Institute of Arts, Design + Technology

DL835 Y4 Final Project: Modular Hi-Fi Sound System

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2021

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Second Reader: Timm Jeschawitz

Abstract

This project aimed to create simple, high- quality audio modules that could be arranged in multiple ways in order to meet the needs of the user. The idea behind the project came from the Hi-Fi sound systems today being a single, expensive package.

Cheap high-quality components that had low distortion and a low signal to noise ratio that were widely available were used to construct these modules which demonstrated that there shouldn't be any reason for a person to listen to low fidelity audio in today's world.

Further inspiration for this project was to understand some of the fundamentals of audio equipment and how they work as well as to gain a better understanding of how the printed circuit boards that we find in a lot of the appliances we use in everyday life.

The areas recorded in this report fit under the following headings, researching, designing, implementing and testing.

Additionally, more modules could be made to add to these already existing modules made in this report

Acknowledgements

The completion of this project wouldn’t have been possible without the constant support and help from my supervisor, Paul Comiskey. Due to the unfortunate circumstance around the world with Covid-19, it made the whole process of college a lot more challenging

Paul Comiskey made it his duty to help me in the construction of this project by providing numerous different components and materials such as wire etc, and for that, I am extremely grateful.

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1. Research Chapter

1.1. Introduction

Audio plays a big part in our lives today, it's in everything from our car radios to our TVs to just general conversation with friends. We have the power to listen to music nearly anywhere from our showers to walking up the street.

This project aims to create a modular Hi-Fi (High fidelity, meaning high accuracy in reproducing sounds) system that can be arranged in a number of ways to suit the user's needs. The project will incorporate several high-quality, low noise circuits to portray a clear and crisp audio experience for the listener.

The modules that will be included thus far will be an audio buffer, an amplifier and an audio equaliser. The audio buffer is used to match the impedance coming from a circuit with high impedance to low impedance. This helps prevent the second circuit from interference from the first circuit because they form a voltage divider which reduces the signal.

An amplifier is used to increase the gain of a circuit. This is useful if we have a signal which is quiet and not very audible. We use the amplifier circuit to increase power to the signal so we can make it more audible.

An audio equaliser (EQ) is used to adjust the balance between different frequency bands. This can be useful if you want to make some bass or treble adjustments to an audio signal. Equalisers work similarly to amplifiers in the sense that it reduces or amplifies a specific frequency band.

With these combined modules, the aim is to build a high-quality sound system that can be used with an array of inputs.

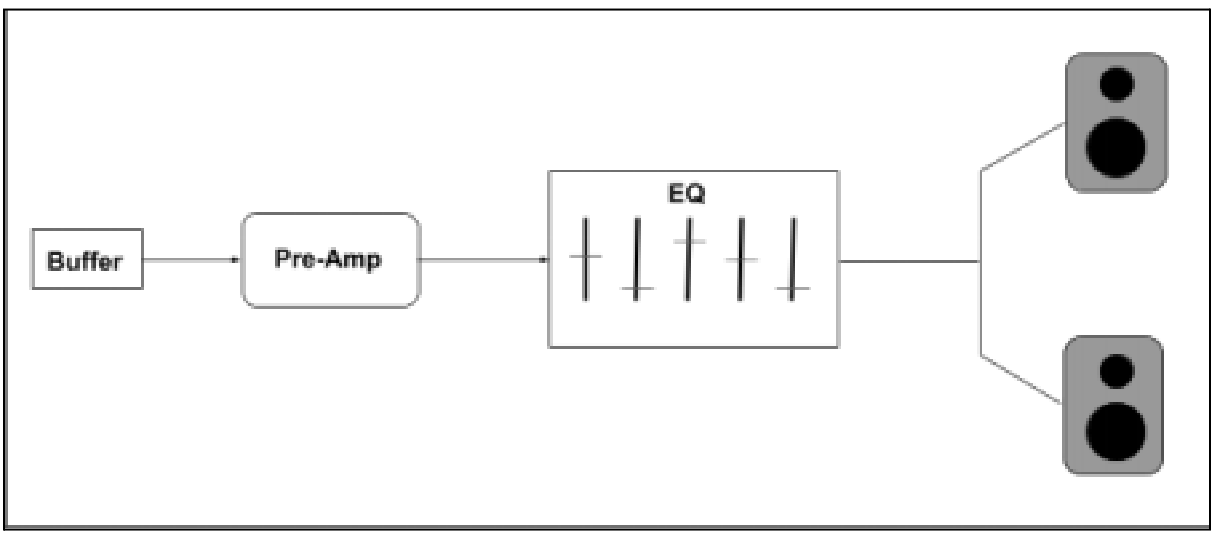

Figure 1.1

A diagram of the signal chain for a Hi-Fi sound system

1.2. Technology

In this area, we will discuss the different technologies that the Hi-Fi sound system will incorporate.

1.2.1. High-Quality Analogue Components

The use of high-quality components in the circuits is extremely important. These modules aim to have low noise and distortion as well as a neutral, uncoloured frequency response. These can be achieved through the use of well-made components. The use of analogue components achieves a smooth listening experience due to the signal being processed by an analogue circuit. This is in contrast to digital components which would need to have an extremely high bit rate to compete with analogue components due to digital signals being in either an on or an off state.

An example of such a component is the TPS7A4701. This component is a low dropout voltage regulator. Due to Hi-Fi systems having a high signal to noise ratio (SNR) every part of a system is important, even the power supply. The TPS7A4701 is a useful module when it comes to low noise with an RMS output of just 2.47 µV for 20-20kHz when the output signal is 5V. (Liu, 2017, p. 8)

1.2.2. Modular Design

Having a modular design for the Hi-Fi sound system has numerous advantages. A concern that some people may have is that they don't have enough space to have one in their home. A Hi-fi system can contain a lot of different types of hardware. Some of these are speakers, an amplifier, an equaliser etc. With the use of a modular design, we can cut back on specific parts to cut down the bulk of one of these systems. This is one of the benefits of a modular design.

Secondly, it could potentially cut out some costs for the users because they build up their Hi-Fi sound systems as their needs change. Some users may only need an amplifier for their needs so that's the only module they would need to purchase and as their needs change over time they can add more modules.

1.2.3. LTspice

LTspice is a simulation software with a built-in schematic and waveform viewer with enhancements and models for easing the simulation of analogue circuits. (Analogue Devices, 2020). Each of the Hi-Fi system modules is designed and tested using this software. It helps us understand how the circuit runs and what needs to be changed to get the desired circuit before we design the PCB (Printed Circuit Board).

The AC analysis test consists of 2 different tests, the bandwidth and Zin vs Frequency. The bandwidth test is used to get an indicator of the frequency range that the amplifier is increasing. The Zout (Output impedance) vs frequency test tells us the impedance at different frequency bands. This shows us different problems that may arise at the different frequency bands in a signal and can help the user to make the necessary changes to the circuit.

The total harmonic distortion (THD) is a unit of measurement that tells you how much of the distortion in a signal is caused by harmonics. This is an important test to run when dealing with audio signals. Lower THD means the audio signal is better at reproducing the original sound. (Williams, 2017)

SPICE Error Log: D:\College\Year 4\Project\Buffer\Simulations\Buffer 3.0\Buffer3.log

```
Circuit: * D:\College\Year 4\Project\Buffer\Simulations\Buffer 3.0\Buffer3.asc

Warning: Multiple definitions of model "2n5401" Type: BJT
Direct Newton iteration for .op point succeeded.
N-Period=1
Fourier components of V(output)
DC component:-0.000210558

Harmonic    Frequency    Fourier     Normalized   Phase      Normalized
 Number       [Hz]      Component    Component   [degree]    Phase [deg]
    1       1.000e+03   9.986e-01   1.000e+00       0.01°       0.00°
    2       2.000e+03   2.634e-05   2.638e-05      90.08°      90.07°
    3       3.000e+03   2.897e-07   2.901e-07      -1.86°      -1.87°
    4       4.000e+03   1.645e-08   1.647e-08    -116.02°    -116.03°
    5       5.000e+03   8.311e-09   8.323e-09    -102.96°    -102.97°
    6       6.000e+03   5.147e-09   5.155e-09     -84.64°     -84.65°
    7       7.000e+03   1.313e-08   1.315e-08     -62.54°     -62.55°
    8       8.000e+03   1.675e-08   1.677e-08     -50.12°     -50.13°
    9       9.000e+03   2.211e-08   2.214e-08     -30.97°     -30.98°
Total Harmonic Distortion: 0.002638%(0.000000%)



Date: Tue Nov 10 17:11:18 2020
Total elapsed time: 0.172 seconds.

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traniter = 2082
tranpoints = 1042
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rejected = 0
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solver = Normal
Matrix Compiler1: 1.91 KB object code size  0.3/0.2/[0.1]
Matrix Compiler2: 2.28 KB object code size  0.2/0.2/[0.2]
```

Figure 1.2

A THD Analysis ran on a buffer circuit

Figure 1.2 is an image of a THD analysis test run on a circuit. Shown in the image are each of the harmonics of the input signal.

A harmonic is a multiple of the fundamental frequency. When two or more of these harmonics interact with each other it causes constructive and destructive interference.

Destructive interference is when two identical waves are 180° out of phase, this results in the amplitude of the wave being weakened. While constructive interference is when two signals are in sync with each other causing a larger amplitude for the signal. (Paul, 2020)

This interference degrades the quality of the audio and is undesired in an audio sound system which is why we test for the THD to prevent signal quality issues.

The Zout analysis test tells us the output impedance of a circuit. This is helpful for impedance matching. Impedance matching helps ensure that maximum power transfer is achieved between 2 different circuits. An example of this is when attaching the amplifier to some speakers. If the impedance isn't matched between two circuits there will be a loss of quality in the signal because they form a voltage divider. Figure 1.3 shows an output waveform of a Zout test.

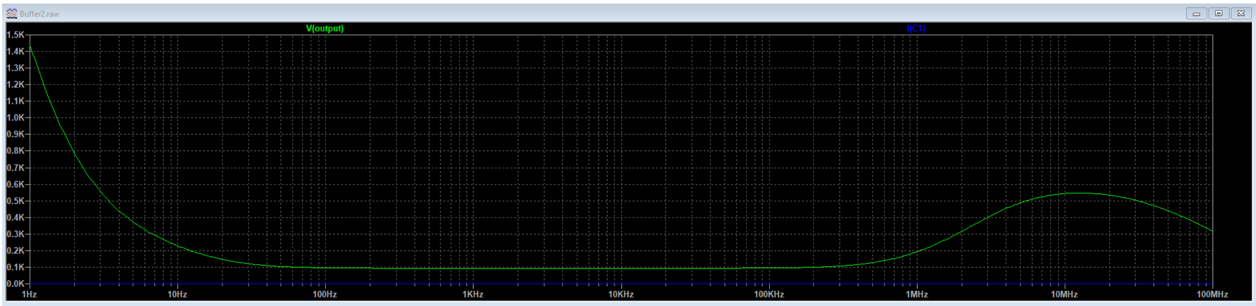


Figure 1.3

Zout Analysis Waveform

1.2.4. Eagle

EAGLE is electronic design automation (EDA) software that lets printed circuit board (PCB) designers seamlessly connect schematic diagrams, component placement, PCB routing, and comprehensive library content. (Autodesk, 2020).

A printed circuit board (PCB) is a board that has copper tracks that carry an electric signal to different pads on the board. Attached to the pads are different types of components such as resistors, capacitors, LEDs, etc. Joining the components to the pad is a metal alloy called solder. This material is heated up to adhere the components to the pads.

After the simulating process is completed and the circuit is behaving correctly, we then build the circuit in Eagle. Eagle is tailored towards PCB design and has a number of useful tools to help in the process. After the schematic is drawn in Eagle, the user can then generate a Gerber file which can be sent to a factory that manufactures PCBs.

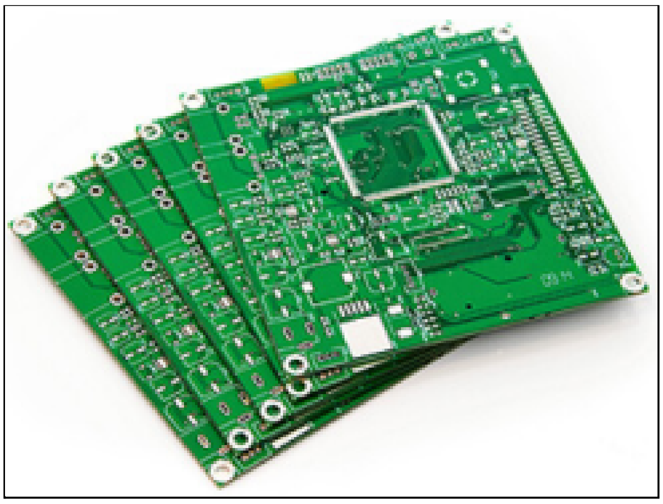


Figure 1.4

An Example of a PCB (Wala, 2017)

1.3. Applications

Applications of such a project would be a user looking to recreate the image that the producer was looking to make when mixing and mastering the song. A Hi-Fi sound system is looking to accurately recreate the original sound.

The term “Audiophile” is a new term that has surfaced in recent years that describes someone who enjoys the highest standard of audio when it comes to the playback equipment used. These people would use well-built amplifiers, headphones and loudspeakers etc to listen to their audio so they could get an accurate representation of a live performance.

Figure 1.5

An Example of a Panasonic Hi-Fi sound system (Panasonic, n.d.)

Figure 1.5 is an example of an all-in-one Hi-Fi system by the company Panasonic. This Hi-Fi sound system consists of an amplifier, a CD player as well as two speakers.

1.4. Requirements

Below are the decisions regarding the requirements for the current project. These are the reasons for selecting certain aspects for the project.

1.4.1. Similar Systems

There aren't many similar systems when it comes to the idea for this project. Most modular systems are made up of different brands that must be bought separately from different vendors. There are makers of different Hi-Fi audio equipment that allow you to use different brands together but often the enclosures are different so the system isn't very aesthetically pleasing.

1.4.2. List of Requirements

Below is a numbered list of set out requirements for this project:

1. A Modular Design
2. High-Quality Circuits
3. Enclosures for Each Module
4. Audio Visualizer

1.5. Conclusion

In my conclusion, I have gained the information needed to begin my work on designing and building a modular Hi-Fi sound system. I have gained knowledge of the different types of technologies I will be using throughout the project and have set out my desired end requirements for the sound system.

2. Design Chapter

2.1. Introduction

The modular Hi-Fi sound system comprises 3 main modules, an audio buffer, a preamp and an audio equaliser. Each of these modules will contain a 9-LED VU meter to display the signal level passing through them. The modules will be connected using a 3.5mm male audio jack connection. The user can interact with certain modules by using a variable resistor (potentiometer) to control different parameters.

One of the common components used throughout each of these modules is the bipolar transistor. The bipolar junction transistor (BJT) is made up of PN junctions creating three terminals that can be connected to. These three terminals are as follows:

1. Base
2. Emitter
3. Collector

These types of transistors have two basic functions, amplification regarding analogue electronics and switching in digital electronics. Due to each of the modules in this project being analogue, the transistors are used in an amplification state and because of this the region that the transistor operates in is the active region. Figure 1 shows the configuration that the audio buffer and preamp circuit are used in.

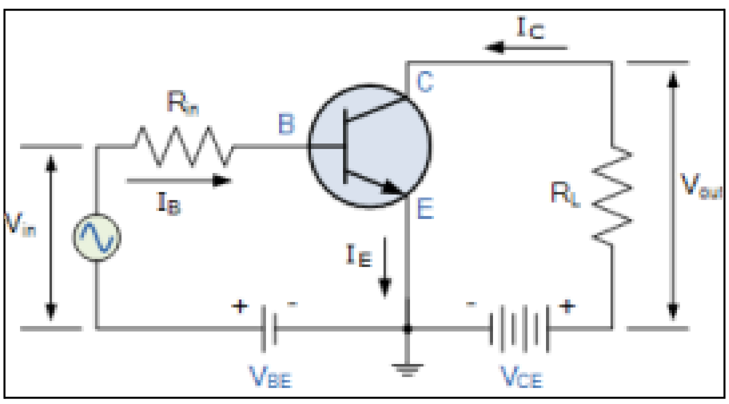


Figure 2.1

Common Emitter Amplifier
(source: https://www.electronics-tutorials.ws/amplifier/amp_2.html)

This circuit aims to amplify a signal coming in through the input (Vin). The sole purpose of an amplifier is to take the input signal and to make it larger (amplified). We want to achieve this without adding unwanted characteristics such as noise and distortion.
To obtain low distortion when used as an amplifier the operating quiescent point needs to be correctly selected. This is the DC operating point of the amplifier and its position may be established at any point along the load line by a suitable biasing arrangement. (Electronic Tutorials, n.d.).

2.2. Overview of the Design

In Figure 2, there is a labelled block diagram of how each of the modules is going to be connected as well as how external devices will be connected. Each device will be connected to one another by 3.5mm male to male audio jack cables.

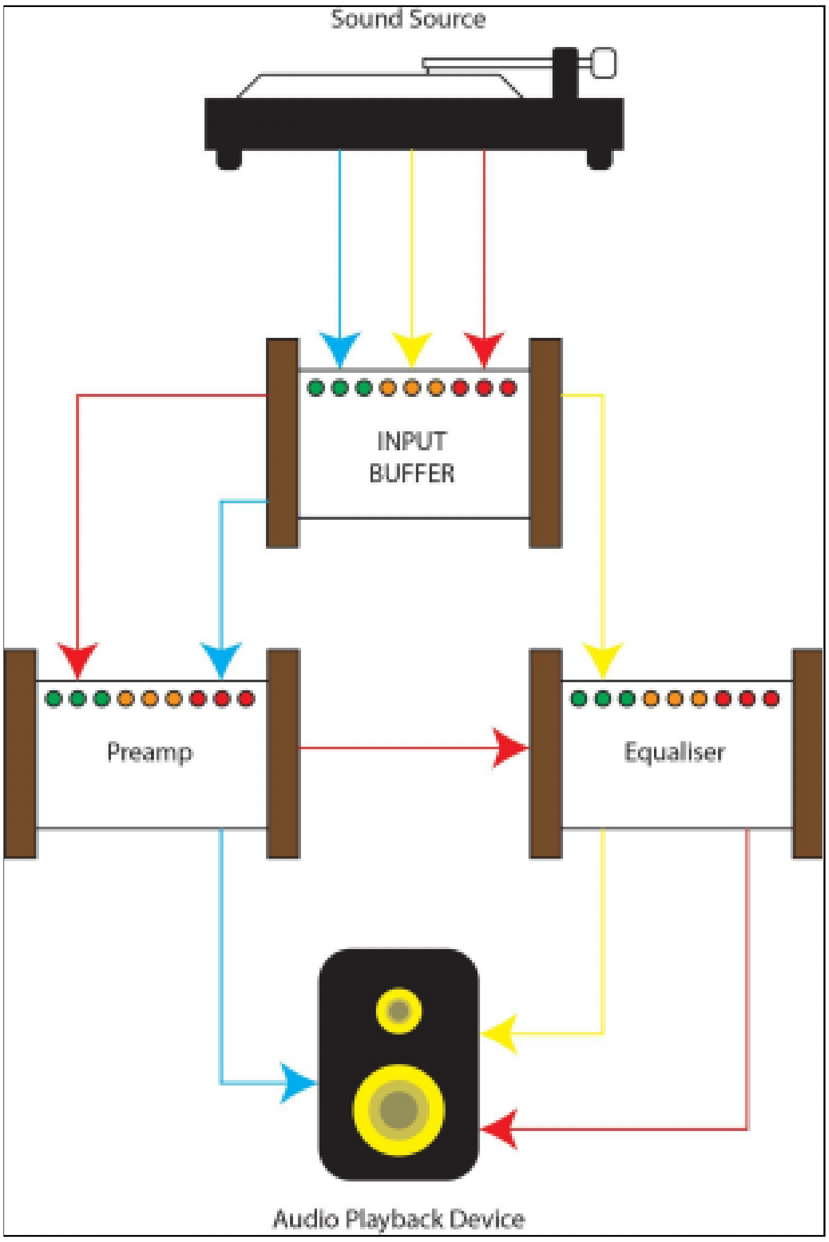


Figure 2.2

Block diagram of separate modules with different configuration paths displayed with different coloured arrows.

