EN2091

Laboratory Practice and Projects

5-Band Equalizer

Team – Hertz Labs

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Abstract

This report contains an overview of the design of a 5-band equalizer based on basic electronic components such as OP AMPs, resistors, capacitors and transistors. The Equalizer is designed to work for an input voltage range of 18-30V and provides highly selective individual band gain adjustment with minimal distortion to the other band responses. The equalizer at rest position introduces minimal distortion to the response.

The fundamental building blocks of the equipment and the core concepts related to it, simulation methodologies, testing methods, components selection, PCB design and enclosure design is briefly discussed in the report.

The final output and audio testing has given very pleasing results with accurate gain adjustments both in audio outputs and oscilloscope measurements proving the effectiveness of the design.

Content

Introduction

An audio equalizer can adjust the output of different frequency bands individually based on a given audio signal. The project was centred around making an equalizer with gain control of 5 individual bands using only basic analog electronic equipment. The audio levels of each band must be graphically indicated using a sound level indicator.

Functionality

The input/ buffer receives the audio signals and add a DC shift to bring the signal to the mid voltage.5 band pass filters tuned to the assigned bands decompose the input audio signals. These filtered signals are added by an adder circuit and the proportions of adding are controlled by volume controllers. (potentiometers). The Output is driven by the same Adder output.

The frequency ranges of each band.

- 20-300 Hz
- 300 - 1 kHz
- 1kHz - 4 kHz
- 4kHz - 10kHz
- 10kHz - 20kHz

System Architecture, Major Design Decisions and Fulfilling the Given Requirements

The design decision was taken to go for a single supply design since we are expecting to rely on a external power supply with normally provides a single supply. (External dual power supplies are rare in market)

So, all the stages of the circuit was designed to work according to it.

Block Diagram

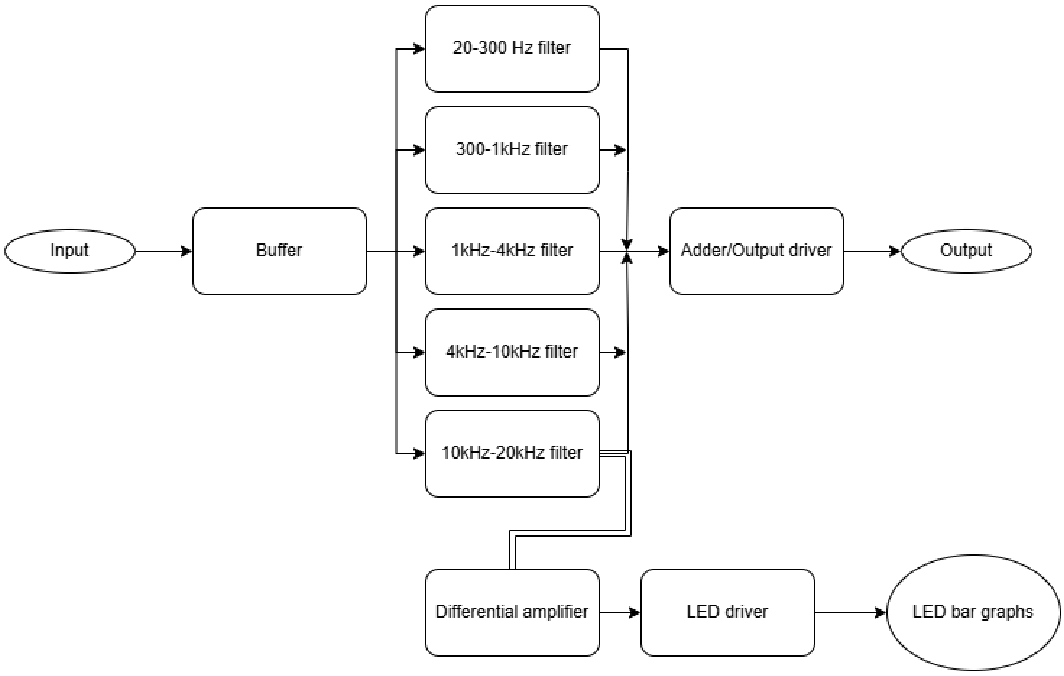


Figure 1-Functional block Diagram

The system is divided into 2 major parts.

