EE389: Electronic Design Lab II

Hi-Fidelity Discrete Audio Amplifier

Group 4

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Project Guide

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*“**Without audio amplifiers**, Elvis Presley and the Beatles would have been limited to audiences within the confines of their audible vocal range. Rock ’n Roll could not exist. All musical instruments would have to be acoustic and there would be no point recording them. Preachers could not be heard in large church buildings, dance bands would have to revert to orchestration and the city of Nashville would have to come up with an entirely new tourist attraction. In essence, **our culture, as we know it today, would die**.”*

***- G. Randy Slone** ,*

‘High power Audio Amplifier Construction Manual’

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1. Introduction

Audio amplifiers are very widely used in day-to-day lives. Many engineers have delved deep in this topic and state-of-the-art audio amplifiers are commercially available.

The aim of this project was to design an analog audio amplifier which was to satisfy the following requirements:

Use of discrete components: Since the goal of this project was to gain experience in analog electronics, it was expected to avoid using commercially available ICs as far as possible.

Hi-Fidelity: It was aimed to obtain uniform gain and minimum noise and distortion in the audio frequency range.

2. Rationale and Motivation

The motivation behind the project was simple. Since most of our experience has been with digital electronics, we wanted to explore analog design.

The choice of analog amplifier was made because analog amplifiers are very widely used and much engineering effort has gone into the same. They have very intricate design and several possibilities to explore.

The approach we took was to study the different facets of amplifiers such as tone control, voltage and power amplification, safety, reliability. Then we studied the design strategies and circuits.

We then tweaked the circuits to accommodate in our requirements and constraints. After simulating them using LTspice, we finalized the designs.

3. Technical Specifications

When we started off the project, the following technical specifications were targeted:

Total Harmonic Distortion (THD): THD is the ratio of sum of powers of all harmonic components to the power of fundamental frequency. Lesser THD implies a more accurate reproduction by reducing harmonics added by the circuit components. For high-fidelity design, a THD below 1% is considered adequate and inaudible to human ear. We aimed at obtaining a **THD of 0.1%.**

Output power: Commercially available audio amplifiers provide an output power of up to thousands of watts from very low power input. For this project, we aimed at obtaining **20W output.**

4. High Level Description

The amplifier consists of three stages:

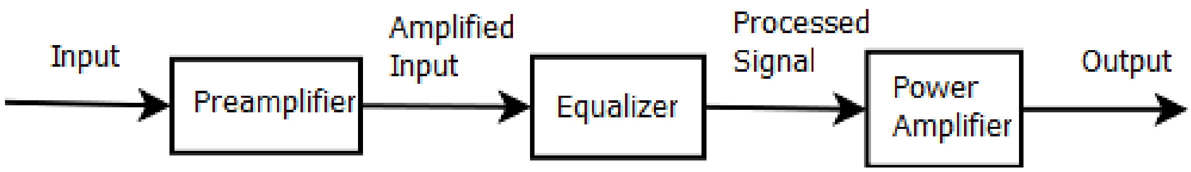
Preamplifier: The input signal is typically very low power. Any further processing, such as tone control, may introduce comparable noise and distortion. The preamplifier is a low-noise low-distortion circuit which amplifies the input so that it can be processed in the future stages.

Tone Control: The tone control or equalizer stage modifies the signal by changing the frequency response of the circuit to suit the listener's liking. It performs two functions:

Treble Boost/Cut: Amplify/Attenuate high frequency components.

Bass Boost/Cut: Amplify/Attenuate low frequency components.

Power Amplifier: The power amplifier stage boosts the signal power in order to drive the output (e.g. speakers)



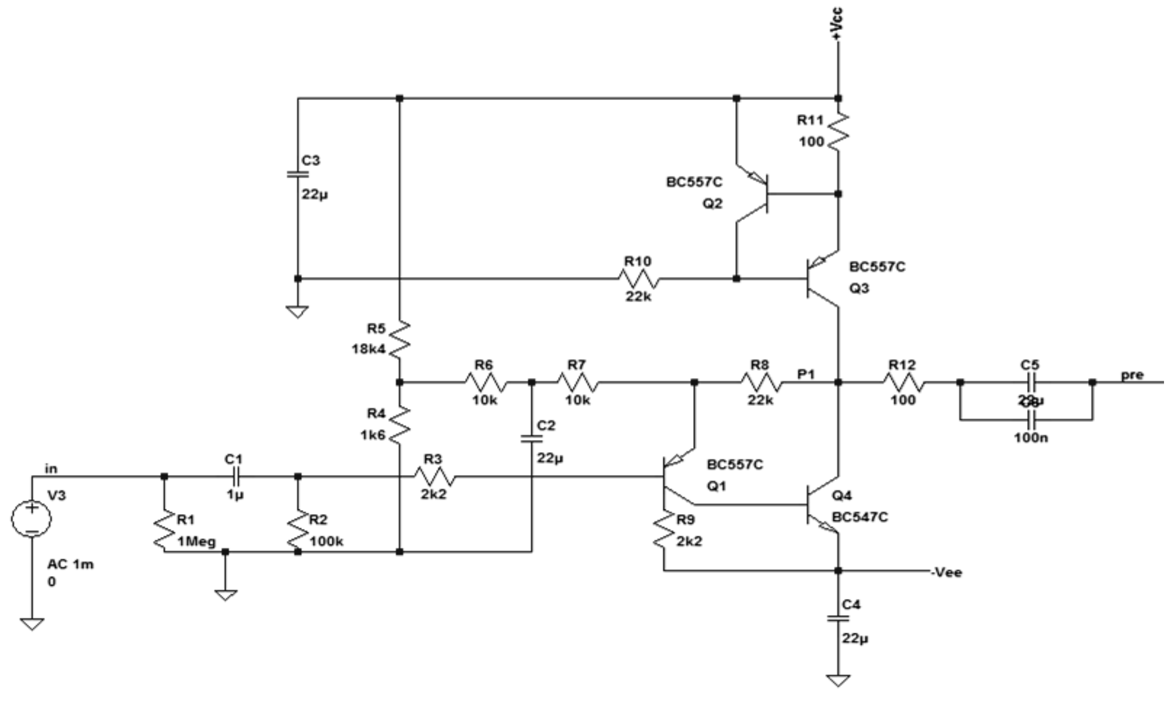
Amplifier Stages: *Block Diagram of the amplifier*

