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DESINING AUDIO AMPLIFIER

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1. Introduction

An audio power amplifier (or power amp) is an electronic amplifier that amplifies low-power electronic audio signals such as the signal from radio receiver or electric guitar pickup to a level that is high enough for driving loudspeakers or headphones. Audio power amplifiers are found in all manner of sound systems including sound reinforcement, public address and home audio systems and musical instrument amplifiers like guitar amplifiers. It is the final electronic stage in a typical audio playback chain before the signal is sent to the loudspeakers.

While the input signal to an audio power amplifier, such as the signal from an electric guitar, may measure only a few hundred microwatts, its output may be a few watts for small consumer electronics devices, such as clock radios, tens or hundreds of watts for a home stereo system, several thousand watts for a night-club's sound system or tens of thousands of watts for a large rock concert sound reinforcement system.

2. Summary

The goal of this project is to make an Audio Amplifier. We will take input from a mic, pass it through a pre-amplifier stage to convert the input into a stronger and noise tolerant signal so that further amplification can be done on it and we also increase the power so that it helps in driving the speaker.

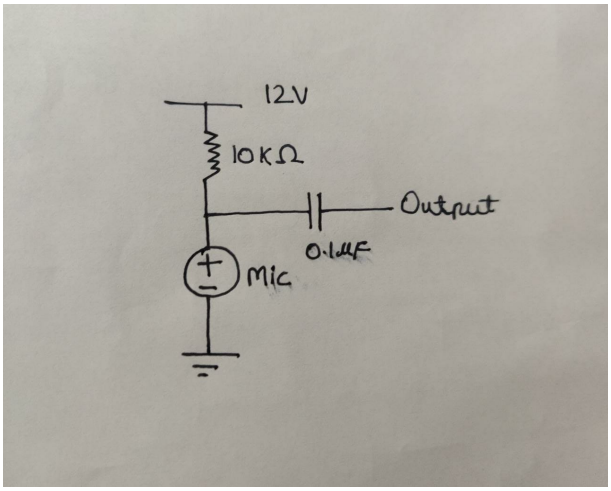
The output is then sent to the Gain Cell so that we get the required voltage for the speaker to function.

The output from the Gain Cell is sent to a filter. We need a band-pass filter which passes frequencies between 20Hz and 20kHz. However, since we are making a first-order filter, we set the cutoffs as 20Hz and 32kHz.

The filtered signal is then sent to a Power Amplifier. The amplifier increases the power of the signal significantly so that a speaker of 8Ω can be operated.