1. Filter section
2. Display control section

Filter section

Consists of 3 stages

1. Input/Buffer stage – A inverting amplifier of gain -2
2. Filter stage - 2 second order Sallen key multiple feedback bandpass filters cascaded to get a fourth order filter for each band. 5 such filters are present.
3. Adder/Output stage – Volume controllers are used to control the contribution from each band and the current is passed through the adder circuit to generate the output voltage.

Additionally, it has a mid-voltage generator section- Mid voltage is taken to act as the virtual ground to simplify the design the single supply op amp circuits.

Display Section

Consists of 2 stages

1. Differential amplifier stage – Sense the current levels of each filter stage flowing to the adder section without introducing distortion to the bands
2. LED driver stage – Drive a 10 LED bar graph display proportional to the voltage output of the first stage.

Additionally, a reference voltage generator and voltage stabilizer circuits are is included for the proper functionality of the above sections

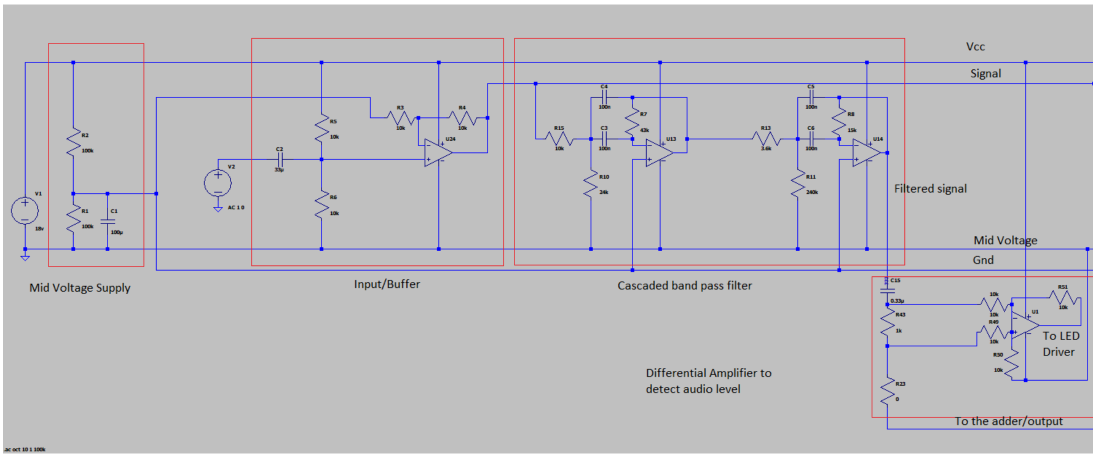


Figure 2-Schematics with the main components

