EW – II
PROJECT REPORT

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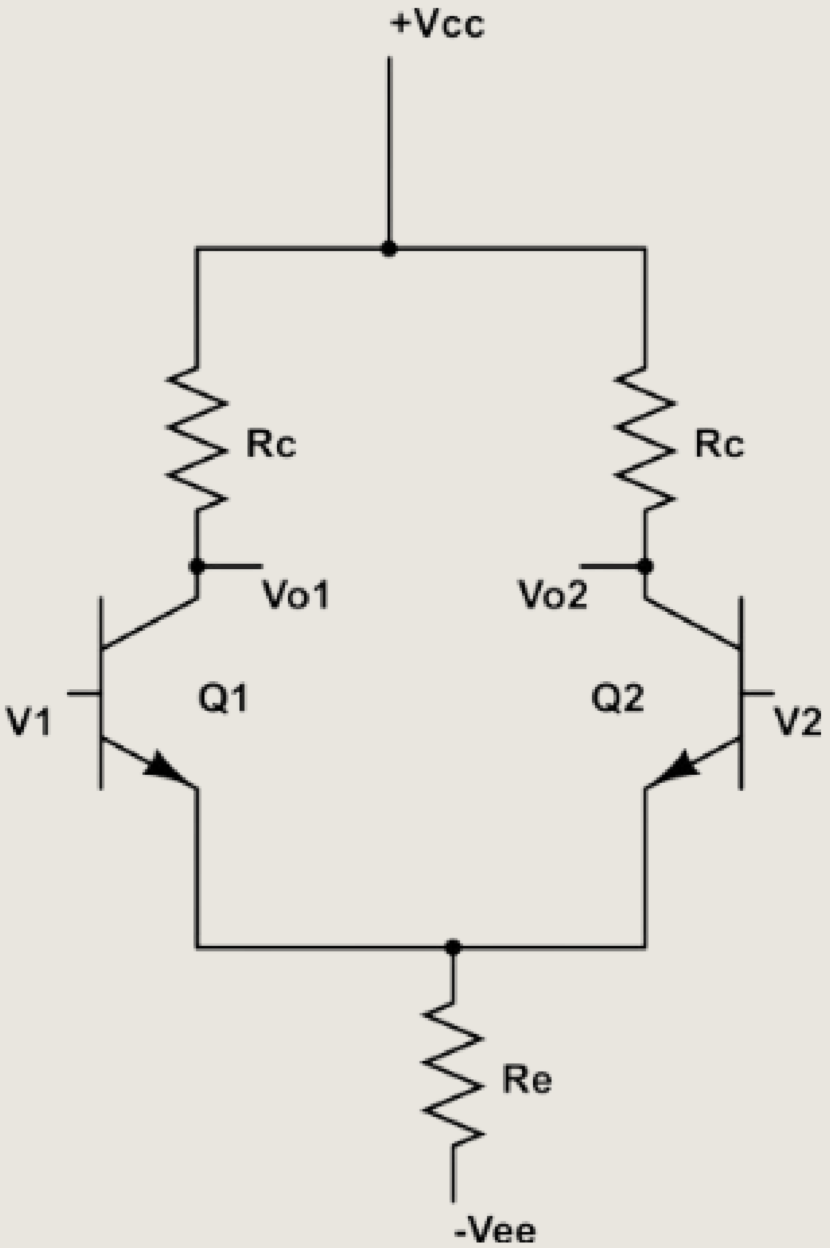
AUDIO AMPLIFIER

PROJECT OVERVIEW

- The aim of this project is to design and develop an audio amplifier that strengthens low power sound signals and drives an 10Ω speaker within a power budget of 0.5W.
- The amplifier is constructed based on several stages, each having a significant contribution towards signal amplification, filtering, and the delivery of power.
- The four stages include -
- Pre-Amplifier Stage – Amplifies low signals while decreasing noise.
- Gain Stage – Adds further voltage amplification.
- Filter Stage – Permits only the specified frequency range to pass. In our case audio signals, ranging from 20Hz to 20kHz.
- Power Amplifier Stage – Provides enough current and voltage to drive the speaker effectively.