5. Circuit Description

The four main stages of the amplifier are described below, along with the circuit schematic and description:

5.1. Pre-amplifier

The preamplifier stage consists of a voltage amplifier. The voltage amplification stage consists of a compound pair with a current source load. The 2 transistors Q2 and Q3 make up the load. Q1 and Q4 correspond to the compound. The gain of the amplifier is limited by global negative feedback. This also makes the gain very predictable. DC coupling is an option by accurately setting the collector of Q2 and Q3 to as close to zero volts. Volume control potentiometer changes the gain of the pre-amplifier by changing the feedback ratio. This affects the DC biasing slightly and hence we have chosen to use AC coupling.



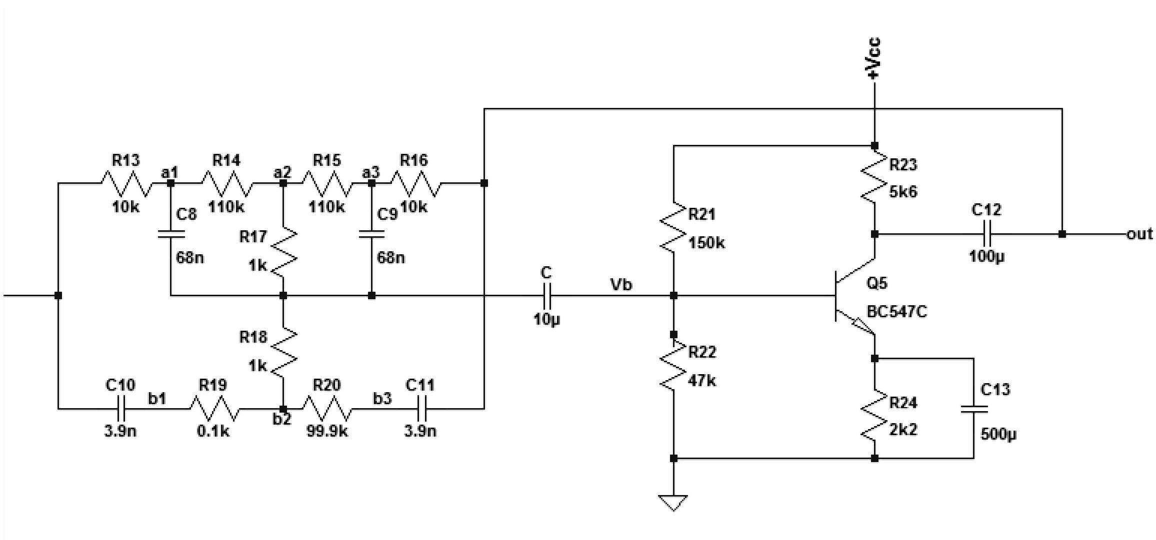
Preamplifier: *Schematic*

The pre-amplifier stage has very high linearity and for the potentiometer ratio chosen can give up to 20dB gain. THD for the pre-amp alone is well below 0.1%. Another notable feature is that the supply is +/-15V which is compatible with the other stages used.

The specifications are summarized in the following table:
Total harmonic Distortion: < 0.1%
Output Impedance: 200 Ω
Minimum Load: 3k Ω
Frequency Response: 10 Hz – 100 kHz (-0.1dB)
Voltage Gain: 20dB nominal
Supply Voltage: ±15V
Supply Current: <10mA

5.2. Equalizer

For equalization we have chosen a simple tone control circuit. More specifically we have chosen the Baxandall tone control circuit. This circuit provides us with bass and treble control. The added simplicity of the circuit is that it needs just one active component to implement. The idea behind it is simple. The upper passive network is supposed to provide a path for the low frequency components and the lower passive network is supposed to provide a path for the high frequency components. By choosing the appropriate value on the potentiometers we can modify both the frequency domain independently. The amplifier ahead of the passive network operates in negative feedback with the passive network setting the amplification ratio for each band of frequencies. This stage is also capacitively coupled to the rest of the network.