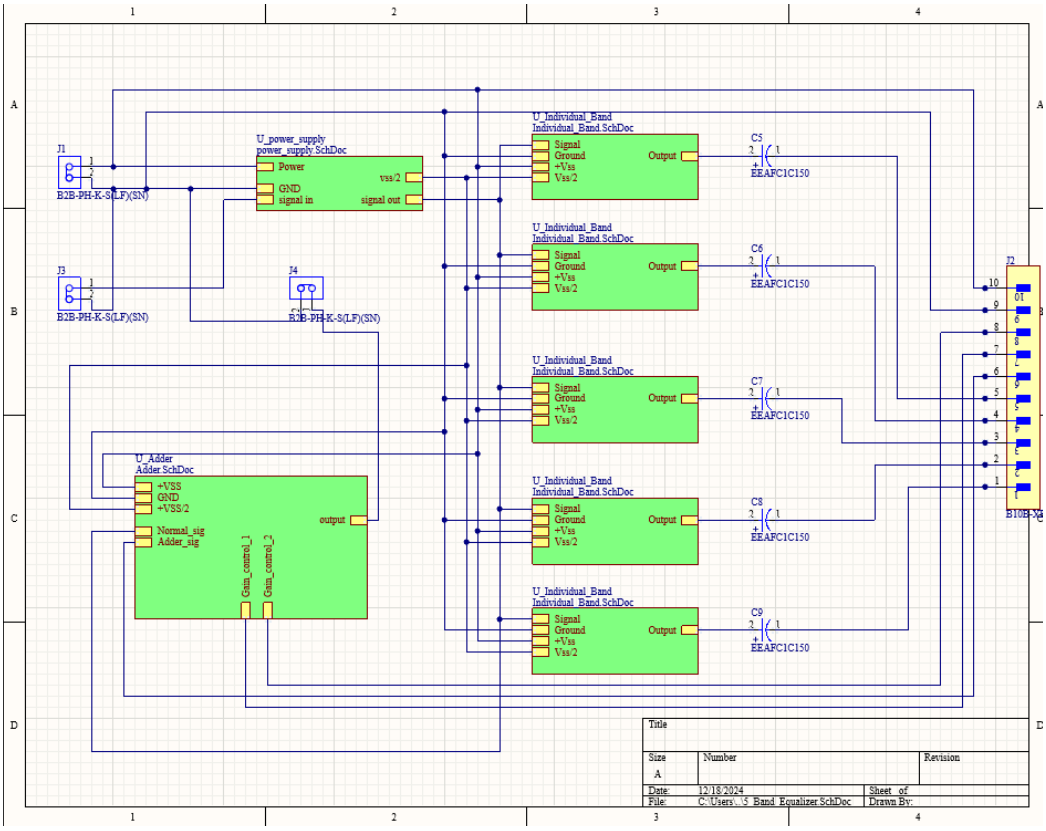


Figure 3-Schematics of the Filter section

Use of analog electronics for implementation (transistors and operational amplifiers)

- **Input/stage**

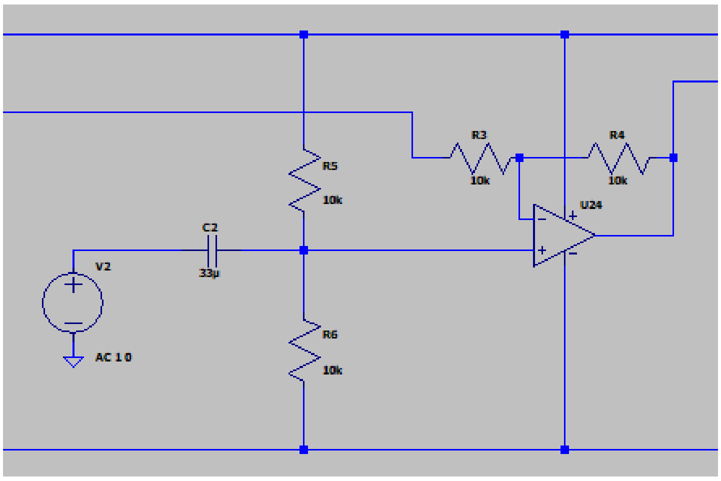


Figure 4-Input Stage

The input stage is an inverting amplifier constructed using a single OP amp and resistors. This stage introduces a DC shift to the signal and give a gain of -2. The gain is introduced to manipulate the signals with minimal introduction of noise from the filters and background noise. The input stage has an almost flat frequency response (High pass)

- **Filters**

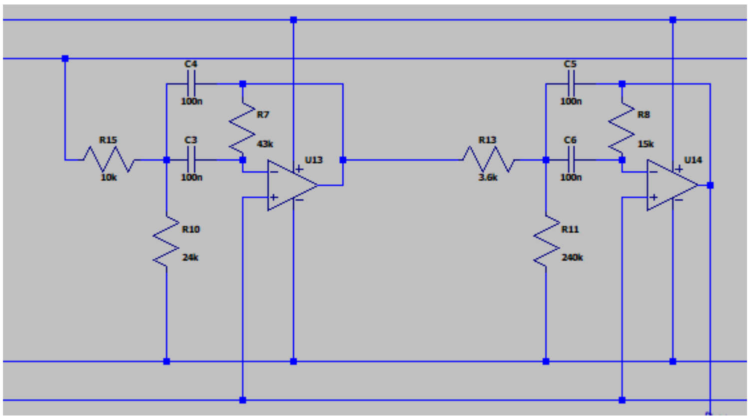


Figure 5- cascaded 2nd order filters(4th order)

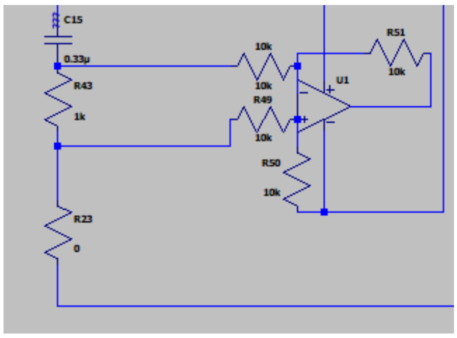
The filter stages is constructed by cascading 2 Sallen key multiple feedback band pass filters to get a fourth order filter. This is used to give a steep roll off which gives a good selectivity. Also, the filters are tuned such that the first filter is handling the first portion of the filter while the second filter handles the second portion of the band. This ensure that the pass band has a flat mid frequency gain.

