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Five Band Audio Equalizer

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Abstract
The **Five Band Audio Equalizer** is an analog signal processing system designed to modify and enhance audio quality by adjusting the amplitude of distinct frequency bands within an audio signal. The system divides the input audio into five specific frequency ranges—20–300 Hz, 300 Hz–1 kHz, 1–4 kHz, 4–10 kHz, and 10–20 kHz—using precision-designed band-pass filters. Each band can be individually amplified or attenuated through a variable gain control stage, enabling users to shape the tonal balance according to preference or acoustic environment. A preamplifier circuit prepares the signal for processing, while a summing amplifier recombines the adjusted frequency bands to produce a clear and balanced output. Additionally, an Light Emitting Diode (LED)-based level display visually indicates the intensity of each band. The system is implemented using operational amplifiers (NE5532) and the LM3915 display driver, ensuring low noise, high fidelity, and efficient visualization. This project demonstrates practical applications of analog circuit design principles, including filter design, signal amplification, Printed Circuit Board (PCB) layout, and system integration for real-world audio enhancement.

Abbreviations and Acronyms

PCB Printed Circuit Board

Op Amp Operational Amplifier

LED Light Emitting Diode

MFB Multiple Feedback

Contents

1 Introduction and Functionality

An **audio equalizer** is a fundamental device used in sound systems to balance and adjust the amplitude of specific frequency components within an audio signal. It enables selective amplification or attenuation of chosen frequency ranges, thereby enhancing tonal quality and the overall listening experience.

In this project, a **Five Band Audio Equalizer** was developed using analog electronic circuits to divide the incoming audio signal into five distinct frequency bands:

- 20–300 Hz (Bass range)
- 300 Hz–1 kHz (Lower midrange)
- 1–4 kHz (Upper midrange)
- 4–10 kHz (Presence range)
- 10–20 kHz (Treble range)

20-300 Hz frequency band is processed using an unity gain Sallen-Key band-pass filter and other frequency bands processed through Multiple Feedback (MFB) filter to isolate its respective range. The filtered signals then pass through individual **gain control stages**, allowing users to adjust amplification levels via variable resistors. The processed signals are subsequently recombined using a **summing amplifier** to produce a customized and balanced output signal.

A **pre-amplifier** boosts the input audio signal to the required level, while a **power amplifier** (based on the LM386 IC) drives the final output with sufficient power. Furthermore, a **LED level indicator** circuit, implemented using the LM3915 LED display driver, provides real-time visual feedback of the audio levels across frequency bands.

Overall, this system integrates the concepts of **analog filtering**, **amplification**, and **signal visualization** into a single compact hardware unit, demonstrating the principles of audio signal processing and analog circuit design in a practical and educational context.

