

**Analog Audio Equalizer with  
Bass, Mid, and Treble Control  
(EE – 213L)**

**October 26, 2025**



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## **Contents**

Contents .....	2
I. Project Goal .....	3
II. Introduction.....	3
III. Real World Impact.....	3
IV. Block Diagram .....	4
V. Description .....	5
VI. Proposed Schematic.....	7
VII. List of Components .....	9
VIII. Expected Outcomes.....	10
VI. Division of Task .....	11
A. References .....	12
B. Data Sheets .....	12

## I. Project Goal

The goal of this project is to design and implement a three-band analog audio equalizer that takes an input sound signal and allows the user to adjust the bass, mid, and treble frequencies independently. The circuit uses active filters and operational amplifiers to isolate and control different frequency bands, providing real-time tonal customization. The processed output is amplified through an LM386 amplifier and played via a speaker. This project aims to offer a hands-on understanding of audio signal processing and analog filter design while delivering an interactive and high-quality sound experience.

## II. Introduction

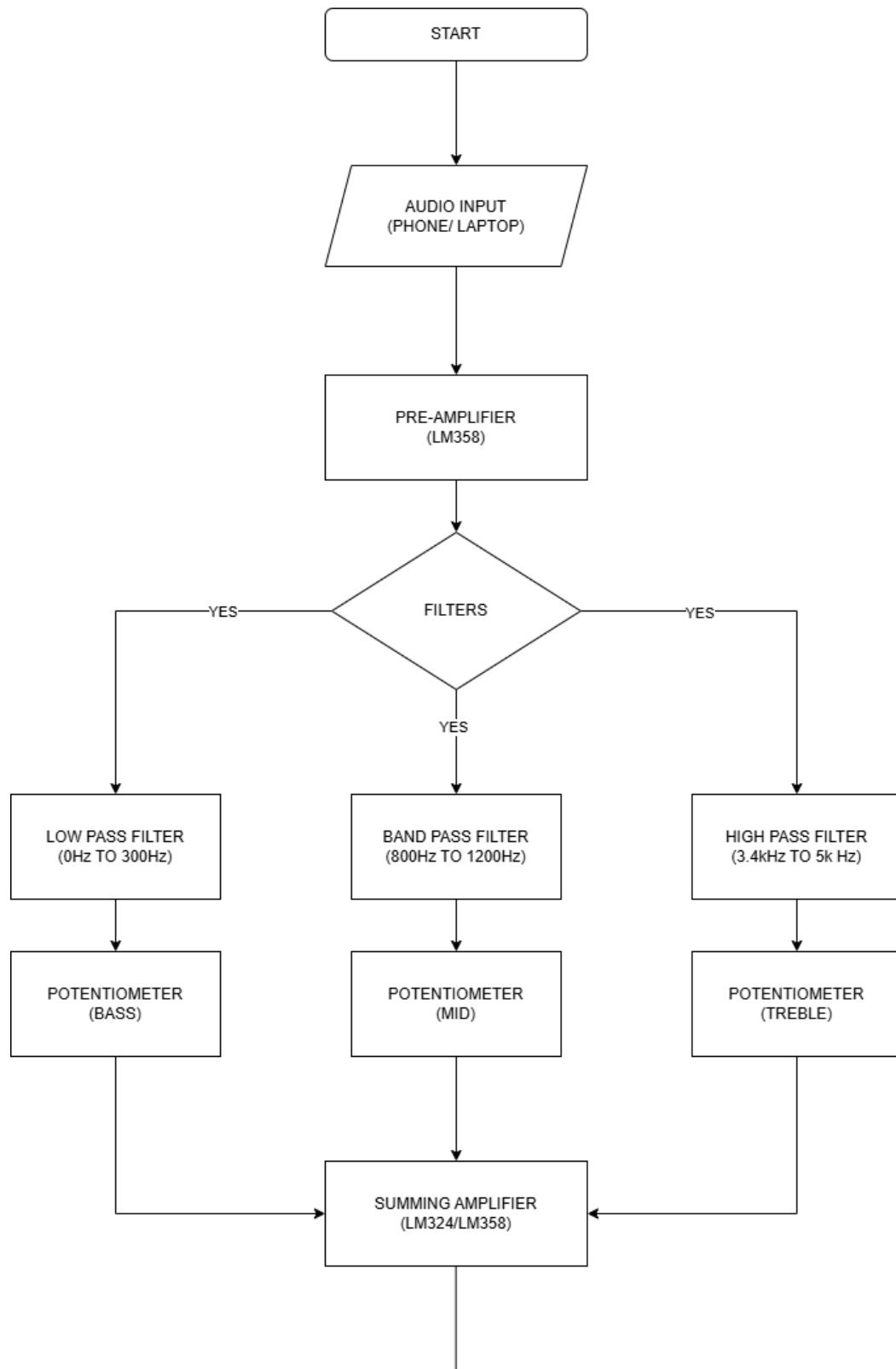
Audio equalization is a key process in sound engineering, allowing selective amplification or attenuation of specific frequency ranges to improve sound quality. In this project, we designed a passive multi-band filter system that divides an input audio signal into three major bands: low (bass), mid, and high (treble) using a combination of low-pass, band-pass, and high-pass filters. Each filter is implemented using operational amplifiers to achieve controllable gain and precise cutoff frequencies. This system models the working of equalizers found in music players, amplifiers, and communication devices.

