Department of Electronic and Telecommunication Engineering

University of Moratuwa

Five Band Equalizer

Group – Electro Mavericks

Name	Index	Contribution
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Abstract

This project presents a five-band equalizer circuit designed for audio frequency adjustment, featuring an Adder Circuit for reuniting the modified frequency spectrum and a Buffer Circuit for separating input from filters. Operational amplifiers, capacitors, and resistors shape each frequency band according to specified parameters. Power is supplied by a separate circuit to obtain +12V and -12V, with audio connections facilitated by 3.5mm jacks for both input and output. Variable resistors enable independent gain adjustment for each frequency band, and user feedback is provided through an integrated LED strip and dot bar display driver IC(LM3914). The operational flow involves taking audio input via a 3.5mm jack, dividing the spectrum into five bands using filters, adjusting gain with variable resistors, and visually assessing gain levels through the LED strip and display. The Adder Circuit combines the modified bands, delivering the final equalized audio through a second 3.5mm audio jack.

1. Introduction

A frequency equalizer, commonly known as an EQ (Equalizer), is a device used in audio systems to adjust the balance of different frequency components in a sound signal. It allows users to boost or cut specific frequencies, tailoring the audio output to match their preferences or the acoustic characteristics of a room. EQs are widely used in music production, live sound setups, and home audio systems to enhance the overall listening experience by fine-tuning bass, midrange, and treble frequencies.

2. Functionality Description

A five-band frequency equalizer divides the audio spectrum into five distinct frequency ranges, each with its own adjustable parameter. Here's a brief description of its functionality:

Band	Range	Mid	description
Base Band	20-300Hz	160	Regulates the low-frequency band, which usually affects the bass range allowing to adjust the bass to get the right balance by boosting or cutting it.
Mid-Low Band	300-1000Hz	650	Focuses on low- to midrange frequencies and useful for modifying the body and warmth of vocals or instruments.
Center Band	1-4kHz	2.5k	Targets midrange frequencies, which affect the fundamental tonal characteristic and permits the audio's presence and clarity to be adjusted.
Mid-High Band	4-10kHz	7k	Deals with mid-to-high frequency ranges and helpful in defining the tone of voices or instruments.
High Band	10-20kHz	15k	Regulates the high-frequency band, which impacts the high-end detail and treble and permits audio brightness and crispness adjustments.

Table 1: Five frequency bands

These five bands offer a flexible tool for adjusting the overall tonal balance in music production, live sound reinforcement, and other audio applications. Users can use them to boost or cut specific frequency ranges in the audio output.

Image of a block diagram

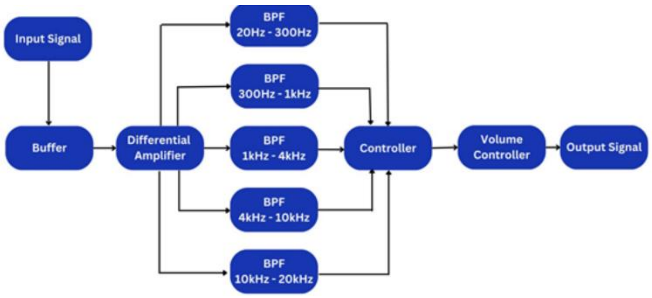


Figure 1: Functional block diagram

2.1 Power Supply

We use a separate circuit to provide a +12V and -12V power supply.

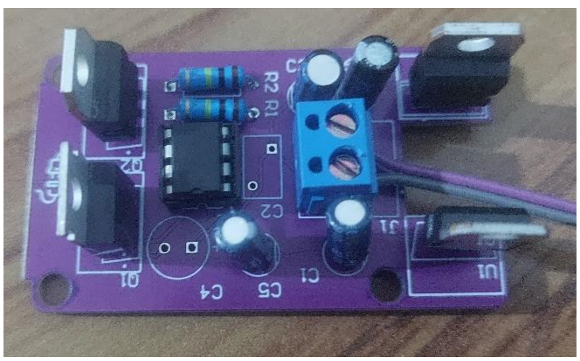


Figure 2: Power circuit

2.2 Input Signal

We've opted for a 3.5mm audio jack to input the audio signal ensuring convenience for our customers. The popularity of this jack enhances compatibility and ease of use in our project.

Figure 3: 3.5mm audio jack

2.3 Buffer Circuit

The Buffer Circuit is employed to isolate input from filters, preventing interference and avoiding excessive current extraction from the signal source The Op-Amp buffer, shown in the figure, may appear redundant as it matches input and output voltages within reachable voltage rails. However, it proves valuable for resolving impedance problems by offering high input impedance, approaching infinity, and low output impedance, ensuring seamless circuit switching without the input signal driving current.

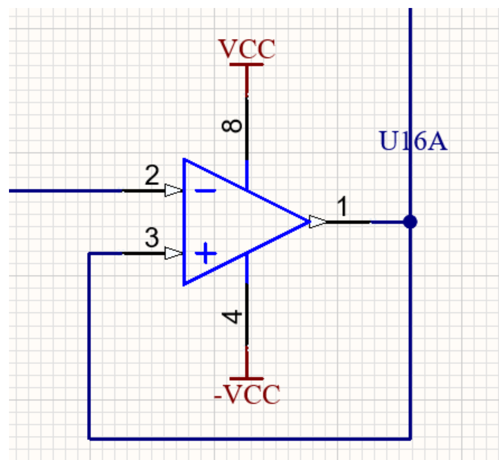


Figure 4: Buffer circuit

2.4 Differential Amplifier

Differential amplifiers excel in noise suppression, tackling both differential and common-mode noise efficiently with op-amps. Common-mode noise typically arises from induced noise in wires or cables, creating a potential difference between signal source ground and circuit ground. Another source is ground potential rise due to external current flow into the circuit's ground. These scenarios cause fluctuations in the circuit reference (ground potential).

Traditional filters struggle with common-mode noise, making differential amplifiers a key solution for effective reduction.