2 System Architecture

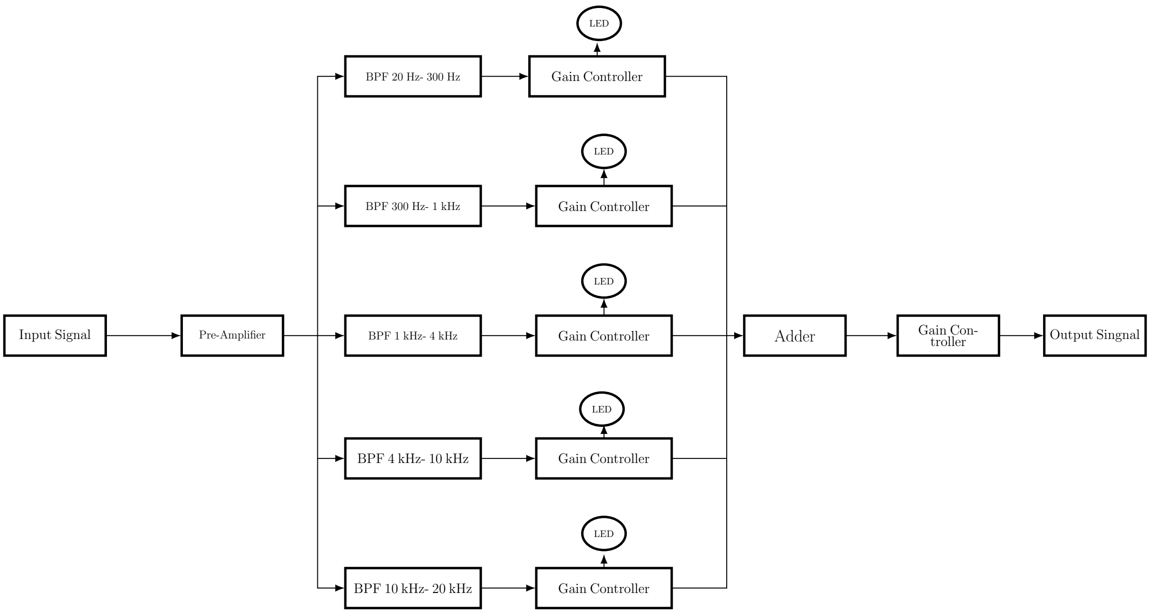


Figure 1: Functional Block Diagram

2.1 Pre-Amplifier Circuit

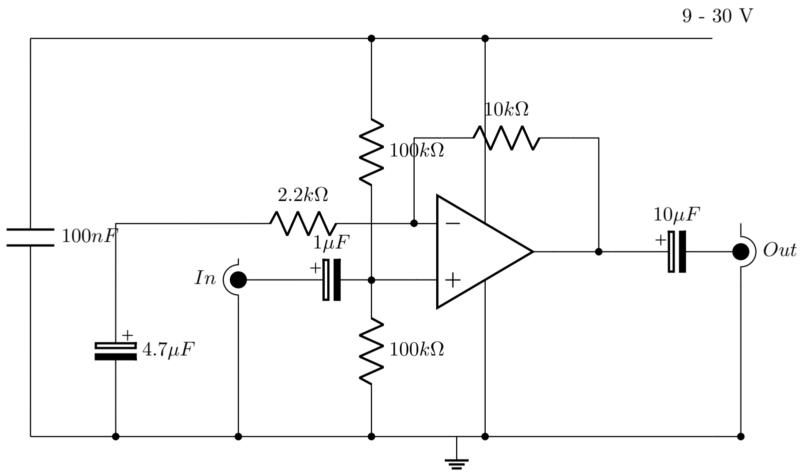
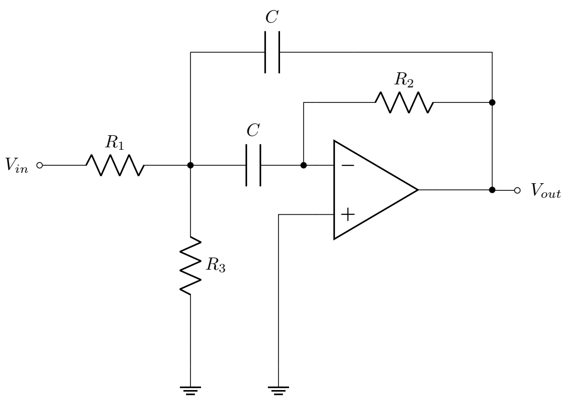


Figure 2: Pre-Amplifier Circuit

2.2 Band Pass Filter Design



- Mid-frequency: $f_m = \frac{1}{2\pi C}\sqrt{\frac{R_1+R_3}{R_1 R_2 R_3}}$
- Gain at f_m: $-A_m = \frac{R_2}{2R_1}$
- Filter quality: $Q = \pi f_m R_2 C$
- Bandwidth: $B = \frac{1}{\pi R_2 C}$

Figure 3: MFB Band-Pass filter

The MFB band-pass allows to adjust Q, A_m, and f_m independently. Bandwidth and gain factor do not depend on R_3. Therefore, R_3 can be used to modify the mid frequency without affecting bandwidth, B, or gain, A_m. Furthermore,

$$R_1 = \frac{R_2}{-2A_m}, R_2 = \frac{Q}{\pi f_m C}, R_3 = \frac{-A_m R_1}{2Q^2+A_m}$$

In order to make Fourth-Order Band-Pass filter, we cascaded two MFB Band-Pass filters. The mid frequency of filter 1 is:

$$f_{m1} = \frac{f_m}{\alpha}$$

the mid frequency of filter 2 is:

$$f_{m2} = f_m \cdot \alpha$$

with Q being the quality factor of the overall filter.

The individual gain (A_{mi}) at the partial mid frequencies, f_{m1} and f_{m2}, is the same for both filters:

$$A_{mi} = \frac{Q_i}{Q}\sqrt{\frac{A_m}{B_1}}$$

Unity-Gain Sallen-Key Band-Pass Filter (For 20-300 Hz)

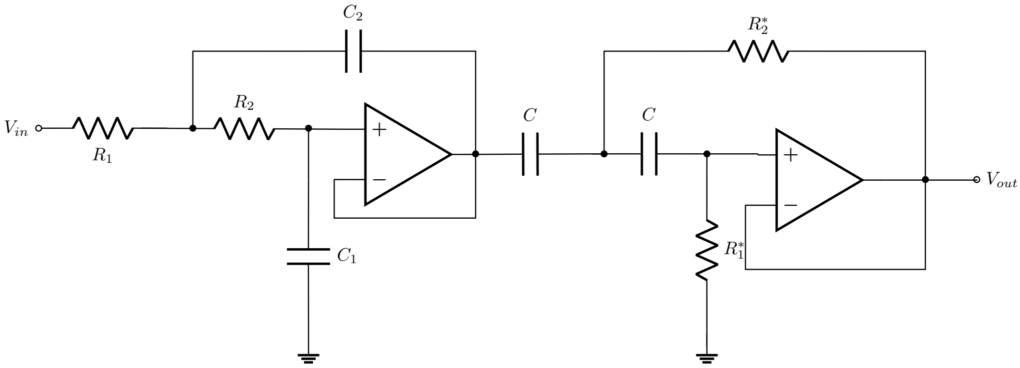


Figure 4: Unity-Gain Sallen-Key Band-Pass Filter

For given C_1 and C_2, the resistor values for R_1 and R_2 are calculated through:

$$R_{1,2} = \frac{a_1 C_2 \mp \sqrt{a_1^2 C_2^2 - 4 b_1 C_1 C_2}}{4\pi f_c C_1 C_2}$$

For given C, the resistor values for R_1^* and R_2^* are calculated through:

$$R_1^* = \frac{1}{\pi f_c C a_1}, R_2^* = \frac{a_1}{4\pi f_c C b_1}$$

Calculated Theoretical Resistor & Capacitor Values for Band-pass Filters[1]

R_1	R_2	C_1	C_2	R_1^*	R_2^*	C
1.2 kΩ	2.2 kΩ	220 nF	470 nF	47 kΩ	27 kΩ	220 nF

Table 1: Resistor and Capacitor values (20 Hz – 300 Hz)

Frequency Range	R_1	R_2	R_3	C
300 Hz – 1 kHz	3.3 kΩ	10 kΩ	3.9 kΩ	100 nF
1 kHz – 4 kHz	2.7 kΩ	8.2 kΩ	6.8 kΩ	33 nF
4 kHz – 10 kHz	2.2 kΩ	6.8 kΩ	1 kΩ	15 nF
10 kHz – 20 kHz	2.2 kΩ	5.6 kΩ	390 Ω	10 nF

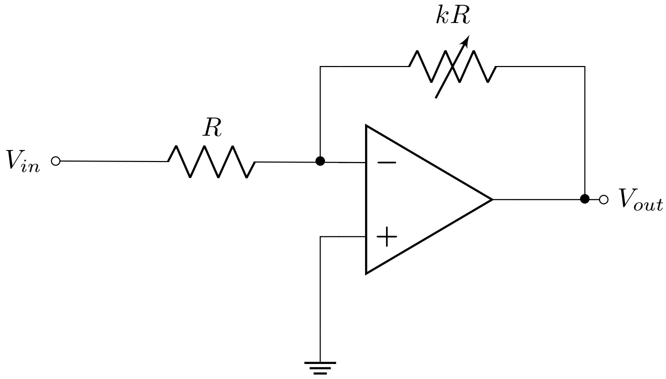
Table 2: Resistor and Capacitor values for 1st MFB Filter