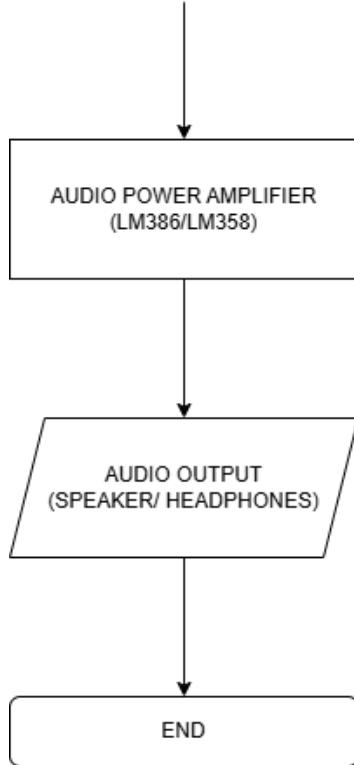
## III. Real World Impact

In modern audio systems, sound quality often varies depending on the environment, speaker characteristics, and the type of content being played. Many low-cost or compact devices lack effective tone control, which results in unbalanced sound, excessive bass, unclear vocals, or harsh trebles. This project addresses this limitation by developing an analog audio equalizer that allows users to adjust the bass, mid, and treble components of a music signal in real time.

By integrating passive filter circuits and an amplification stage, the system enhances listening quality and provides users with greater control over how audio is perceived. Such a design finds practical application in car audio systems, portable speakers, home entertainment setups, and even professional mixing consoles, where precise sound adjustment is essential. Additionally, this project demonstrates the core principles of signal processing, filter design, and op-amp applications, making it valuable for both educational and practical engineering purposes.

#### IV. Block Diagram





## V. Description

- **Audio Input:**  
The song enters through a 3.5mm audio jack breakout board from your phone/laptop.
- **Pre-Amplification Stage:**  
Boosts the small input signal to a usable level and makes sure the filters receive a strong enough input for proper tone control.
- **Filter Section:**  
The signal is split into three paths on the breadboard, each containing a different passive filter:  
 -Low-pass filter → passes bass frequencies (below ~300 Hz)  
 -Band-pass filter → passes mid frequencies (~800Hz to 12kHz)  
 -High-pass filter → passes treble frequencies (above ~3.4 kHz)
- **Gain Control (Potentiometers):**  
Each path includes a potentiometer to adjust how loud that frequency range is just like the *Bass, Mid, and Treble knobs* on a music system.
- **Mixing Stage:**  
The outputs from all three filters are recombined into a single mixed output using a summing amplifier.