3. Design of Audio Amplifier

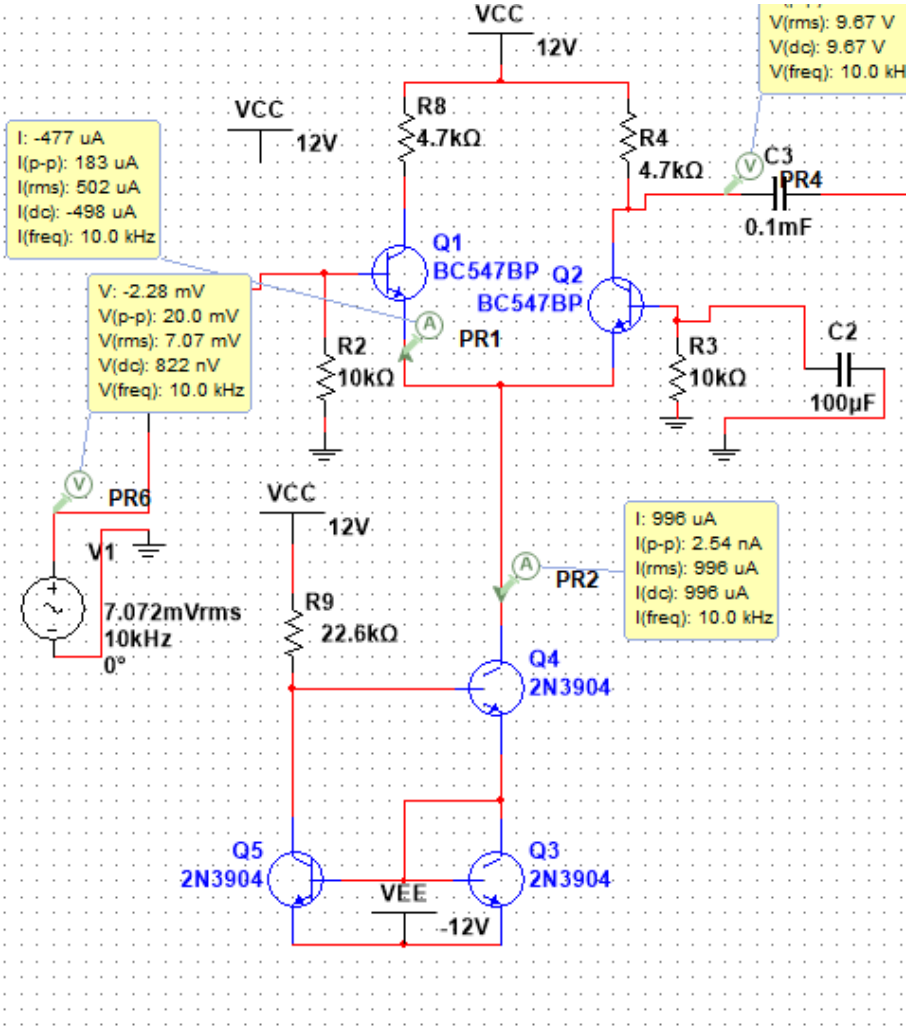
3.1 Mic



This is a standard circuit for a mic. A 12kΩ resistor is used to control sensitivity of the mic and the capacitor is used to remove the DC component, so that only AC signal passes.We adjusted the values of the resistor and capacitor accordingly so that it allows less noise and better input power.