Frequency Range	R_1	R_2	R_3	C
300 Hz – 1 kHz	15 kΩ	47 kΩ	15 kΩ	10 nF
1 kHz – 4 kHz	3.3 kΩ	10 kΩ	6.8 kΩ	10 nF
4 kHz – 10 kHz	2.7 kΩ	8.2 kΩ	1 kΩ	6.8 nF
10 kHz – 20 kHz	1.8 kΩ	5.6 kΩ	330 Ω	6.8 nF

Table 3: Resistor and Capacitor values for 2nd MFB Filter

[1] See Appendix A for practical resistor & capacitor values.

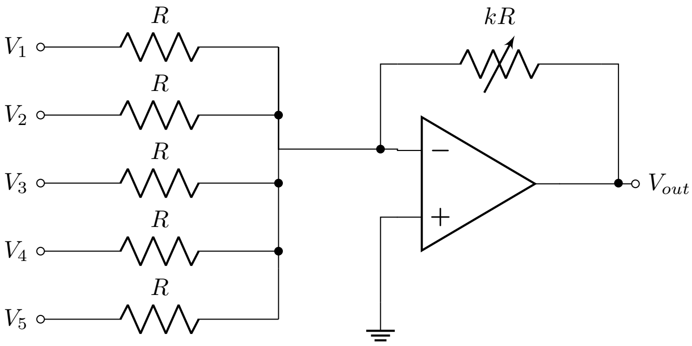
2.3 Gain Controller



$$\frac{V_{in} - 0}{R} = \frac{0 - V_{out}}{kR}$$
$$V_{out} = -kV_{in}$$

Figure 5: Gain Controller

2.4 Adder & Gain Controller



$$\sum_{i=1}^{5} \frac{V_i - 0}{R} = \frac{0 - V_{out}}{kR}$$
$$V_{out} = -k \sum_{i=1}^{5} V_i$$

Figure 6: Adder and Gain Controller

2.5 LED Display

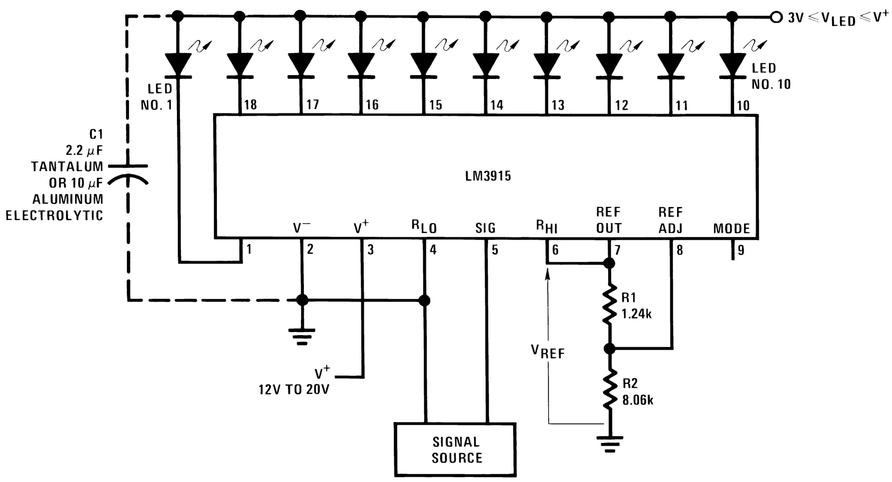


Figure 7: Circuit connection for LED display

2.6 Power Amplifier Circuit

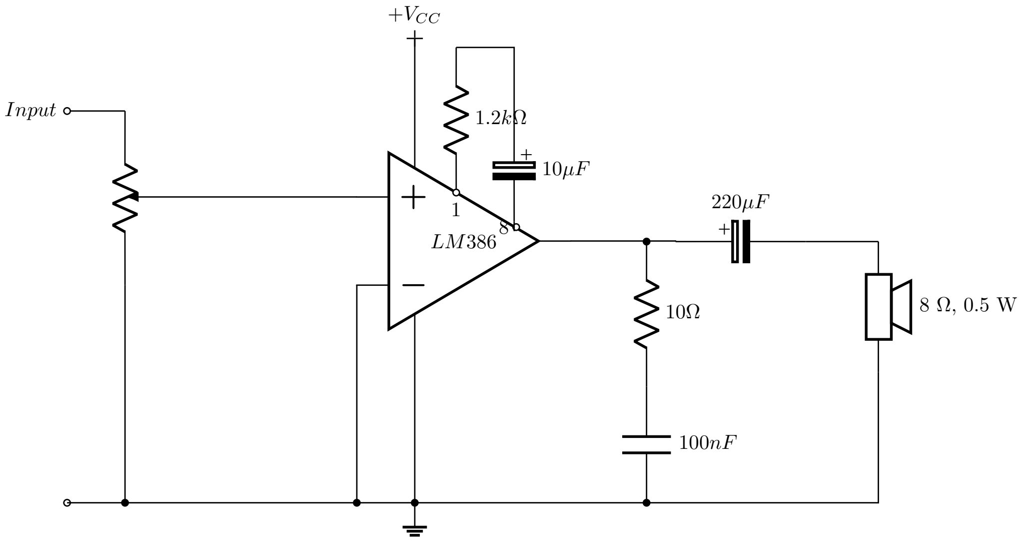


Figure 8: Power Amplifier Circuit

3 Component Selection (Main electronic components)

1. **NE5532 Operational Amplifier**
   - **Low Noise**: $5\,\mathrm{nV}/\sqrt{\mathrm{Hz}}$ suitable for high-fidelity audio
   - **Bipolar Input**: Ensures low offset and distortion in precision audio
   - **Dual Channel**: Two Operational Amplifier (Op Amp) per IC for compact design
   - **High Slew Rate**: $9\,\mathrm{V}/\mu\mathrm{s}$ supports wide dynamic range
   - **Wide Bandwidth**: 10 MHz gain-bandwidth product for audio applications
   - **Wide Supply**: $\pm 3\,\mathrm{V}$ to $\pm 20\,\mathrm{V}$ operation for design flexibility
   - **High Drive Capability**: Can directly drive $600\,\Omega$ loads
2. **LM3915 Dot/Bar Display Driver**
   - Logarithmic 3 dB/step response for audio
   - Direct LED drive without current-limiting resistors
   - Simple setup with minimal external components
   - Over-voltage protection (±35V) on input