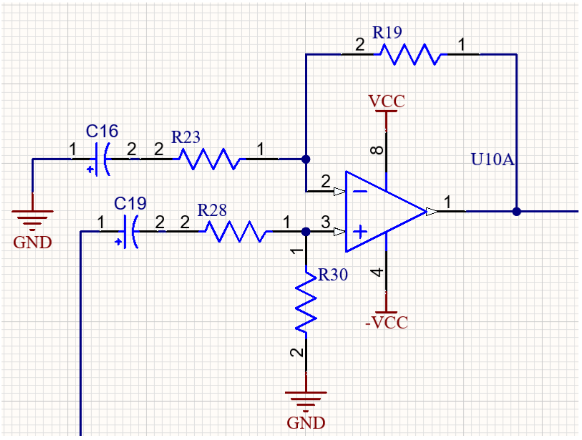


Figure 5: Differential amplifier

2.5 Filters (BPF)

In the selection of filters for our project, we deliberated between active and passive options, ultimately opting for active filters due to their 0dB gain in the pass band, high input, and low output impedance. These characteristics make active filters ideal for cascading and immune to load impedance effects. Active filters can also boost signals in the pass band and maintain consistent performance regardless of the load, distinguishing them from passive filters. After settling on active filters, the choice shifted to specific types, and we decided on multiple feedback filters for their simplicity and reliability, especially for band-pass applications. Opting for a fourth-order multiple feedback filter was a strategic decision to achieve sharp edges without overly complicating the implementation.

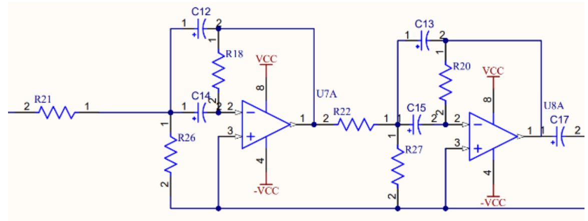


Figure 6: Cascaded multiple feedback filter

2.6 Gain Amplifier

For amplifying each specific band of the input signal, we implemented gain control ranging from 0 to 10 by adjusting the variable resistor values.

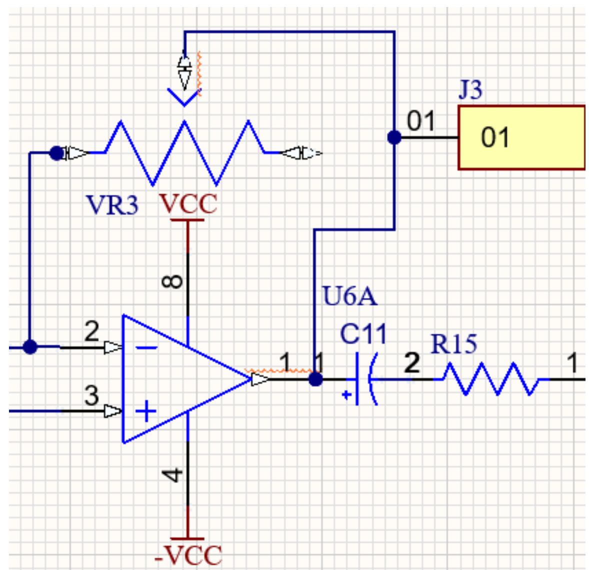


Figure 7: Gain amplifier

2.7 Variable Scaling Adder

The circuit combines five filtered outputs, producing a scaled sum with adjustable gain (up to 10). This configuration serves as a volume controller, allowing effective control over the audio output.

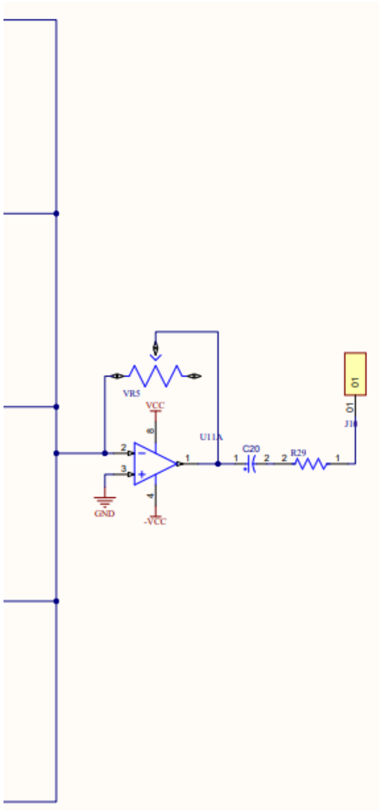


Figure 8: Variable adder

Used ICs - TL072 and NE5532P

TL072CP IC:

Used for all filters and the differential amplifier.

Figure 9: TL072 IC pinout

Features:

- High Slew Rate: 20 V/µs
- Low Noise: 18 nV/√Hz (typical) at f = 1 kHz
- Wide Power Supply Range: -40V to +40V
- Low Power Consumption
- Capability to Handle Higher Noise Input Signals: Better than NE5532 IC

NE5532P IC:

Used for amplifiers in filters.

Figure 10: NE5532 IC pinout

Features:

- High Slew Rate: 9 V/µs
- Wide Power Supply Range: -40V to +40V

2.8 LED Audio Level Visualizer

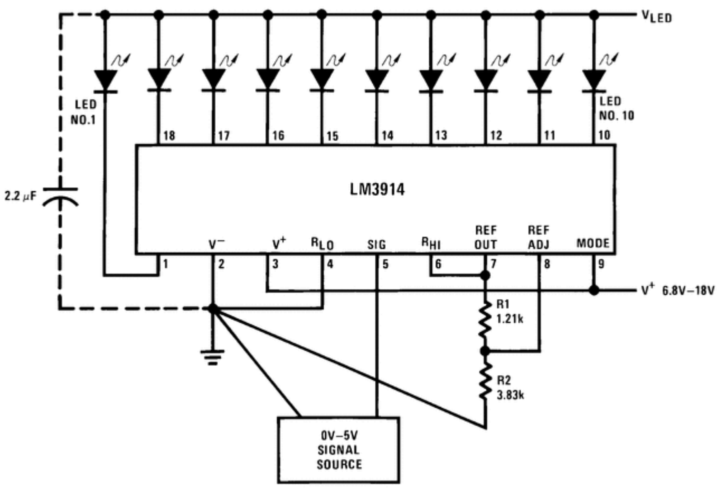


Figure 11: LM3914 circuit diagram

LED strips are used to show the gain of each band visually, making it easier to adjust individual bands. Through the LED strips, the gain levels are shown, giving a clear visual cue. The LM3914 IC is used to drive the LEDs in accordance with the audio output signal, resulting in a dynamic and educational display of the gain levels for each band. A 3.5mm audio jack is also used for audio output. Schematic files and PCB designs are attached to appendices.