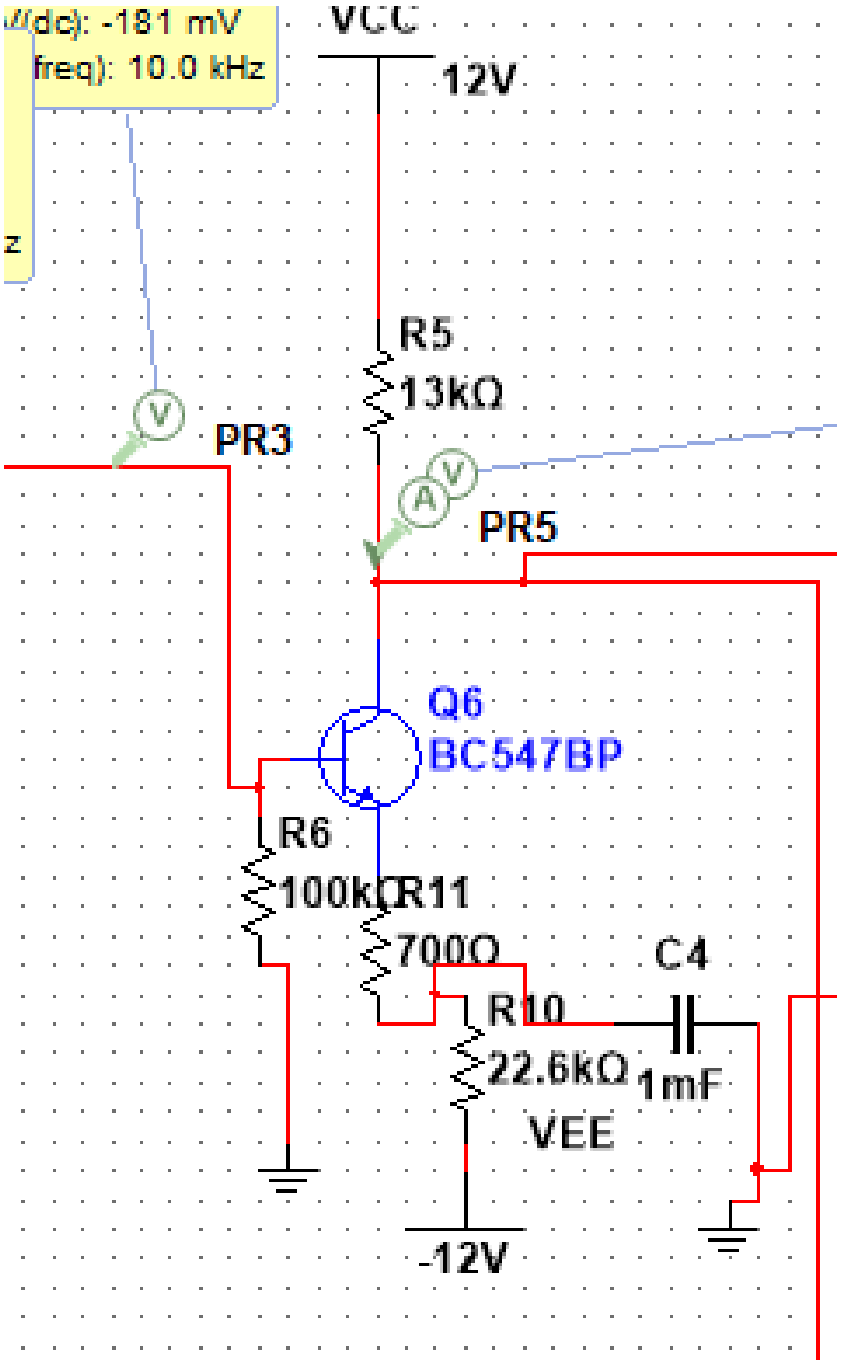
The output of this mic is given to next stages for further processing.

3.2 Pre-amplifier



The requried gain is obtained in 2 stages . Here, we stabilize the input and reduce the noise from the input.This is implemented using a Differential Amplifier so that noise(DC0 is reduced. The noise is reduced by the common mode gain(which is set to 0) or the CMRR of the differential amplifier.The input is stabilised by the differential mode gain.