2.2.1. Circuit Diagrams

In this section of the report, each module's schematic and its function will be explained.

The Audio Buffer

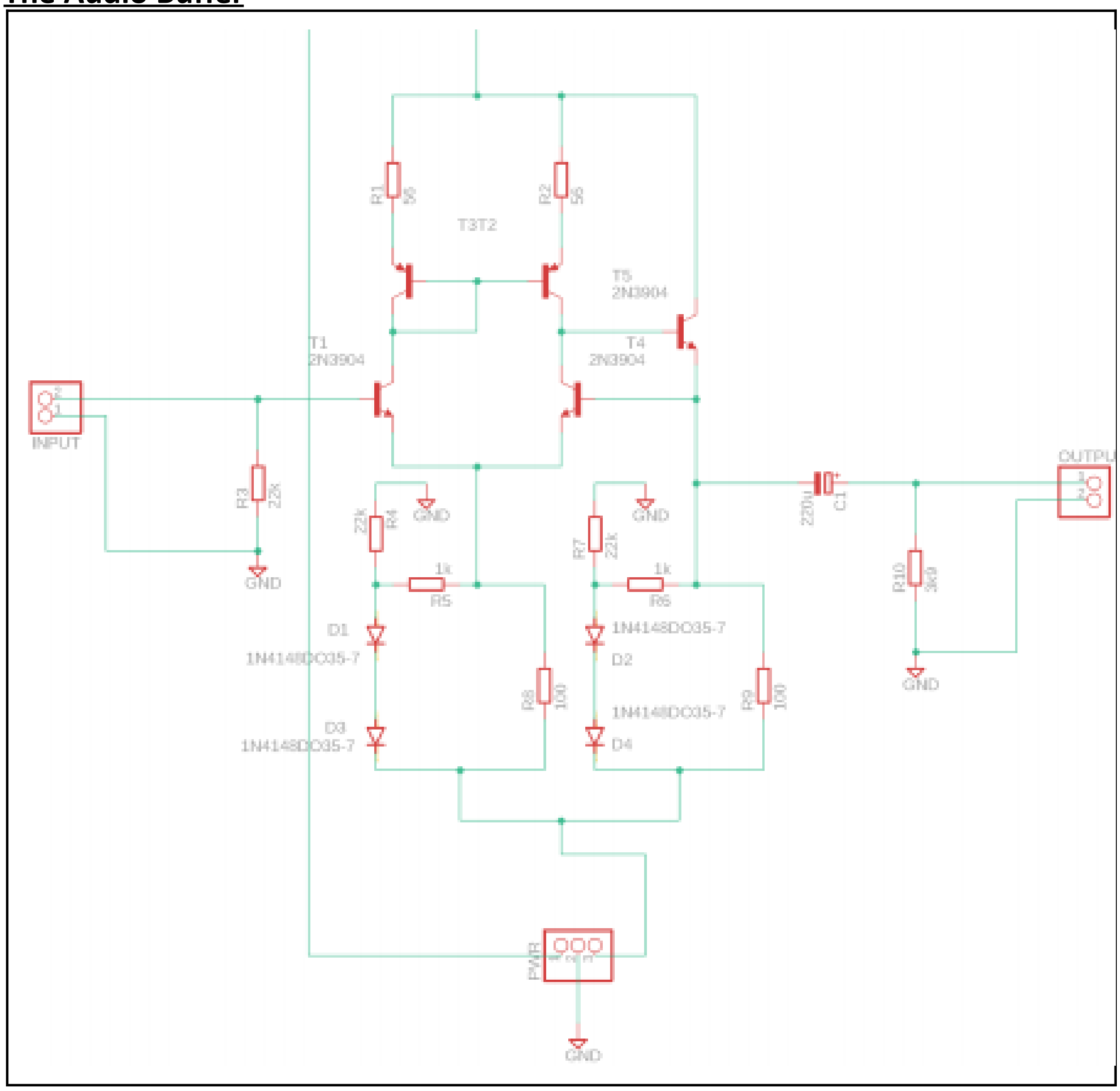


Figure 2.3

Audio Buffer Schematic

The schematic seen in Figure 3 is an audio buffer. The purpose of this circuit is to transfer a current from a device connected to its input which has a low output impedance to a circuit that has a high impedance.

If the impedances of two circuits are not matched it will cause a loss of level in the signal. Due to the nature of this project, we want the audio signal to maintain its level throughout so matching the impedance from the sound source is extremely important.

2.2.2. The 2N3904 Transistor

The 2N3904 is the NPN bipolar junction transistor used in this circuit. The reason for choosing this component are as follows:

- It has extremely low distortion so it is ideal for high-quality audio applications.
- It has a frequency response that matches that of the human ear, 20Hz - 20kHz.
- The component is also widely available which made sourcing it an easy task.

NPN (Negative, Positive, Negative) transistors work by passing electrons (negative charge) from the emitter, pin 1, to the collector, pin 3. The emitter "emits" electrons into the base, which controls the number of electrons the emitter emits. Most of the electrons emitted are "collected" by the collector, which sends them along to the next part of the circuit. (Blom, n.d.)

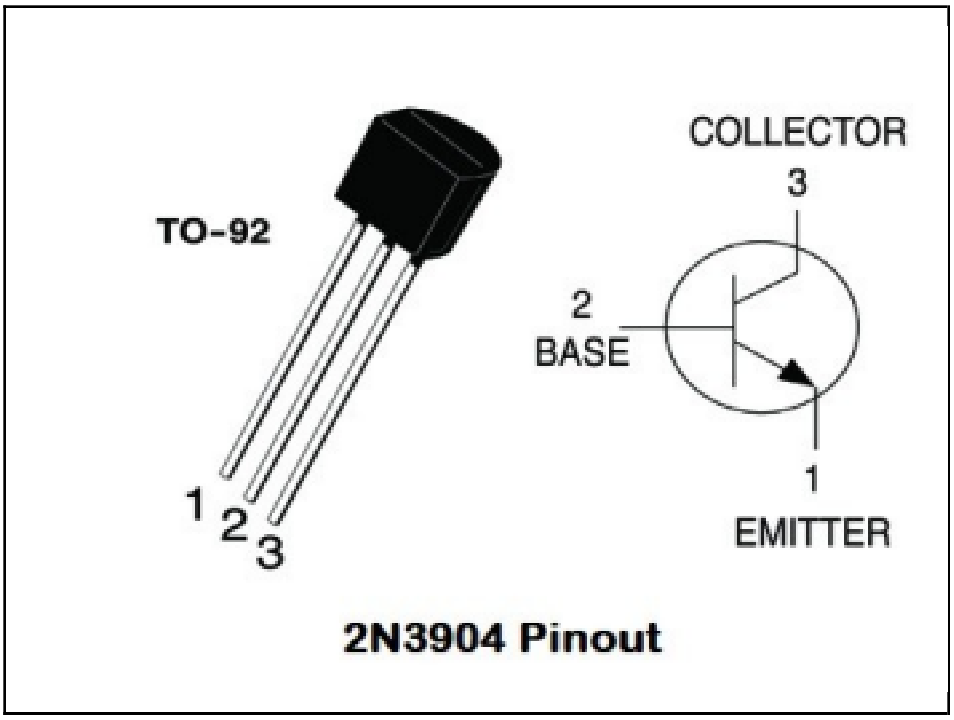


Figure 2.4

A 2N3904 Transistor with Labelled Pins

(source: https://www.rs-online.com/designspark/basics-of-2n3904)

2.2.3. The Molex Connector (Figure 5)

The use of male Molex connectors can be seen in the circuit schematic as INPUT, OUTPUT and PWR. These were chosen due to their abundance in electronic component supply shops and their cheap nature. They are versatile in the sense that if there was ever something to go wrong with either input, output or power, they could be easily replaced compared to if there were wires soldered directly to the PCB.

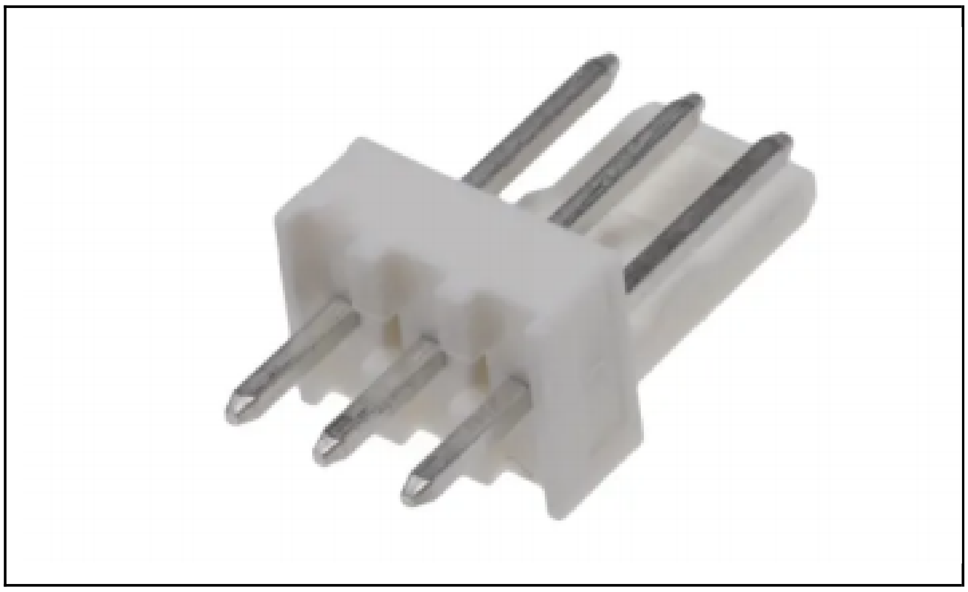


Figure 2.5

A 3 Pin Male Molex Connector

(source: https://uk.rs-online.com/web/p/pcb-headers/4838477/)

2.2.4. The 1N4148 Diode

The 1N4148 is a signal diode used in the audio buffer circuit. They are labelled as D1, D2, etc, and are connected in series (one after another). These diodes help protect the board from excess voltage coming into the circuit from its input. (Signal Diode Arrays, 2019)

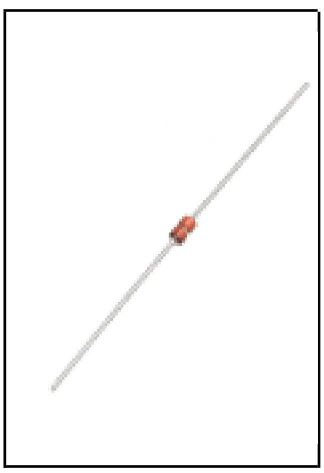


Figure 2.6

1N4148 Signal Diode

(source: https://www.probots.co.in/1n4148-small-signal-diode.html)

The Preamp

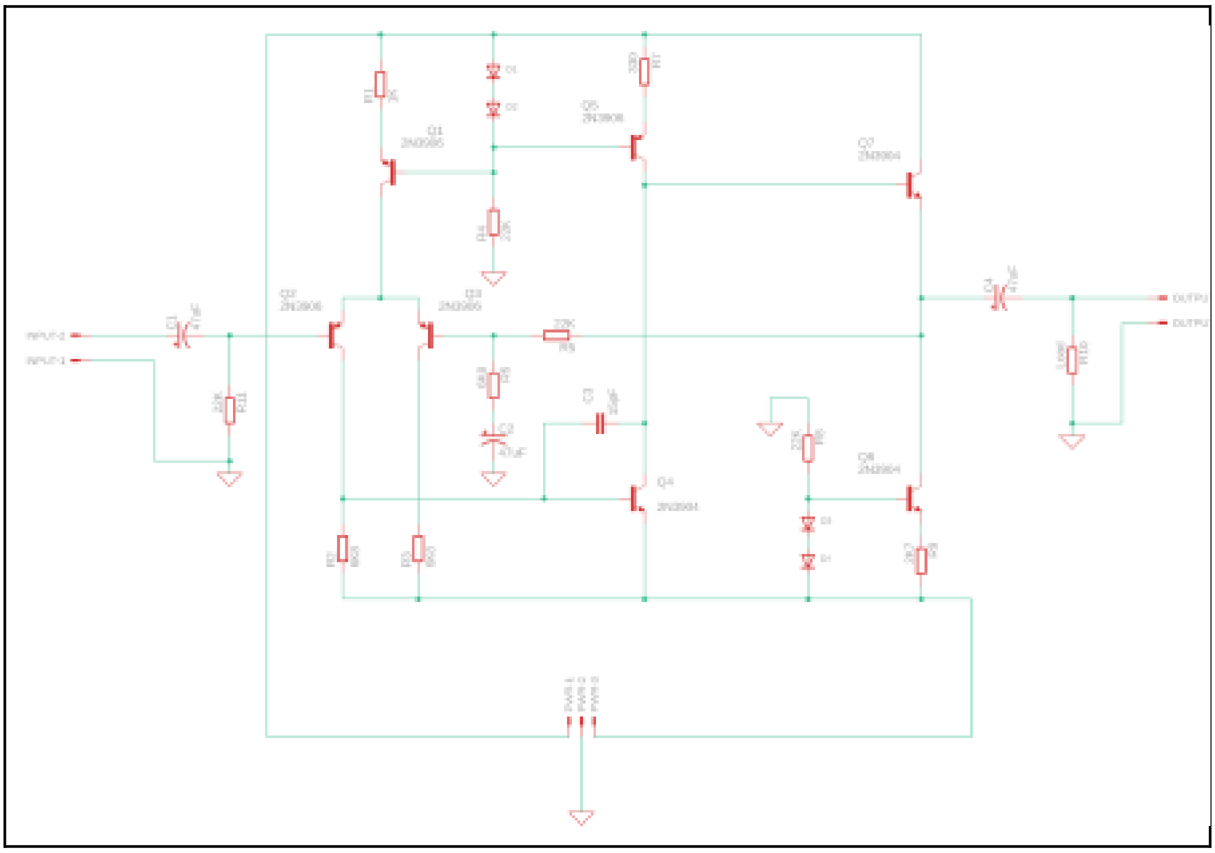


Figure 2.7

Preamp Schematic

The schematic shown in Figure 2.7 is an audio preamp. This circuit is used to amplify low-level signals from devices such as a record player to line level. Line level is the industry-standard operating level for recording equipment and is usually rated at -4dBu in audio equipment such as mixing desk and signal processing equipment.

The Equaliser

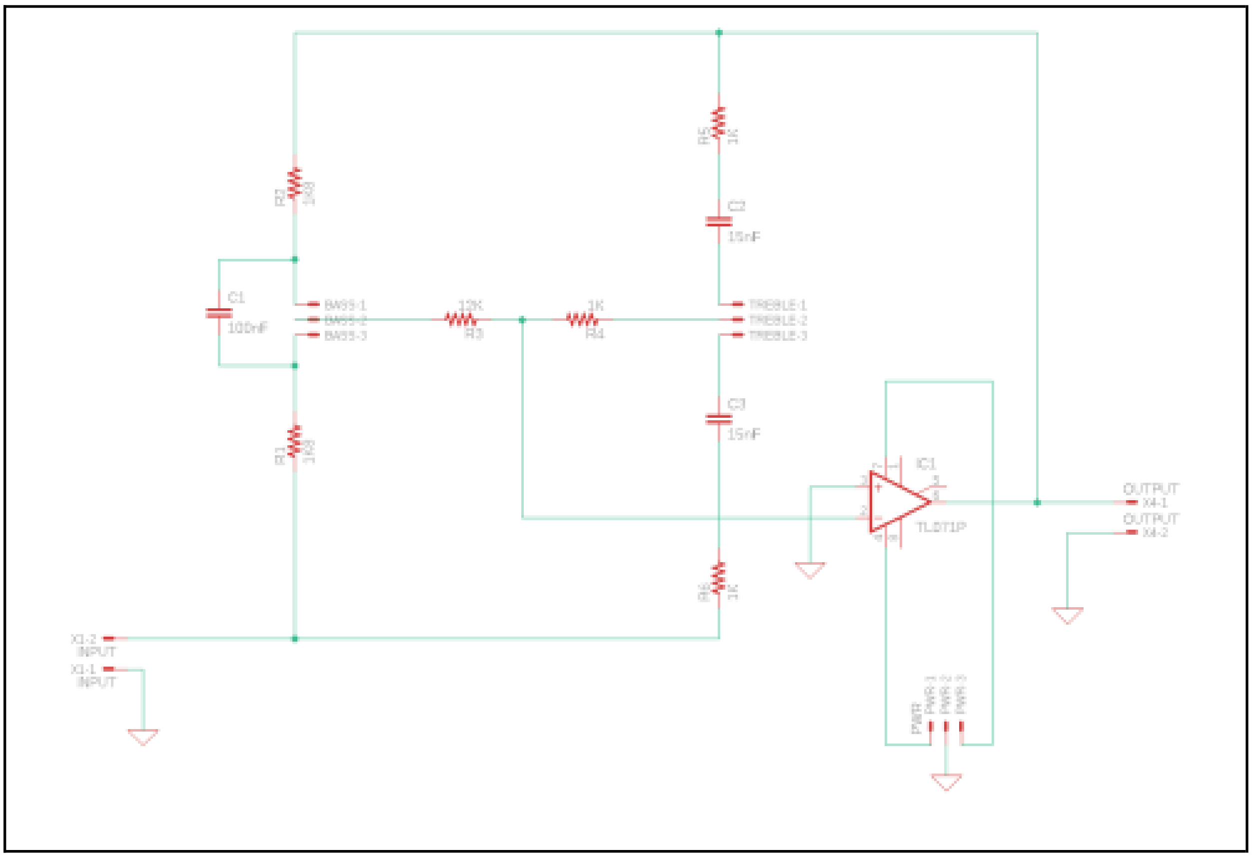


Figure 2.8

Equaliser Schematic

The schematic that is displayed in Figure 2.8 is an audio equaliser. The purpose of this circuit is to be able to adjust the frequency response in different frequency bands. For example, If the listener has trouble separating the bass from the high frequencies, they can use an equaliser to make the bass frequencies louder to be able to hear them with better clarity. This circuit allows the user to adjust the bass and treble parameters using a potentiometer. That will be attached to the PCB with a Molex connector.