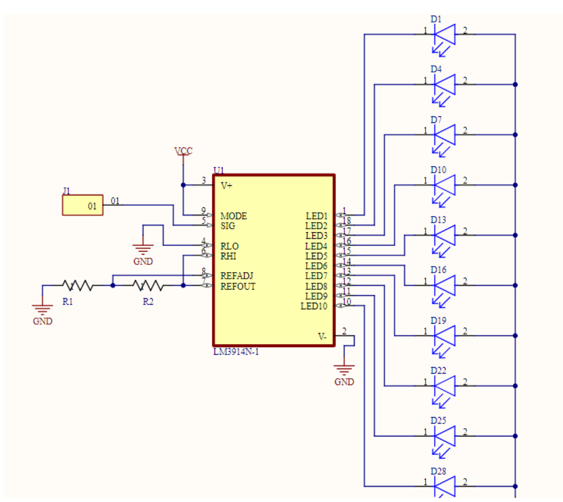


Figure 12: LED circuit for one band

3. System Model

3.1 4th order multiple feedback filter

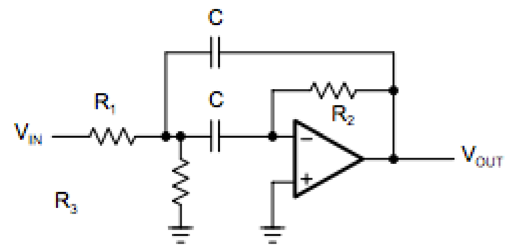


Figure 13: Multiple feedback filter

Transfer Function for 2nd Order Multiple Feedback Bandpass Filter:

$$A(s) = \frac{-\frac{R_2R_3}{R_1+R_3}C\omega_m \cdot s}{1 + \frac{2R_1R_3}{R_1+R_3}C\omega_m \cdot s + \frac{R_1R_2R_3}{R_1+R_3}C^2 \cdot \omega_m{}^2 \cdot s^2}$$

Calculations

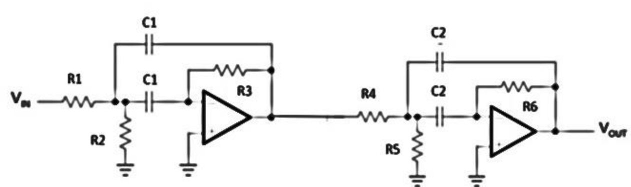


Figure 14: Cascaded muliple feedback filter

TL072CP IC is used as a non-inverting amplifier, with a 4th order multiple feedback bandpass filter constructed by cascading two 2nd order bandpass filters. The transfer function and equations for calculating resistance and capacitance values for the filters are also mentioned.

Circuit Configuration:

1. Amplifier Configuration:

- IC Used: TL072CP
- Configuration: Non-inverting amplifier
- Input: Passive high-pass filter connected to non-inverting input pin (pin 3)
- Gain Formula: Gain = R1/ R2

2. Filter Configuration:

- Filter Type: 4th order multiple feedback bandpass filter
- Construction: Cascaded two 2nd order active bandpass filters

Cascaded Filter Transfer Function:

The transfer function for the 4th order MFB filter is obtained by cascading two 2nd order filters.

$$\text{mid-frequency: } f_m = \frac{1}{2\pi C}\sqrt{\frac{R_1 + R_3}{R_1 R_2 R_3}}$$

$$\text{gain at } f_m: \quad -A_m = \frac{R_2}{2R_1}$$

$$\text{filter quality:} \quad Q = \pi f_m R_2 C$$

$$\text{bandwidth:} \quad B = \frac{1}{\pi R_2 C}$$

$$A(s) = \frac{\frac{A_{mi}}{Q_i}\cdot \alpha s}{\left[1 + \frac{\alpha s}{Q_1} + (\alpha s)^2\right]} \cdot \frac{\frac{A_{mi}}{Q_i}\cdot \frac{s}{\alpha}}{\left[1 + \frac{1}{Q_i}\left(\frac{s}{\alpha}\right) + \left(\frac{s}{\alpha}\right)^2\right]}$$

Parameters and Equations:

- A_{mi} - mid frequency,
- Q_i - pole quality of each filter
- α and $1/\alpha$ - factors by which the mid frequencies of the individual filters
- f_{m1} and f_{m2} - can be calculated from the mid frequency.
- f_m: overall bandpass.

α is calculated using the successive approximation equation:

$$\alpha^2 + \left[\frac{\alpha \cdot \Delta\Omega \cdot a_1}{b_1(1 + \alpha^2)}\right]^2 + \frac{1}{\alpha^2} - 2 - \frac{(\Delta\Omega)^2}{b^1} = 0$$

Resistance Calculation:

Due to the complexity of the calculations, the filter wizard is recommended for obtaining resistance and capacitance values directly.

Here are the values we used in each frequency band.

Band	R1	R2	R3	R4	R5	R6	C1	C2
20Hz - 300Hz	48k	68k	180k	15k	15k	47k	6.8nF	68nF
300Hz- 1000 Hz	3.3k	2k	10k	1.5k	910	4.7k	100nF	100nF
1kHz -4 kHz	3k	6.8k	10k	910	2k	3k	10nF	100nF
4kHz - 10kHz	1.8k	820	5.6k	1.8k	820	5.6k	10nF	20nF
10kHz - 20kHz	3.6k	750	11k	620	130	1.8k	3.3nF	33nF