Adder stage

Adder is an OP amp based single supply adder circuit which combines the signals from the filters proportional to the resistance introduced by the volume controllers between the filter and the adder. The adder circuit is also inverting the signal which ultimately converts the signal to the original phase.

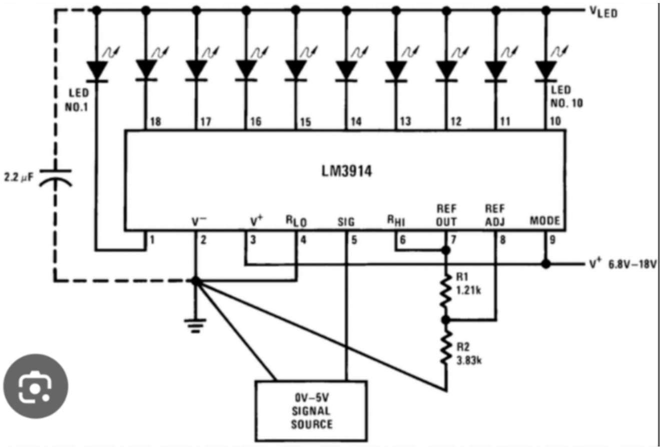
Differential amplifier

The differential amplifier is connected to the saturation control resistor. The differential amplifier senses the voltage difference between the resistor which is proportional to the current flow through it. Then it outputs the output which is in the range of the input



signals to the display driver. Due to the high input impedance of the differential input this does not introduce any distortions to the signal.

Display driver.



We have used a 10 segment display driver(LM3914) which switches the LEDs proportional to the input voltage ranging from 0-5V

Capable of adjusting the gain individually across 5 frequency bands.

As described previously this requirement is achieved by filtering the signal into several bands and then controlling the contribution of each band to the final output individually.

Mechanisms to avoid signal saturation.

A current control resistor is introduced between the filters and the volume controllers which limits the current to the adder stage. This ensures that the final output stage will not be saturated by any means. The value of this resistor is calculated such that for any position of the volume controller the input current to the adder circuit is controlled and the output is not saturated. Furthermore, all the filters are designed to handle input voltage variations way beyond the normal audio line voltages. This ensures that for any normal audio signal, the input/buffer stage and the filter stages will not saturate. The supply voltage of the system was selected to be 18V which was decided on the fact that 12V supply voltage is the minimum voltage needed to avoid saturation of the signals.

Component Selection

Op amp selection – We decided to use TL 072 OP amp for all the circuits in the system.

The TL072 operational amplifier (op-amp) is often considered good for audio applications due to several characteristics that make it well-suited for this purpose:

1. **Low Noise:** The TL072 has low noise characteristics, which are crucial in audio applications where signal fidelity is important. Low noise helps in maintaining the quality of the audio signal being amplified.
2. **High Input Impedance:** The TL072 has a high input impedance, which means it won't load down the preceding stages in an audio circuit. This is important to prevent signal loss and distortion.
3. **Wide Bandwidth:** The TL072 has a wide bandwidth, making it suitable for audio applications where a broad frequency range needs to be amplified without distortion.
4. **Low Distortion:** The TL072 has low distortion characteristics, which are essential for maintaining the fidelity of audio signals as they pass through the amplifiers and filters.
5. **Dual Op-Amp Configuration:** The TL072 is a dual op-amp in a single package, which is convenient for filter stages since each stage needs 2 OP amps.
6. **Ease of Use and supply:** It is a commonly used and well-documented op-amp, making it easier for designers to find information, application notes, and example circuits for audio applications.

   We used SMD Op amps for all the filters and the adder to increase the compactness of the PCB and we used a Through hole Op amp since this has to introduce a DC sift for the signal

Resistors - All the resistors were selected based on the calculations needed for filters and the other circuits. All the resistors are 0.25W resistors since all the circuits deal with signals. The resistor selection for the op amp circuits were done such that they fall in the range of 1kohm to 100kohm to avoid injection of thermal noises to the signals.