Equalizer: *Schematic*

5.3. Power Amplifier

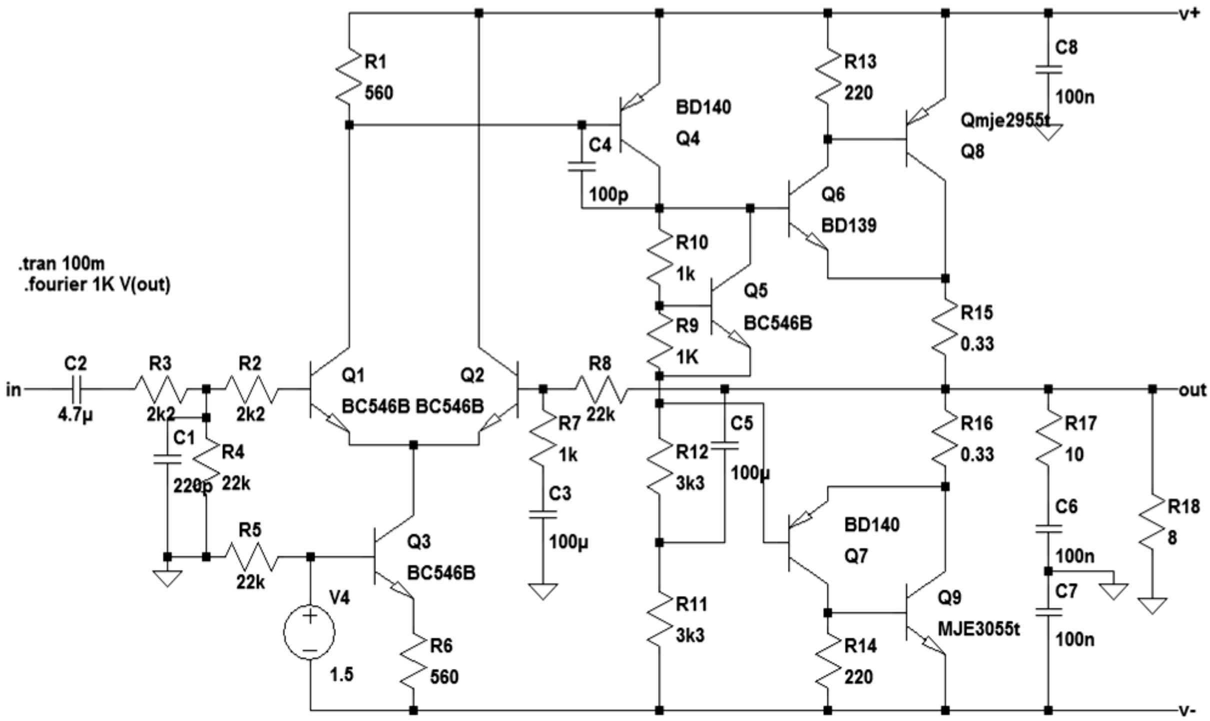
The power amplifier is based on a very standard desgin template. The idea is that we have a input-stage followed by a voltage-amplification stage followed by an output stage

The circuits chosen for the three stages are as follows:

Input stage: Long Tailed Differential Pair with a Current Source Load

Voltage Amplification Stage (VAS): Common Emitter

Output Stage: Class AB output stage



***Power Amplifier:** Schematic*

5.4. Power Supply

The power supply is custom designed. It consists of 20-0-20 transformer, with a 3A current rating follwed by a bridge-rectifier and capacitors to maintain the output voltage. For the equalizer part of the circuit this supply is then regulated to +/-15V supply.

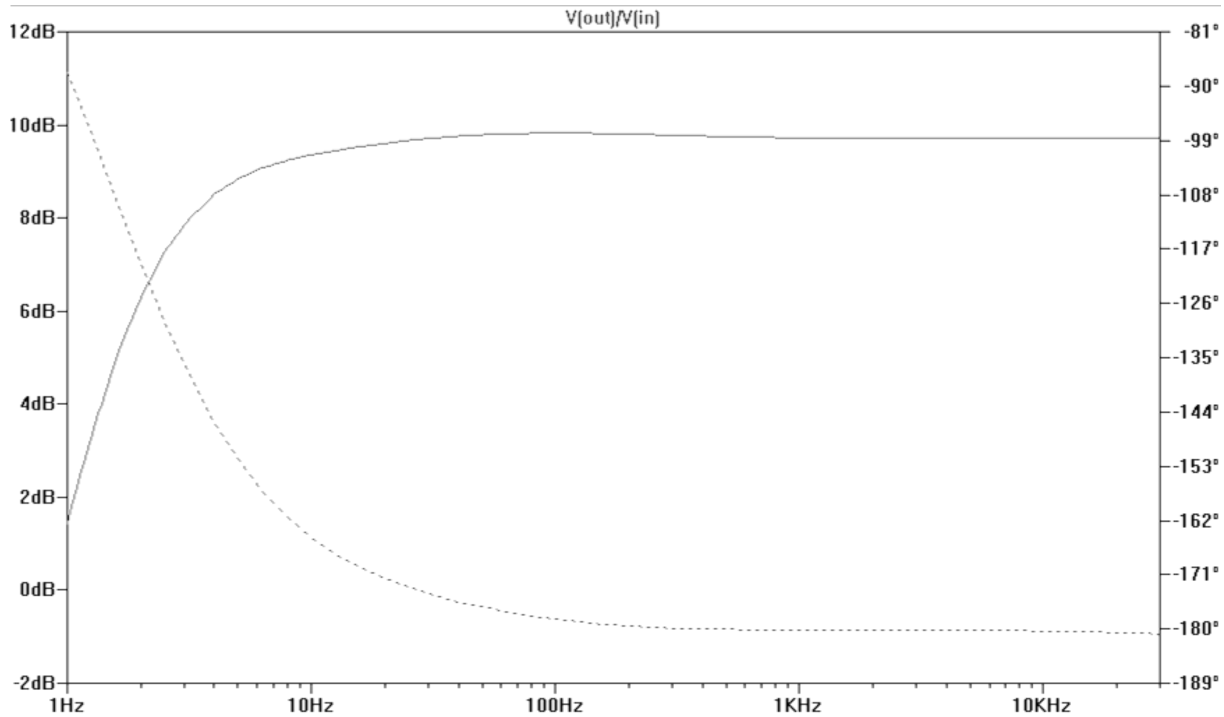
6. LTspice Results

The results of SPICE simulations for all the three are included below

6.1. Pre-amplifier

For the preamplifier, the DC operating point analysis showed the output bias to be 0.0008 V which is close to zero as required.

The AC analysis shows the gain to be constant at 10dB in the audio range.