Figure 9: NE5532P Operational Amplifier

Figure 10: LM3915 Dot/Bar Display Driver

4 PCB Design

We designed 4 separate PCBs using Altium Designer. (Why 4 PCBs?[2])

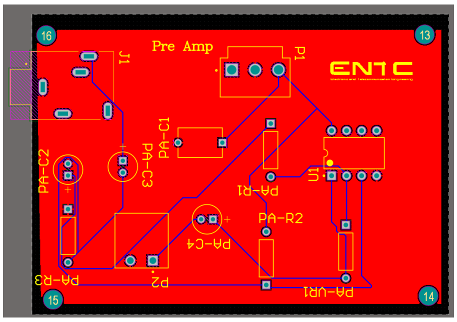


Figure 11: 2D pathway of Pre Amplifier Circuit

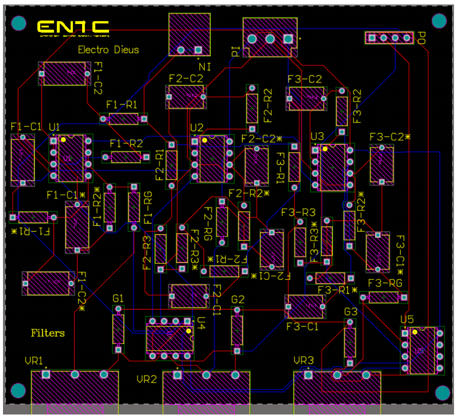


Figure 12: 2D pathway of Filter Circuit

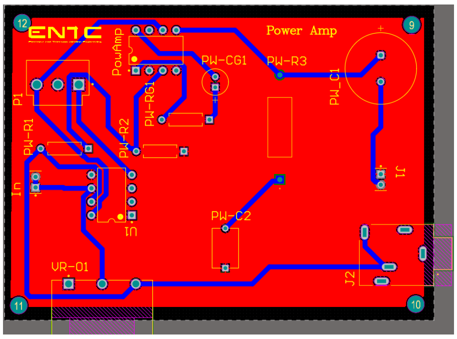


Figure 13: 2D pathway of Power Amplifier Circuit

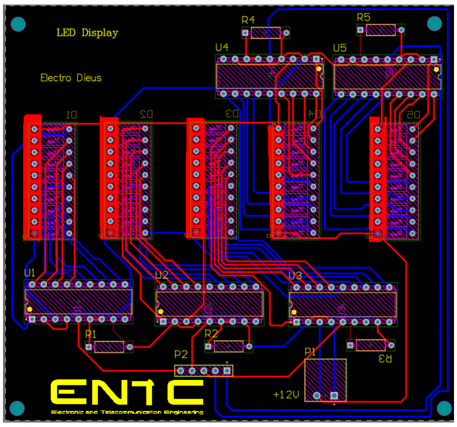


Figure 14: 2D pathway of LED Display Circuit

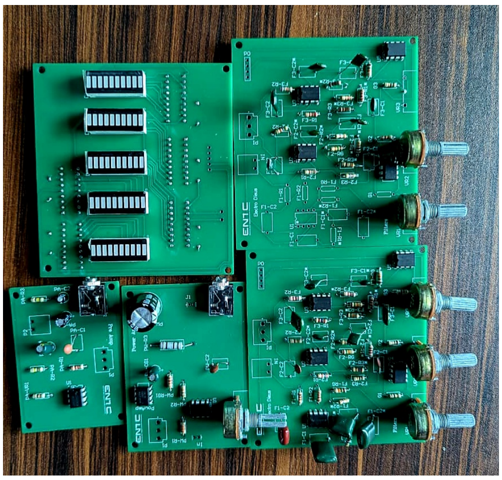


Figure 15: Soldered PCBs

[2]See Appendix B.