Display driver – LM3914

1. **Bar/Dot Display Modes:** The LM3914 can operate in either bar mode or dot mode, allowing flexibility in how the display is presented based on the application requirements. We decided to use the bar mode
2. **Linear Voltage Scale:** The LM3914 has a linear voltage scale, which is useful for applications where a linear representation of levels or quantities is needed, such as audio level indicators which is exactly our requirement.
3. **Wide Voltage Range:** The LM3914 can operate over a wide range of supply voltages, making it versatile and suitable for various power supply configurations. This makes the use of a separate supply circuit to the display drivers unnecessary.
4. **Internal Voltage Reference:** The LM3914 includes an internal voltage reference, simplifying the design by eliminating the need for an external voltage reference. This gives our device the ability to work on defferent supply voltages while still maintaining a fixed scale.

16.5.1.2 Multiple Feedback Topology

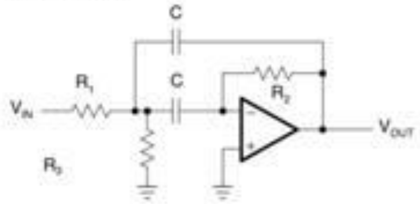


Figure 16–34. MFB Band-Pass

The MFB band-pass circuit in Figure 16–34 has the following transfer function:

$$A(s) = \frac{-\frac{R_2 R_3}{R_1 + R_3} C\omega_m \cdot s}{1 + \frac{2R_1 R_3}{R_1 + R_3} C\omega_m \cdot s + \frac{R_1 R_2 R_3}{R_1 + R_3} C^2 \cdot \omega_m{}^2 \cdot s^2}$$

The coefficient comparison with Equation 16–9, yields the following equations:

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

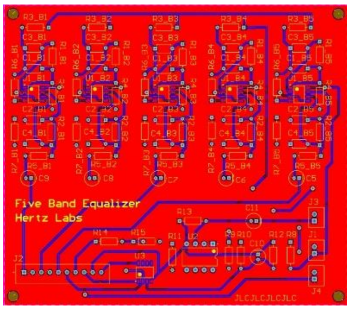
	$R_1\uparrow$	$R_2\uparrow$	$R_3\uparrow$	$C\uparrow$
f_m	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$
A_m	$\downarrow$	$\uparrow$	–	–
B	–	$\downarrow$	–	$\downarrow$

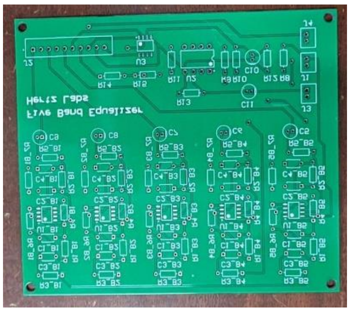
PCB Design

The printed circuit board (PCB) for the 5-Band Audio Equalizer was designed using Altium Designer with 100 mm × 84 mm dimensions. The design utilizes a two-layer PCB architecture to accommodate the circuit complexity while maintaining an organized layout.

The PCB was fabricated in China and shipped to Sri Lanka for assembly and testing. The trace width for signal lines is 0.254 mm, ensuring optimal current flow and signal integrity. The drill hole diameter for PCB mounting is 3 mm, providing adequate mechanical support and alignment.

The placement of components was carried out systematically to ensure clarity and ease of understanding. Each frequency band is distinctly organized, enabling intuitive identification and streamlined troubleshooting. This structured layout enhances both the functionality and usability of the PCB, facilitating efficient assembly and testing processes.

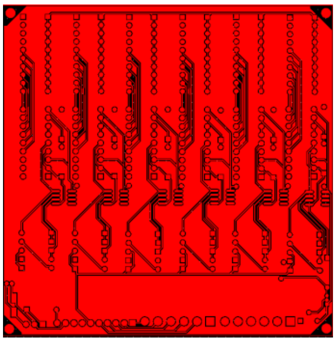


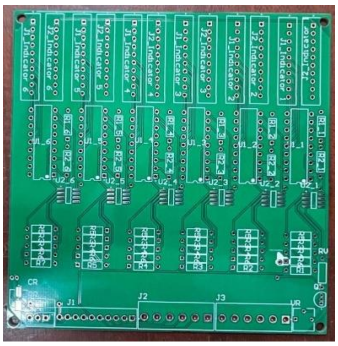


In addition to the main PCB, a separate display PCB was designed for the 5-Band Audio Equalizer using Altium Designer. This PCB measures 100 mm × 100 mm and features a two-layer design to support the display components.