VU Meter

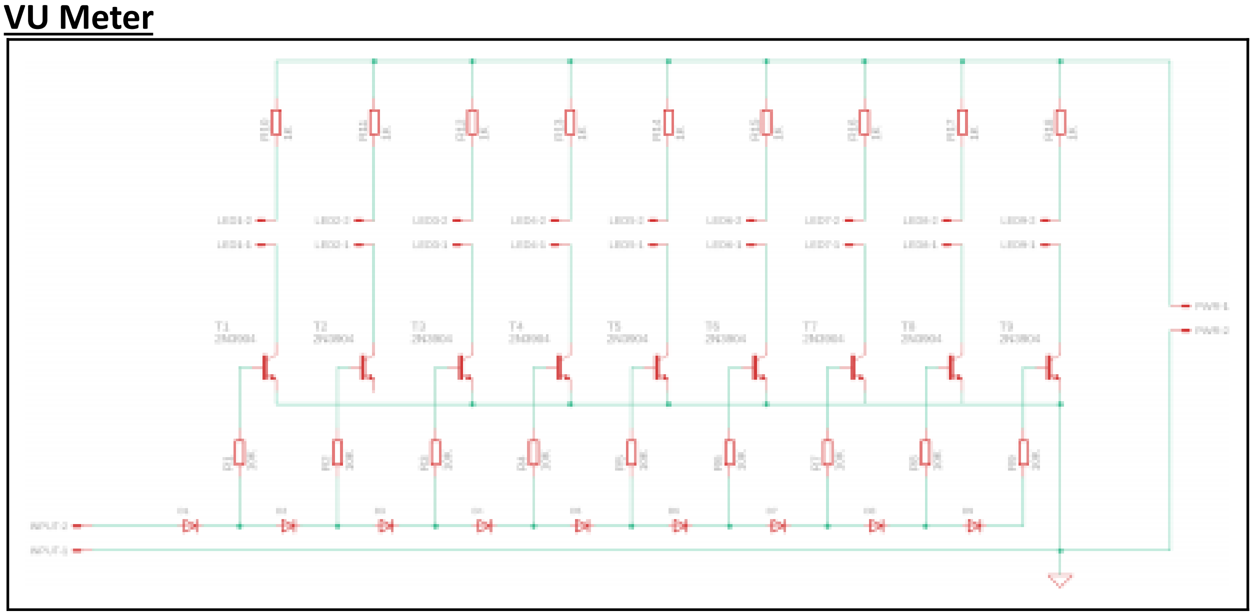


Figure 2.9

VU Meter Schematic

The schematic seen in Figure 2.9 is a VU Meter. The VU meter will consist of 9 light-emitting diodes (LEDs) and will tell us the strength of the signal going through each of the modules. There will be three different zones for the signal which will be represented by three sets of LEDs. A green zone, an orange zone and a red zone. Green is the signal is at a safe level and red means the opposite. The VU meter will be attached to the input of each module.

2.2.4. Transistors

As seen throughout each of the schematics, there are several transistors used. A transistor is a device that is used to regulate voltage or current. It acts as a switch or a gate for electronic signals (Tech Target Contributor, n.d.).

The reason for choosing transistors over integrated circuits (IC) are as follows:

1. Due to the nature of ICs, it is hard to obtain low noise and high voltage operation. This would be a huge disadvantage when using ICs for designing Hi-Fi modules. We want the lowest signal to noise ratio possible.
2. Transistors are known for their extremely long life due to their simplistic nature. ICs are made up of multiple components and with more components comes greater room for error. If a single component in the IC fails the whole IC goes down.
3. ICs tend to be quite fragile, rough handling or excessive heat may damage the component which will then be non-usable.

2.3. Simulations

While designing each module a number of tests were carried out to ensure that the quality of each module was of the highest standard. A programme called LTspice was used to simulate different versions of each module. (Analog Devices, n.d.).

2.3.1. LTspice

LTspice is a piece of analogue electronic circuit software developed by Analog Devices. This software comes with an abundance of analogue components that can be used to draw and simulate many different circuits. It also allows users to view different input/output waveforms which are highly beneficial when designing audio circuits.

2.3.2. Tests

There were three different sets of tests carried out on each of the components. Those three tests were as follows:

1. AC Analysis
2. THD Analysis
3. Zout Analysis

2.3.3. AC Analysis

The alternating current (AC) analysis tests two different parameters.

Bandwidth

The first is the circuit's bandwidth. This test allows the user to view the frequency range over which the module can operate. An example of where this test can be beneficial is when testing an amplifier circuit. The bandwidth test allows the user to view the frequency range that the amplifier can amplify. Figure 10 shows us what the output for one of these tests would look like. To view bandwidth in LTspice the user must plot V(out).

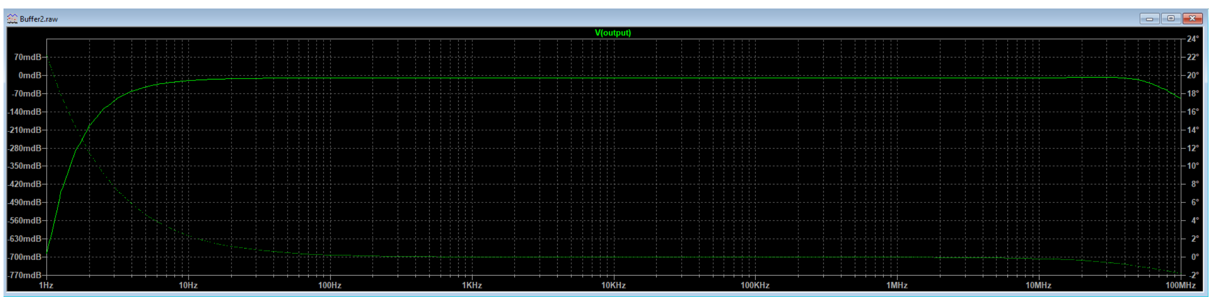


Figure 2.10

A bandwidth test output from LTspice

2.3.4. Zin Vs Frequency

The second is the impedance in (Zin) vs the frequency. When there are components such as operational amplifiers, capacitors, transistors etc. In a circuit it causes the input/output impedance to vary in different frequency bands. This test allows us to view the potential problematic frequencies and will show us that we may or may not need to change something in the circuit to fix the problem.

In order to view Zin vs frequency in LTspice, the user must plot V(in)/I (c1) and change the left y-axis to linear to show ohms and the right y-axis to ‘do not phase’(Do not plot).

2.3.5. THD Analysis

The total harmonic distortion (THD) analysis allows the user to see the distortion caused by harmonics in the signal. Harmonics are currents or voltages in electronic systems that cause problems with the quality of power. Harmonics can be described as sound waves that have an integer multiple of the initial signal. Figure 2.11 shows the fundamental tone and the different harmonics that follow. The more harmonics a wave has the worse the distortion of the signal.

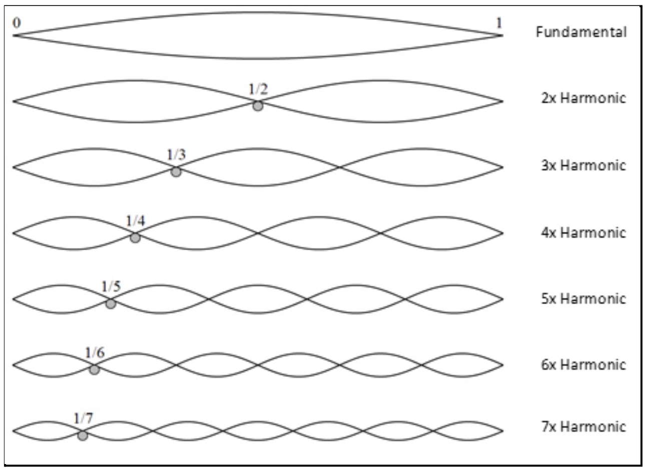
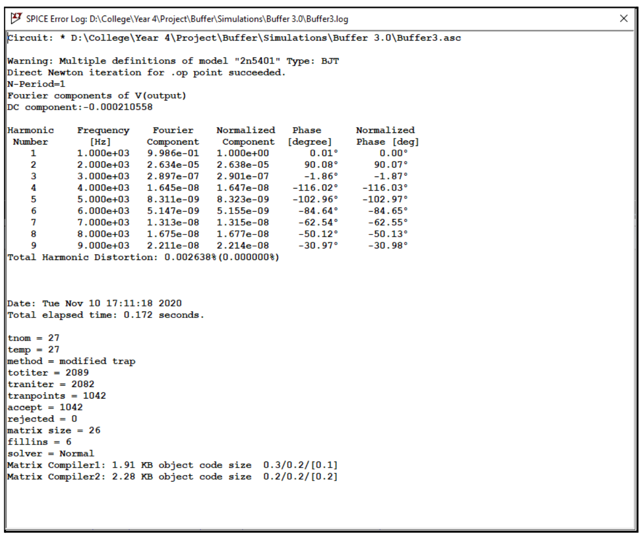


Figure 2.11

Harmonics

(source: https://physics.stackexchange.com/questions/111780/why-do-harmonics-occur-when-you-pluck-a-string)

These harmonics are caused by electronic equipment with nonlinear loads which draw in current or voltages in pulses. These pulses distort the audio signal which in succession cause harmonic currents to flow back into other parts of the system (Grainger Editorial Staff, n.d.).



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Circuit: * D:\College\Year 4\Project\Buffer\Simulations\Buffer 3.0\Buffer3.asc

Warning: Multiple definitions of model "2n5401" Type: BJT
Direct Newton iteration for .op point succeeded.
N-Period=1
Fourier components of V(output)
DC component:-0.000210558

Harmonic    Frequency    Fourier    Normalized   Phase      Normalized
 Number       [Hz]      Component    Component  [degree]    Phase [deg]
    1       1.000e+03   9.986e-01   1.000e+00      0.01°       0.00°
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    3       3.000e+03   2.897e-07   2.901e-07     -1.86°      -1.87°
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    6       6.000e+03   5.147e-09   5.155e-09    -84.64°     -84.65°
    7       7.000e+03   1.313e-08   1.315e-08    -62.54°     -62.55°
    8       8.000e+03   1.675e-08   1.677e-08    -50.12°     -50.13°
    9       9.000e+03   2.211e-08   2.214e-08    -30.97°     -30.98°
Total Harmonic Distortion: 0.002638%(0.000000%)



Date: Tue Nov 10 17:11:18 2020
Total elapsed time: 0.172 seconds.