5 Enclosure Design

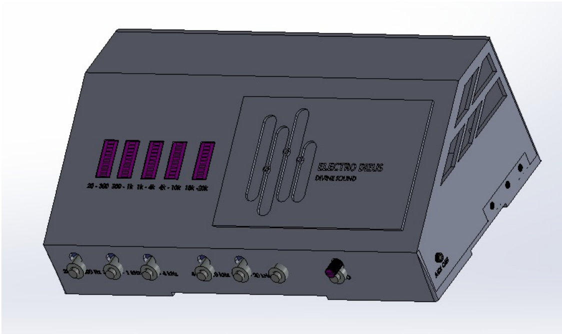


Figure 16: Enclosure front view

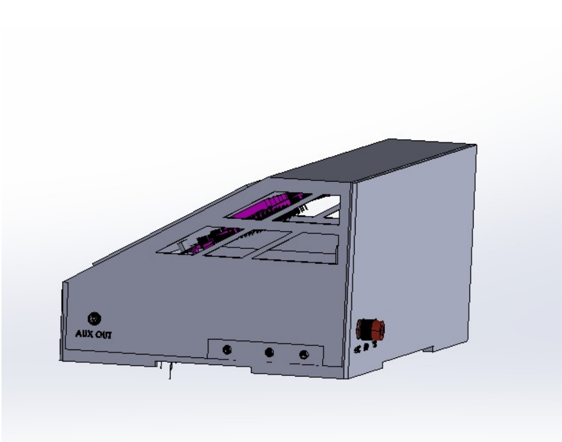


Figure 17: Right side view

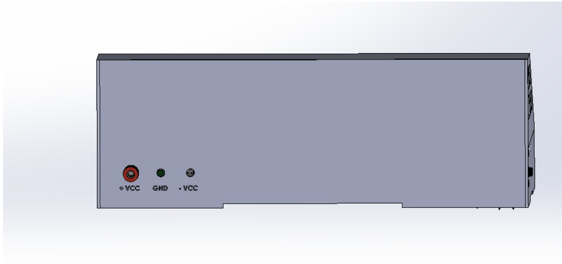


Figure 18: Back view

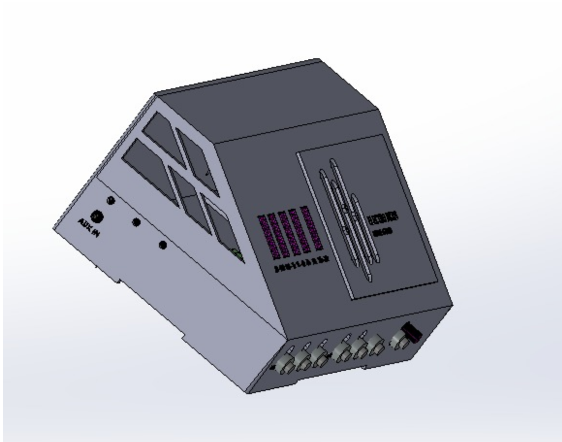


Figure 19: Left side view

Figure 20: Final product

6 Software Simulation and Hardware Testing

6.1 Software Simulation (Using LTspice)

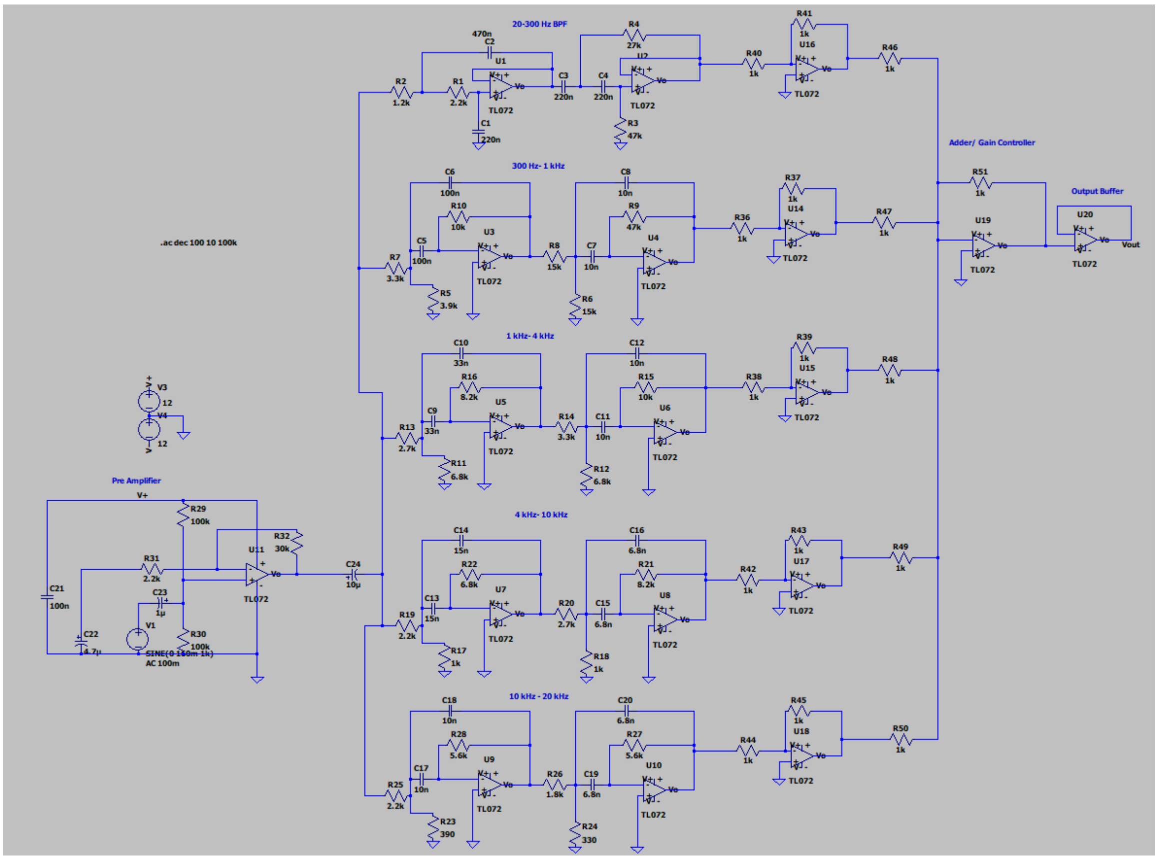


Figure 21: Circuit Diagram

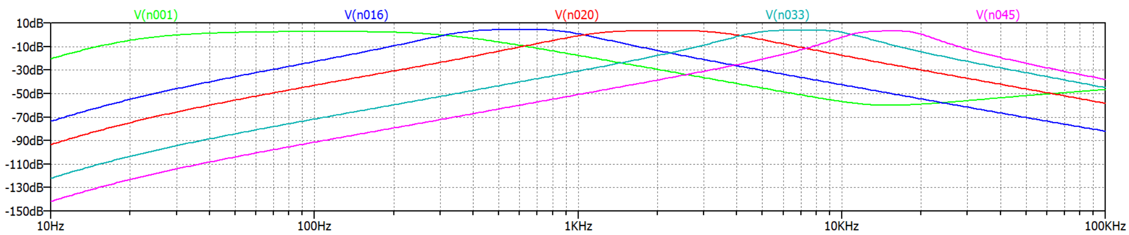


Figure 22: Frequency Response of Each Filter

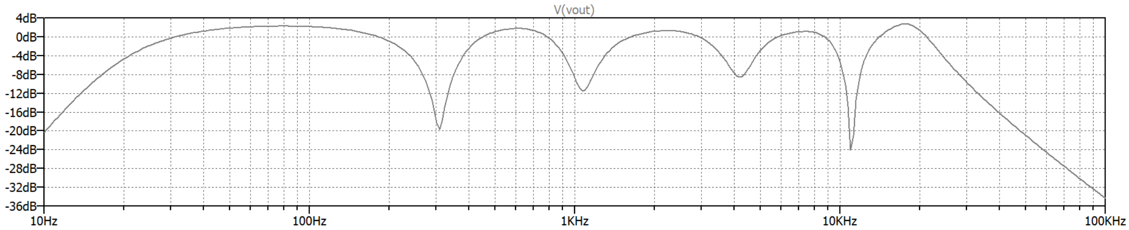


Figure 23: Overall Frequency Response

6.2 Hardware Testing

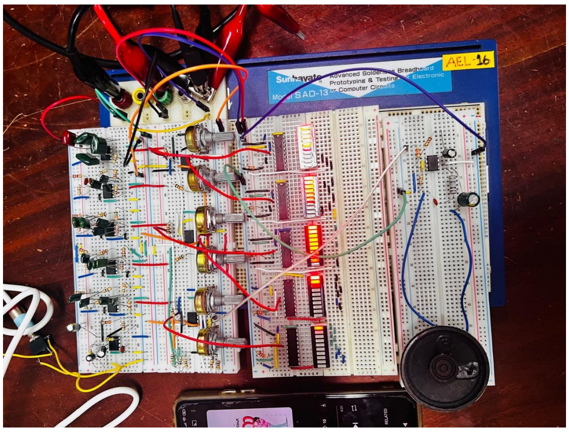


Figure 24: Breadboard implementation

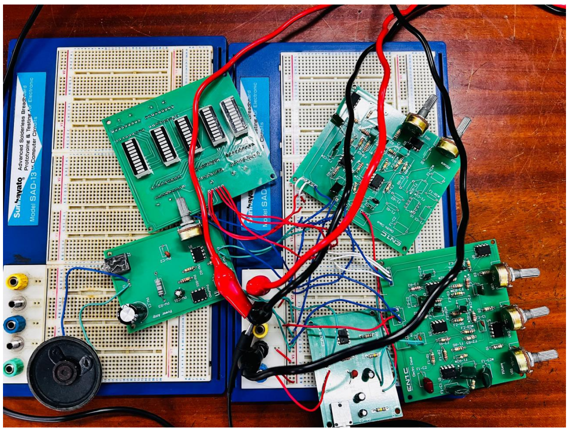


Figure 25: PCB testing

7 Conclusion & Future Works

The **Five Band Audio Equalizer** successfully achieves its primary objective of dividing an input audio signal into five distinct frequency bands and allowing individual gain control for each band. Through the integration of pre-amplifier, band-pass filter, gain control, adder, and power amplifier stages, the system provides a fully analog audio equalization platform with real-time visual feedback using an LED display. The implemented filters effectively cover the entire audible range from 20 Hz to 20 kHz, enabling fine-tuned tonal adjustment and improved sound clarity. Experimental testing confirmed that the circuit delivers stable operation with low distortion and noise, demonstrating the effectiveness of the NE5532 Op Amp and LM3915 LED display driver in high-fidelity analog applications.

Future development of the project can focus on several enhancements. Firstly, the system can be expanded into a **stereo equalizer** by duplicating the current design for left and right audio channels, enabling complete two-channel sound processing for improved spatial audio experience. Secondly, designing a dedicated **power supply unit** with voltage regulation and