The trace width for signal lines is 0.254mm, ensuring reliable electrical connections, while the drill hole diameter is maintained at 3 mm for PCB mounting.

The components on the display PCB, such as the LED bar graph displays and sliding potentiometers, are strategically organized to align precisely with the corresponding features of the enclosure. This alignment ensures seamless integration of the display interface with the enclosure design, resulting in a user-friendly and visually coherent system layout.





Enclosure Design

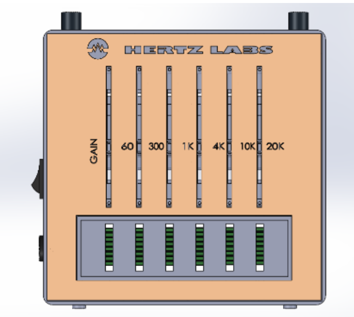
The enclosure for the 5-Band Audio Equalizer was designed using SolidWorks and consists of three distinct components: the Main Container, the Lid, and the Face. The enclosure dimensions are 150 mm × 142 mm, ensuring compactness while accommodating all required components.

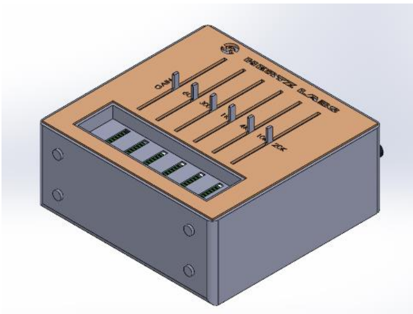
- The Main Container and Lid were fabricated using 3D printing technology with PLA+ filament for enhanced durability and precision.
- The Face of the enclosure was laser-cut from a plywood sheet, providing a robust and aesthetically appealing front panel.

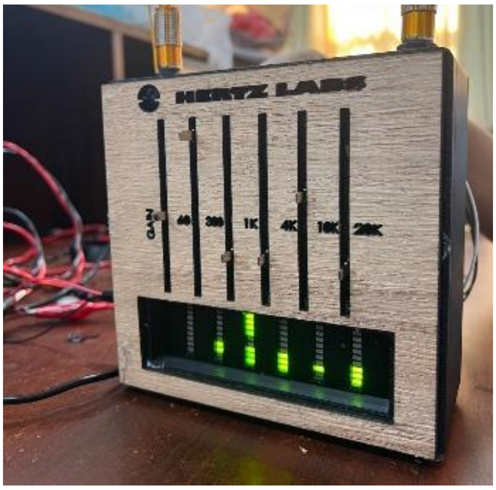
The enclosure integrates the following components:

- 5 sliding potentiometers for adjustable gain control.
- 5 LED bar graph displays for real-time visual feedback.
- 1 switch for system control.
- 2 audio jack connectors (65 mm) for audio input and output.
- 1 barrel jack connector for power supply.

The main PCB is mounted on the inner face of the lid, while the display PCB is securely mounted inside the Main Container. Both PCBs are positioned in a face-to-face configuration, simplifying wire connections and minimizing signal interference, ensuring efficient assembly and reliable operation.