- **Amplification (LM358):**

The mixed audio signal is fed into an LM358 amplifier to boost the sound to a level suitable for driving a small speaker.

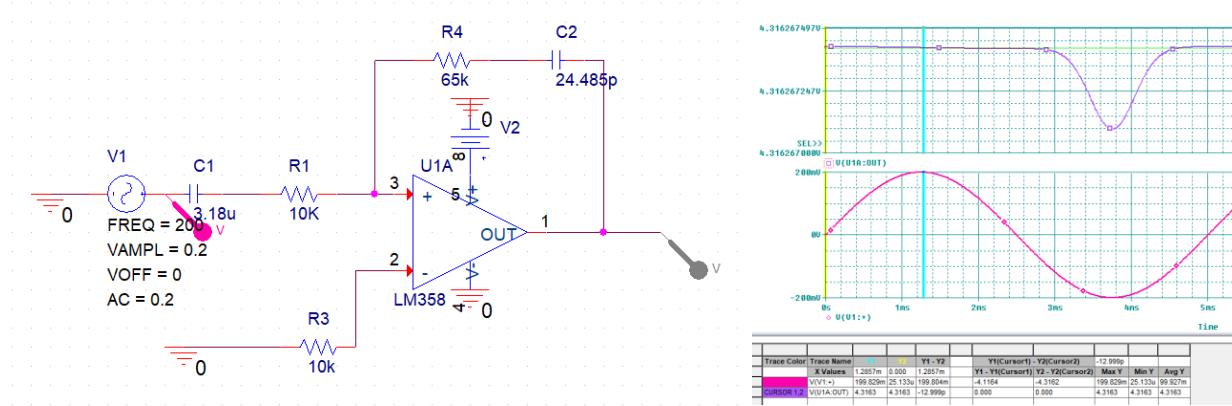
- **Audio Output:**

The amplified signal passes through another 3.5mm audio jack breakout board and finally to a speaker or headphones, where you can hear the filtered (equalized) audio.

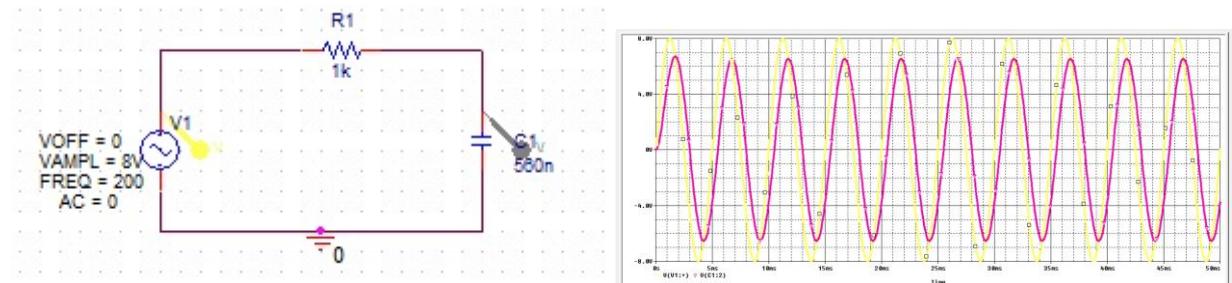
## VI. Proposed Schematic

The final schematic will be the combination of all different stages into one big circuit as shown in the block diagram.