PRE – AMPLIFIER STAGE

WORKING PRINCIPLE

- A differential amplifier in common mode
- The input received from mic is very weak(a few mV) so it is necessary to remove noise to maintain the signal. This also helps in matching impedances with next stage.
- Noise in grounded input and actual input are out of phase so they get cancelled.
- It amplifies the signal enough to let it be amplified by gain stage.
- Configuration used is Single Input Balanced Output (SISO)

CALCULATIONS

$$\text{gain} = -g_m R_c$$

$$\text{Gain} = \left(\frac{I_c}{V_T}\right)\left(\frac{R_c}{2}\right)$$

$$I_c = I_s \, e^{V_{BE}/V_T}$$

$$I_c = 2.39\times10^{-14} \times e^{0.72/0.026}$$

$$I_c = 268.75\times10^{-16}\times10^{10}$$

$$I_c = 268.75\ \mu A$$

$$\text{gain} = -g_m R_c$$

$$11 = \frac{268.75\times10^{-6}}{26\times10^{-3}} \times \frac{R_c}{2}$$

$$11\times10^{3} = 5.168 \times R_c$$

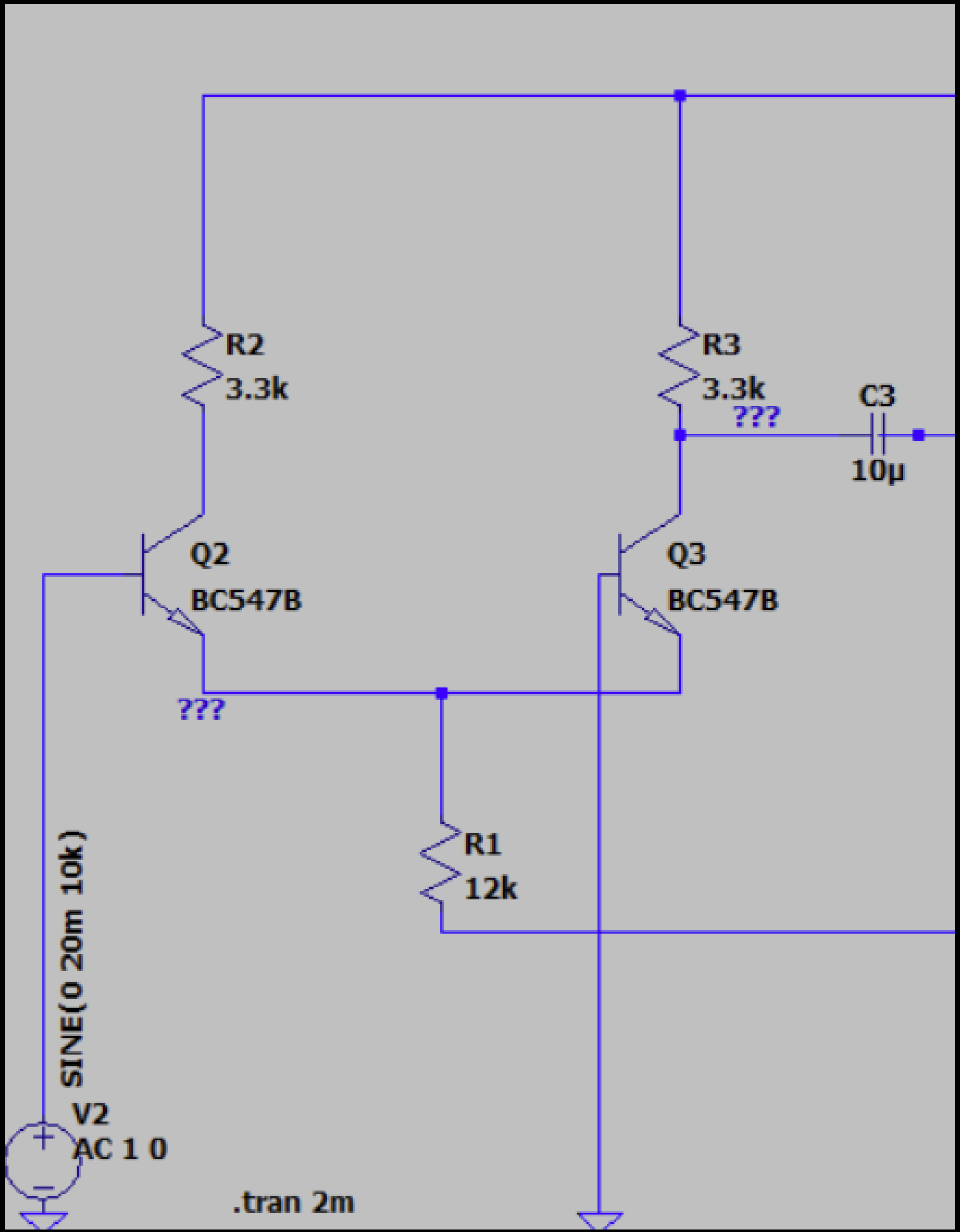
$$R_c = 2.92k\Omega \approx 3k\Omega \qquad \boxed{R_c = 3k}$$