tnom = 27
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rejected = 0
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solver = Normal
Matrix Compiler1: 1.91 KB object code size  0.3/0.2/[0.1]
Matrix Compiler2: 2.28 KB object code size  0.2/0.2/[0.2]
```

Figure 2.12

A THD output from LTspice

LTspice will give the user each of the harmonics as well as the total harmonic distortion in the circuit. Figure 2.12 is an image of how the THD output looks like from LTspice. For the user to view the THD in LTspice, they must use a 1kHz sine wave as the input, run a transient (.tran) simulation and right-click on the waveform window and select view then spice log error.

2.3.6. Zout Analysis

Impedance out (Zout) analysis is a test used to find the output impedance from each module. Let us say that if the output impedance of circuit A drives circuit B, it makes a voltage divider with the input impedance of circuit B. This means that if the impedance is not matched between the two connecting circuits there will be a loss of signal between them both. This will affect the quality of the audio signal which, due to the project being a Hi-Fi sound system, is not a characteristic we want. This test allows us to measure the output impedance which in turn helps us impedance match between different modules.

In order to view the impedance out in LTspice, the user must run an AC (.ac) simulation and disconnect the signal generator from the input. The user must then obtain V(out)/I (i1) and change the left y-axis to linear to show ohms and the right y-axis to 'do not show'.

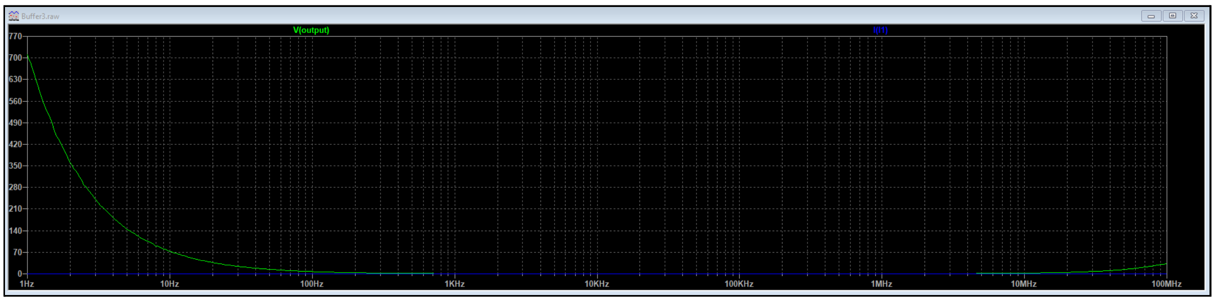

Figure 2.13

The output for a Zout analysis from LTspice

2.4. PCB Design

For the schematics to be turned into something that can be manufactured, they first have to be designed in printed circuit board (PCB) software.

2.4.1. Autodesk Eagle

Autodesk Eagle is an electronic design automation (EDA) software that lets printed circuit board (PCB) designers seamlessly connect schematic diagrams, component placement, PCB routing, and comprehensive library content (Autodesk, n.d.).

This piece of software allows the user to draw a circuit schematic using the different parameters that go with each of the components such as their size and their values etc. You can then transform the schematic into a PCB layout where the user must layout the components on an area representing the size of a PCB itself. Figure 2.14 shows a completed PCB layout for the preamplifier circuit from Eagle.

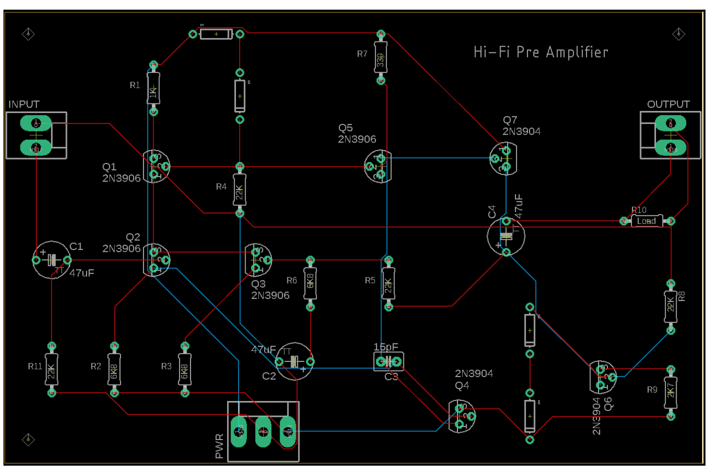

Figure 2.14

A finished PCB layout

A PCB is a board that has lines and pads that connect various parts. The PCB in Figure 14 shows us this. The red lines represent conductive tracks on top of the board and the blue lines represent conductive tracks on the bottom of the board. The green circles are conductive pads that each of the components are soldered to.

2.5. Enclosure and 3D Fabrication Design

The enclosure for each of the modules will consist of a white acrylic enclosure and wooden side panels. Each module will have its name laser printed onto its faceplate as well as the name of each of the inputs and outputs etc. The VU meter will also have the LEDs mounted to the faceplate of the module so the user can see the signal strength for the desired module.

2.5.1. Audio Buffer

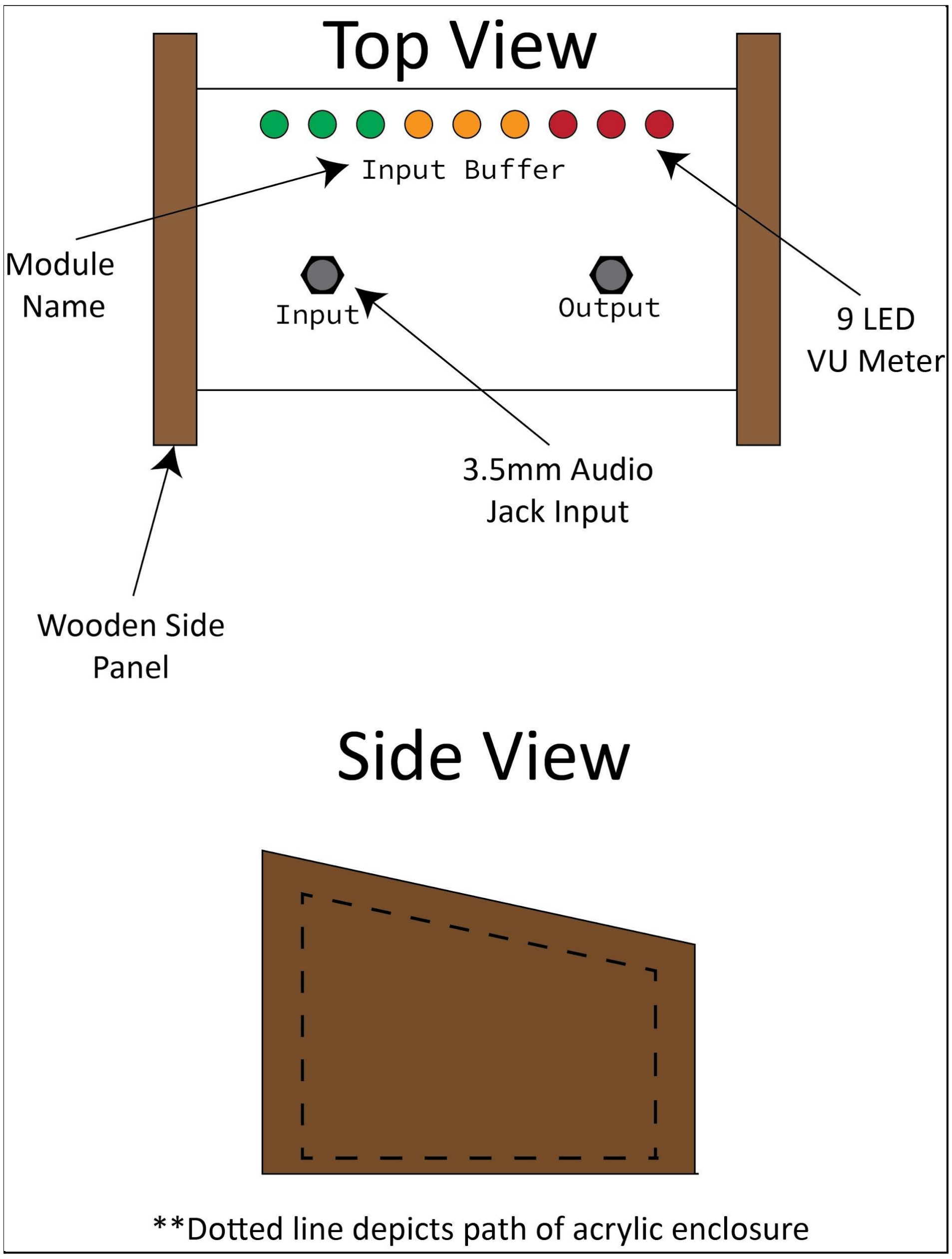

Figure 2.15

Audio Buffer Enclosure

2.5.2. Equaliser

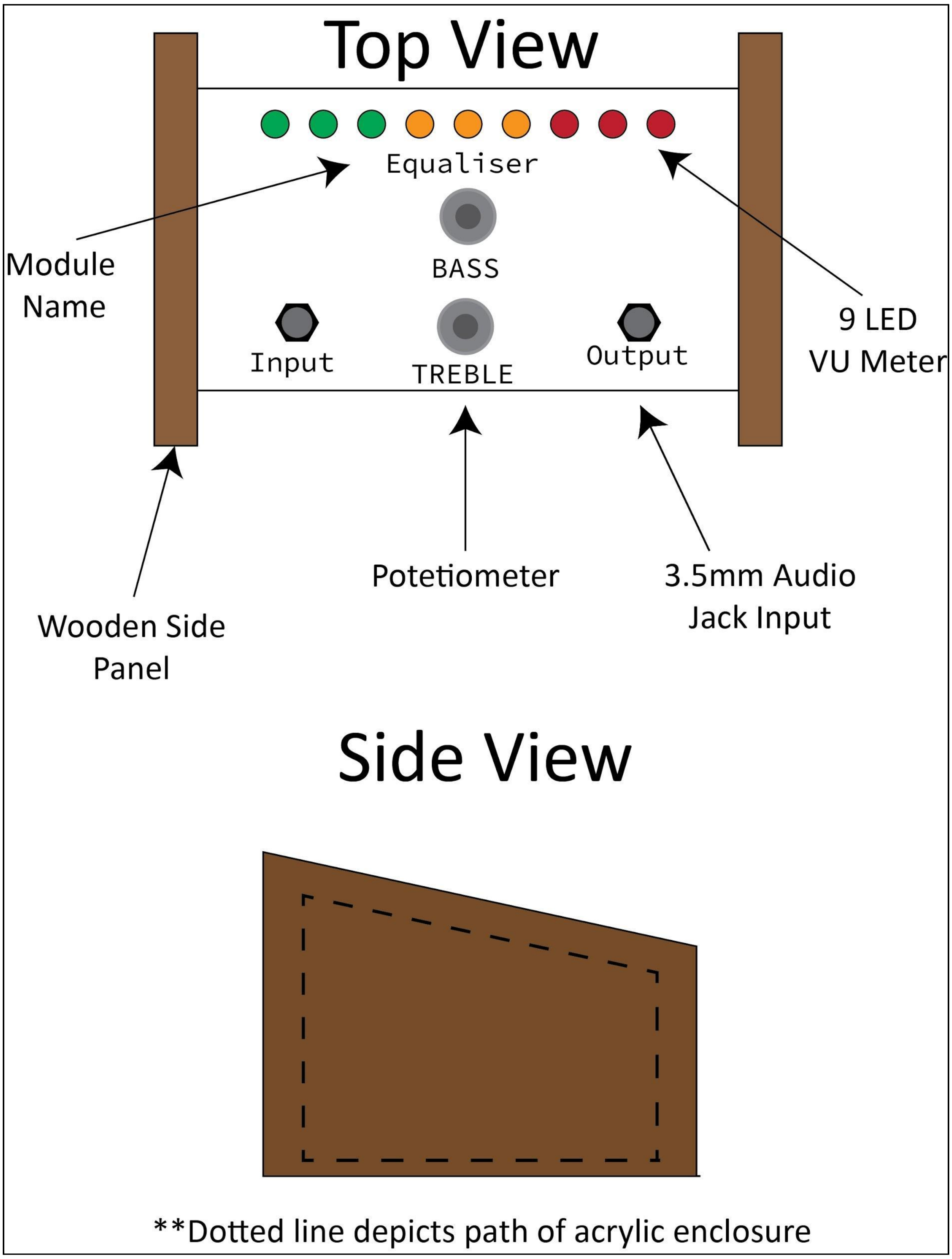

Figure 2.16

Equaliser Enclosure

2.5.3. Preamp

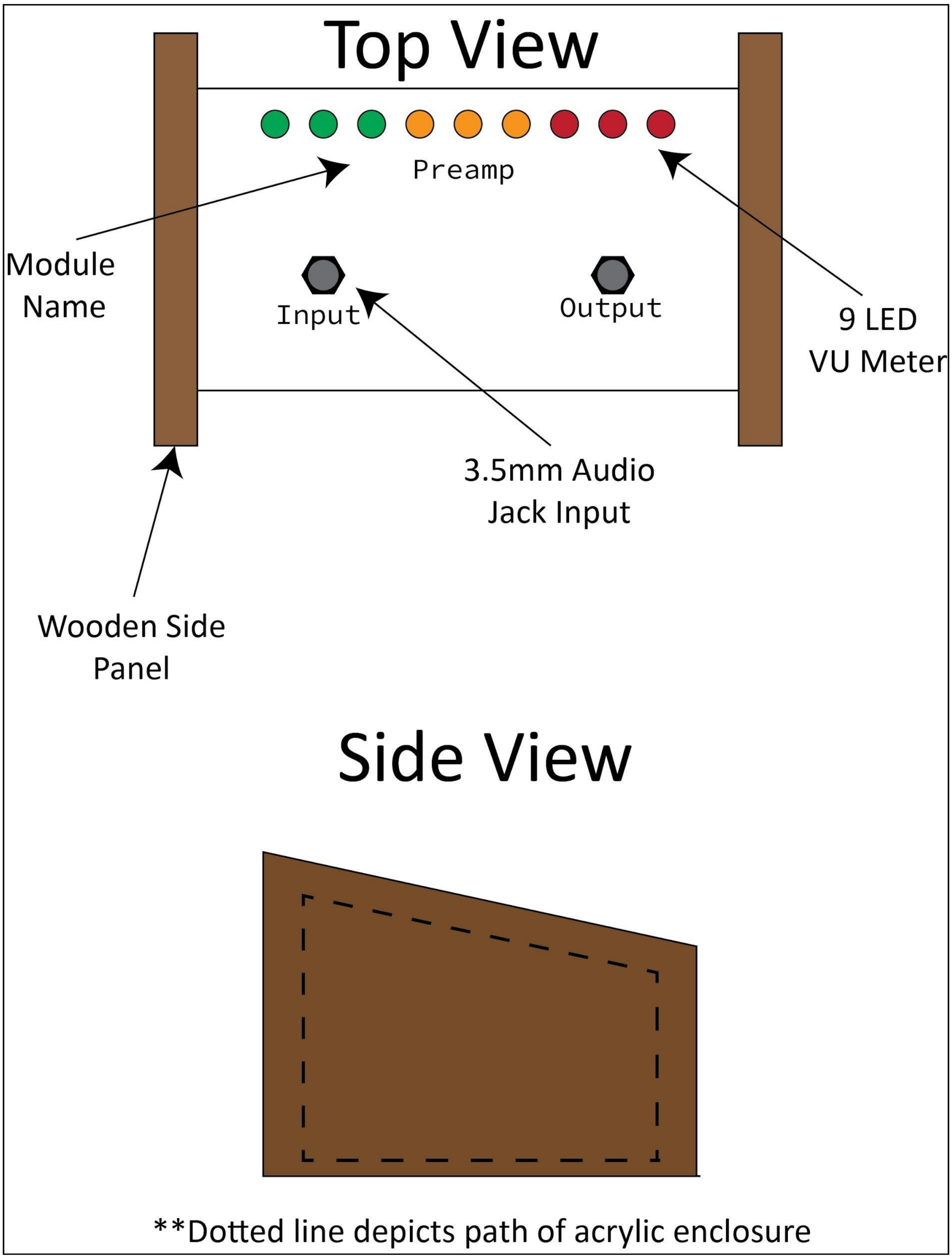

Figure 2.17

Preamp Enclosure

2.6. Conclusion

Up until this point, the work achieved is as follows:

- Completed simulations and tests on different variations of each module.
- Have successfully designed and sent off a PCB for each module to be manufactured.
- Have extensively broadened my electronics design knowledge.
- Have designed an enclosure for each of the modules.

Many issues arose in different parts of the design process such as certain simulations not working on modules. After retracing each step to test the modules the errors were found and the problem was resolved.

Another error also arose when designing the PCB for the equaliser and preamplifier circuit. when uploading the files to Seeedstudio, the company that manufactures the PCBs, the tracks resorted to a size that wasn't compatible with the manufacturer's design rules. I then had to adjust the design to meet the requirements which solved the issue.

The process that was followed from start to finish was to simulate each circuit. After adequate simulating was achieved, each schematic was designed using the knowledge from simulating different versions of each module. Ensure that the PCB layouts were error-free and that they followed the design rules used for seed studio.

The next task is to solder the components to the PCBs, test that everything is working correctly and then fabricate each of the modules.

3. Implementation Chapter

3.1. Introduction

This area will focus on the prototypes of each of the circuits, how they work, as well as the errors that arose and the solutions used to fix them. After carefully simulating each of the circuits in the program LTspice It was time to build a physical prototype.

The method used to prototype each circuit was with a breadboard. A breadboard is a board with horizontal and vertical conductive tracks that can be used to connect electrical components without the need for soldering. The breadboard was a simple yet effective way to test out each of the different modules because there was no need to solder components together which made the process fast and simple.

Due to the accuracy of the virtual simulations of each circuit in LTspice, there was only a need for one prototype for each of the modules.

3.2. Safety

Safety is a number one priority when building each of the modules, especially in the current circumstances due to Covid-19 and not being able to work on campus. The same safety guidelines that apply in the lab in college apply at home. The following headings are taken from the low-risk standard risk assessment document which has been observed before starting the project.

3.2.1. Fire

As there was a lot of soldering in this project there was the hazard of a fire starting due to the extremely hot temperatures of the soldering iron. Due to this reason, all flammable material such as paper etc was kept a great distance away from the work area to ensure optimum safety in regards to fire.

3.2.2. Fumes

As there was soldering in this project there were hazardous fumes generated from the solder. To ensure that the safety guidelines were met in this process the following practices were adhered to:

- Keep the area of work well vented.
- Avoid inhaling the fumes of the solder.
- Take a break every hour or so.

3.2.3. Electrocution/Electric Shock

Due to working with power supplies, there was a risk of electrocution/electric shock. In order to ensure the optimum safe working environment the following practices were followed:

- Keep liquids away from the equipment.
- Don’t use the equipment if it is slightly damaged in any way.

3.2.4. Heavy Equipment

There was no use of heavy equipment in this project.

3.2.5. Drilling Injuries

As there was a mistake made in the production of the PCB. There were no mounting holes drilled by the manufacturer so they had to be drilled by hand. During this process, safety goggles were used and loose clothing was tucked away safely.

3.2.6. Cutting Injuries

There was no chance of a cutting injury in the building of this project due to the fabrication being built by an external source.

3.3. Input Buffer Prototype

The input buffer is the module used to transform the impedance from one circuit to another. In this case, it would be from the audio source, e.g. a vinyl player.

3.3.1. Prototype Process

After careful research and testing of different buffer circuits, it was time to build the buffer circuit that had the best Hi-Fi audio capabilities. This Hi-Fi audio input buffer was built with rather easy to find components. The main components used in this circuit are some NPN and PNP transistors.

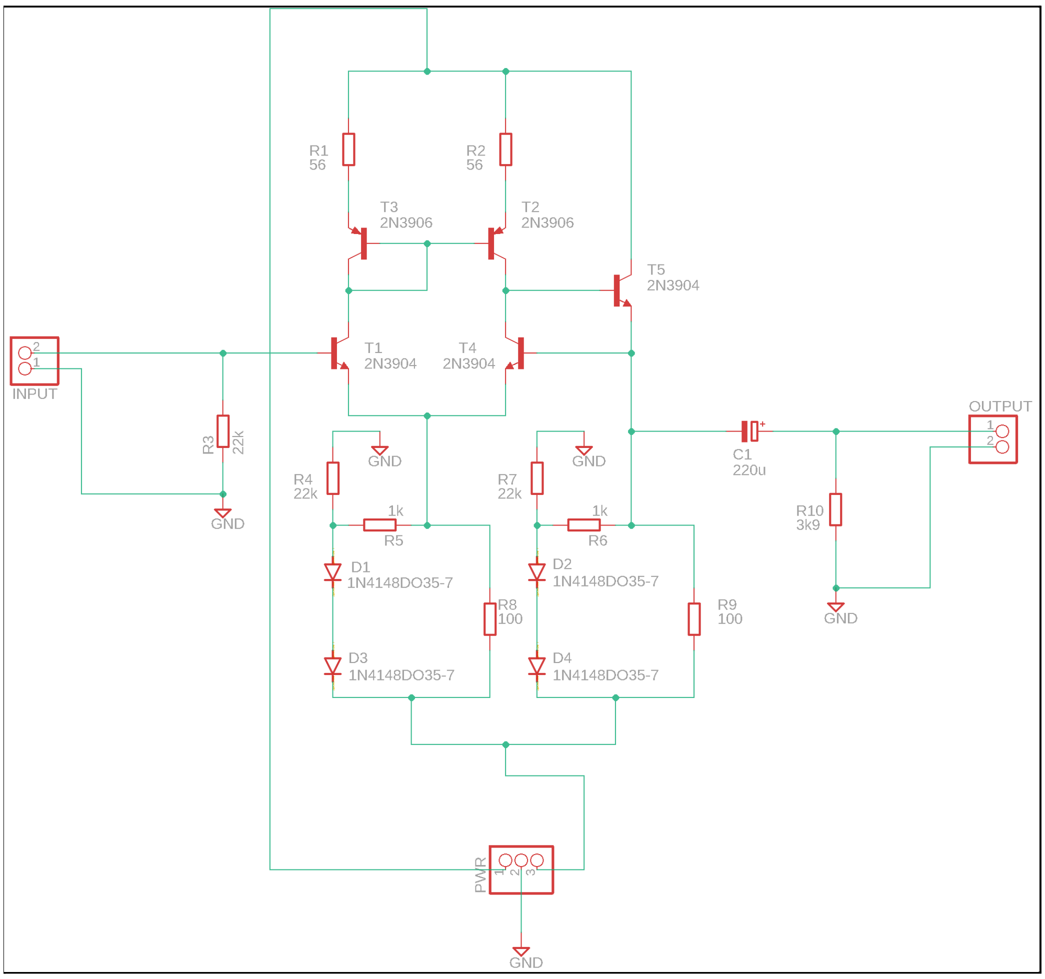

Figure 3.1

Input Buffer Circuit

The first components that were placed into the breadboard were T1 and T4 as seen in Figure 3.1, these are both 2N3904 NPN transistors. These two transistors are the first components that the input signal. These transistors act as a transconductance amplifier by subtracting the input and feedback voltages from the input source. It essentially turns the input voltage into a current output.

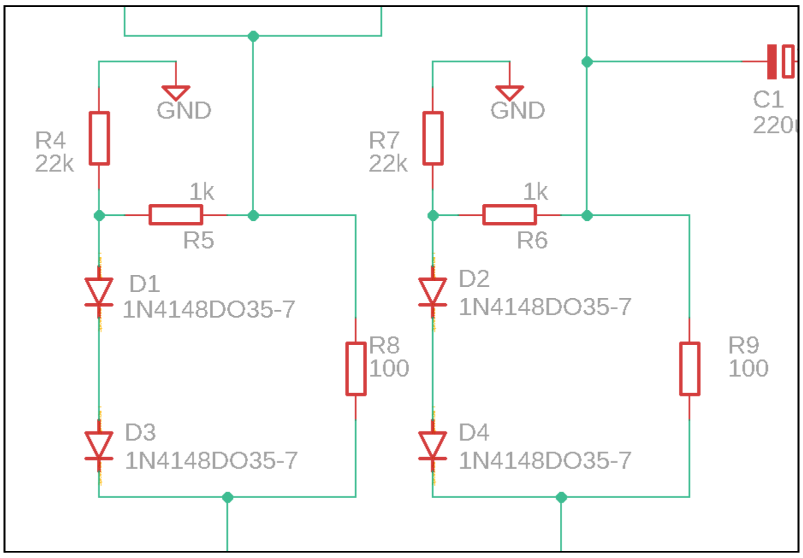

Figure 3.2

Constant Current Sources

The next set of components that were placed in the breadboard was for the two current sources. As seen in Figure 3.2. One of the current sources is made up of the following components:

- 2 x 1N4148 Signal Diodes
- 1 x 100Ω Resistor
- 1 x 1kΩ Resistor
- 1 x 22kΩ Resistor

These components were added to the breadboard, ensuring each of the diodes was in the correct orientation.

3.3.2. Outcome

The prototype was a great success and worked as intended. Although the input and output were not through an audio jack the basic fundamental of the module worked. The following characteristics were achieved in the prototype:

- Low Signal Distortion
- The output signal was unchanged from the Input
- Low Signal To Noise Ratio

3.4. Equaliser Prototype

An equaliser is a tool used to boost or cut different frequencies in an audio signal. In this case, it used to cut or boost bass and treble frequencies.

3.4.1. Prototype Process