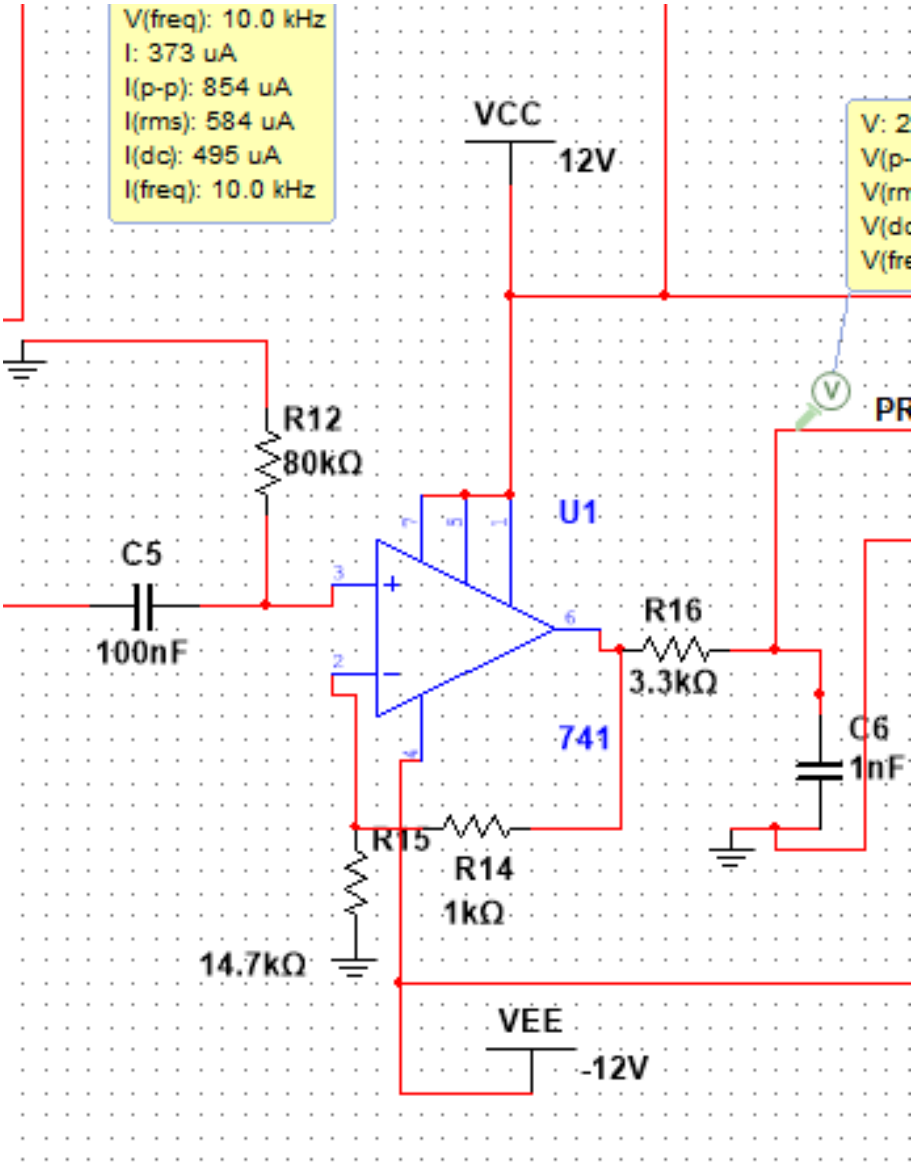
3.3 Gain Cell



In this stage, the voltage gets amplified.This can be achieved through implementing a Common Emitter Amplifier which has our required gain. To ensure no

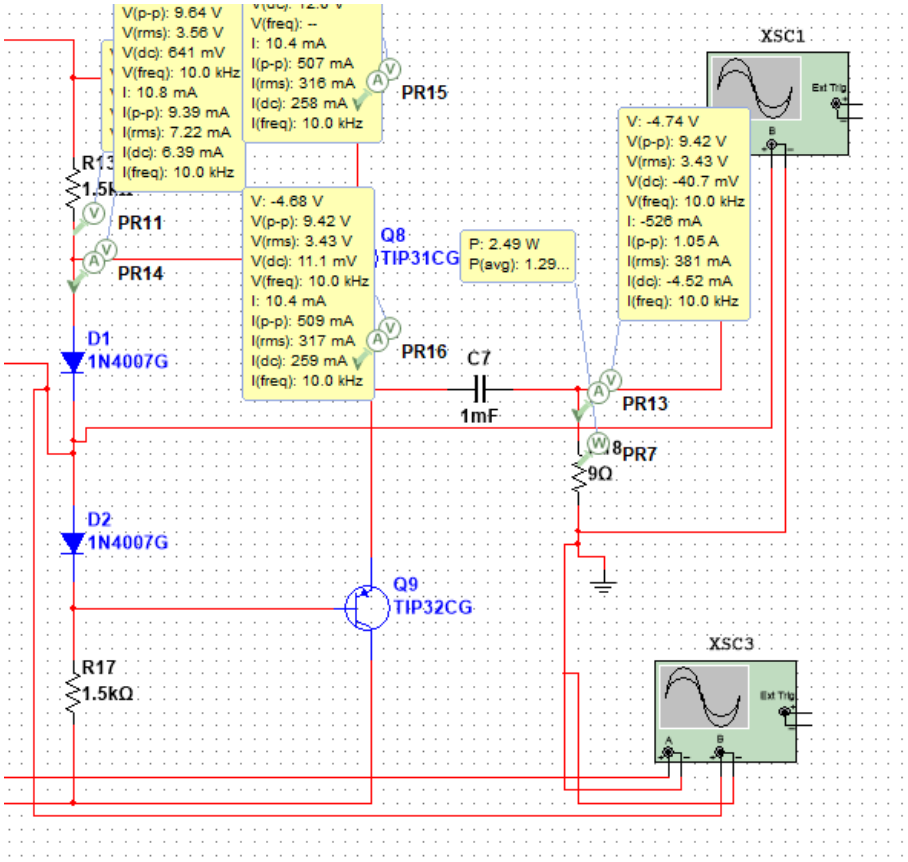
loading on the previous stages we used common emitter in the gain stage which produces gain with high input impedance.

