how to solder components to the PC board as well as check the connections to make sure everything was working.

Another challenge that was persistent throughout the building process was the small form factor of the amplifier and case. It was a significant challenge at times to solder wires to contacts or fit them through holes because of the small size. Some of the challenges came as a direct result of my own ignorance prior to the purchase of the parts, which made assembly much more difficult than it needed to be. Of particular challenge was soldering wires to the potentiometer (Figure 4), as the contacts were weak and also within very close vicinity of one another. In order to provide the wires with shielding from one another, Darby Hewitt suggested encasing each wire with heatshrink. This worked, but also made the wires slightly heavier. This resulted in the potentiometer contacts breaking a few times, which caused some headache but wasn't impossible to fix.

FIGURE 4: THE INFERNAL POTENTIOMETER (P2U4103-ND)

The audio jacks also caused some headache to the effect of not being the type that screws to surfaces. With the help of Professor Errede and a few permanently borrowed screws, nuts, washers, and foam, I was able to affix the jacks to the bottom of the casing.

Upon testing the circuit for the first time, there was a short. This was apparent because the circuit got very hot very quickly. After double-checking all of the solders, nothing seemed to be wrong. However, Darby once again assisted me in this endeavor and alerted me to the possibility of the opamp possibly shorting because of exposure to the soldering heat. Upon replacing the opamp with another, the circuit worked perfectly.

OPAMP SELECTION

Testing the characteristics of the opamps in the circuit is the main objective of this project. An ideal opamp will take a signal and an inverted signal, and attempt to level out the voltages of each. The way this basically manifests in this simple circuit is amplification of sound signal. However there is the issue that there is no such thing as an ideal component in the real world. Thus there is much variation between various opamp chipsets, which all try to do a similar thing in various ways. This variation results in some chips having different qualities than others in terms of sound amplification.

Granted that I was running on a poor college student's budget, I could never hope to test opamps as extensively and exhaustively as I would have ideally imagined. To achieve more realistic results, I chose to whittle down the selection of opamps to be tested via a few criteria. The first of these criteria was limiting the opamps to be tested to only be ones that would fit into my existing circuit and have the same pin layout as the chip the circuit was originally designed for, the OPA2132. However even with this criterion there were too many opamps to choose from. So, with some researching on head-fi.org, I narrowed down the opamp selection to a few that are more commonly used and/or similar to the original OPA2132. This resulted in the following: OPA2132, NE5532, LM4562, OPA2277, OPA2134, and the LM6172.