Table 2: Resistor and capacitor values

4. Simulation

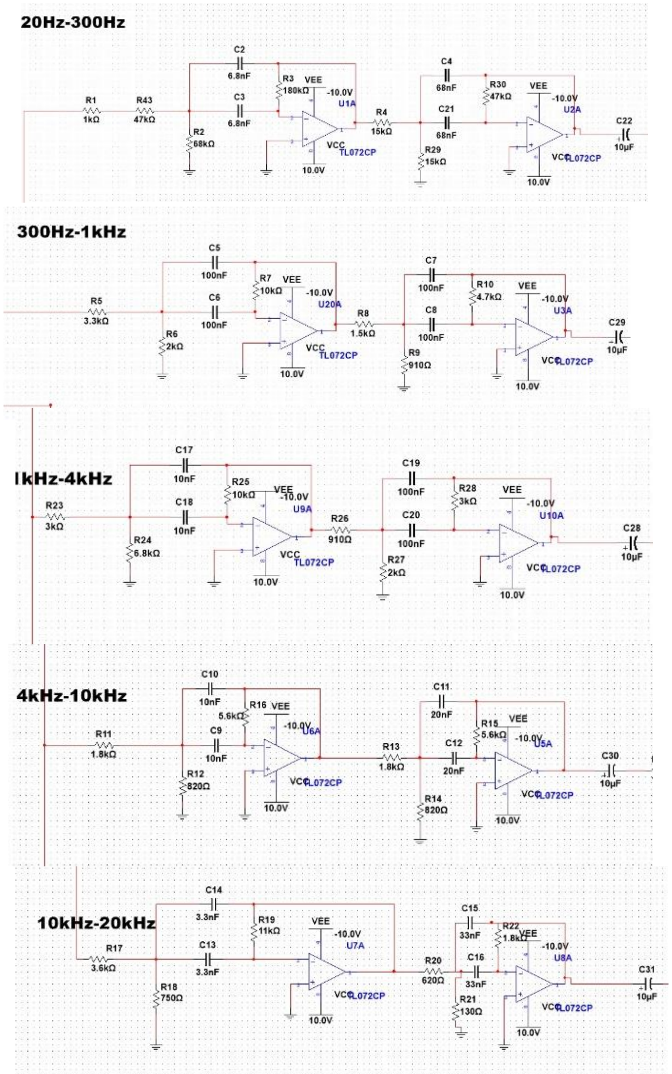
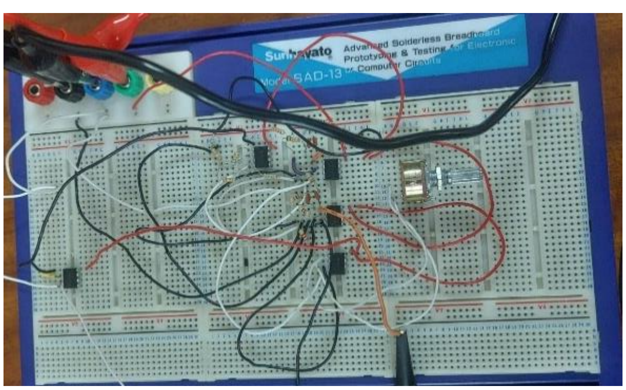


Figure 15: Multisim simulation circuit

5. Testing



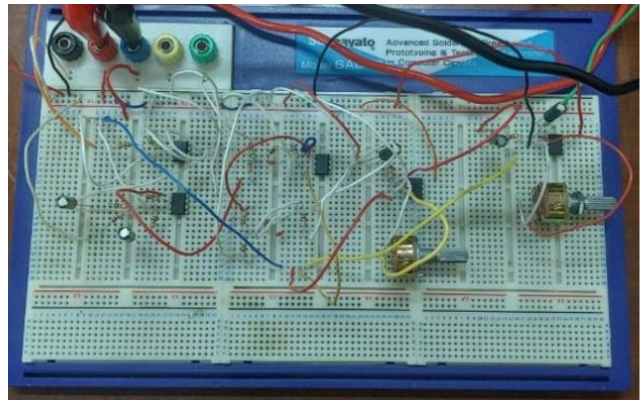


Figure 16: Bread board implementation images

5.PCB Design

We designed 3 separate PCB circuits for Equalizer circuit, led display (audio spectrum display) and a power supply circuit.

5.1 Equalizer

Figure 17: Equalizer circuit

5.2 Led Display

Figure 18 and 19: LED display circuit

5.3 Power Supply

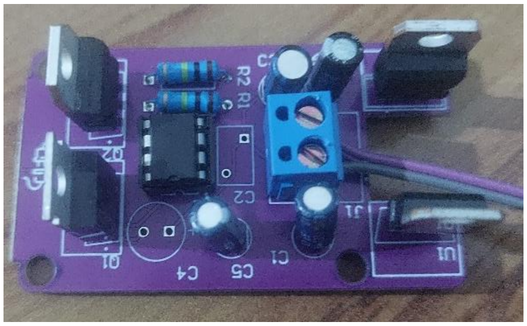


Figure 20: Power supply circuit

Schematic files, 2D pathway layers and 3D designs of the PCBs are attached in appendices.

6. Enclosure Design

6.1 About this Product

The EQ5 audio equalizer features flexible aux volume adjustment with EQ band center frequencies at 160 Hz, 650 Hz, 2.5 kHz, 7 kHz and 15 kHz. Each band is equipped with a distinct Frequency control for precision. The product operates on a 12V DC power supply. To measure audio signal levels, the circuit utilizes the LM3914N, a dot/bar display driver that effectively controls a set of LEDs.

6.2 Product Specifications

Model: EQ5

Material: Plastic

Weight: 335g

Size: 200 mm × 170 mm × 90 mm

Power Supply: 30V

7. Conclusion

This product introduces an innovative active equalizer with a streamlined approach, rapid balancing speed, and straightforward implementation compared to existing current-controlled equalizers. The equalizer, designed to operate within five distinct frequency bands (20-300 Hz, 300-1 kHz, 1 kHz-4 kHz, 4 kHz-10 kHz, and 10 kHz-20 kHz), comprises a power supply, audio source, buffer, differential amplifier, band-pass filters, controller, and volume controller. Gain adjustments for different frequency bands are achieved through variable resistors, and the individual bands are subsequently merged to generate a unified audio signal.

8. Acknowledgement

We extend our sincere gratitude to Dr. Perera M.T.U.S.K. Sampath for his invaluable guidance and initial project idea, which set the foundation for our work. Dr. Prathapasinghe Dharmawansa and Dr. Chamira U. S. Edussooriya deserves recognition for offering a clear understanding of filters, a crucial aspect of our project developed with the knowledge gained in semester 3. We appreciate the assistance of our department's non-academic staff for supporting with breadboard implementations. Lastly we convey our thanks to JLCPCB and 3d printing companies for their contribution. Their collective efforts have significantly contributed to the successful completion of this project.