3.4 Filter



The Filter here filters out the unwanted band of frequency .This can be achieved through implementing a band pass filter.It is designed by cascading a active high pass filter with a low pass filter interlinked by a amplifying component.And ensuring the unit gain through the Op-amp.

3.5 Power Amplifier



It acts as a Current gain stage.Power amplifier is able to draw high currents from the source which helps to start the load and can sustain where as other transistors can blow out.Because, junction area of power transistor is greater than normal transistor.Here, we will be using a Class AB output stage as it overcomes a lot of the problems with Class A and B output stages.

4. Implementation and Analysis of the Audio Amplifier

Input $\rightarrow$ 20mV,1kHz Sine wave.

4.1 Differential Amplifier

Setting the Quisient state values are important because it ensure the working of our circuit in linear region.

Base Biasing

A resistance of 10kΩ is connected to ground to ensure that I_b passes through the transistor and the base is biased to a voltage near 0V.

Current Biasing

A fixed current of 1mA is passed through the circuit to ensure the fixed quiscent state values at collector and emitter.

To achieve this, we used Wilson current mirror. R_{Wilson} = (V_{CC} - V_{EE} -1.4)/I_{Ref}.

$$R_{Wilson} = (12 - (-12) - 1.4)/10^{-3}.$$
$$R_{Wlsion} = 22.6k\Omega.$$

Use of Current Mirror

- High Output Impedance - will not load .
- Constant r_e value so that gain remains rhe same.
- High CMRR which helps in removing the noise.
- Robust to voltage changes .

Calculations

$$\text{Gain} = g_m R_C.$$

For single ended output,

$$\text{Gain} = \frac{g_m R_C}{2} = \frac{R_c}{2r_e} = \frac{4700}{2*50} = 47\text{V/V}$$

Input Impedance = $2^*(((\beta+1)^*(r_e)) + R_B) = 2 * ((101 * 50) + 100k) = 210k\Omega$

Output Impedance = $R_C = 4.7k\Omega$

4.2 Gain-Stage

We use Common Emitter amplifier for the rest of the gain due to its high input impedance and

Biasing

Circuit is biased at 0.5mA by placing 180 kΩ at base and 11.3kΩ at emitter.

$$I_{Req} = 0.5mA. V_B \approx 0\text{V}.\ V_{BE} \approx 0.7\text{V}$$

$$R_E = V_{BE} - V_{EE}/I_{Req} = (0.7 - (-12))/0.5mA = 22.6k\Omega$$

To ensure that $V_{CB} > -0.4, For I_{Req} = 0.5mA R_C = 13k\Omega.$

Calculations

Input Impedance = $(\beta+1)\ ^*(r_e + R_e) = (101) * (50 + 700) = 75.8k\omega$

$$Output Impedance \approx R_C = 13k\Omega.$$

$$Gain = -\alpha R_C/(r_e + R_e) \approx -R_C/(r_e + R_e) = -13k/(25 + 700) = -14v/v$$

TOTAL GAIN : $G1 * G2 = 47 * 14 \approx 660v/v$

4.3 Filter

We use an active band-pass filter which is combination of passive high pass and a passive low pass filter with an Op-Amp of unit gain.