The chosen EQ is the Baxandall two-capacitor high-frequency control EQ. The reason for choosing this circuit over other EQ circuits was that it allows small amounts of bass boost to be used in the audio signal to amend speaker inadequacies without affecting the whole bass frequency range which is a good characteristic to have in a Hi-Fi module as you want the audio signal to be as untouched as possible.

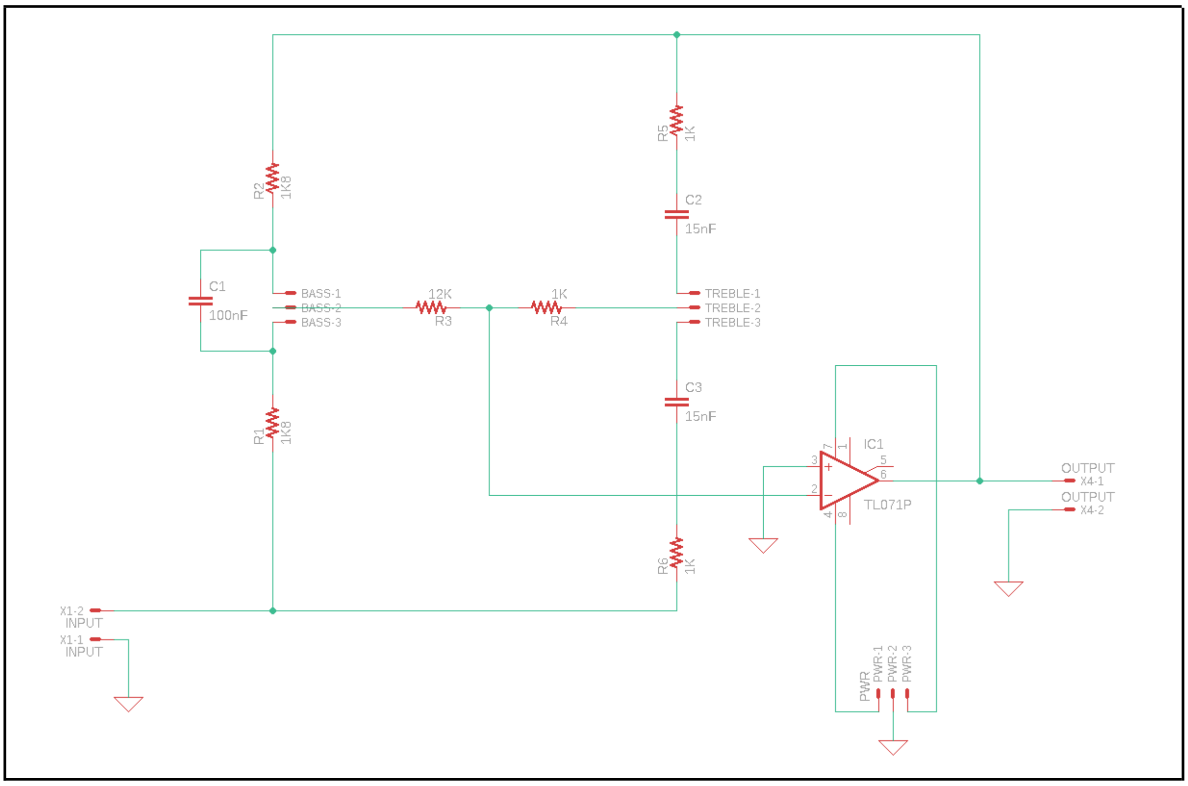

Figure 3.3

Equaliser Circuit

The first component added to the breadboard was the op-amp. In this case, the TL071 op-amp was used as it has a low signal to noise ratio as well as a low total harmonic noise value which made it a good component for this application.

After placing the op-amp onto the breadboard the non-inverting input (**+**) was grounded and the positive power rail was added to pin 7 and the negative power rail was added to pin 4.

Two resistors, a 12kΩ and a 1kΩ were then added to the inverting input (**-**) of the op-amp to form a voltage divider. Attached to the opposite legs of these two resistors was the wiper terminal, the middle leg, of a 10k potentiometer. These potentiometers are used to boost or cut the frequencies in the bass and treble range. Resistors 1, 2, 5 and 6 were then added as well as the capacitors 1, 2 and 3.

A 1k8Ω resistor (R1) was added to the first leg of the bass potentiometer, followed by another 1k8Ω resistor (R7) on the third leg of the potentiometer. There was a 100nF capacitor connected to the first and second leg of the same potentiometer.

On the first and third leg of the treble potentiometer, there was a 15nF capacitor (C2, C3) followed by a 1kΩ resistor (R5, R6)

3.4.1. Outcome

The prototype was a success and there were no errors. Thanks to simulating the circuit in LTspice any errors that arose were resolved in that stage.

There was a slight change in the prototype as there were no 10k potentiometers on hand so a 100k potentiometer was used in both cases, for the bass and the treble. This didn't have a huge impact on the output results.

The following bullet points were achieved in the prototype:

- Bass Cut & Boost
- Treble Cut & Boost
- Low Signal to Noise Ratio

3.5. Preamp Prototype

A preamp is a type of amplifier used to bring a weak audio signal up to a level that is strong enough to be tolerant to noise as well as further types of processing.

3.5.1. Prototype Process

The preamp consists of three main stages, the differential input stage which uses the components Q1-Q3, the voltage amplifier stage which uses Q5 and Q4 and finally the unity-gain output stage which uses the Q7 and Q8; these components can be seen in Figure 3.4.

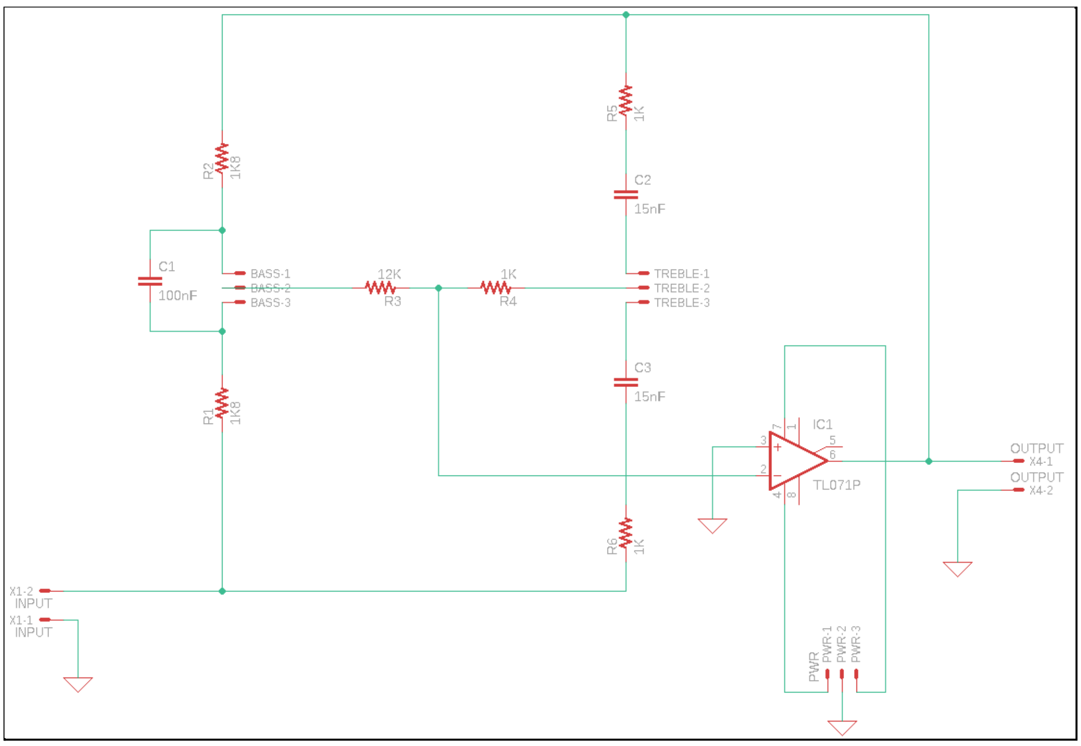

Figure 3.4

Preamp Circuit

As this was a larger circuit, there was a need for two breadboards to ensure there was enough space for each part of the circuit.

The process started by placing Q2 and Q3 into the breadboard. These two components were 2N3906 PNP transistors. These transistors are used to subtract the input and feedback voltages essentially acting as a transimpedance amplifier by turning the input voltage into an output current.A 6k8Ω resistor was then attached to the collector of each of the transistors which were then attached to the negative power rail and Q1 was then attached through its collector's leg to the emitter of Q2 and Q3. There are then 2 resistors, a 22kΩ and a 6k8Ω as well as a 47uF capacitor attached to the base of Q3.

The voltage amplifier stage was then breadboarded starting with the main components, Q4 and Q5. These 2N3904 NPN transistors act as a transconductance amplifier which is the opposite of what we have seen in the first stage. It takes current and outputs voltage.

This stage has a low impedance due to the negative feedback from the 15pF capacitor (C3) attached to the base and emitter of Q4. There is then a 330Ω attached to the emitter of Q5 which is then attached to the positive power rail.

Diodes D1 and D2 are connected to the base of Q5 as well as Q1.

The third stage which is the unity gain buffer is then breadboarded on the second breadboard. This uses the components Q7 and Q8 which are 2N3904 NPN transistors. The 2 1N4148 signal diodes are then placed with a 22kΩ and a 2k7Ω resistor to form the current source.

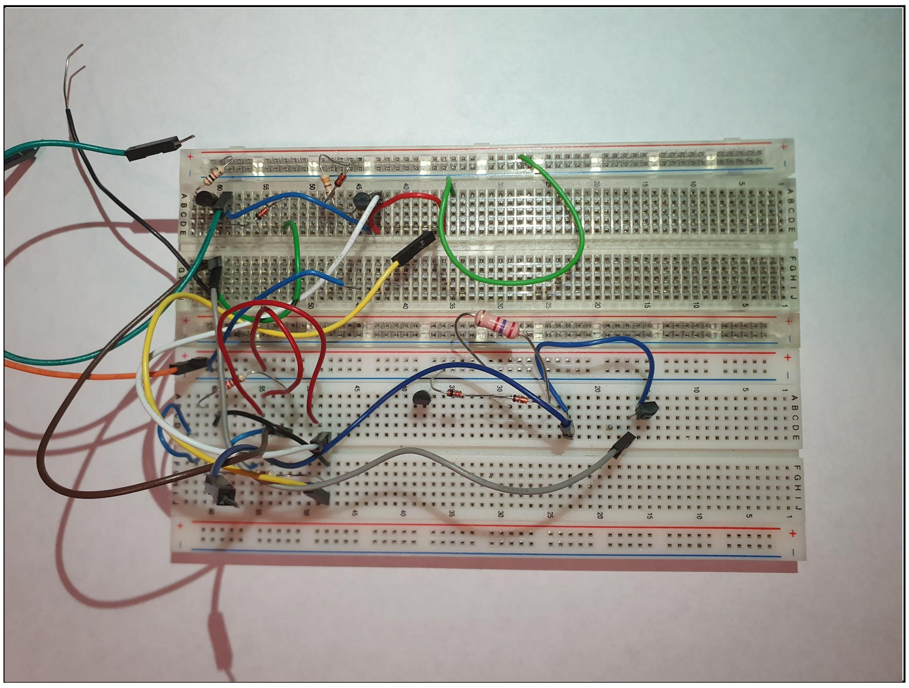

Figure 3.5

Preamp Prototype

3.5.2. Outcome

The prototype was a success and worked as intended, The output signal was larger than the input signal. There were some component legs placed in the wrong track of the breadboard which caused some confusion but was fixed when the circuit got a review.

3.6. Input Buffer PCB

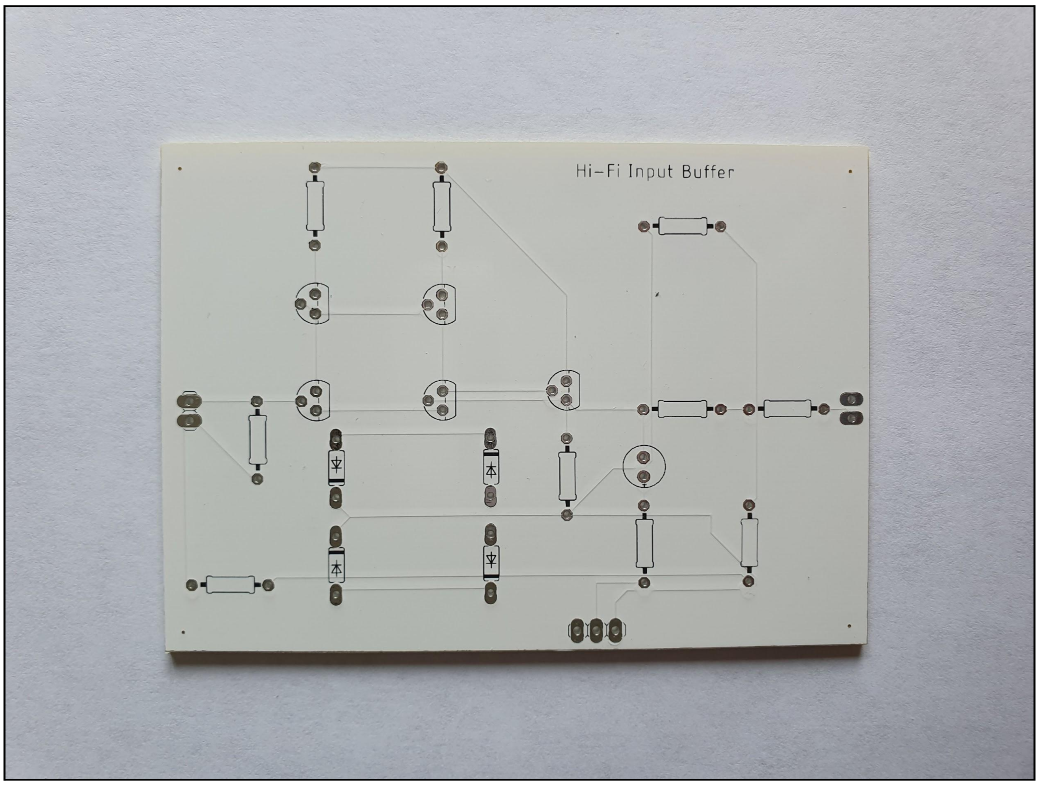

Figure 3.6

Input Buffer PCB

3.6.1. PCB Construction

Due to there being no text on the PCB, The first step in the construction process was to get up the .brd file from Autodesk Eagle. This helped ensure that each component was put in the correct place.

After gathering the correct components for this specific module it was time to start carefully placing each leg of the components through the holes assigned for them on the PCB.

The first components placed onto the PCB were the transistors, these were the most tedious due to their three legs. It was possible to get a transistor holder which could go into the through holes on the PCB for the transistors but they weren't mandatory.

The four signal diodes were then placed into position as well as each of the resistors and then finally the capacitors.

After this was complete a review of each of the components was done to make sure that they were the correct component and in the correct orientation. Once this was completed it was time to solder each of the components into place ensuring that there was an adequate amount of solder on each component to give a good connection.

There were screw terminals placed onto the input and output holes on the PCB, this made it easy to replace an audio jack if there were any errors or damage to the wire. There was originally going to be a 3-pin Molex male header for the power but after realizing certain components were not correct it was easier to solder the wires directly to each of the holes. An image of the finished PCB can be viewed in Figure 3.7.

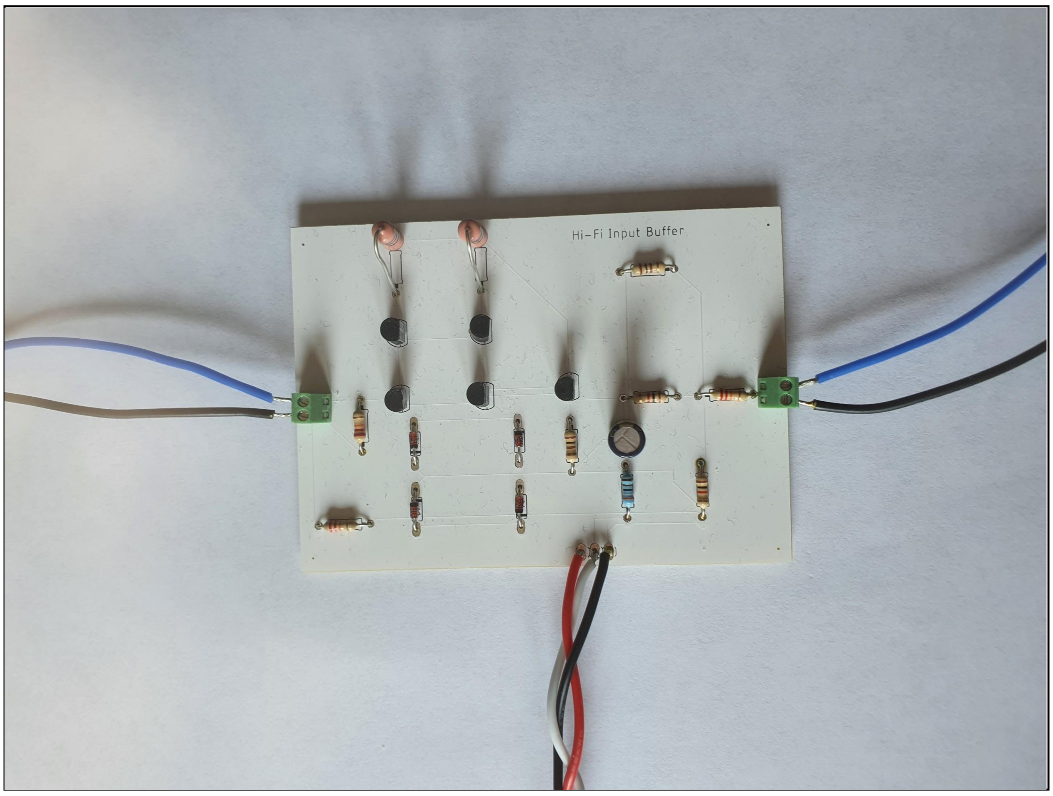

Figure 3.7

Completed Input Buffer PCB

3.6.2. Errors

The input buffer PCB had some errors that were forgotten about in the design process. The text and values for each of the components weren't placed on the correct layer so it was difficult to judge which components went where.

3.6.3. Solution

The solution to this problem was to get the PCB design up on a laptop that has the names, values and location of each of the components and work off of that.

3.7. Preamp PCB

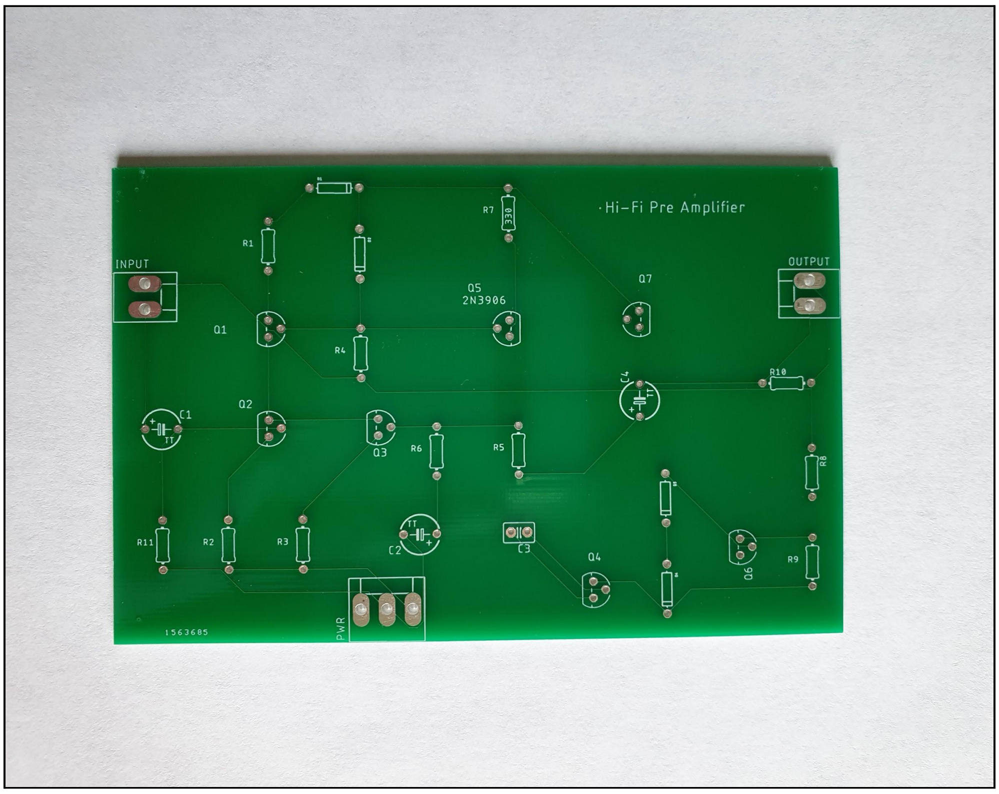

Figure 3.8

Preamp PCB

3.7.1. PCB Construction

The same procedure that was used in the input buffer was used in this circuit. Starting by placing the transistors in first as they were the components that were hardest to place. After this was completed the signal diodes, resistors and then capacitors were placed into their correct locations. While placing each of the components in, the legs at the back of the PCB were spread to fix each of the components into place.

As there were not any screw terminals left, the wires for the input and output were soldered directly to the PCB. Each of the wires was colour coded to show which was the ground and which was the input/output signal used. The input/output signal wire is blue and can be seen in Figure 3.9.

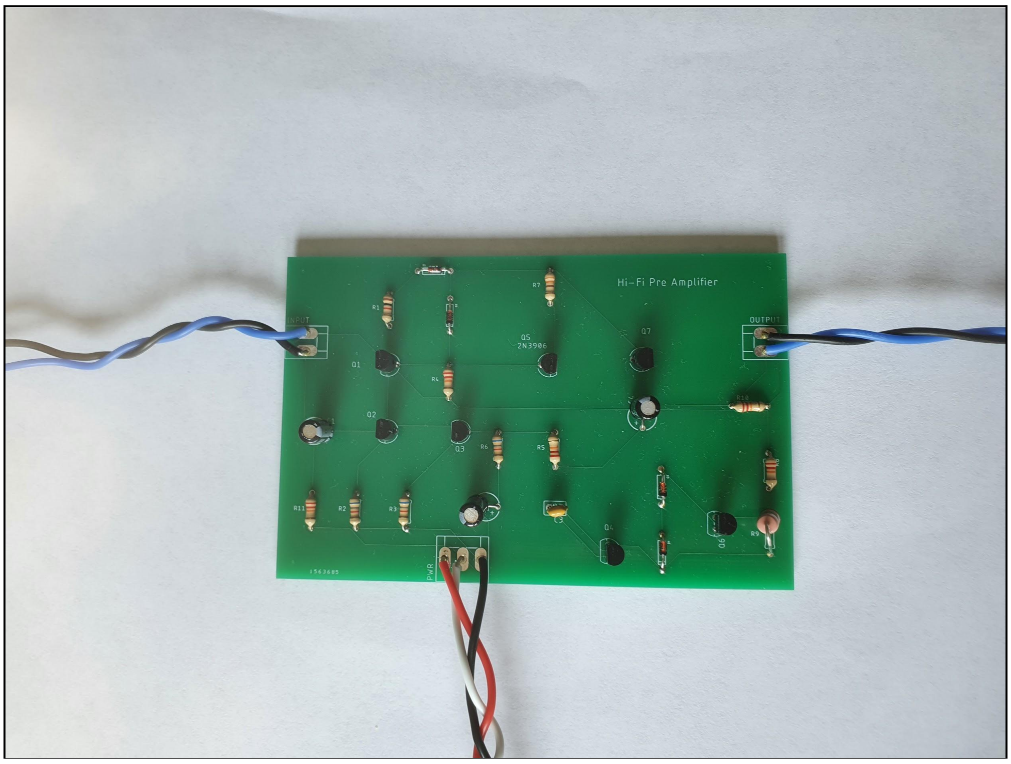

Figure 3.9

Completed Preamp PCB

3.7.2. Errors

Similar to the previous PCB there were no values for each of the components on the PCB but there were names for each of the components which made it a bit easier to understand.

3.7.3. Solution

The solution was the same as prior, to look at the schematic on a laptop to ensure the component placement was correct.

3.8. Equaliser PCB

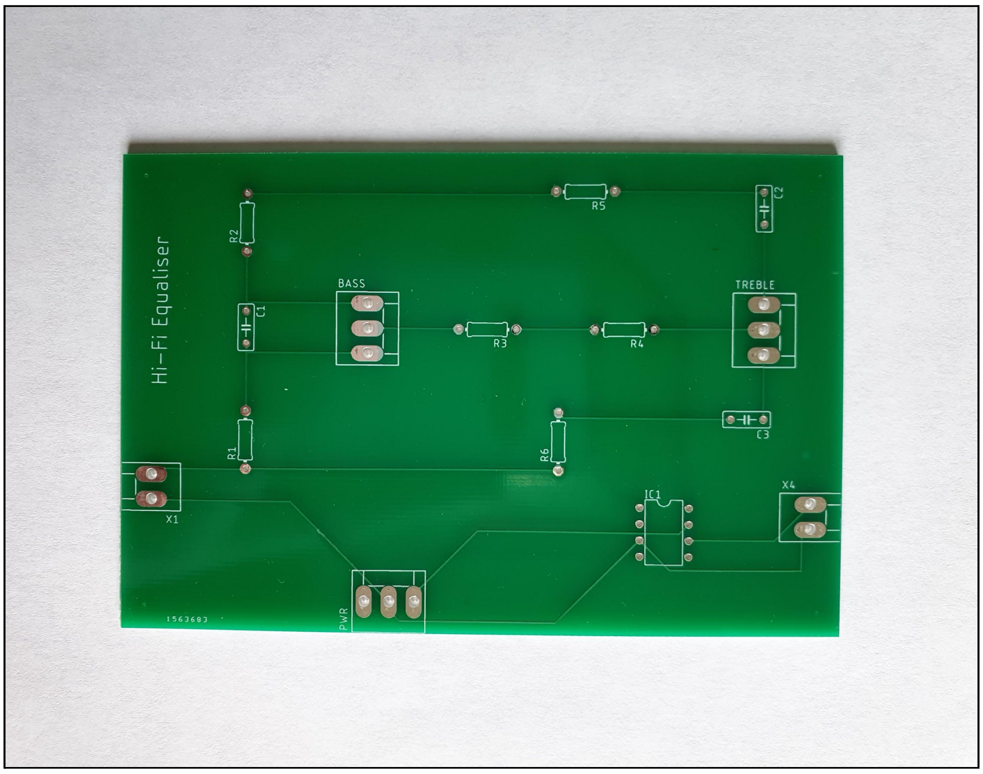

Figure 3.10

Equaliser PCB

4.8.1. PCB Construction

After ensuring the correct components were set aside for this circuit it was time to start placing each component into each position.

Due to the chance that the IC could be damaged by the heat off the soldering iron, an IC socket was used instead of directly soldering the IC to the PCB. After this was soldered into place, it was time to focus on the potentiometers.

A Molex connector was going to be used for this part. The reason for this was that it made replacing the components a lot easier but due to an error and time limitations wires were soldered directly to the PCB instead. Before soldering the wires to the PCB, the wires were first soldered to each of the potentiometers.

After the potentiometers were soldered into place the other components such as the resistors and capacitors could now be attached to the board.

The last thing was to then attach the power wires to the board as well as the input/output wires. These used the same colour code as before to keep the same design over each of the modules.

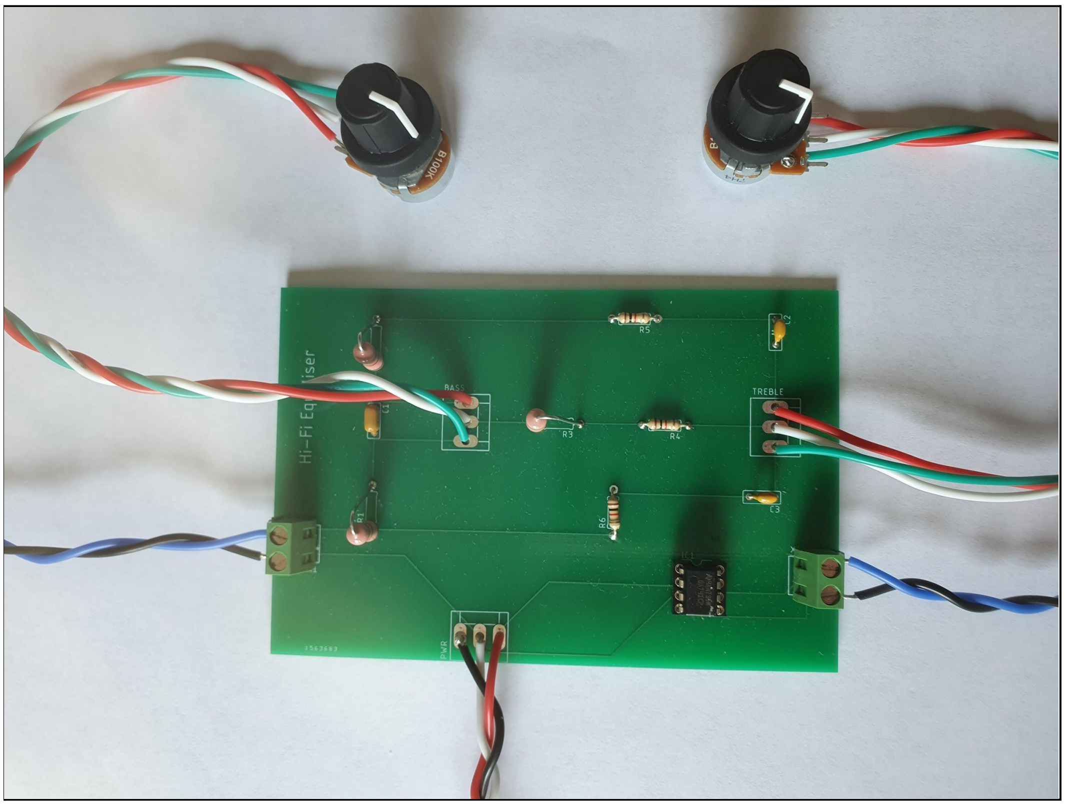

Figure 3.11

Completed Equaliser PCB

38.2. Errors

Due to ordering the wrong Molex connectors, they would not fit into the holes on the board. The pitch was too small on the parts that had been ordered.

3.8.2. Solution

In order to fix this error, the wires were soldered directly to the PCB.

3.9. VU Meter PCB

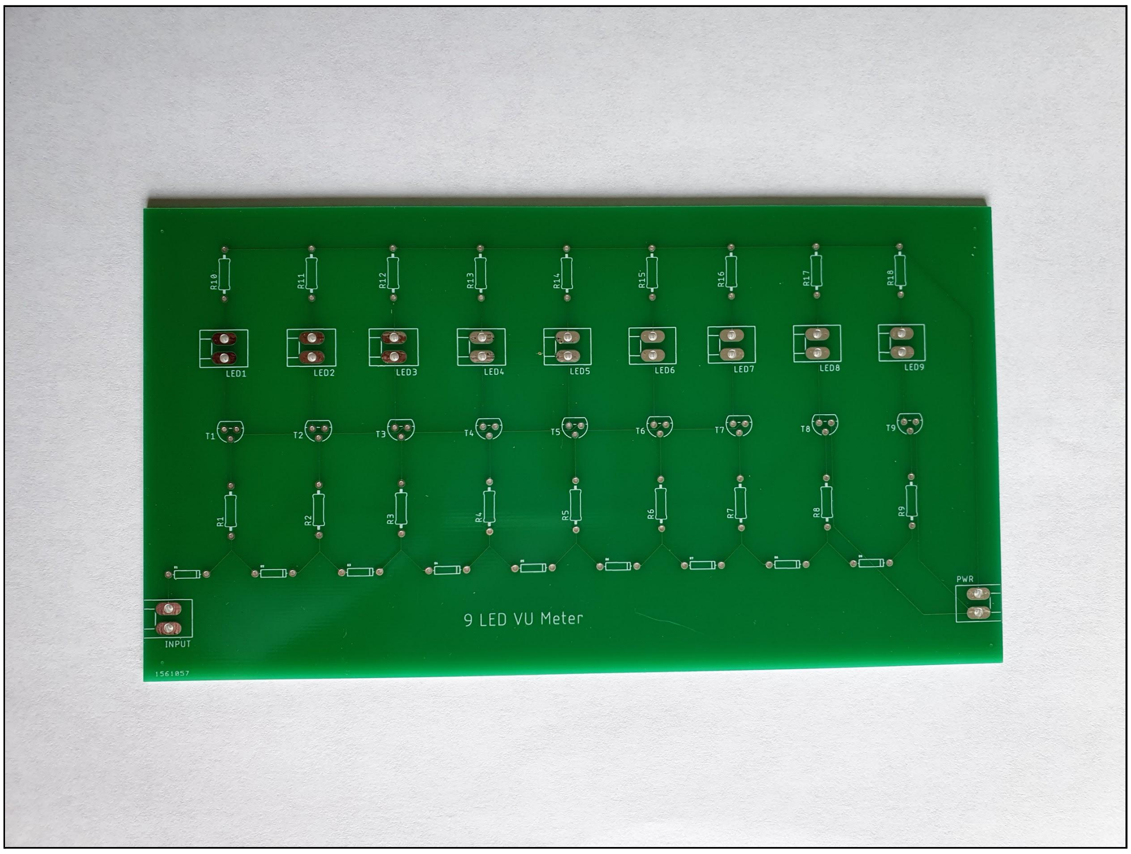

Figure 3.12

VU Meter PCB

3.9.1. PCB Construction

This was the most tedious PCB as there were three of them to build. There were a large number of components needed for this module. Arranging each of the components prior to the assembly helped speed up the process immensely.