9. Appendices

9.1 Appendix A - Simulations

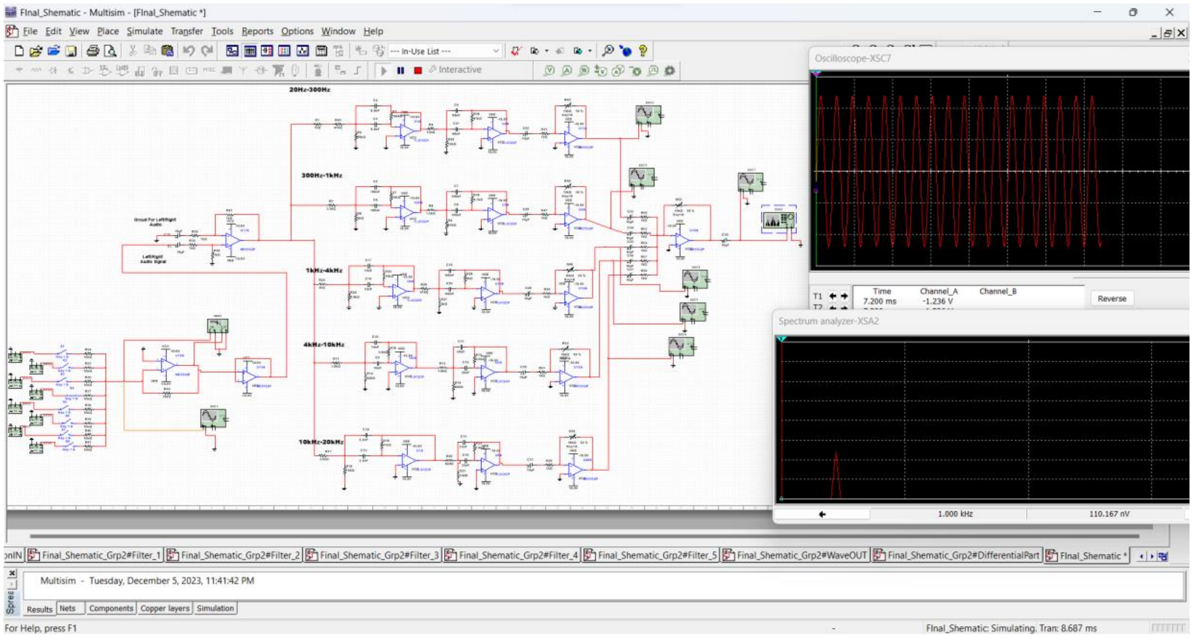


Figure 21: Multisim Simulation

9.2 Appendix B – PCB Designs

1) Equalizer circuit

i. Schematic file

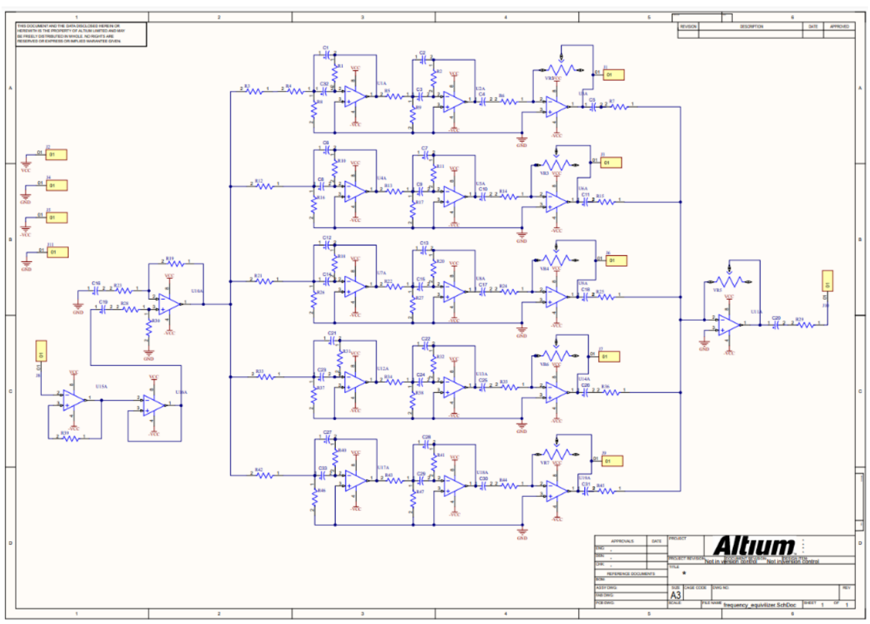


Figure 21: Equalizer circuit Schematic File