LOW PASS FILTER
$V_{Out}/V_{In} = 1/(1+RCS)$
The filter should allow frequencies less than 20kHz.SO,
$V_{Out}/V_{In} \ll 1$ for f$>$ 20kHz
So, values of R and C are chosen accordingly as 3.3kΩ and 1nF respectively. So $f_{cutoff} = 1/2\pi$* R1*C1 $\approx$ 22kHz

HIGH PASS FILTER
$V_{Out}/V_{In} = RCS/(1+RCS)$
The filter should allow frequencies greater than 20Hz.SO,
$V_{Out}/V_{In} \ll 1$ for f$<$ 20Hz
So, values of R and C are chosen accordingly as 80kΩ and 100nF respectively. So $f_{cutoff} = 1/2\pi$* R2*C2 $\approx$ 20Hz

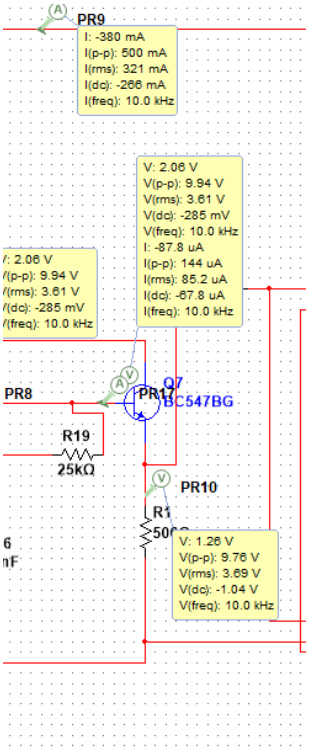
Filter Gain

Filter Gain = 1 + (1k/14.7k) $\approx$ 1.
The high pass filter is placed first due to its high input impedance which ensure there is no loading effect.

4.4 Power-Amplifier

As the output impedance of the filter is low, it may effect both power amp and filter cutoff so, to get rid of this, we place a buffer in between filter and power amp. so to stablise signal and reduce loading.

4.4.1 Buffer



A buffer can be used to stabilise the input and to reduce the loading effect.Generally Common Collector with high value of resistance is used for this.So, we place R_E as 500Ω for impedance matching.

4.4.2 Power-Amplifier

To drive the speaker, we need atleast 1-1.5W power.Normal transistor will not allow high current, so we use power transistors(TIP-31CG TIP-32CG).The circuit produces gain of 1v/v with high current gain.

For biasing, we place we resistors on both sides so that the diodes wont burn which help in reducing the current through the diodes and maintain the DC points.

Diodes are helpful in maintian base-emitter voltage at 0.7V.