filtering will ensure stable performance and minimize noise interference. Additional improvements could include integrating tone presets, miniaturized PCB layouts, and incorporating protection circuits to increase durability and user convenience. These developments would transform the prototype into a fully functional and reliable consumer-grade audio equalizer system.

8 Contribution of Group Members

Student's Name (Index No.)	**Contribution**
Tennakoon U.G.R.B. (230629R)	Filter calculations, PCB design, Testing & debugging, Soldering
Ratnayake R.M.S.H. (203548R)	PCB design, Circuits design, Circuits simulation, Soldering
Shehan M.N.N. (230613M)	Breadboard implementation, Enclosure Design, Testing
Dissanayake R.K.T. (230164K)	Breadboard implementation, Testing, Assembling

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We would like to express our sincere gratitude to **Mr.Chanula Luckshan**, our project supervisor, for his continuous guidance and support throughout the development of the *Five Band Audio Equalizer* project. His valuable suggestions at the early stages of circuit design and his assistance in identifying and correcting errors during PCB and enclosure design were instrumental in achieving a successful outcome.

We also wish to extend our appreciation to **Dr.Pranjeevan Kulasingham**, our Signals and Systems lecturer, for providing us with a comprehensive understanding of analog filter design principles, which formed the foundation for our filter implementation in this project.

Our heartfelt thanks go to **Dr.Sampath Perera**, the module coordinator of EN2091 Laboratory Practice and Projects, for his overall supervision, encouragement, and for providing the necessary resources to complete this project effectively.

Finally, we would like to acknowledge the support of all the **laboratory assistants** of the Department of Electronic and Telecommunication Engineering for their technical help, timely guidance, and assistance during the hardware testing and implementation stages.