ii. 2D pathway

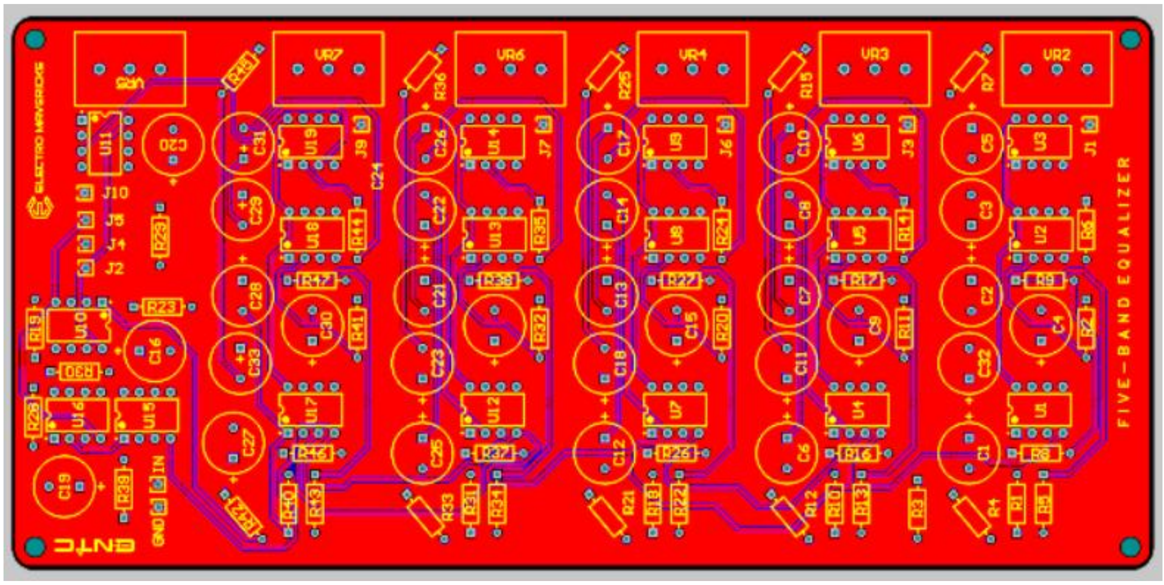


Figure 22: Equalizer circuit 2D pathway

iii. 3D model

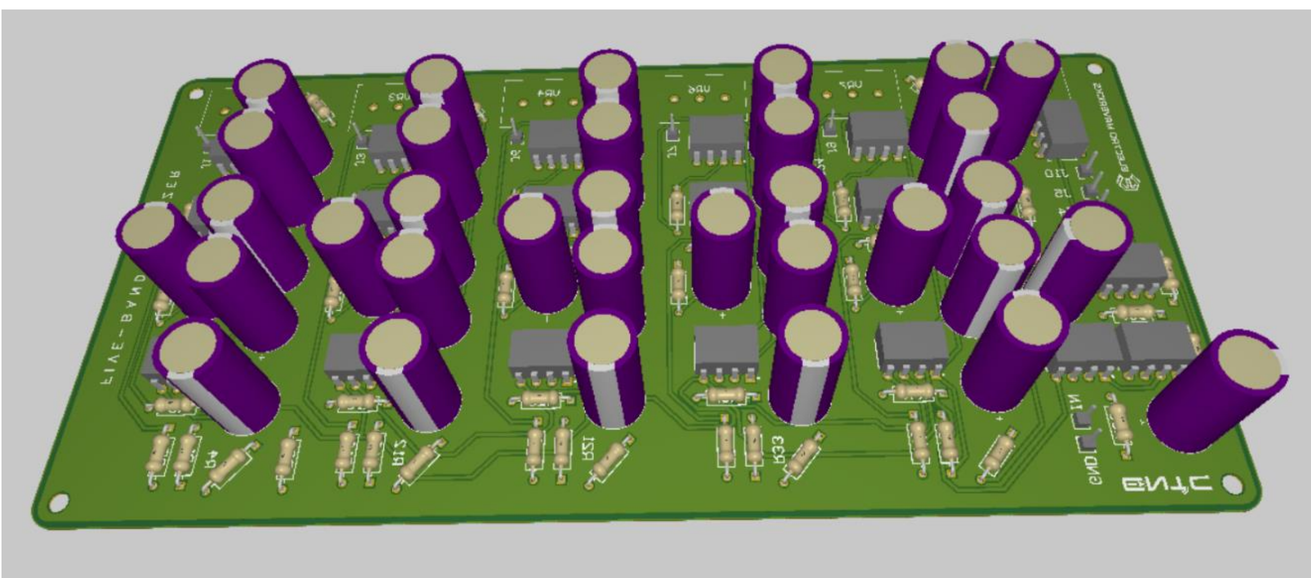


Figure 23: Equalizer circuit 3D model

2) LED display circuit

i. Schematic file

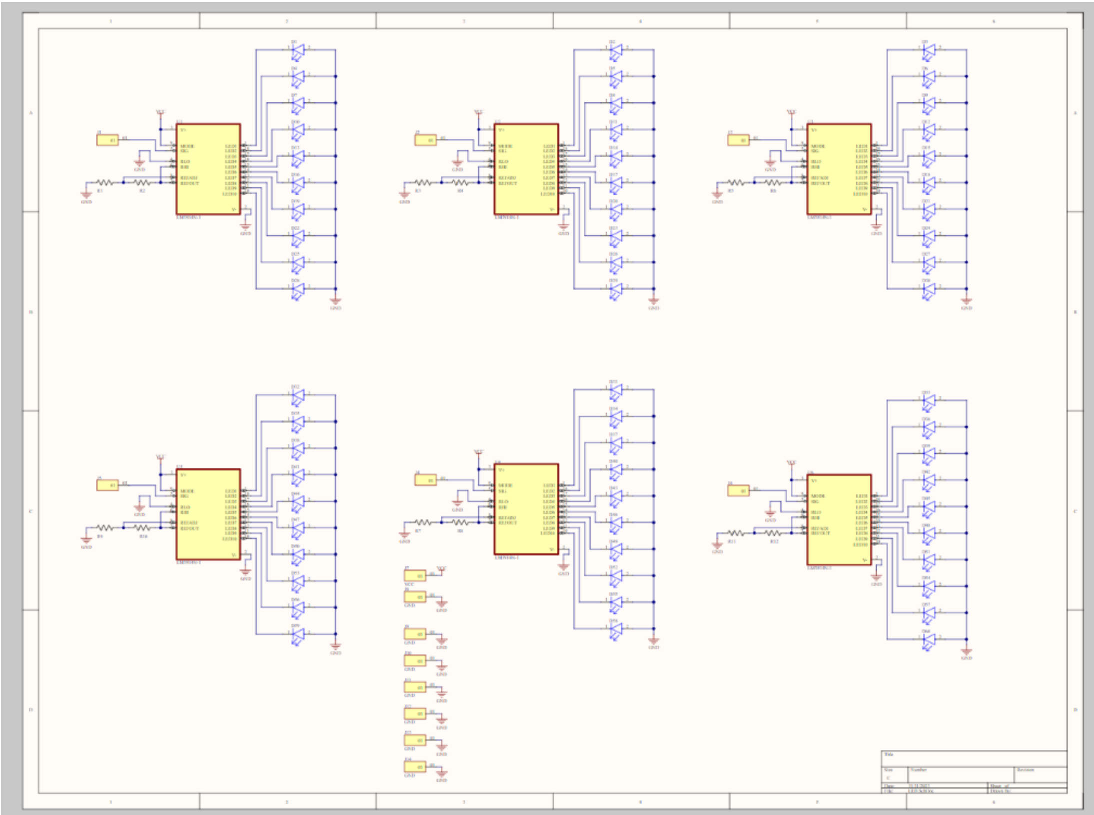