$$I_c = \frac{\overset{5V}{V_{CC}} - \overset{0.7V}{V_{BE}}}{2R_E}$$

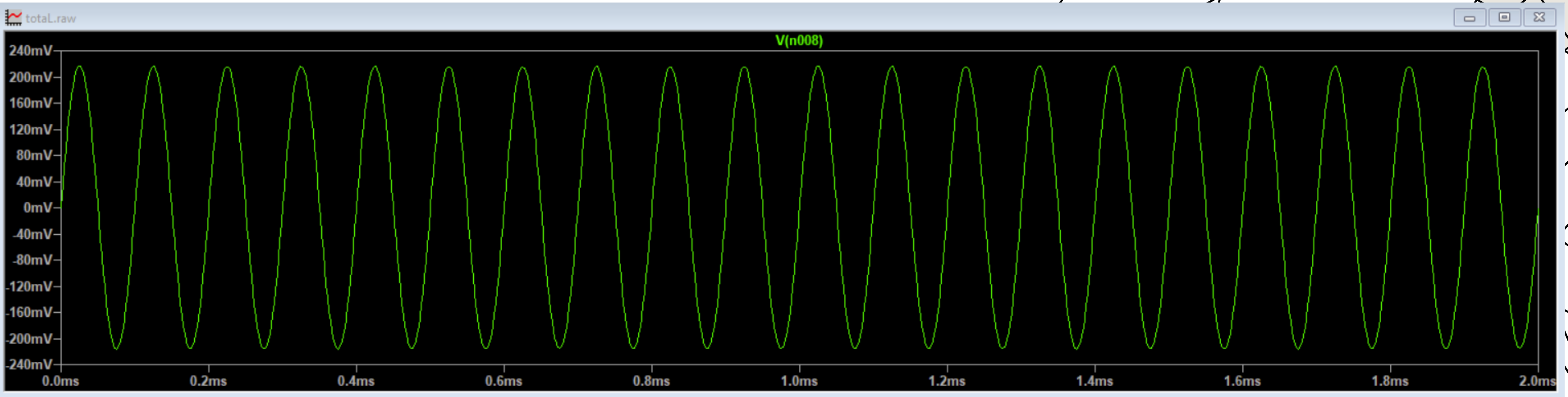