The first group of components that were soldered to the board was the transistors. Each board had 9 transistors to be soldered as well as 9 x 1N4148 signal diodes, 9 x 1kΩ resistors, 9 x 10kΩ Resistors as well as 9 LEDs. The LEDs had wires soldered to them prior to them being soldered to the board. This made attaching them to the board a lot easier.

This process was repeated two more times after this for the VU meter for the other modules. An image of the finished PCB can be seen in Figure 3.12.

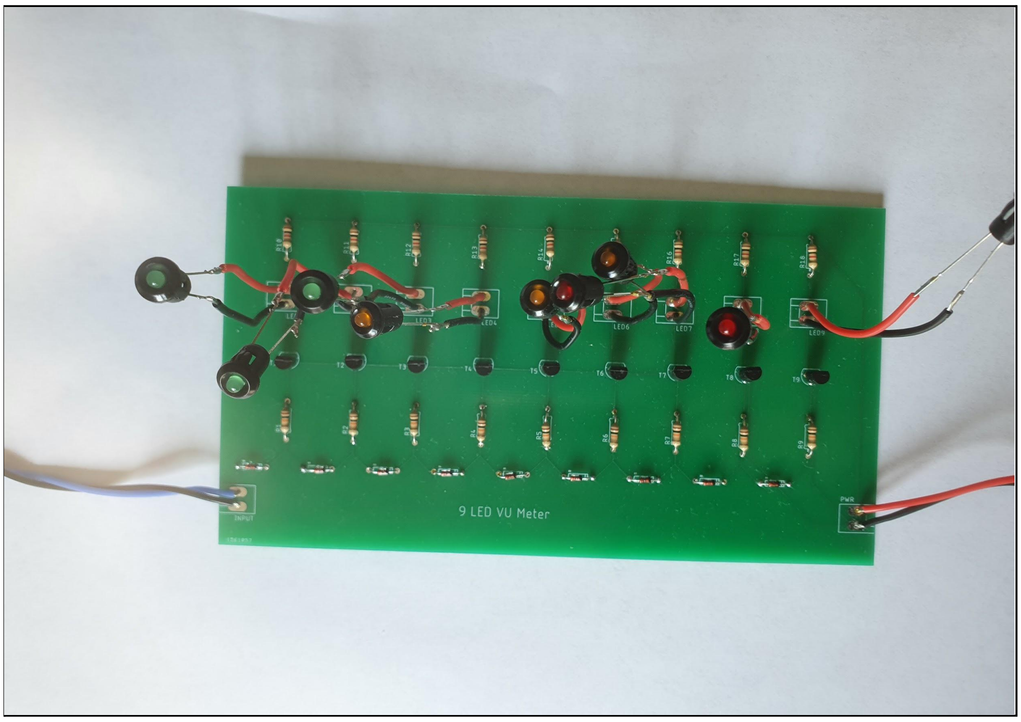

Figure 3.13

Completed VU Meter PCB

3.9.2. Errors

After receiving the PCB for the VU meter there was an error found on the transistor T2. The emitter leg was not attached to the ground track on the board.

3.9.3. Solution

In order to fix this error, the emitter of T2 was soldered to the emitter of T3. This grounded the emitter and solved the grounding issue. An image of this can be seen in Figure 3.14.

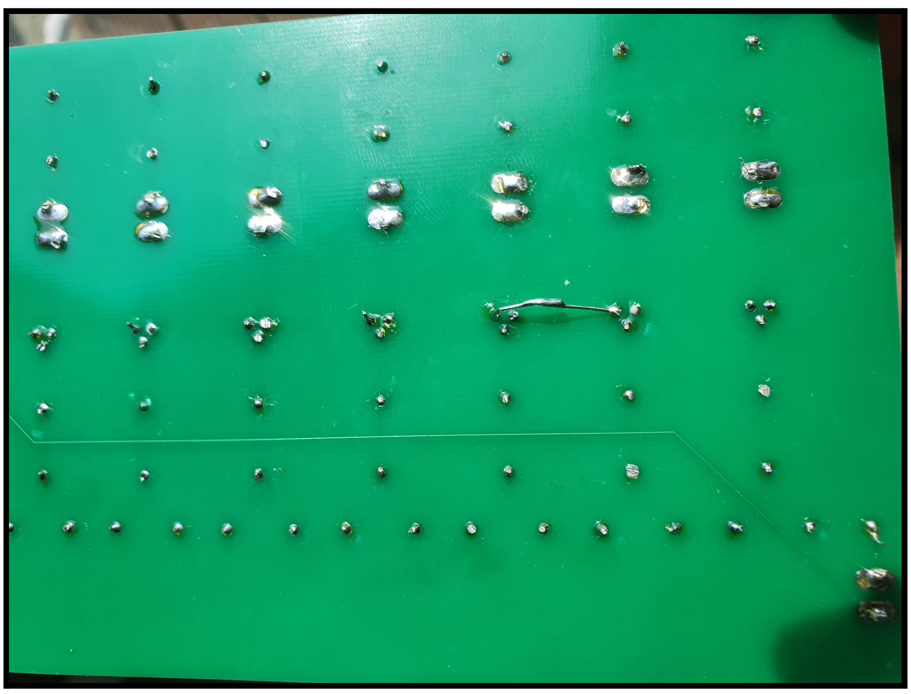

Figure 3.14

Two Emitter Legs Soldered Together

3.10. Conclusion

The modular Hi-Fi sound system has progressed immensely since the idea came about. From the simulations in LTspice to the breadboard prototypes to the final PCBs. A number of issues arose throughout this process but after some careful thinking and consideration, they were resolved.

A huge amount of work was put into the construction of each of the modules and it has paid off. Each module is now fully functional and is ready to be tested which can be viewed in the next chapter.

4. Testing & Results Chapter

4.1. Results and Testing Strategies

The results gathered in this chapter were from many different sources. One of these sources is from simulations that were run in LTspice prior to building each of the circuits to ensure that each of the modules was working and was at a Hi-Fi standard.

The second source is from the PCB itself. An oscilloscope was used to monitor the input and output of each of the modules when the testing was taking place. This allowed us to view the input signal, which was coming from a signal generator, and the output signal from the PCB. Figure 4.1 shows a block diagram of how each module was set up for testing.

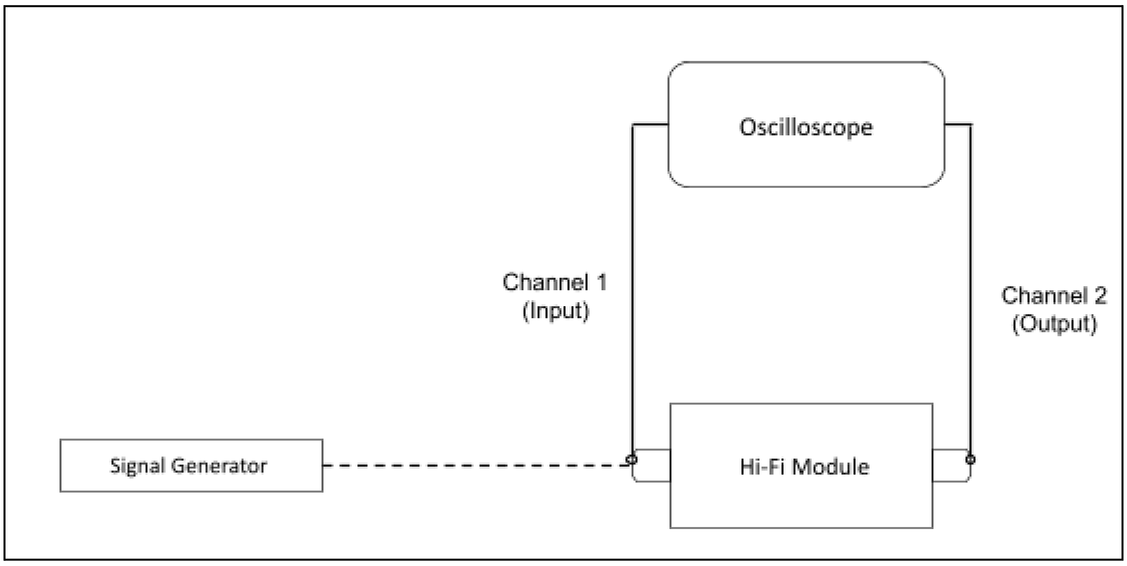

Figure 4.1

Testing Configuration Setup

4.2. Tests and Results

This section will cover the method of the tests carried out on each of the circuits.

4.3. Preamp Testing & Results

The equipment used in this test are listed:

- **Dual Power Supply:** A dual power supply was needed due to the preamp module requiring a positive and negative power rail.
- **Signal Generator:** The signal generator was used to generate an input signal.
- **Oscilloscope:** The oscilloscope was used to display the input and output waveforms.

4.3.1. Hardware Parameters

Power Supply	±12V
Signal Generator	1kHz Sine Wave

4.3.2. Setup Process:

Step 1:
Set up the dual power supply so that it is configured to have a positive and a negative power rail.

Step 2:
Attach the red wire to the positive power rail, the white wire to ground and the black wire to the negative power rail of the PCB.

Step 3:
Connect the two BNC to crocodile clip leads to the oscilloscope and then connect channel one to the input of the preamp module and attach channel two to the output of the module. This will give us the waveforms for each of these signals, allowing us to compare the two.

Step 4:
Attach the BNC lead to the signal generator and attach the opposite end to the input of the preamp module. This will generate a signal that can be used to test the module. For this test, the signal generator was set to a 1kHz sine wave.

Step 5:
Turn on the power supply and set the power voltage.

Step 6:
Record Results.

4.3.3. Results

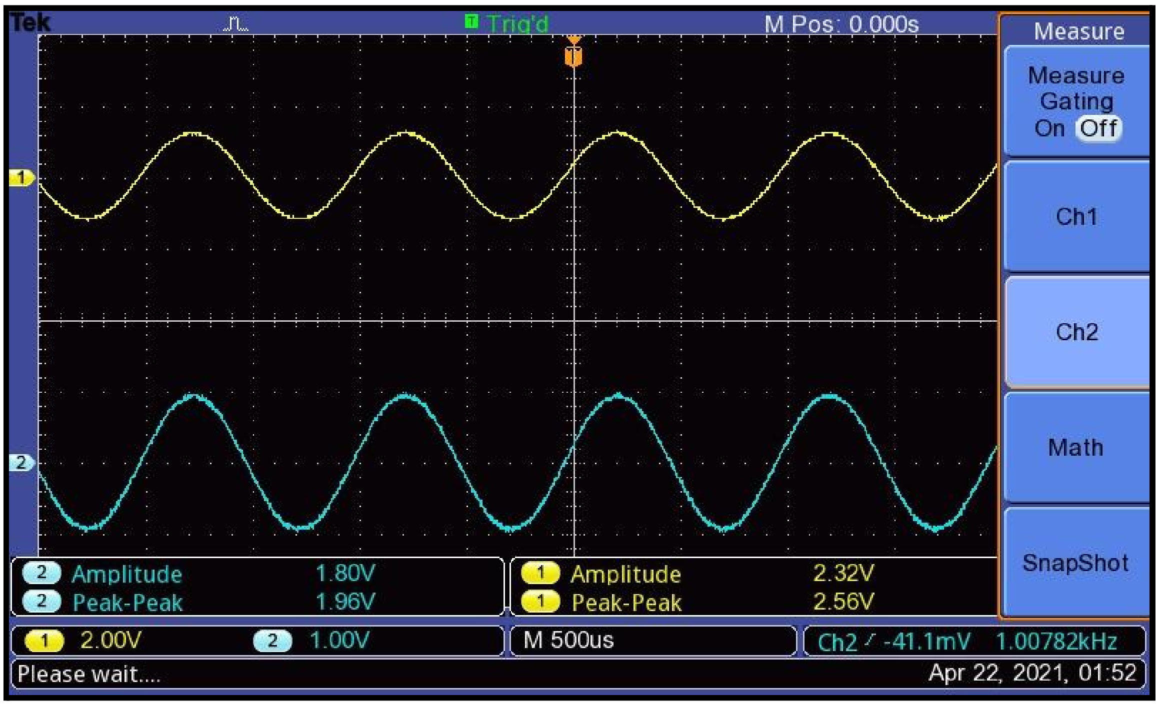

Figure 4.2

Preamp Oscilloscope's Input/Output Waveforms

As seen in Figure 4.2, the output waveform (Blue) has been amplified by the circuit. This displays the preamp module completing its required function. Figure 4.3 shows the setup of the test for the preamp module.

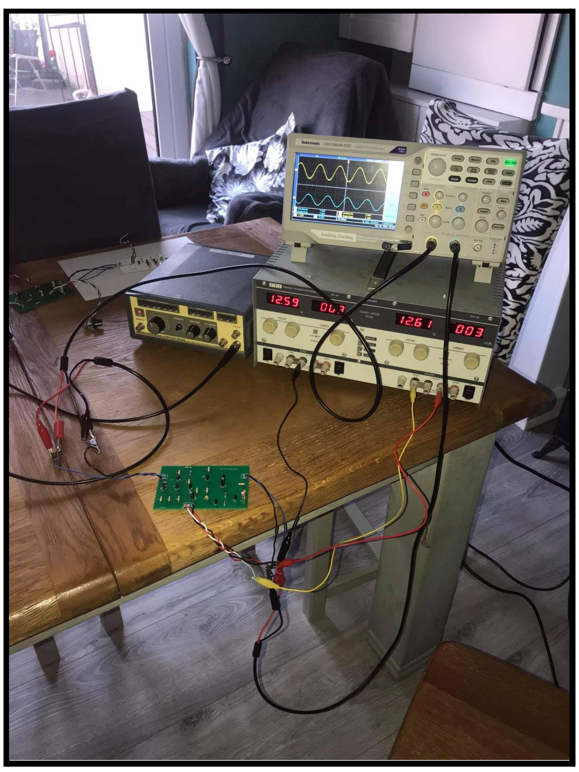

Figure 4.3

Preamp Test Setup

4.4. Equaliser Testing & Results

The equipment used in this test are listed:

- **Dual Power Supply:** A dual power supply was needed due to the preamp module requiring a positive and negative power rail.
- **Signal Generator:** The signal generator was used to generate an input signal.
- **Oscilloscope:** The oscilloscope was used to display the input and output waveforms.

4.4.1. Hardware Parameters

Power Supply	±9V DC
Signal Generator	1kHz Sine Wave

4.4.2. Setup Process:

Step 1:
Set up the dual power supply so that it is configured to have a positive and a negative power rail.

Step 2:
Attach the red wire to the positive power rail, the white wire to ground and the black wire to the negative power rail of the PCB.

Step 3:
Connect the two BNC to crocodile clip leads to the oscilloscope and then connect channel one to the input of the preamp module and attach channel two to the output of the module. This will give us the waveforms for each of these signals, allowing us to compare the two.

Step 4:
Attach the BNC lead to the signal generator and attach the opposite end to the input of the equaliser module. This will generate a signal that can be used to test the module. For this test, the signal generator was set to a 1kHz sine wave.

Step 5:
Turn on the power supply and set the power voltage.

Step 6:
Ensure both potentiometers are set at a 12 o'clock position before recording the results.

Step 7:
Record Results.

4.4.3. Results

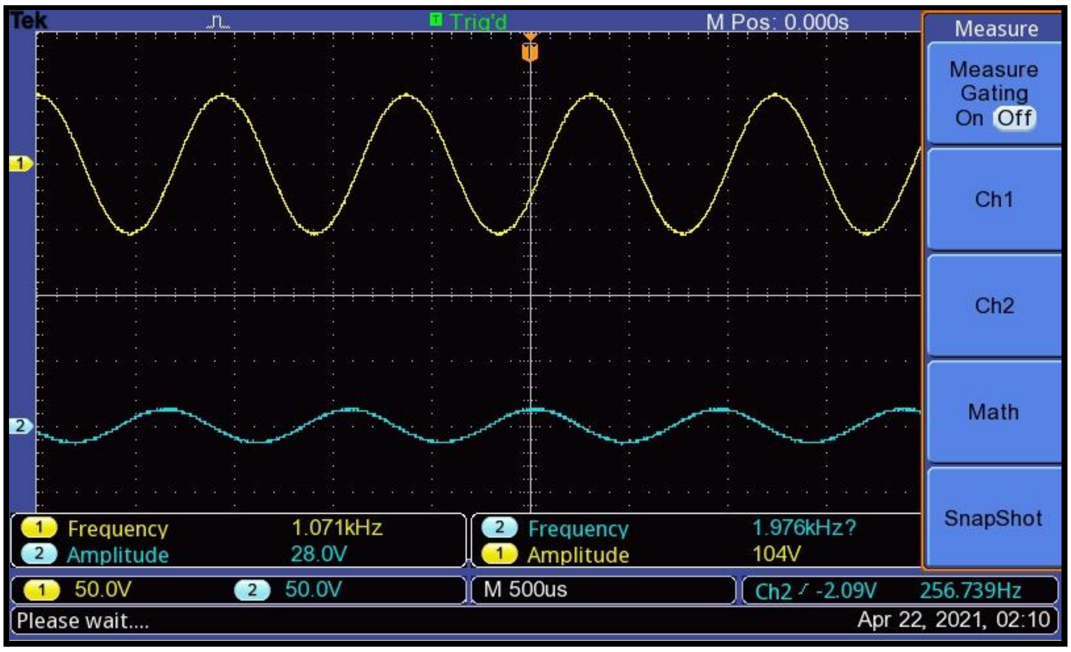

Figure 4.4

Equaliser's Oscilloscope Input/Output Waveforms

As seen in Figure 4.4 the frequency on the output (blue) is larger on the output. This was achieved by leaving the bass potentiometer at a neutral position and turning the treble potentiometer clockwise. This boosted the frequency from 1.07kHz to 1.97kHz. Figure 4.5 is an image of the configuration setup of the test.

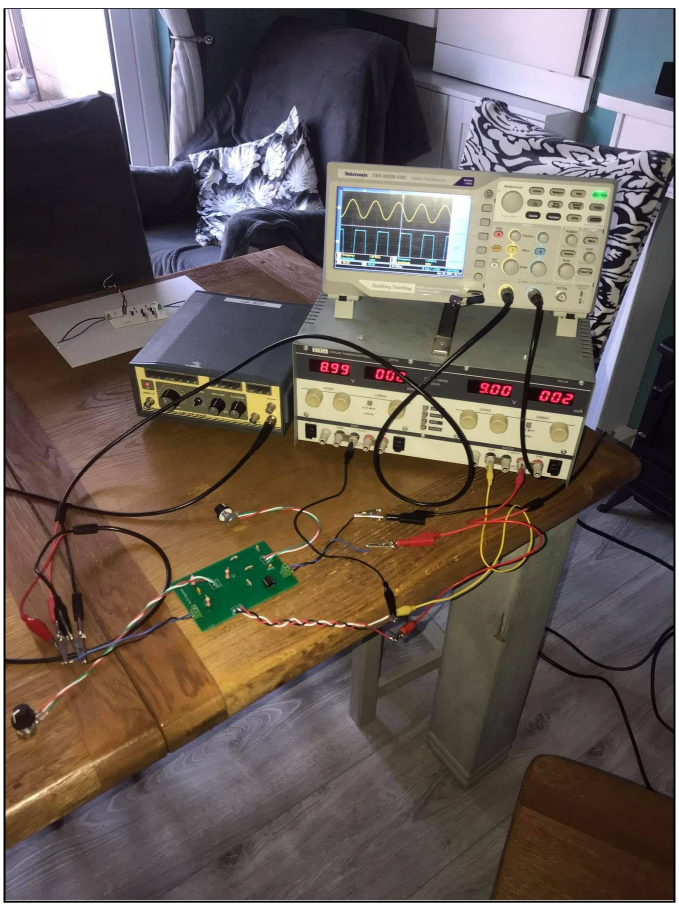

Figure 4.5

Equaliser Test Setup

4.5. Input Buffer Testing & Results

The equipment used in this test are listed:

- **Dual Power Supply:** A dual power supply was needed due to the preamp module requiring a positive and negative power rail.
- **Signal Generator:** The signal generator was used to generate an input signal.
- **Oscilloscope:** The oscilloscope was used to display the input and output waveforms.

4.4.1. Hardware Parameters

Power Supply	±12V
Signal Generator	1kHz Sine Wave

4.4.2. Setup Process:

Step 1:
Set up the dual power supply so that it is configured to have a positive and a negative power rail.

Step 2:
Attach the red wire to the positive power rail, the white wire to ground and the black wire to the negative power rail of the PCB.

Step 3:
Connect the two BNC to crocodile clip leads to the oscilloscope and then connect channel one to the input of the preamp module and attach channel two to the output of the module. This will give us the waveforms for each of these signals, allowing us to compare the two.

Step 4:
Attach the BNC lead to the signal generator and attach the opposite end to the input of the buffer module. This will generate a signal that can be used to test the module. For this test, the signal generator was set to a 1kHz sine wave.

Step 5:
Turn on the power supply and set the power voltage.

Step 6:
Record Results.

4.5.3. Results

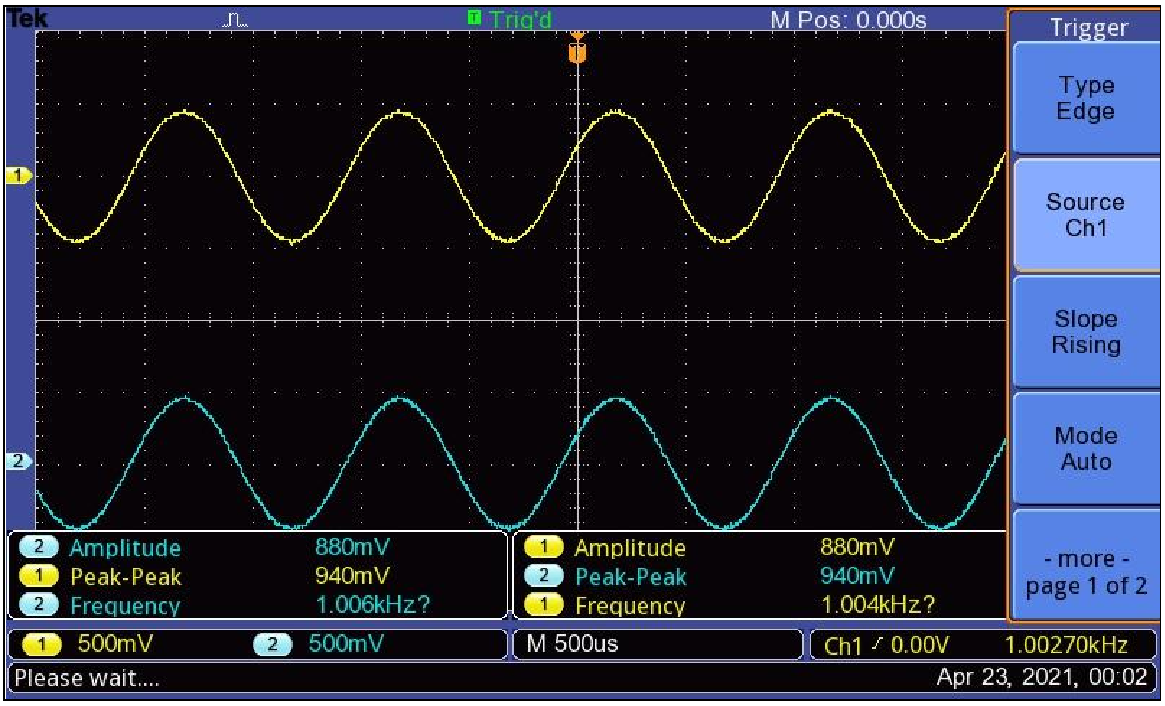

Figure 4.6

Input Buffer Oscilloscope Input/Output Waveforms

Figure 4.6 displays the input and output waveforms measured through an oscilloscope. When passing an audio signal through an input buffer the audio signal should remain unchanged. The function of a buffer is to match impedances, this shouldn't have an impact on the waveform.

The Input buffer is working as intended. The output waveform is unchanged after passing through the buffer.

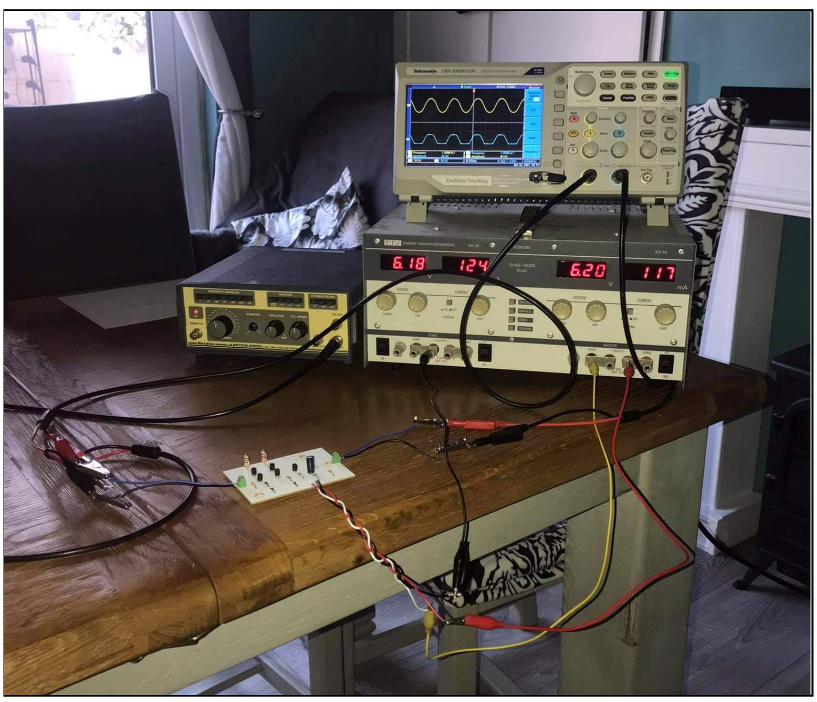

Figure 4.7

Input Buffer Test Set-up

4.6. VU Meter Testing and Results

The equipment used in this test are listed:

- **Dual Power Supply:** A dual power supply was needed due to the preamp module requiring a positive and negative power rail.
- **Signal Generator:** The signal generator was used to generate an input signal.

4.6.1. Hardware Parameters

Power Supply	+9V
Signal Generator	1kHz Sine Wave

4.6.2. Setup Process:

Step 1:
Set up the dual power supply so that it is configured to output 9V DC.

Step 2:
Attach the red wire to the positive power rail and the black wire to ground.

Step 3:
Attach the BNC lead to the signal generator and attach the opposite end to the input of the VU meter module. This will generate a signal that can be used to test the module. For this test, the signal generator was set to a 1kHz sine wave.

Step 4:
Turn on the power supply.

Step 5:
Record Results.

4.6.3. Results

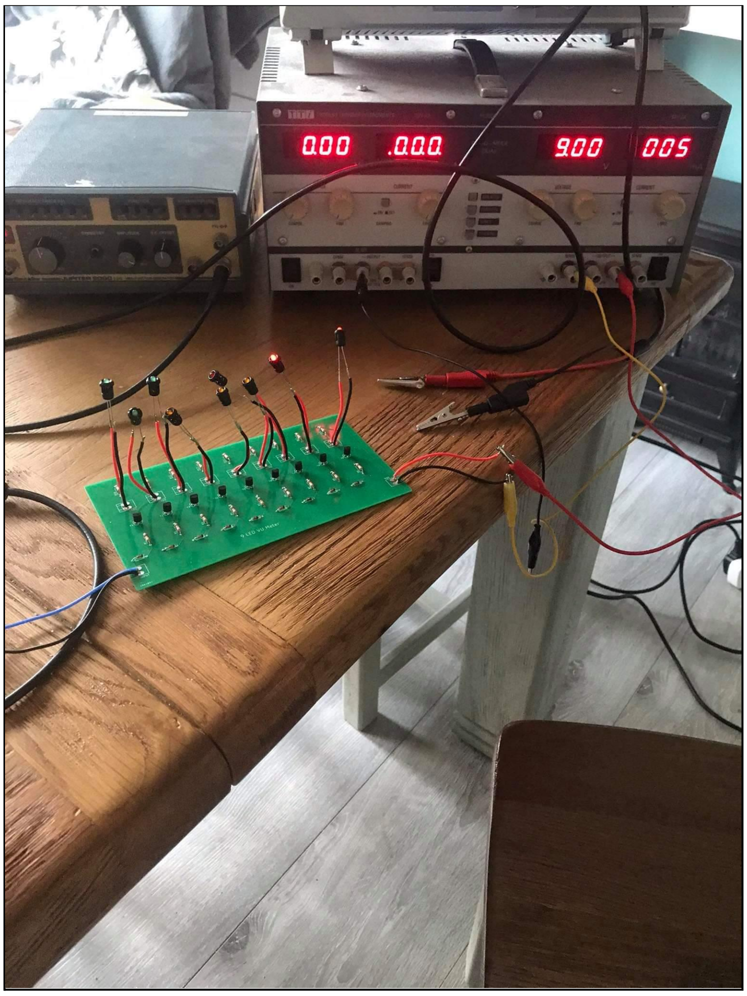

Figure 4.8

VU Meter Test Setup

As shown in Figure 4.8, The LED is lighting up displaying the power levels of the signal that is going into the input.

5. Conclusion

This report has outlined the development of the modular Hi-Fi sound system which was concluded in the 2020/21 college year in the Creative Media Technologies course in the Institute of Arts, Design + Technology, Dún Laoghiare.

Now finished, the modular sound system is capable of matching the impedance from one device to another which results in the full audio signal being transferred from one device to another without added noise or distortion.

It also provides a preamp that brings a low-level signal from a device such as a record player to line level, which is the standard operating level of recording gear.