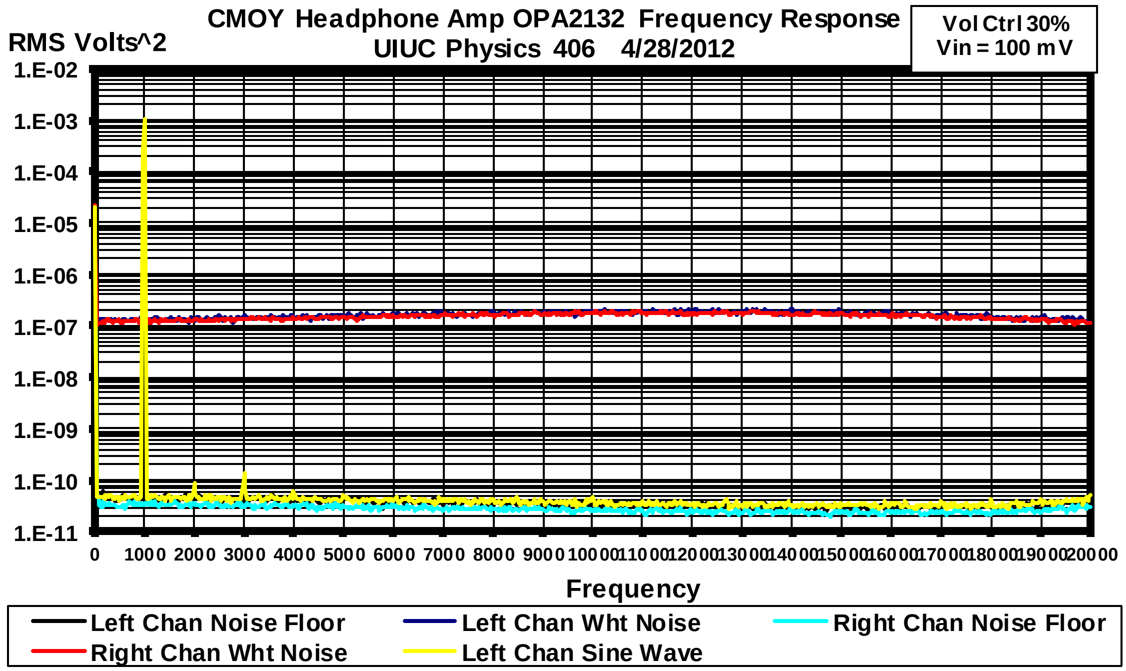

FIGURE 5: OPA2132 FREQUENCY RESPONSE DATA

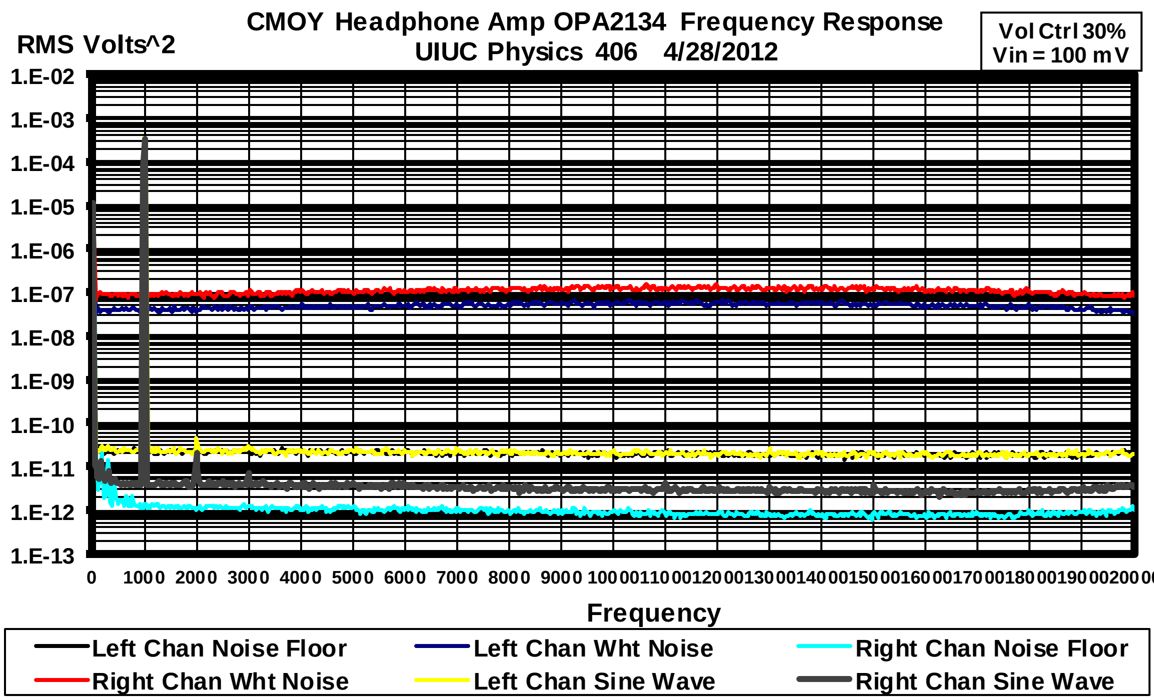

FIGURE 6: OPA2134 FREQUENCY RESPONSE DATA

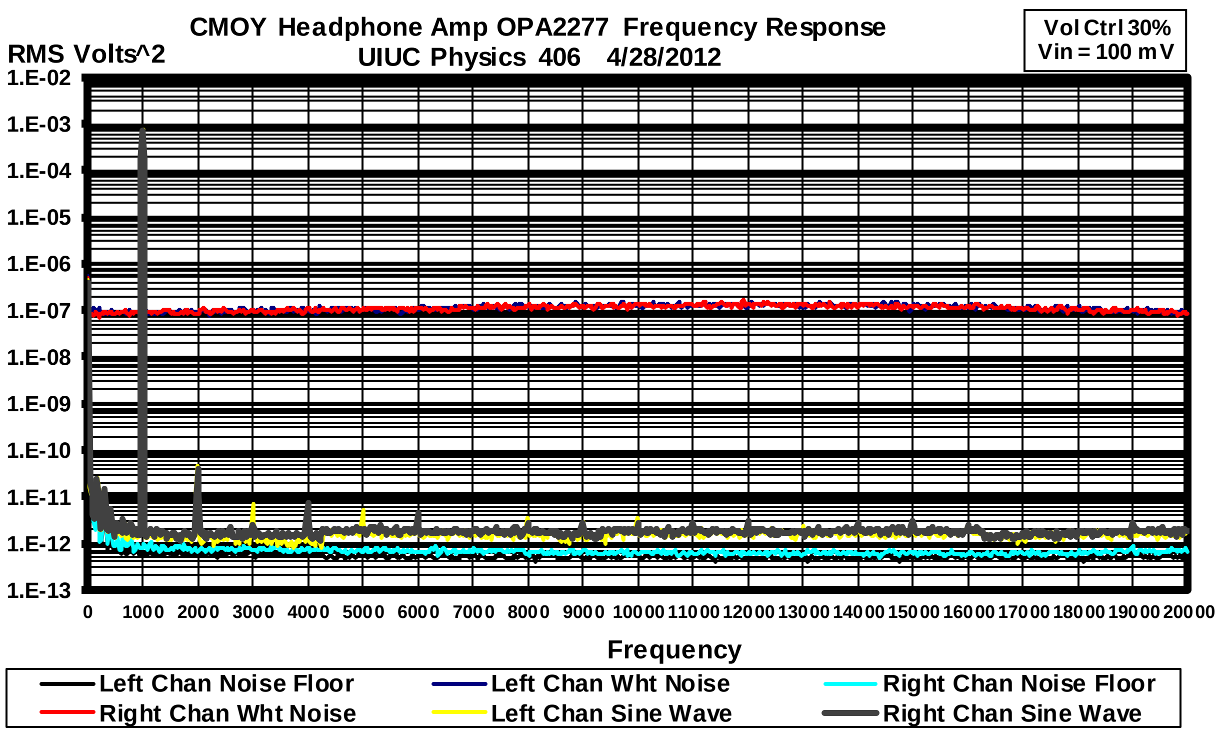

FIGURE 7: OPA2277 FREQUENCY RESPONSE DATA