Figure 24: LED display schematic file

ii. 2D pathway

Figure 25: LED display 2D pathway

iii. 3D model

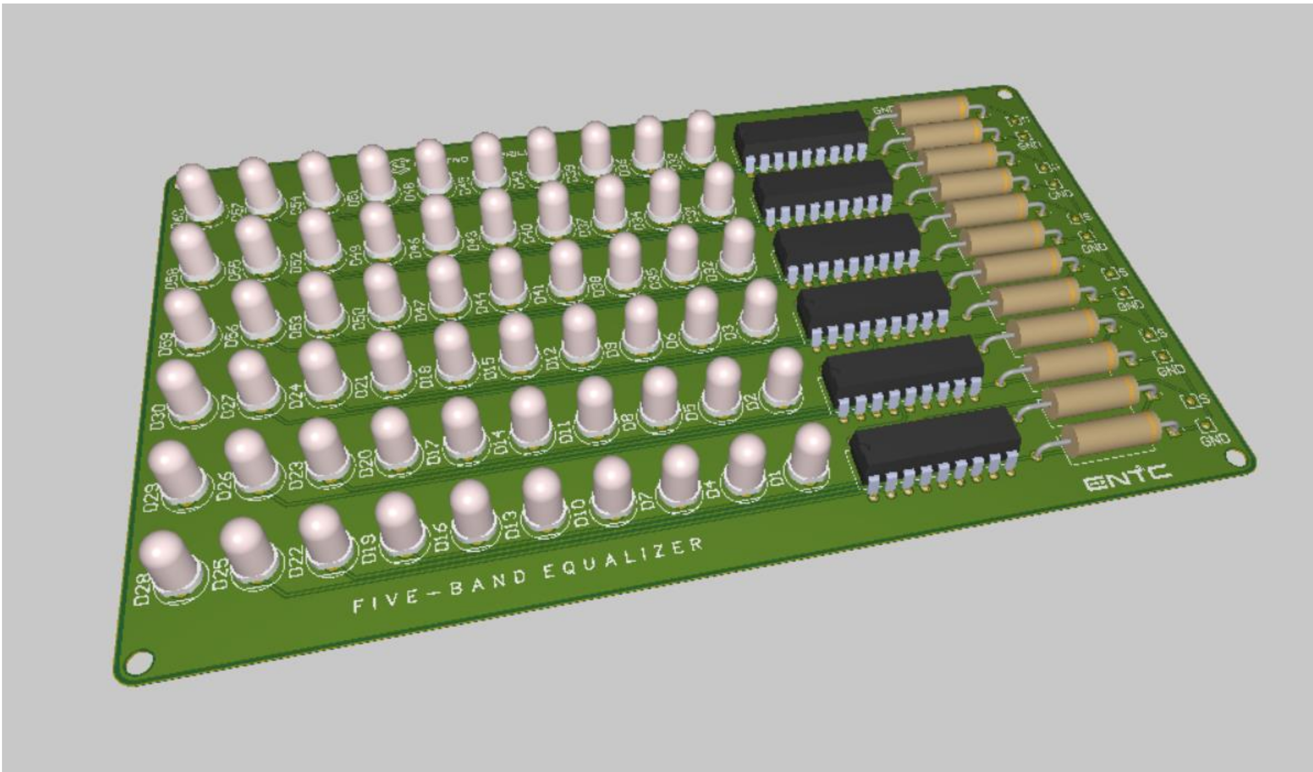


Figure 26: LED display 3D model

9.3 Appendix C – Enclosure Design

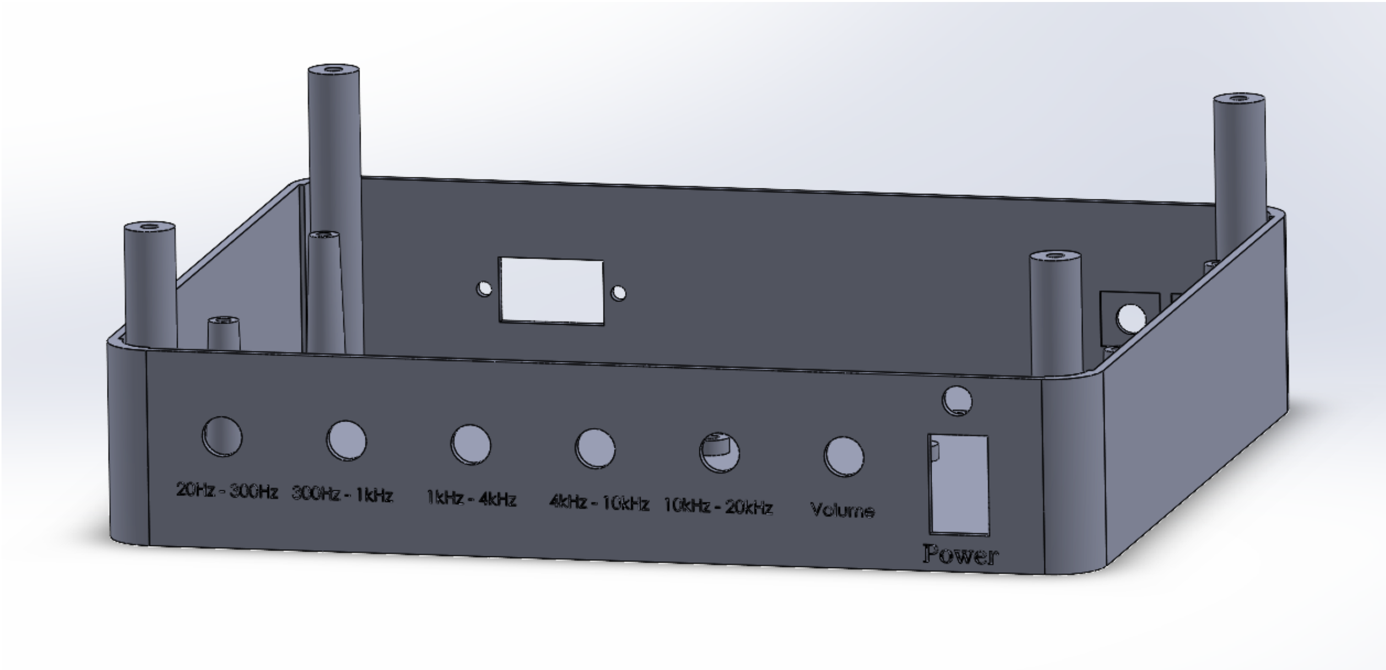


Figure 27: Enclosure Bottom part