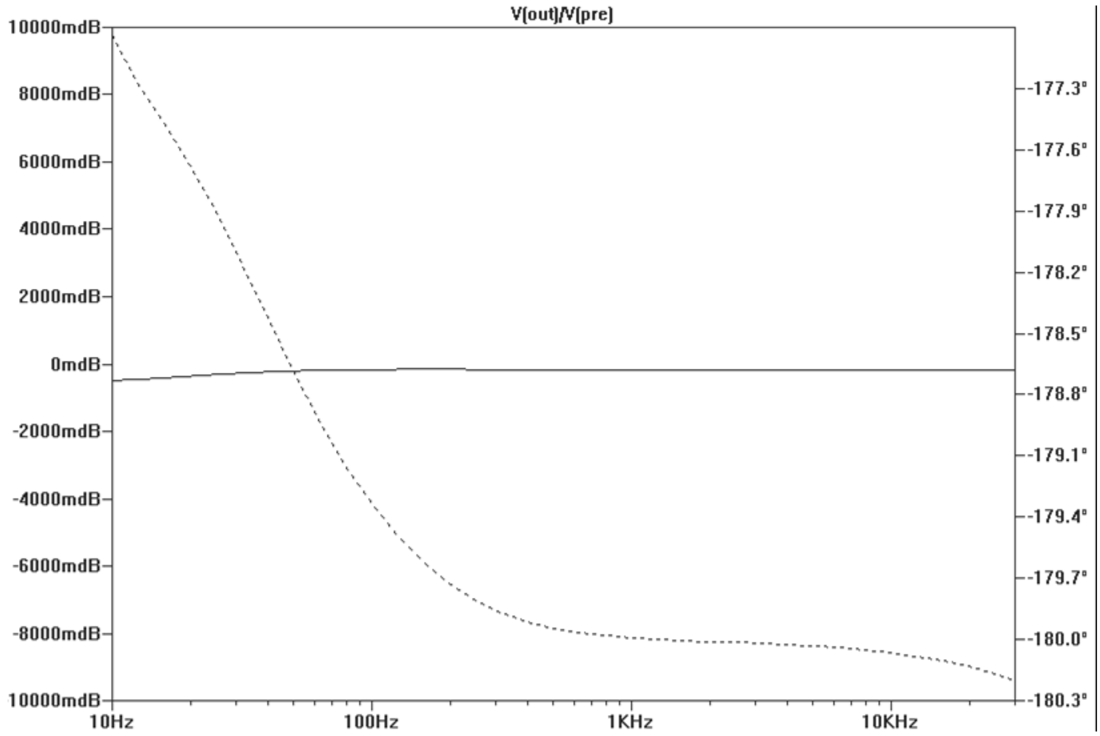
Preamplifier Output: *Uniform gain for 20Hz to 20kHz.*

6.2. Tone Control

The DC operating point of the output after tone control stage is also observed to be 0.0008 V.

In normal mode, the tone control circuit merely passes the signal as it is. The attenuation is of the order of 0.2 dB

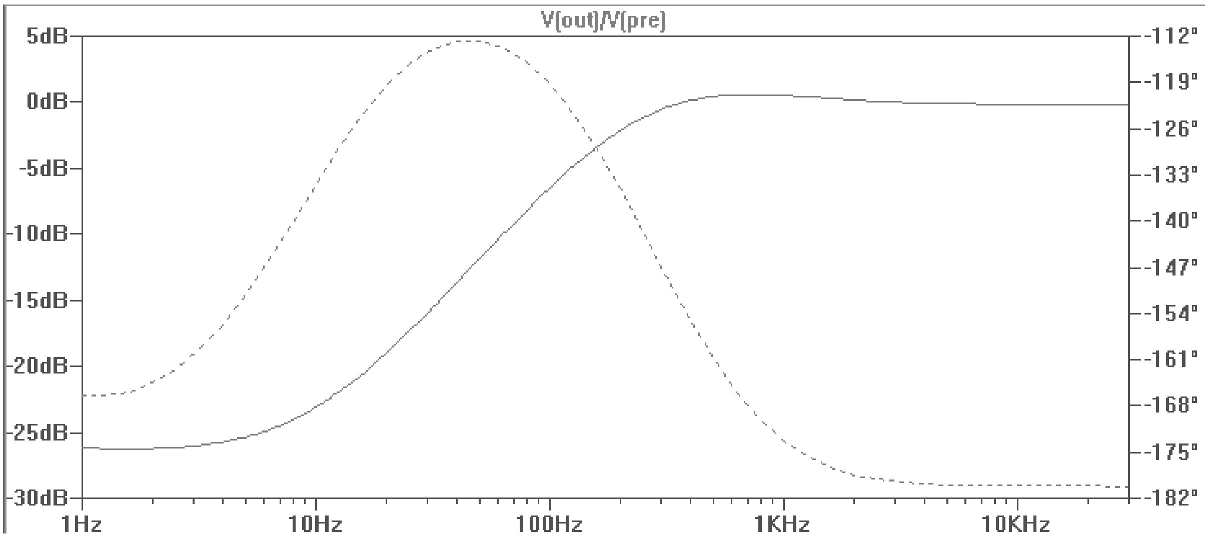
Thus, in absence of any tone control settings, we obtain a flat response with no gain of attenuation.