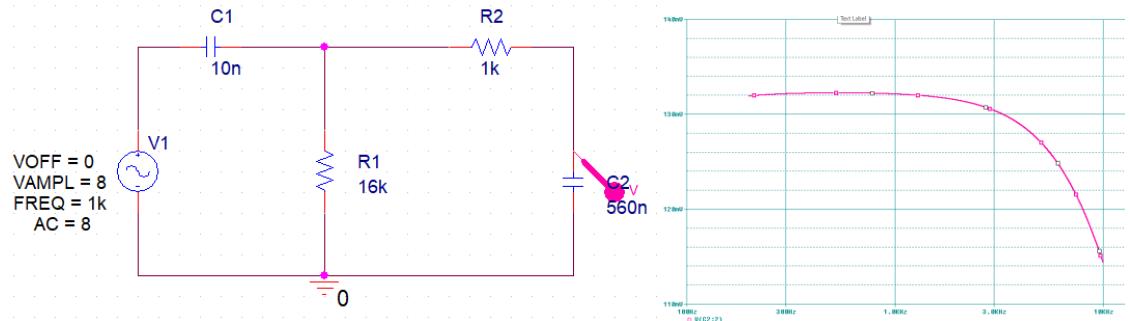
- Pre-Amplification Schematic



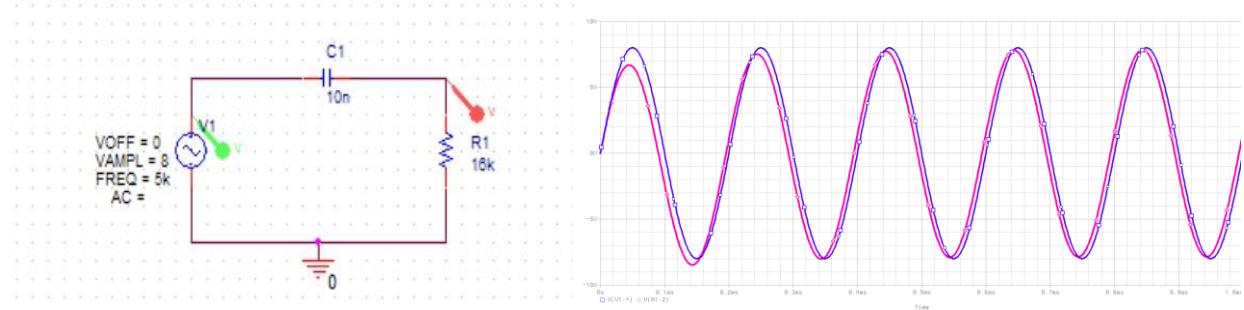
- Passive Low-Pass Filter Schematic



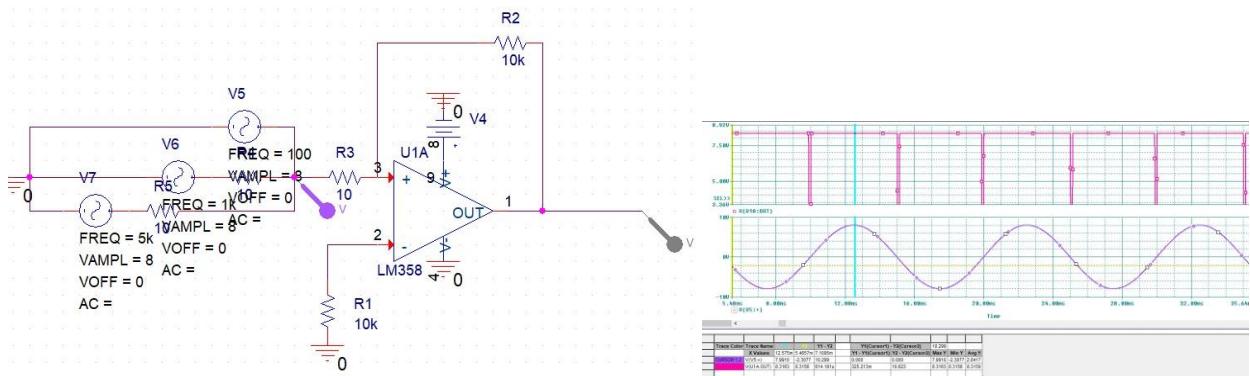
- Band-Pass Filter Schematic



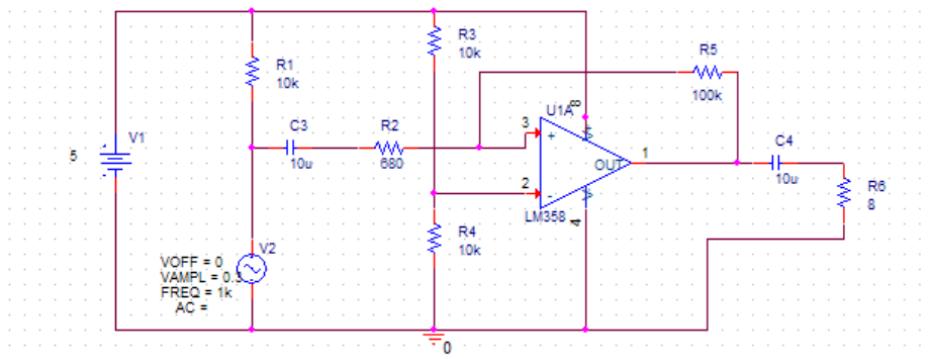
- Passive High-Pass Filter Schematic



- Summing Amplifier



- Audio Power Amplifier



## VII. List of Components

Components	Purpose
OP-AMPs (LM324, LM358, LM386, LM741)	Used for preamplifier, summing amplifier stage and power audio amplification.
Capacitor	Define filter frequency response, coupling/decoupling signals, stabilize power supply.
Resistor	Set filter cutoff frequencies, op-amp gain, and voltage divider for biasing Vref.
Potentiometer	Act as adjustable gain controls for Bass, Mid, and Treble (tone control knobs).
Audio Jack Breakout Board	One for input (from phone/laptop) and one for output (to speaker/headphones).
Breadboard	For assembling the circuit hardware.
Power Supply / 9V Batteries	Powers the entire circuit (both op-amps and amplifier).
Laptop	To generate or record audio signals and documentation.
Speaker/Headphones	Outputs the filtered and amplified audio signal.
Connecting Wires	Used to interconnect all components on the breadboard.
PCB	For assembling the circuit hardware.
Veroboard	For assembling the circuit hardware.
Multimeter	To measure voltage, current, and resistance at various points.
Oscilloscope	To visualize and analyze input/output audio waveforms.
Function Generator	To provide test input signals (e.g. sine waves at different frequencies).
Soldering Iron	For soldering components onto the PCB.
Soldering Wire	Used to make electrical connections between components.
Cutter	To cut wires.
Plier	To hold and place components on the breadboard.
Stripper	To cut the edges of the wires.

## VIII. Expected Outcomes

- **Functional 3-Band Audio Equalizer Circuit**  
The project is expected to produce a working audio equalizer capable of dividing an input audio signal into three distinct frequency bands — bass (low), mid, and treble (high). Each band can be independently adjusted using potentiometers to control gain, allowing for precise tone shaping.