Calculations

$$I_{Ref} = (V_{CC} - V_{EE} - 2*V_D)/R_{bias} = 22.6k/2.4k = 9.42mA$$

$$\text{Power} = I^2R_L \approx 1.2W$$

5. Results

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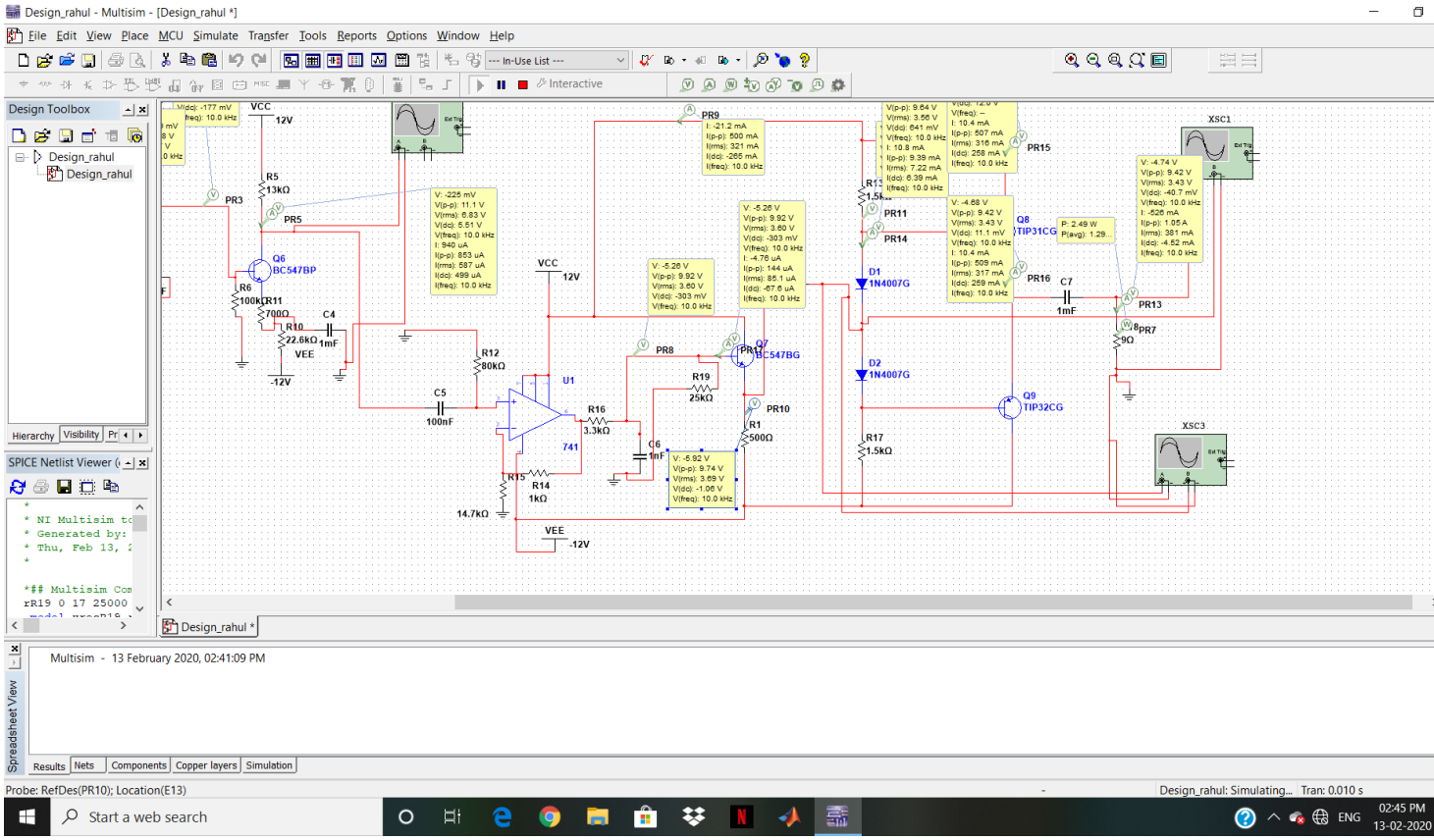
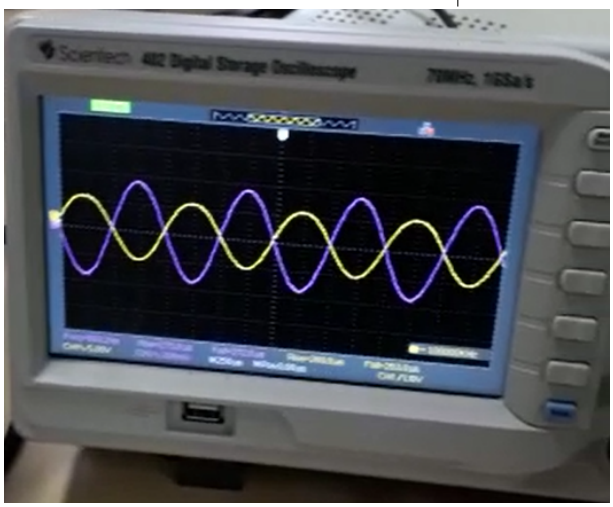