Tone Control: *Normal Mode*

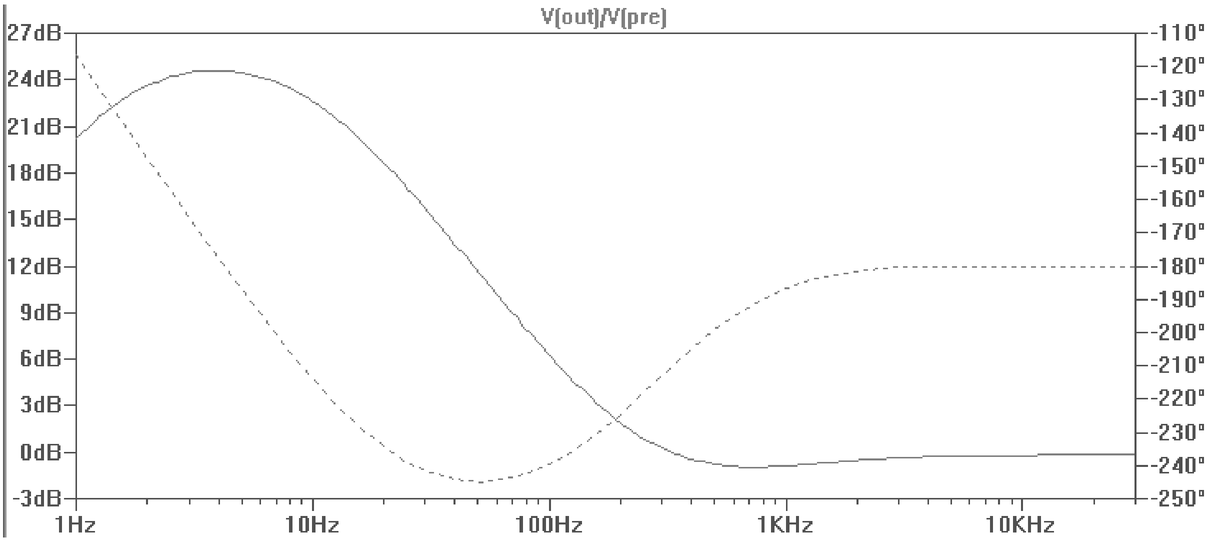
By changing the potentiometer values for bass and treble arms in the Baxandall circuit, the following four conditions were obtained – Bass cut, Bass boost, Treble cut, Treble boost. These were analyzed separately and the following results were observed:

Bass Cut: Low frequencies are attenuated and high frequencies are passed ahead with no change.



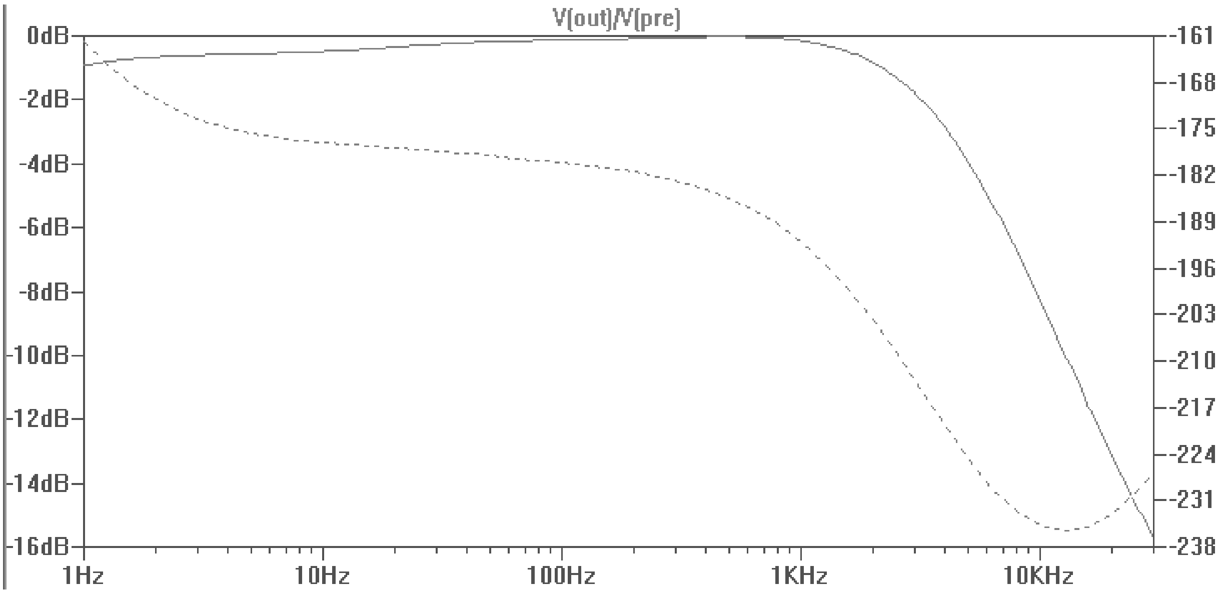
Tone Control: *Bass Cut*

Bass Boost: Low frequencies are amplified and high frequencies passed as they are.