References

[1] Texas Instruments, *op Amps for Everyone Design Guide*, Rev. 8, Advanced Analog Products, SLOD006B, Aug. 2002. [Online]. Available: https://web.mit.edu/6.101/www/reference/op_amps_everyone.pdf

[2] Texas Instruments, "NE5532 — Dual, 30-V, 10-MHz, low-noise operational amplifier for audio applications," TI product page (Datasheet Rev. J), Jan. 27, 2015. [Online]. Available: `https://www.ti.com/product/NE5532`

[3] Texas Instruments. *LM3915 Dot/Bar Display Driver Datasheet*, SNVS740C. Revised Mar. 2013. [Online]. Available: `https://www.alldatasheet.com/datasheet-pdf/view/558236/TI/LM3915.html`

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Appendix

A Practical Resistor & Capacitor Values

R_1	R_2	C_1	C_2	R_1^*	R_2^*	C
1.2 kΩ	2.2 kΩ	220 nF	470 nF	47 kΩ	27 kΩ	220 nF

Table 4: Resistor and Capacitor values (20 Hz – 300 Hz)

Frequency Range	R_1	R_2	R_3	C
300 Hz – 1 kHz	2.7 kΩ	10 kΩ	10 kΩ	100 nF
1 kHz – 4 kHz	2.7 kΩ	8.2 kΩ	15 kΩ	33 nF
4 kHz – 10 kHz	2.2 kΩ	6.8 kΩ	1.2 kΩ	15 nF
10 kHz – 20 kHz	1.8 kΩ	5.6 kΩ	470 Ω	10 nF

Table 5: Resistor and Capacitor values for 1st MFB Filter

Frequency Range	R_1	R_2	R_3	C
300 Hz – 1 kHz	8.2 kΩ	27 kΩ	27 kΩ	10 nF
1 kHz – 4 kHz	2.2 kΩ	8.2 kΩ	15 kΩ	10 nF
4 kHz – 10 kHz	2.2 kΩ	6.8 kΩ	1.2 kΩ	6.8 nF
10 kHz – 20 kHz	1.5 kΩ	3.9 kΩ	390 Ω	6.8 nF

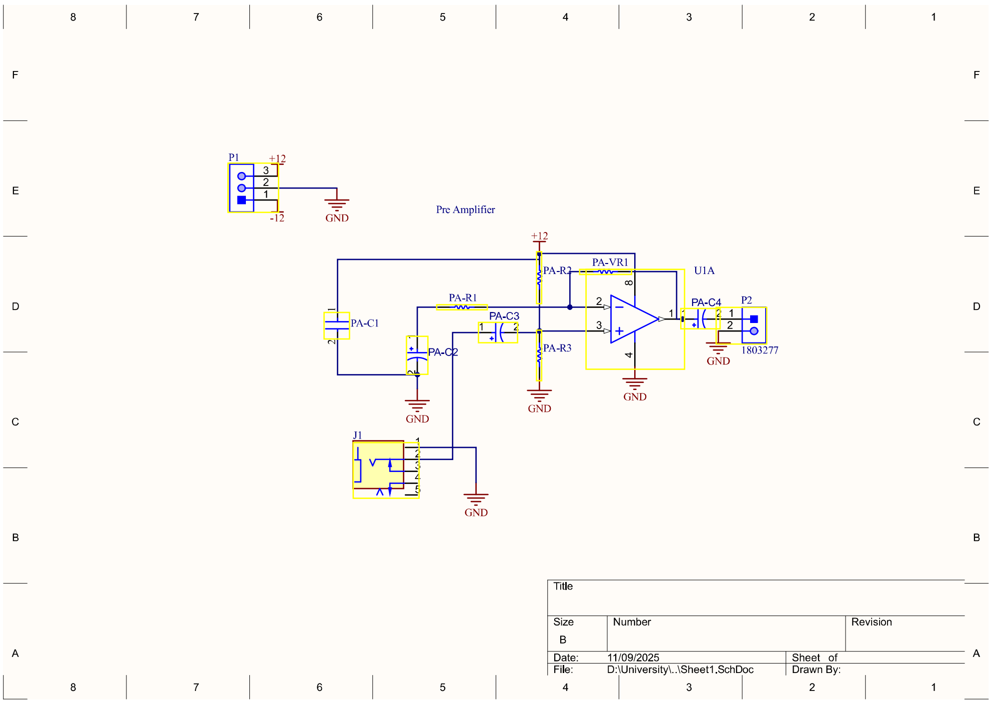
Table 6: Resistor and Capacitor values for 2nd MFB Filter

B PCB Schematics

PCB Partitioning as a Cost-Reduction Strategy

The initial hardware implementation consisted of two printed circuit boards (PCBs): a main circuit PCB measuring 162.94 mm × 112.52 mm and a display PCB measuring 119.63 mm × 58.67 mm. The total estimated manufacturing cost for this configuration was approximately $20.

To minimize fabrication costs, the final design was divided into four smaller modular PCBs, each with dimensions below 100 mm × 100 mm. This allowed the design to qualify for low-cost prototyping services offered by PCB manufacturers. Consequently, the total fabrication cost was reduced to $8 (four boards at $2 each). This partitioning approach resulted in a **60% reduction in manufacturing cost**, achieved without compromising system functionality or performance.