Lastly, it is now capable of boosting or attenuating low frequencies (bass) and high frequencies (treble) through the use of an equaliser.

The first step followed to produce the end product was to research the area of Hi-Fi sound systems and to find and test high-quality audio circuits. This played an important role in the progression of the project due to the need for the circuits to be of a high fidelity standard.

The second step was to design each module carefully, taking in different considerations such as how the user will interact with each module and the quality of each of the modules outputs.

After this stage was completed, the third stage of implementation could be started. This stage covered building prototypes and finding solutions to problems that arose along the way. Once this was completed the final product could be then manufactured and tested.

Finally, the last stage could then be executed which was to test each of the end products and ensure they were up to the standard which was set out at the start of this report.

Throughout this project, a lot of skills that had been picked up in the four years of studying Creative Media Technologies were improved significantly and the knowledge of analogue circuits and how they were built has been built upon vastly.

The final product stayed true to the requirements set out at the beginning of the project and is now a fully functional modular Hi-Fi sound system that can be expanded in the future if needs be.

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Appendix 1: Low Voltage Directive

CMT Projects

‘Low Voltage Directive’ Compliance Statement.

DIRECTIVE 2006/95/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 12 December 2006 on the harmonisation of the laws of Member States relating to electrical equipment designed for use within certain voltage limits (codified version) (Text with EEA relevance)

Otherwise known as the Low Voltage Directive (LVD).

If the electrical aspects of your project have a voltage between 50 and 1000 V for alternating current and between 75 and 1500 V for direct current, for voltages at the electrical input or output (not internally), then you are signing to confirm that it complies with all the safety requirements of the LVD. You must read the LVD and analyse your project before signing, taking advice where necessary.

Student name: Josh Henvey

Student signature: Josh Henvey

Date: 25/04/2021

Project supervisor or delegated representative who is an engineer by discipline:

Name: Paul Comiskey

Signature: Paul Comiskey

Date: 26/04/2021

Appendix 2: Risk Assessment

CMT (DL835) Student Projects
20/21 – Homeworking and Covid-19
'Low Risk+'

Standard Risk Assessment Template
For activities carried out in the School of Creative Technologies facilities **and at the student's home.**
These are projects where all Hazards are Ranked as a 3rd Rating.
See Risk Rating Matrices on Pages 10 and 11.

Project Risk Assessments and the methodology are needed to comply with the Safety, Health and welfare at work act 2005 and all other relevant Legislation. This document is based on the 'Joint Risk Assessments' procedure – IADT – December 2010.

The document has been updated to now include:

- Home Working risk identification and control – highlighted in italics
- Covid-19 risk identification and control – highlighted in bold
- The Low Voltage Directive, LDV (previously in a separate document

PLEASE NOTE: HOME-WORKING AND COVID-19 HAVE RAISED THE LEVEL OF THE RISK OF HOME WORKING AND LAB WORKING SO THAT THE LOW-RISK TEMPLATE IS NOW OF A LEVEL IN BETWEEN THE LOW AND MEDIUM RISK LEVEL AS DEFINED IN THE PREVIOUS ACADEMIC YEAR.

PROGRAMME/YEAR:

STUDENT NAME: Josh Henvey	**SUPERVISOR:** Paul Comiskey
DIGITAL SIGNATURE: Josh Henvey	DIGITAL SIGNATURE: Paul Comsikey
DATE: 25/04/2021	DATE: 26/04/2021

By signing this assessment, it is agreed by all parties that:

- The student has taken part in the relevant class session and/or seen the accompanying PowerPoint presentation
- The full facts relating to the health and safety aspects of the project have been declared by the student
- All parties are fully aware of the safety risks
- All parties will implement the control measures detailed, in order to reduce the contribution of the hazards to the level of the risks detailed.

Location of Work:	*Relevant Campus facilities such as the laboratories, and at the student's home*

Brief RELEVANT Details of the project: 20 words, highlighting the current drawn from the power supply and any processes that may be dangerous in the lab or at home.	The current drawn from the power supply was a relatively low amount which should still be treated with the same safety measures as if it was a larger current.

Step 1: Initial Hazards Identification

Risk Assessment No.	**INITIAL HAZARD**
1	Electrocution
2	Fire
3	Cutting injuries
4	Drilling injuries
5	Heavy equipment
6	Burn Injury
7	Fumes

Step 2: Risk Assessment Forms

(Start Overleaf)

Significant Hazard and consequences:	**1. Electrocution**

Who might be exposed to the hazards:	*Students, staff and household members.*

Proposed Control Measures – to be written in conjunction with the project supervisor and revised at key project milestone dates	*Develop projects that consume low current (less than 1A) and use batteries or well-maintained AC/DC conversion units, particularly for the home environment.* Circuit design must include features that will minimise the likelihood of electrocution of anybody, when in an unsafe mode, e.g. use of fuses and circuit breakers *in the lab and home devices and supplies.* Short circuits should be identified and removed before the testing stage. Cable and insulation should be checked before the testing stage. Power supply equipment should be PAT tested on a regular basis in the lab. *Faulty power supply equipment at home should be identified and repaired by a qualified electrician before being used again.* *Liquid* sources should be kept away from the project, when in operation. Components, whether connected to power supplies or not, should be fully discharged before inspections – isolated from power supplies, are commenced. Eg discharge capacitors greater than 50µF via a 100Ω resistor. Be aware of the locations of first aid kit and fire extinguishers, *in the laboratory or in the home; familiarise yourself and* use these items if suitably competent/trained. *Be aware of actions that need to be taken in the event of electrocution, such as calling emergency services, resuscitation, and wearing insulation if touching the person electrocuted.*

Significant Hazard and consequences:	**2. Fire**

Who might be exposed to the hazards:	*Students, staff and household members.*

Proposed Control Measures – to be written in conjunction with the project supervisor and revised at key project milestone dates	Maintain tidy work practices on benches, the laboratory environment and *household surfaces.* Keep combustible materials, eg paper, plastic, away from heat sources, such as soldering irons. Stow heat sources away safely when not in use, eg use a sturdy soldering iron stand. Circuit design must include features that will minimise the likelihood of a fire, when in an unsafe mode, e.g. use of fuses and circuit breakers. Short circuits should be identified and removed before the testing stage. Suitable cable and insulation should be used, with a safety margin on the rating and size. *Liquid* sources should be kept away from the project, when in operation. Be aware of the locations of first aid kit and fire extinguishers, *in the laboratory or the home; familiarise yourself and* use these items if suitably competent/trained. *Put in place measures that make the home working area is fire separated from other parts of the home, make that place relatively free of combustible materials, ensure there is some form of smoke detection in place, ensure there is a clear path to the nearest exit of the house.* In the event of a fire, leave the laboratory/building *or household working area/home* in an orderly manner, and sound the fire alarm if it has not already automatically activated.

Significant Hazard and consequences:	**3. Cutting injuries**

Who might be exposed to the hazards:	*Students and household members.*

Proposed Control Measures – to be written in conjunction with the project supervisor and revised at key project milestone dates	Maintain tidy work practices on benches/ laboratory environment *and household surfaces*. Develop projects with the minimum requirement for cutting any jagged-edged in the final manufactured item. Use of quality, maintained tools and clamps if necessary. Use of a cutting board and goggles. Clear a space around the cutting area before commencing work. Tie back hair and loose clothing from the cutting area. Remove jewellery. Be aware of the location of the first aid kit *in the laboratory and at home* and use the kit if suitably competent/trained.

Significant Hazard and consequences:	**4. Drilling injuries**

Who might be exposed to the hazards:	*Students, staff and household members.*

Proposed Control Measures – to be written in conjunction with the project supervisor and revised at key project milestone dates	*In the laboratory*, only use the drilling equipment if training, given by staff, has been undergone. *At home, follow all manufacturer's instructions in using a drill.* Use of quality maintained drilling equipment and goggles. Secure drill bit and table. Use the drill guard. Check all fastenings are complete before switching on the drill machine. Drill machines *and equipment* should be tested and checked on a regular basis. Develop projects with the minimum requirement for cutting any jagged-edged in the final manufactured item. Use of quality, maintained tools and clamps if necessary. Use of a cutting board and goggles. Clear a space around the cutting area before commencing work. Tie back hair and loose clothing from the cutting area. Remove jewellery. Be aware of the location of the first aid kit *in the laboratory and at home* and use the kit if suitably competent/trained.