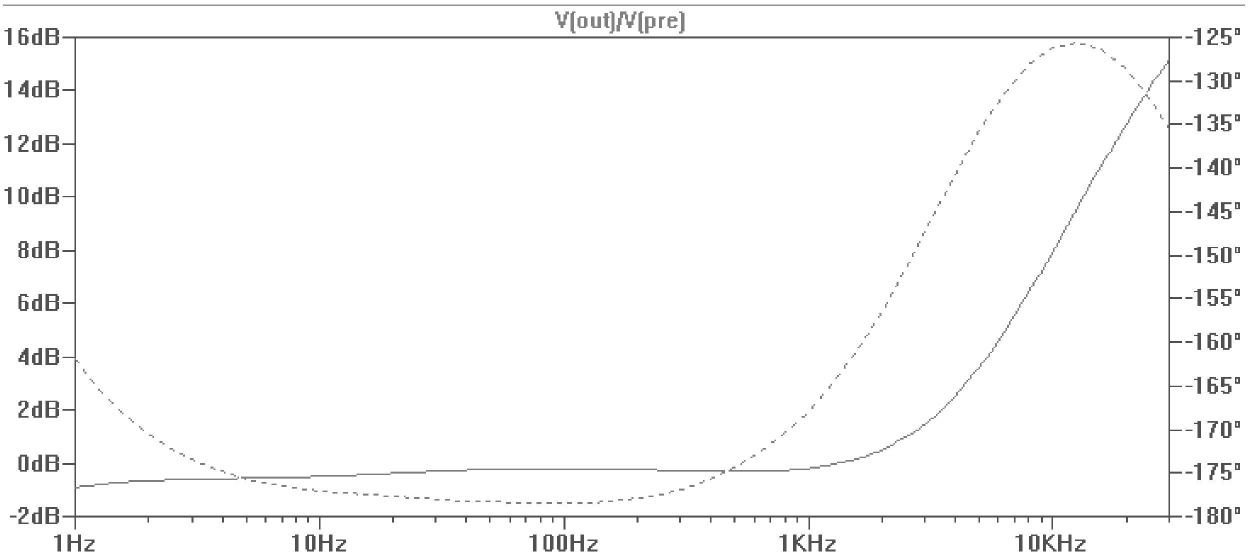
Tone Control: *Bass Boost*

Treble Cut: High frequency attenuation is obtained.



Tone Control: *Treble Cut*

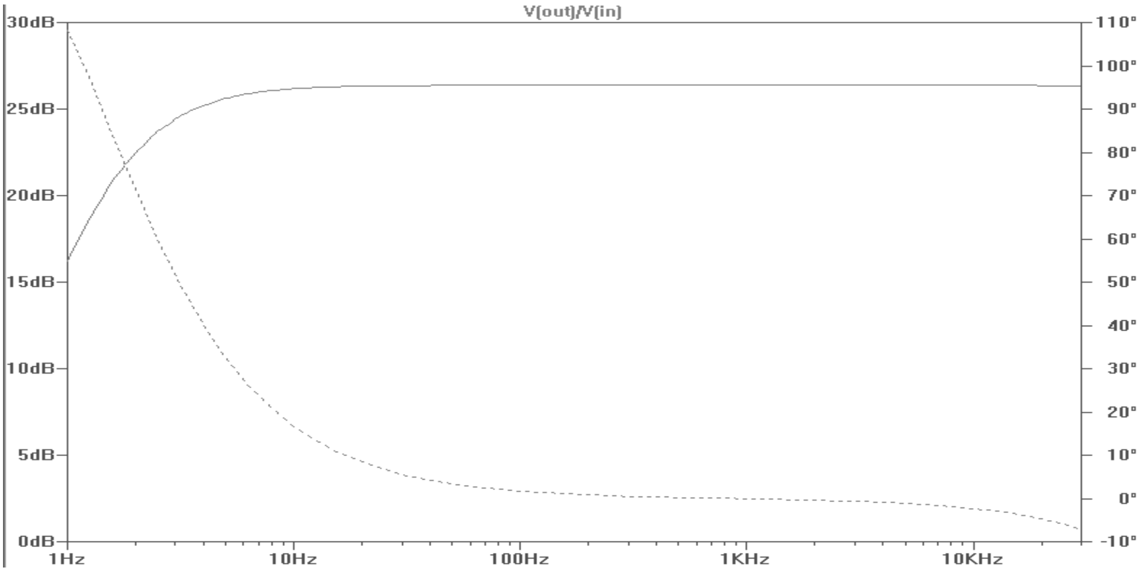
Treble Boost: High frequencies are amplified and low frequencies are almost unaffected.



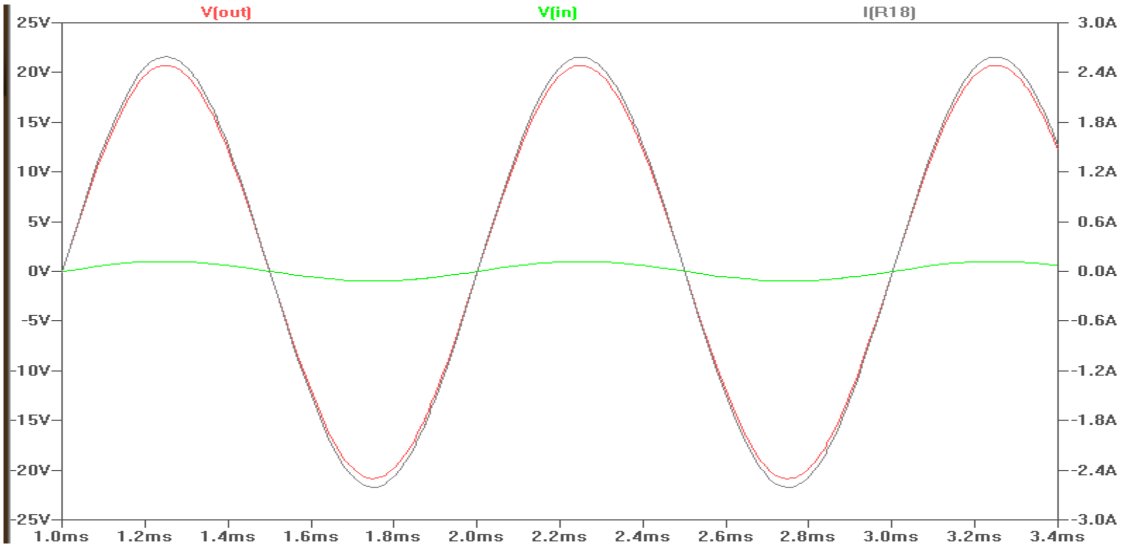
Tone Control: *Treble Boost*

6.3. Power Amplifier

The frequency response of the power amplifier shows a uniform gain in the audio range while the transient response shows an output voltage of ~20V and output current of ~2.5A.