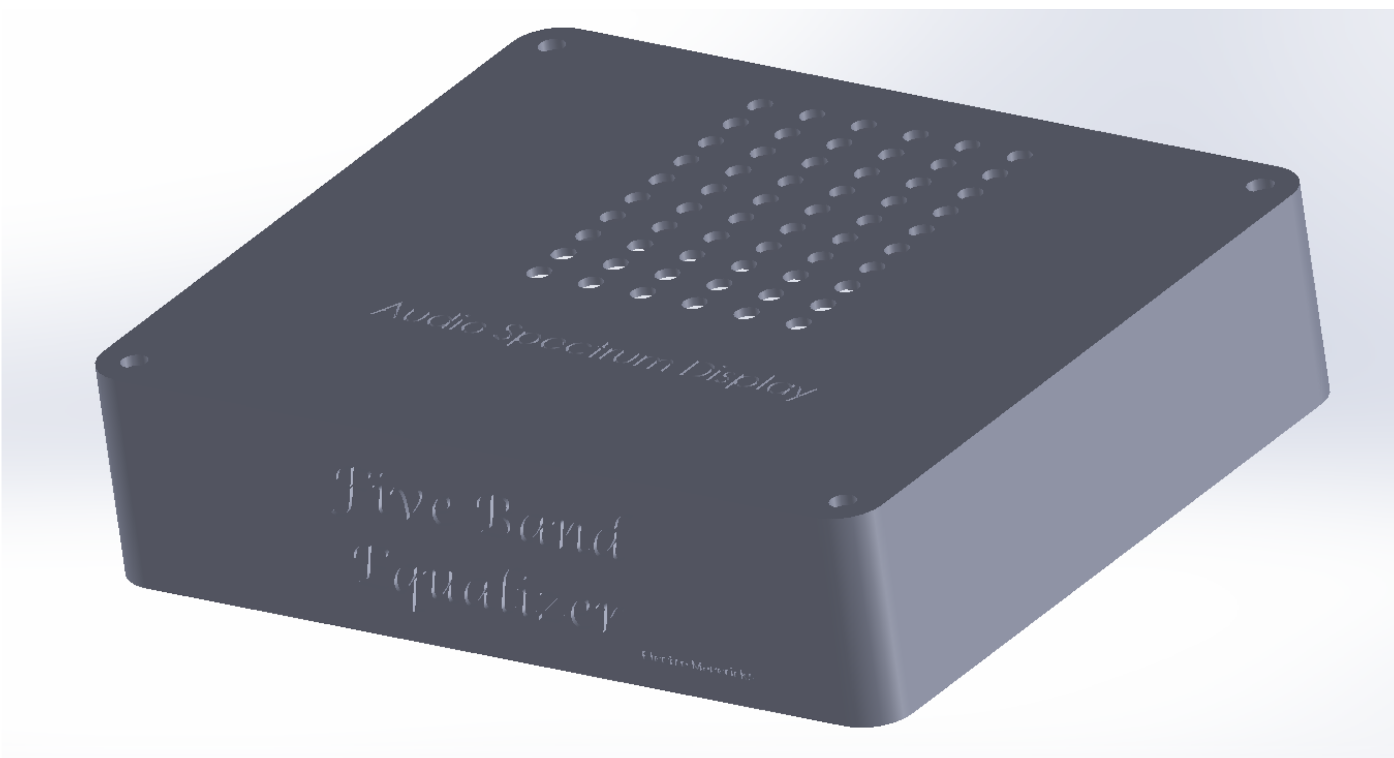


Figure 28: Enclosure Lid

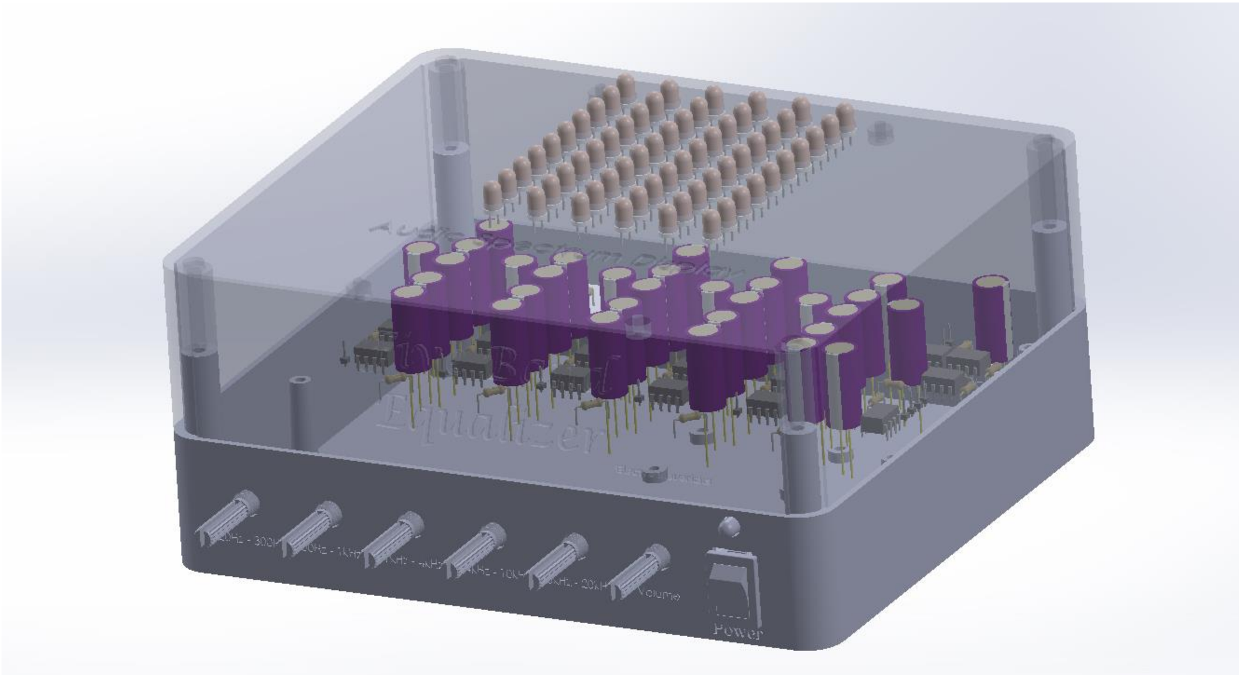


Figure 29: Enclosure Assembly view

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Used Software:

- Filterpro
- Filter Design Tool | Filter Wizard | Analog Devices