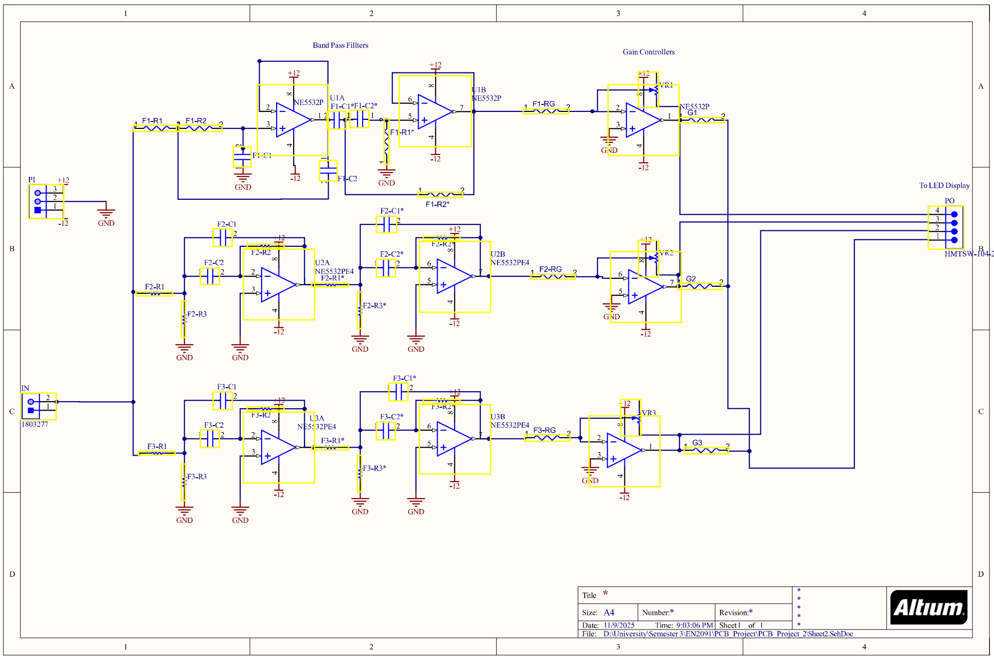
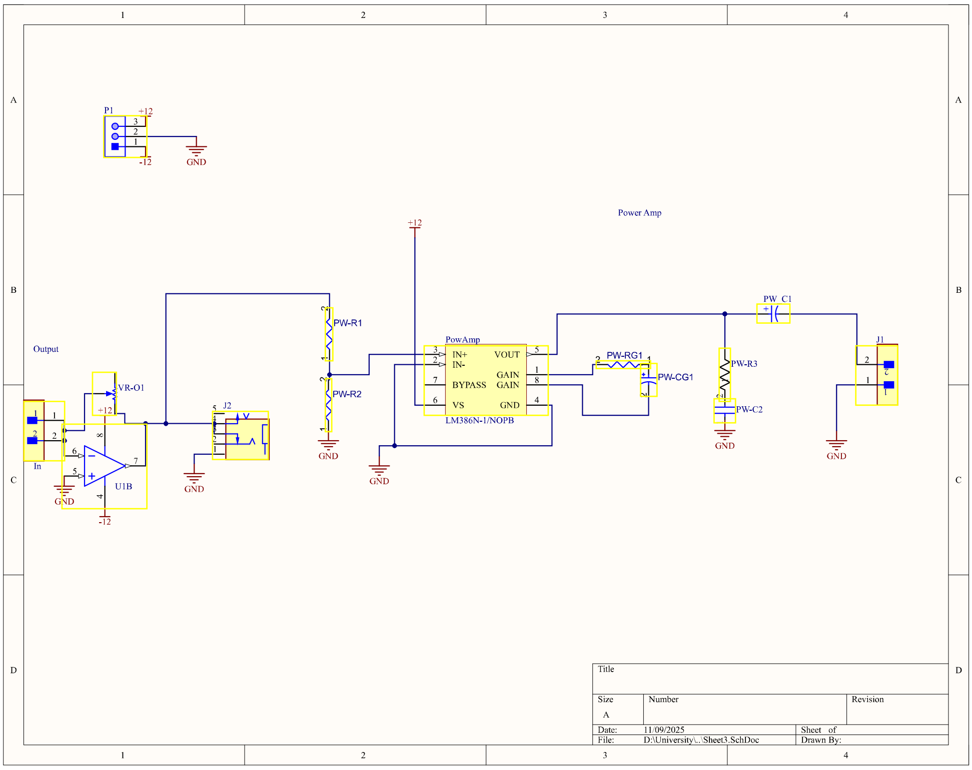


Figure 26: Pre-Amplifer & Filters



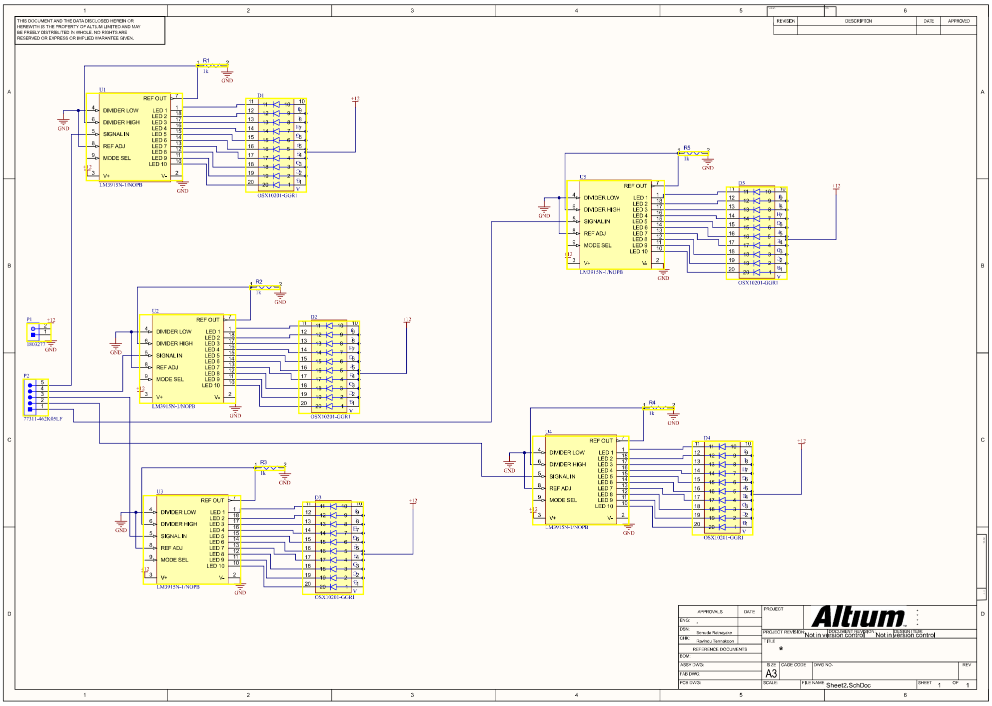


Figure 27: Power Amplifier & Display