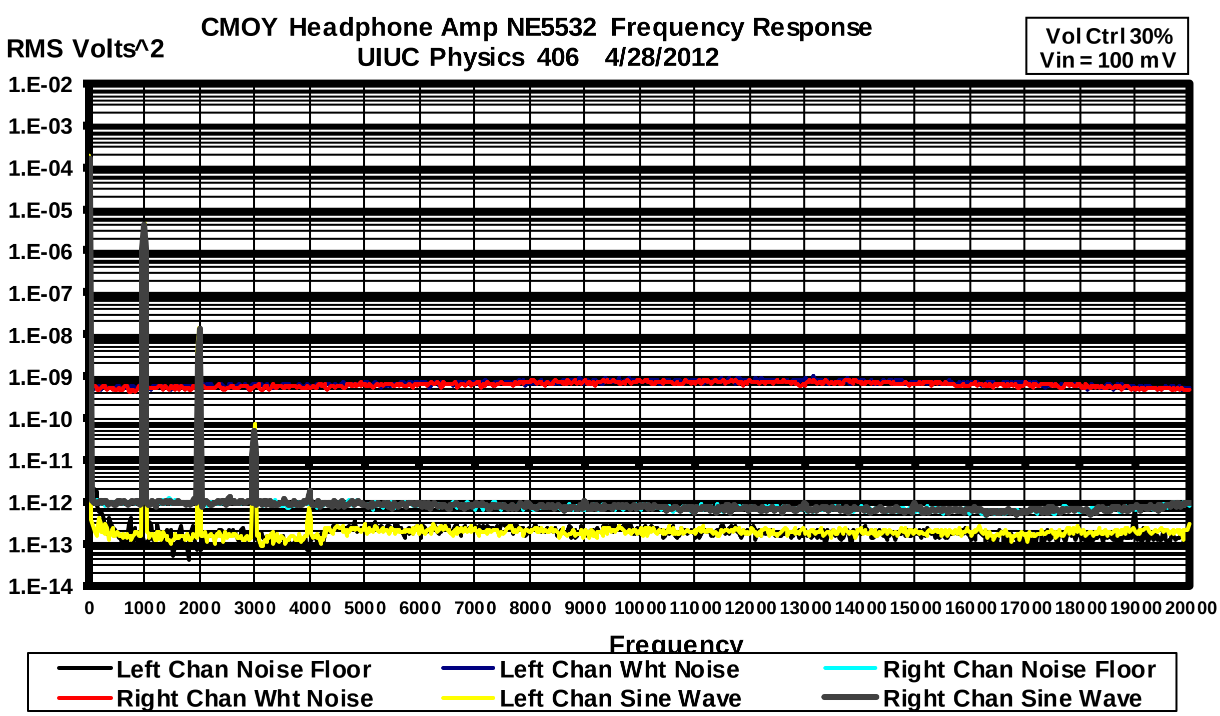

FIGURE 8: NE5532 FREQUENCY RESPONSE DATA

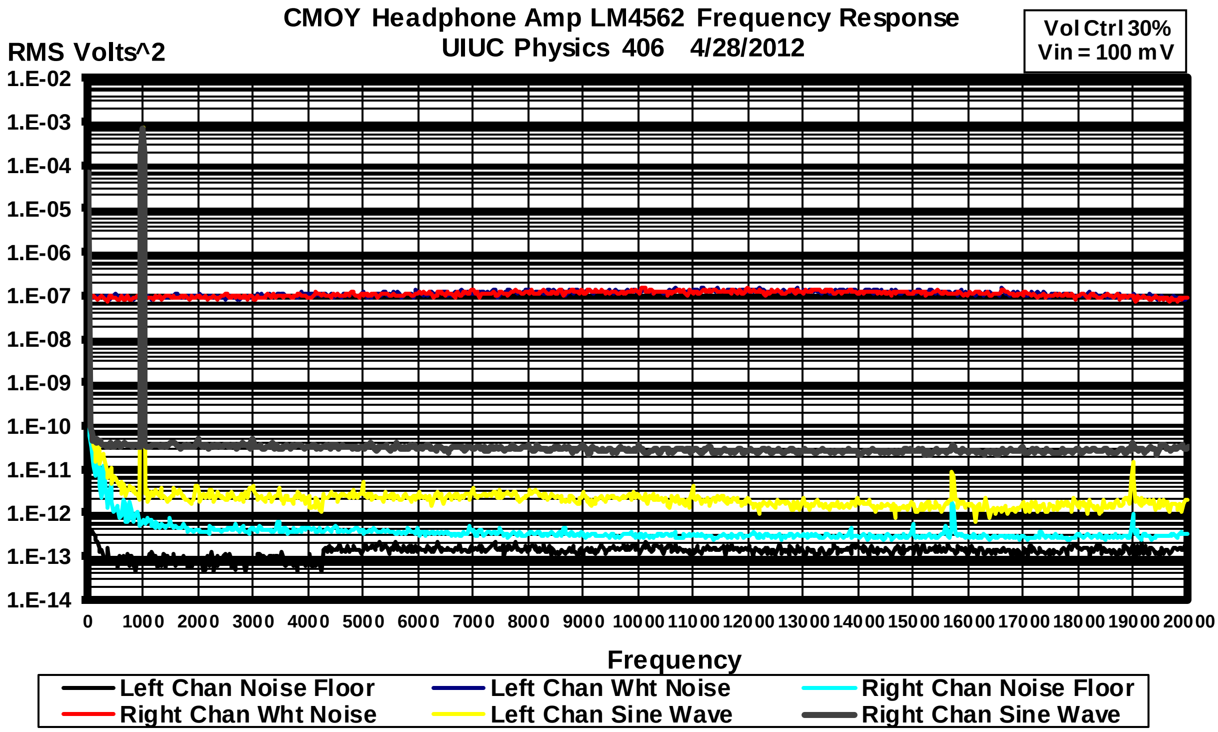

FIGURE 9: LM4562 FREQUENCY RESPONSE DATA

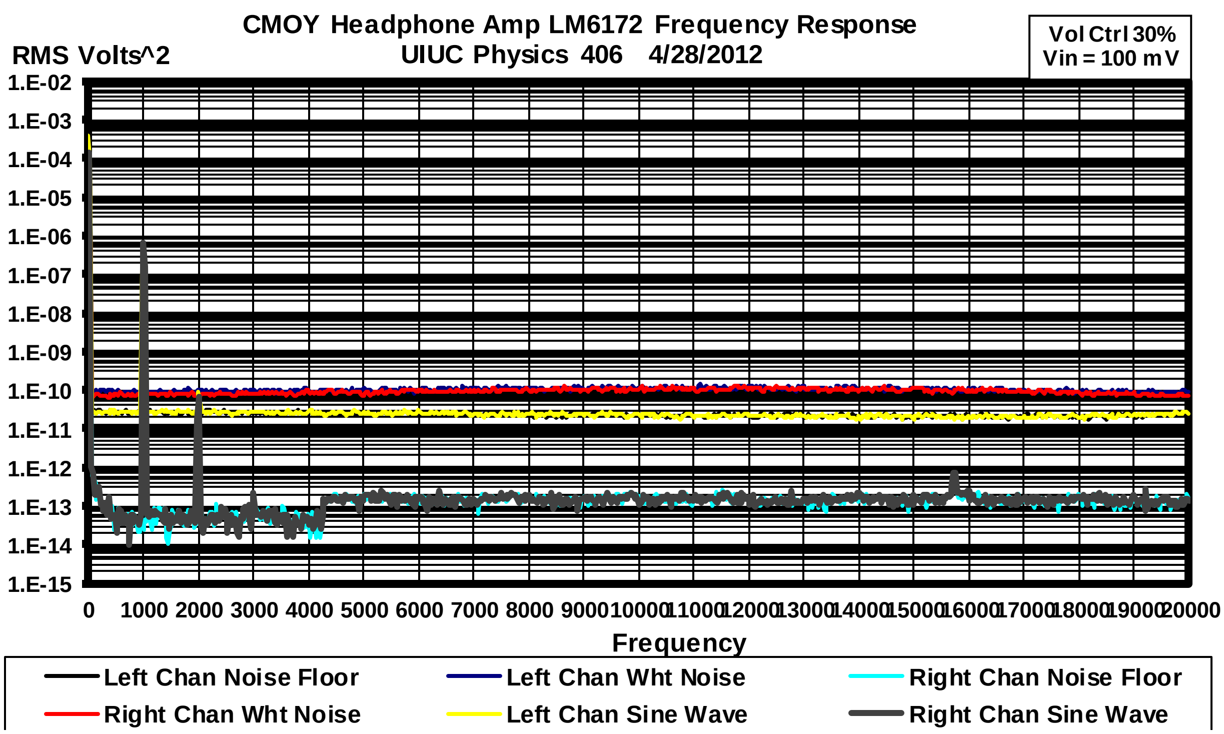

FIGURE 10: LM6172 FREQUENCY RESPONSE DATA

The above figures display frequency response data of each opamp inserted into the circuit for each channel for noise floor, white noise, and sine wave response at 1kHz. There are several common things between the 6 opamps. Every opamp was tested with a single 9V battery to drive it. Given that some of the chips may require near that value to become stable, this may explain some of the small amounts of distortion shown in the graphs above.