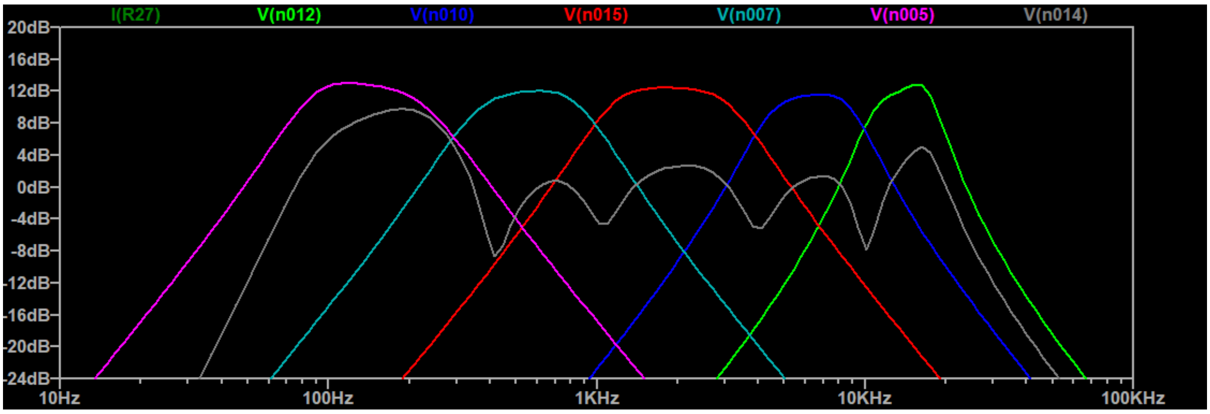






Software Simulation

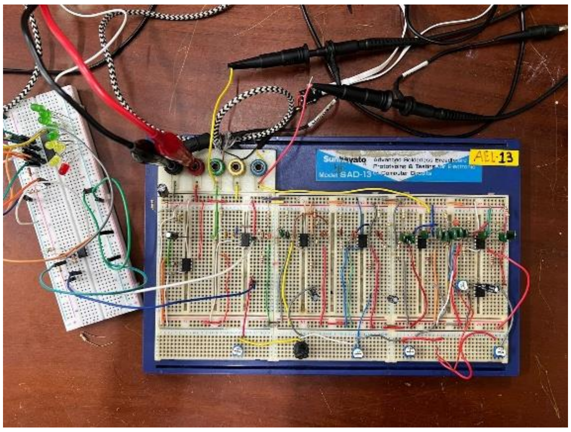
The circuit was simulated using LTSpice software to verify its performance and optimize component values. The output response for each frequency band was plotted, demonstrating accurate results with a well-defined roll-off at the frequency edges. Based on the simulation results, appropriate resistor and capacitor values were carefully selected to ensure precise frequency band separation and optimal performance of the 5-Band Audio Equalizer.



This image shows the response of each individual filter and the overall response of the equalizer when the system is at neutral position. Contribution of each band to the output can be adjusted by varying the potentiometers

Practical Implementation and Testing

The circuit was implemented on a breadboard following the simulation for practical verification. The resistor values were fine-tuned through experimentation to optimize the output response. This step ensured the circuit achieved the most accurate and reliable performance, aligning closely with the simulated results.



After optimizing the circuit on the breadboard, the PCB layout was designed using Altium software. The PCB was fabricated and tested to ensure proper functionality. All components were carefully soldered onto the PCB, and the assemblies were integrated into the enclosure. The final product was subjected to comprehensive testing, where it successfully met the expected performance criteria, validating both the design and implementation processes.

Conclusion

In conclusion the component selection and the circuit design is very robust and the testing proved that the system has met all the design requirements. The use of analog circuits for audio applications can preserve the quality of th audio signals and also at the same time cost effective for small scale audio signal processing. The 5 band analog equalizer can be further extended to handle multiple bands in the audio frequencies.

Future Work

1. **Custom Power Supply Development**
   Currently, the device is powered using the laboratory signal generator to supply the required voltage. As part of future improvements, a dedicated in-house power supply will be designed and implemented to provide a stable 18V power source, ensuring portability and independence from external equipment.

2. **Optimization of LED Bar Graph Display**
   The LED bar graph displays did not perform as expected, with the levels not accurately reflecting changes in the signal output. Further testing and analysis of the display circuit are necessary to identify the discrepancies. An improved design will be implemented to achieve precise and reliable visual output for the display.

Individual Contribution

220247J	Jayakody J.A.K	Overall circuit design, Display PCB Design, Simulations, Circuit Building, Breadboard Implementation, Documentation.
220455U	Pelagewatta H.P	Main PCB Design, PCB Testing, Soldering
220252U	Jayarathne H.A.C.N	Enclosure Design, Assembling, Filter Calculations and Testing, Documentation
220064U	Bandara M.A.G.S.	Filter Calculation, Documentation

References

https://www.ti.com/lit/ds/symlink/lm3914.pdf

https://www.ti.com/lit/pdf/sloa096

https://medium.com/@vgr0876/5-band-audio-equalizer-8df9b991d8ea