Power Amplifier: *Frequency Response*

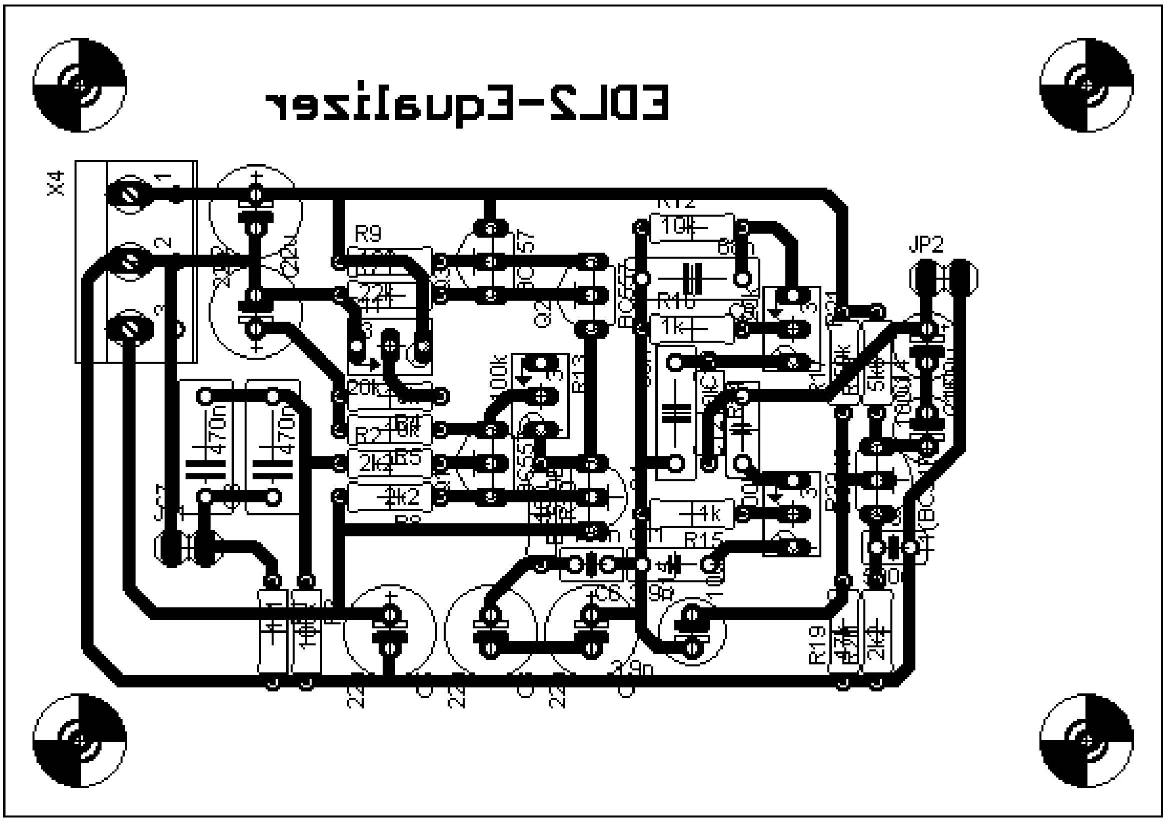


Power Amplifier: *Transient Response*

7. Fabrication

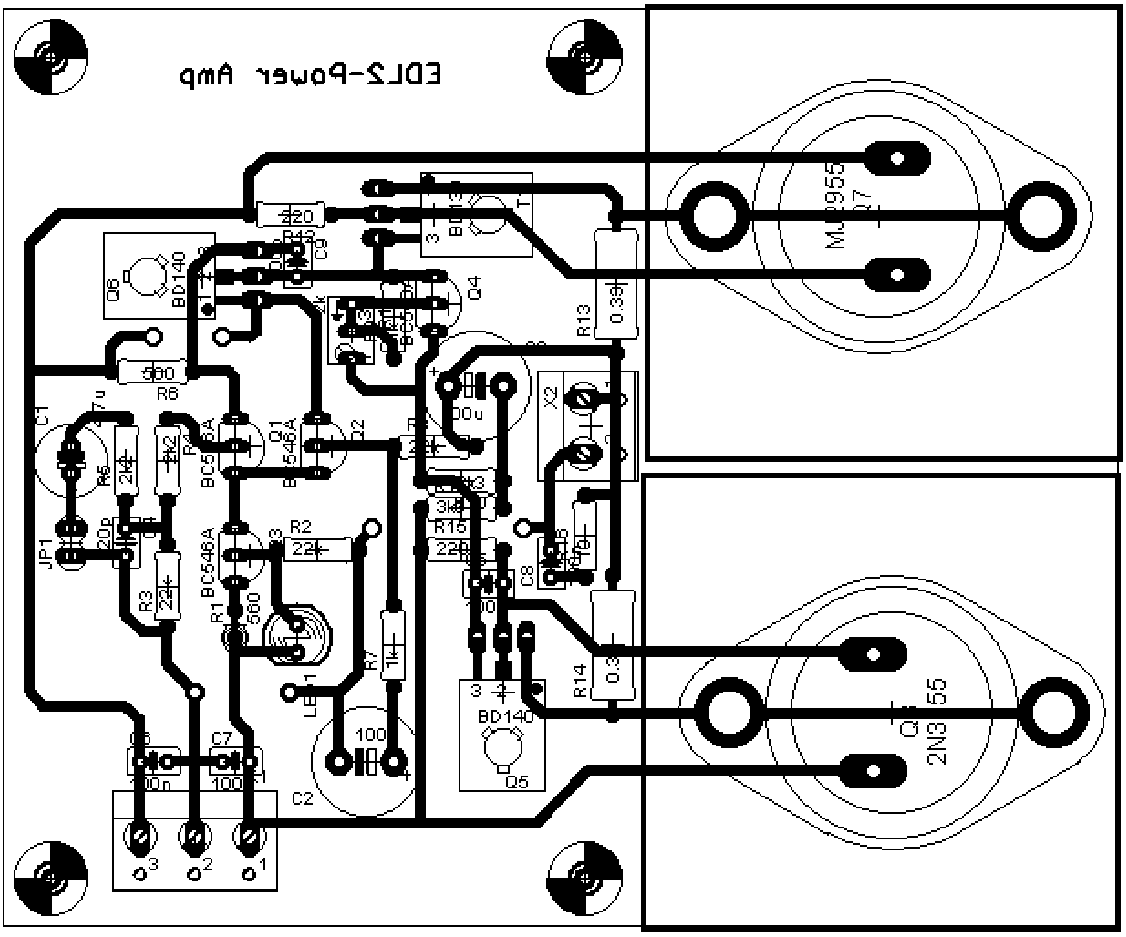
The circuit is routed on 2 boards, one for preamplifier and equalizer and the other containing the power amplifier. The designs for the same are:

Preamplifier and Equalizer



Preamplifier and Equalizer: *PCB Layout*

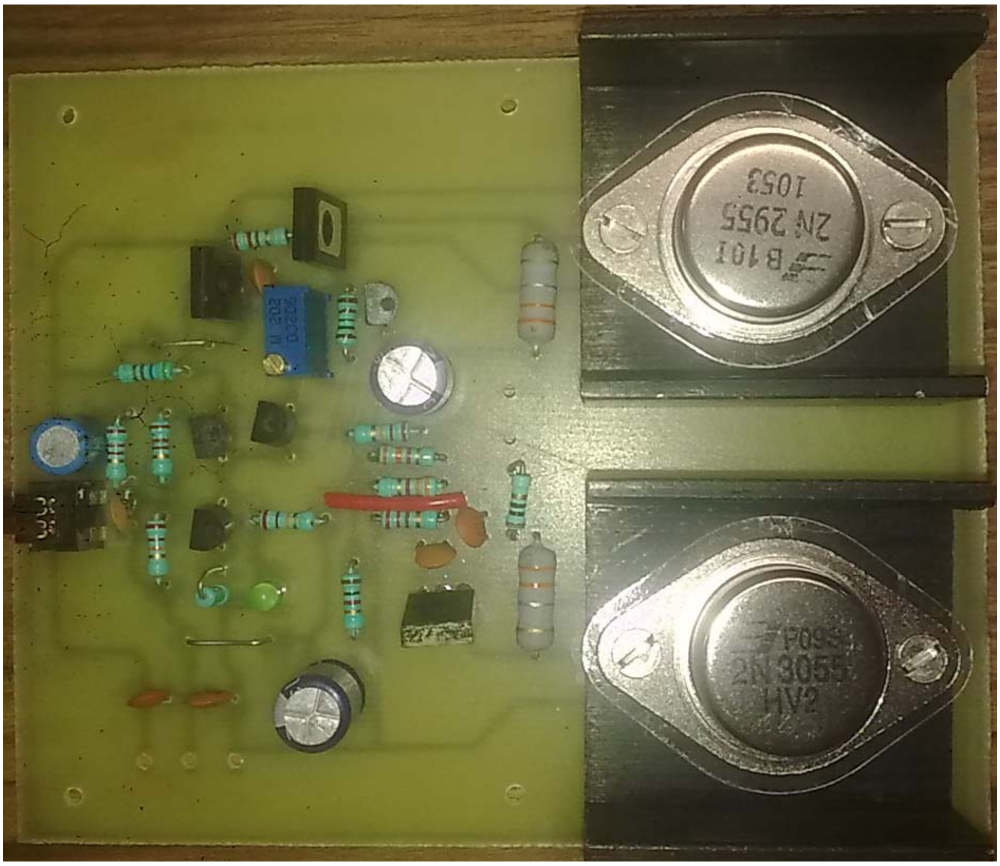
Power Amplifier



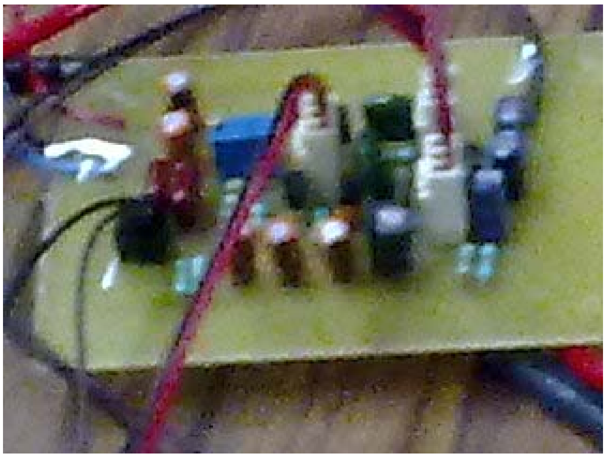
Power Amplifier: *PCB Layout*

The preamplifier and equalizer board is stacked on the left side of the power amp board. The large squares around the power transistors are heat-sinks.

The Final Boards



Power Amplifier *(Above) and* ***Preamplifier an Equalizer*** *(Below): Final Circuits*



8. Conclusion

The results obtained were satisfactorily close to the targeted values. This amplifier is suitable for low power applications such as music systems for personal use, e.g. household speakers/music system in a vehicle.

The design can be improved by using more advanced designs such as multi stage amplification, IC components, high power devices, digital controls and better fabrication to obtain better THD and higher output power.

We can conclude that, the purpose of this project, which was to explore analog design and lay a foundation for future work, has been fulfilled.

References

Audio Power Amplifier Handbook: Douglas Self

The Art of Linear Electronics: John Linsley Hood

High power Audio Amplifier Construction Manual: G. Randy Slone

Self of Audio: Douglas Self

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Elliot Sound Products Website: http://sound.westhost.com

Notes for EE735: Prof. D. K. Sharma, IIT Bombay.