First of all, white noise frequency response has a very low and wide hump in the mid range peaking around 12.5kHz. However, overall, every chip had a relatively flat frequency response.

Noise floor measures how much internal sound is produced when no signal is being input. For listening purposes, the lower this is, the better. First of all, the small jump near the 4kHz mark should not actually be there, and in fact only started appearing after one of the frequency spectra analyzer's random recalibrations. Any small peaks in the noise floor could be caused by a number of things, including other appliances plugged in the vicinity, electromagnetic interference from phone signals, etc. According the Professor Errede, the disparity between the left and right channel levels is mostly due to bad manufacturing practices, which result in variations even within the same model type. From lowest noise floor to highest noise floor: LM6172, LM4562, NE5532, OPA2277, OPA2134, OPA2132.

The sine wave response of the opamps largely shows how much distortion is introduced as the signal is amplified. Having only the one harmonic at 1kHz signifies that little or no distortion is introduced from the input signal into the output signal. The levels of the subsequent harmonics are also telling of how audible the distortion actually is. Given that the graphs are semilog plots, differences between the harmonic levels like in the OPA2132 (Figure 5) and OPA2134 (Figure 6) are almost impossible to hear. On the other hand, there is the frequency response from the NE5532, which contains a lot of distortion. From lowest amounts of distortion to highest amounts of distortion according to graphs are: LM4562, OPA2132, OPA2134, OPA2277, LM6172, NE5532.

The following is a very brief pricepoint comparison between the opamps, to perhaps show some insight into price – quality ratios. In order of increasing price from lowest to highest: NE5532, OPA2134, LM4562, LM6172, OPA2277, OPA2132. The NE5532 costs about $0.60, when purchased individually and can cost as little as $0.25 per when purchased in bulk. This was the chip with the highest distortion, so given that it is so cheap, its distortion levels make some sense. The OPA2134 performed almost as well as the OPA2132, with the exception of channel levels disparity, which can most likely be attributed to build quality. Given this, consumers pay a hefty premium for the small difference between the OPA2134 and OPA2132 ($2.94 vs. $6.72). The other opamps cost about $4 each.

A special note on the LM6172: It should never ever be used in this circuit for listening purposes. After doing some research, I found that the input bias current in the LM6172 is on the order of microamps, whereas the other opamps have input bias currents on the order of nano or picoamps. This current forced across the 100kΩ resistor creates a 0.4 V DC offset, and with the resistor configuration as it is, the gain of the circuit is 11, thus making the DC offset 4.4V. This much voltage in a headphone music signal is enough to make them explode.

THE FINAL PRODUCT/CONCLUSIONS

At the time of writing, I was unable to extensively carry out qualitative listening tests with these opamps. I did, however, listen to the OPA2132 for about 2 hours up til now. Listening tests were carried out by initially testing the signal with a cheap pair of headphones to make sure nothing would explode, and then switching to studio monitors (ATH-M50). The change is subtle, but the OPA2132 makes the sound slightly warmer and helps to make the bass slightly punchier. Overall, not a very significant change but worth it to an audiophile like myself.

FIGURE 11: COMPLETED CMOY HEADPHONE AMP TURNED ON!

In the end, building the CMOY headphone amp was a very good learning experience; learning to solder and learning about various electronic components I would otherwise never have reason to interact with. The whole project only cost about $60 and if I were to have not purchased all of the extra opamps, the project would have probably cost around $40. Overall, a very good deal and now I have a headphone amplifier that improves my listening experience. Thanks to Professor Errede for the assortment of screws, nuts, foam, and guidance. My years in engineering have finally been actualized in a physical form, manifested in this wonderful CMOY headphone amp!