- **Clear Signal Amplification through Preamplifier Stage**  
The preamplifier (implemented using an op-amp such as LM741/LM358) is expected to successfully boost the weak input audio signal from the source to a sufficient level for further processing without introducing distortion or noise.
- **Smooth Frequency Control via Tone Adjustment Knobs**  
The bass, mid, and treble knobs will enable smooth and continuous adjustment of each frequency band's intensity.
  - Increasing the bass knob enhances low-frequency sounds (e.g. drums, bass guitar).
  - Increasing the mid knob enhances vocals and mid-range instruments.
  - Increasing the treble knob enhances high-frequency components (e.g. cymbals, strings).
- **Accurate Summation of Frequency Bands**  
The summing amplifier stage will combine the three processed signals into a single composite audio output without phase distortion or signal loss. This ensures that the modified sound maintains clarity and balance across all frequencies.
- **Audible Output through Power Amplifier Stage**  
The LM386/LM358 audio amplifier will amplify the summed signal sufficiently to drive a small speaker. The expected output is a clear and adjustable audio playback reflecting the chosen bass, mid, and treble settings.
- **Visualization and Testing**  
Using an oscilloscope, the waveform of the processed audio signal should display noticeable amplitude variations corresponding to different knob positions. The frequency response curves should confirm effective separation and control of low, mid, and high bands.
- **Stable and Low-Noise Operation**  
The entire circuit is expected to operate stably under the given supply voltage (9–12V), with minimal background noise, hum, or distortion during playback.
- **User-Friendly and Compact Design**  
The final prototype is expected to be compact, easy to operate, and demonstrate a clear understanding of audio signal processing, filtering, and amplification concepts.