Significant Hazard and consequences:	**5. Heavy equipment**

Who might be exposed to the hazards:	*Students, staff and household members.*

Proposed Control Measures – to be written in conjunction with the project supervisor and revised at key project milestone dates	Maintain tidy work practices on benches and the laboratory environment. Undertake heavy lifting only if suitable advised and/or trained. Correct posture and lifting procedures. Use mechanical lifting aids where possible and appropriate. One or more persons to be involved in lifting or supervising the lifting of heavy equipment. *Take help from a household co-habitant where necessary, appropriate and possible.* Clear a space around the lifting area before commencing work. Tie back hair and loose clothing from the cutting area. Remove jewellery. Use protective footwear, and also headwear if necessary.

Significant Hazard and consequences:	**6. Burns**

Who might be exposed to the hazards:	*Students and household members.*

Proposed Control Measures – to be written in conjunction with the project supervisor and revised at key project milestone dates	Maintain tidy work practices on benches and the laboratory environment. Only use soldering irons and other hot-works appliances if training, given by staff, has been undergone. Keep combustible materials, e.g. paper, plastic, away from heat sources, such as soldering irons. Stow heat sources away safely when not in use, eg use a sturdy soldering iron stand. Cable and insulation should be checked before using soldering irons, or electrically powered hot-works appliances. Use gloves, goggles and other personal protection equipment where necessary. Use cooling equipment, such as wet sponges for soldering irons. Do not allow water from any source to penetrate electrical cables and wires. *Let members of the household know you are using a hot device. Keep soldering irons and other hot devices away from children and vulnerable adults.* *Make sure the device is placed stably on the working surface, away from combustibles including mains cables, particularly that belonging to the device.* Tie back hair and loose clothing from the cutting area. Remove jewellery. Be aware of the locations of first aid kit and fire extinguishers, *burn gel and plasters, in the laboratory and at home*, and use these items if suitably competent/trained. In the event of a fire, leave the laboratory/building *or household working area/home* in an orderly manner, and sound the fire alarm if it has not already automatically activated. Electrically powered hot-works equipment, such as soldering irons, should be checked and tested on a regular basis. *If found to be faulty, particularly at home, it should be repaired by a competent electrician before being used again.*

Significant Hazard and consequences:	**7. Fumes**

Who might be exposed to the hazards:	*Students and household members.*

Proposed Control Measures – to be written in conjunction with the project supervisor and revised at key project milestone dates	Use fume extraction equipment, eg. for solder fumes. Keep laboratories *and household working areas* well ventilated. Take frequent breaks from activities generating fumes, *in the open air.* Employ a higher level of control measures when an individual suffers from a respiratory condition, such as asthma, taking advice from a GP**. In particular, take advice from a GP before you use a device that generates fumes, particularly if you have or have had a respiratory condition or disease such as Covid-19.** Solder fume extraction equipment and other similar items should be maintained checked and tested on a regular basis.

Significant Hazard and consequences:	**8. Infection of Covid-19**

Who might be exposed to the hazards:	**Students, Staff, and household members.**

ProposedControl Measures – to be written in conjunction with the project supervisor and revised at key project milestone dates	**Follow ALL government guidelines, those from the Health Services Executive and the Health & Safety Authority. Keep updated daily on changes to these guidelines via their authorised websites.** **<u>These include, and interpreted thus, but not limited to:</u>** **Use personal protective gear for the face, such as a recommended mask for a professional environment, or a close-fitting vizor, or both, in the lab,** **Be aware of all laboratory provisions for Covid-19 safety.** **Be aware of the Covid-19 safety station in the laboratories – containing hand sanitiser, blotting paper, disposable gloves. Use these items before commencing the lab session, if necessary and afterwards especially if food is consumed before and after the lab session. At home, set up an equivalent Covid-19 station, and use the equipment as you would in the lab.** **<u>It is expressly forbidden to eat in the labs, and it is recommended to do the same at home.</u>** **Wipe down all surfaces before, during (if compromised) and after the lab sessions and at home, including touchpoints such as door and equipment handles.** **Do not touch the face, head unless the hands are clean with sanitiser.** **Cough into your elbow if necessary or into a tissue which you should then dispose of the tissue in the flip-top bins in the lab and wash your hands with soap or use a hand sanitiser.** **Keep more than 2m in distance from anybody else in the laboratory. Navigate yourself around the lab to avoid close contact.** **Keep laboratories and household working areas well ventilated.** **Take frequent breaks from activities generating fumes, in the open air.**

	Employ a higher level of control measures when an individual suffers from a respiratory condition, such as asthma, taking advice from a GP. Take advice from a GP before you use a device that generates fumes, particularly if you have or have had a respiratory condition or disease such as Covid-19. **Enter and leave the lab in an orderly manner, ensuring social distancing, even in an emergency, such as a fire incident.** **Follow the regulations of disposal or high-temperature cleaning, relating to your personal protective equipment.**

Additional Hazards and Control Measures to be identified here, in the same format as the preceding sections. Paste in more pages if necessary:

Significant Hazard and consequences:	

Who might be exposed to the hazards:	*Students and household members.*

ProposedControl Measures – to be written in conjunction with the project supervisor and revised at key project milestone dates	Abide by the safety measures set out in the risk assessment form.

Risk Rating Matrices

By looking at the hazard and asking how many people will be exposed to it, decide on the probability of an incident/accident occurring.

Example: Take an extension lead trailing along the floor up against the wall. The extension lead is a hazard and if it is in an office with one person working in it the probability and likelihood is "improbable" (see table No.1) because the lead is along the wall. However, if the lead is in a corridor with 200 people walking by there is a chance that someone could kick it out from the wall accidentally and create a greater probability/likelihood of a loss occurring thus upping its rating to "remote".

When this is done you must decide on the seriousness of the loss, using the four columns on the left side of Table No.2 below.

Example: Firstly taking the one person office example from above the possibility/likelihood is "improbable "but the result might be a "minor injury" e.g. scrape or a bruise. This gives us an "acceptable risk no action required" If we were to put the lead on a building site across an unguarded stairwell with 50 people using it the result is now possibly "fatal". This gives us a "1ST rank action".

Table No. 1:

PROBABILITY/LIKELIHOOD	DESCRIPTION
Likely/frequent	Occurs
Probable	Not Surprised. Will occur several times.
Possible	Could occur sometimes.
Remote	Unlikely, though conceivable.
Improbable	So unlikely that probability is close to zero.

Table No. 2:

	LIKELY	PROBABLE	POSSIBLE	REMOTE	IMPROBABLE
Fatal	1st	2nd	2nd	3rd	
Major Injury/ permanent disability	2nd	2nd	3rd		
Minor Injury	3rd	3rd			
No Injury					

By using the matrices above we now have an action needed ranking system. This means we can prioritize the hazards depending on their ranking.

Table No. 3:

	1st rank actions - requires measures to be put into place within a few hours
	2nd rank actions - requires measures to be put in place within a few days
	3rd rank actions - requires measures to be put in place within a few weeks
	4th Rank action – requires measures to be put in place within a few months.

Taking all this information and pooling it in the Initial Hazard Identification log we can now prioritise the hazards in the left-hand column "Risk Assessment No." This number will appear on the top left of the risk assessment forms for easy referencing.

Low + Risk Project – Risk Rating Summary

Risk Assessment No.	**INITIAL HAZARD**	**Probability**	**Ranking**
1	*Electrocution*	*Possible*	*3rd*
2	*Fire*	*Possible*	*3rd*
3	*Cutting injuries*	*Possible*	*3rd*
4	*Drilling injuries*	*Possible*	*3rd*
5	*Heavy equipment*	*Possible*	*3rd*
6	*Burns*	*Possible*	*3rd*
7	*Fumes*	*Possible*	*3rd*