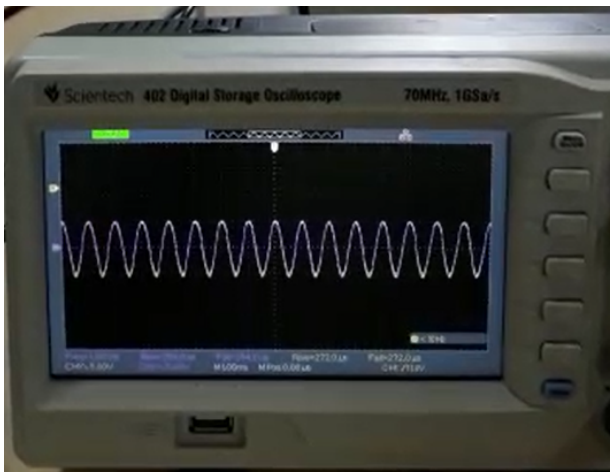
Complete Circuit.

Theoretical Gains	
Circuit component	Gain
Differential Amplifier	47 V/V
Gain Stage	14 V/V
Pass-band Filter	1.01 V/V
Power	1.56W

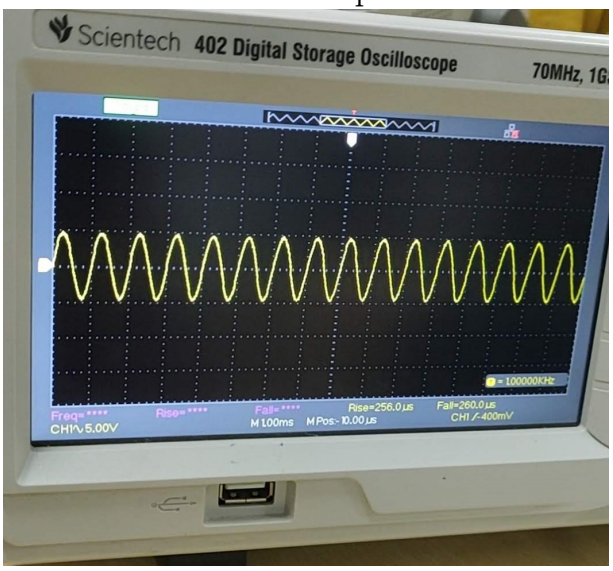
Observed Values	
Circuit component	Value
Diff. Amp. Gain	45 V/V
Gain Stage Gain	12.5 V/V
Pass-band Filter Gain	1.04 V/V
Final Output	4.95 V
Power	1.3W



Diff amp-Blue(200mV/div) Gain Cell – Yellow (5-V/div)

(50).png (50).png 

Filter Output



Power Amp Output

6. Additonal-Features

6.1 Bass and Treble Controls

We can control the frequency band of the audio amplifier by using an OP-Amp with potentiometers. The frequency range controls like bass and treble is very useful for all the users.

6.2 Volume Control

We can control the volume of our Audio Amplifier by installing a potentiometer after the Voltage Gain Stage. This will be extremely helpful for the users to have control over it.

7. Conclusions

Audio electronics can be summarized as converting sound to electrical signals, processing the electrical signals, and turning these processed signals back into sound. This is a straightforward objective; nevertheless, this particular discipline of electrical engineering covers many areas of the EE world. In fact, many practicing engineers spend their entire careers researching, developing, and designing audio electronics and related equipment.

Resources

- Microelectronics and Circuits by Sedra and Smith.
- www.electronictutorials.com
- Audio Amplifier Hand Book - Douglas Self