## IX. Division of Tasks

The project was divided among team members to ensure efficient workflow and proper coordination between design, simulation, and hardware implementation stages. Each member will contribute according to their area of expertise and interest, as outlined below:

Tasks	Description	Member(s)
<b>Problem Identification &amp; Research</b>	Researching real-world issues related to audio filtering and deciding on the equalizer design concept.	Syeda Fatima Alam
<b>Circuit Design &amp; Calculations</b>	Designing low-pass, band-pass, and high-pass filter circuits; calculating component values (resistors, capacitors) and gain.	Syeda Sidrah Bilal Hashmy, Rafay Ahmed Khan
<b>Simulation (PSpice)</b>	Building and simulating the circuit on PSpice to verify cutoff frequencies, gain, and frequency response.	All
<b>Hardware Implementation</b>	Constructing the circuit on breadboard/Veroboard, wiring components neatly, and ensuring proper grounding.	All
<b>Testing &amp; Troubleshooting</b>	Measuring output using oscilloscope and function generator; comparing practical and simulated results.	All
<b>Report Writing &amp; Documentation</b>	Preparing project proposal, progress reports, and final documentation including data analysis and results.	All
<b>Presentation &amp; Demonstration</b>	Preparing and delivering the final presentation and explaining the project operation to evaluators.	All

## A. References

References in IEEE standard format.

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- [2] R. Teja, “Summing Amplifier,” *ElectronicsHub*, Apr. 2, 2024. [Online]. Available: <https://www.electronicshub.org/summing-amplifier/>. [Accessed: Oct. 26, 2025].
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- [4] “Build a Great-Sounding Audio Amplifier with Bass Boost from the LM386,” *CircuitBasics*. [Online]. Available: <https://www.circuitbasics.com/build-a-great-sounding-audio-amplifier-with-bass-boost-from-the-lm386/>. [Accessed: Oct. 26, 2025].
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## B. Data Sheets

- [1] Texas Instruments, “LM741 Operational Amplifier Datasheet (Rev. D),” Oct. 30, 2015. [Online]. Available: <https://www.ti.com/lit/ds/symlink/lm741.pdf>. [Accessed: Oct. 26, 2025]
- [2] Texas Instruments, “LM358 Dual Operational Amplifiers Datasheet (Rev. J),” Mar. 14, 2022. [Online]. Available: <https://www.ti.com/lit/ds/symlink/lm358.pdf>. [Accessed: Oct. 26, 2025].
- [3] Texas Instruments, “LM324 Quad-Operational Amplifier Datasheet (Rev. SLOS066AD – September 1975, Revised October 2024),” [Online]. Available: <https://www.ti.com/lit/ds/symlink/lm324.pdf>. [Accessed: Oct. 26, 2025].
- [4] Texas Instruments, “LM386 Low Voltage Audio Power Amplifier Datasheet (Rev. D),” Aug. 31, 2023. [Online]. Available: <https://www.ti.com/lit/ds/symlink/lm386.pdf>. [Accessed: Oct. 26, 2025].

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