$268.75\ \mu A$

$$R_E \le 12.08k$$

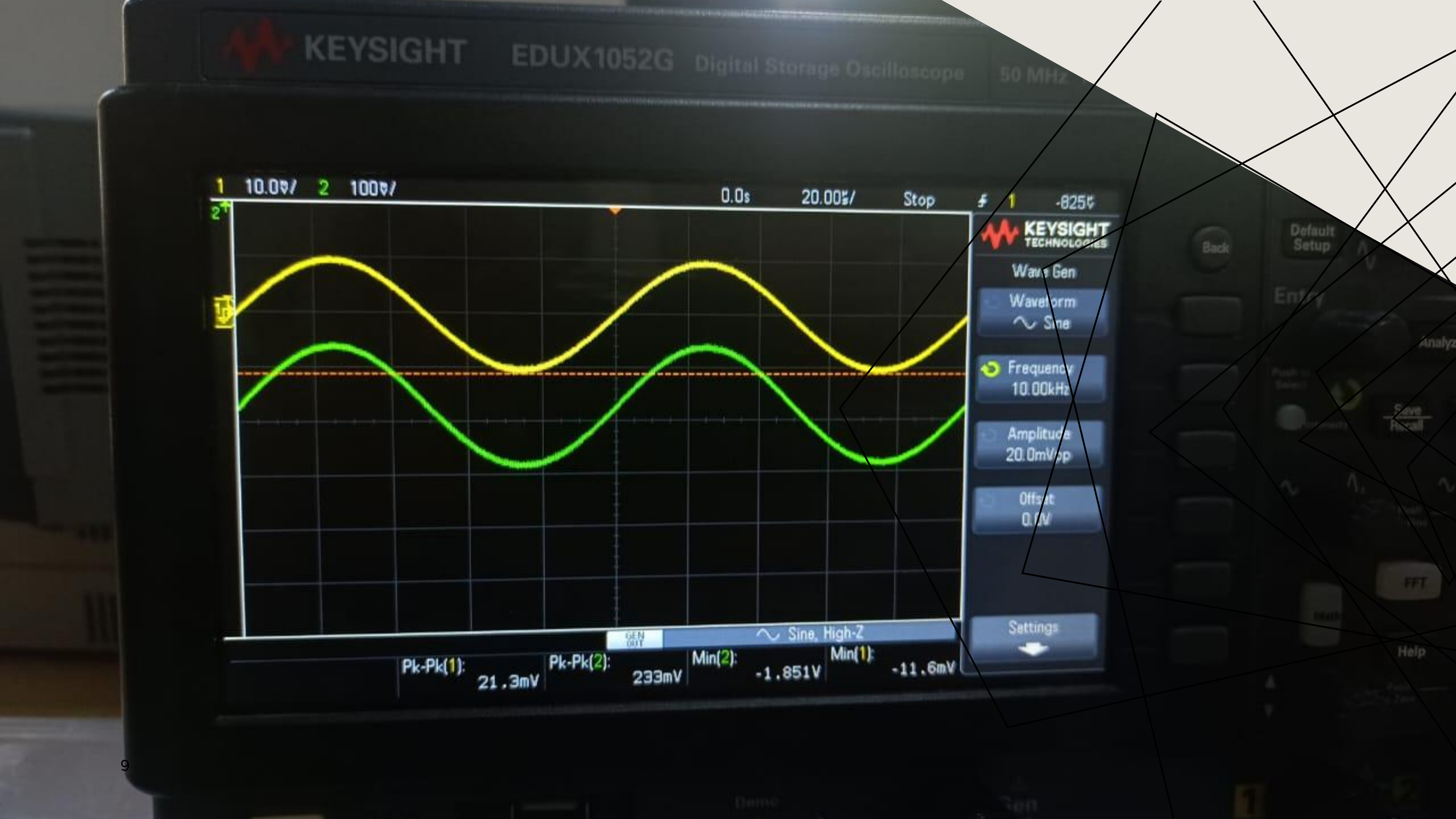
$$\therefore \boxed{R_E = 12k}$$

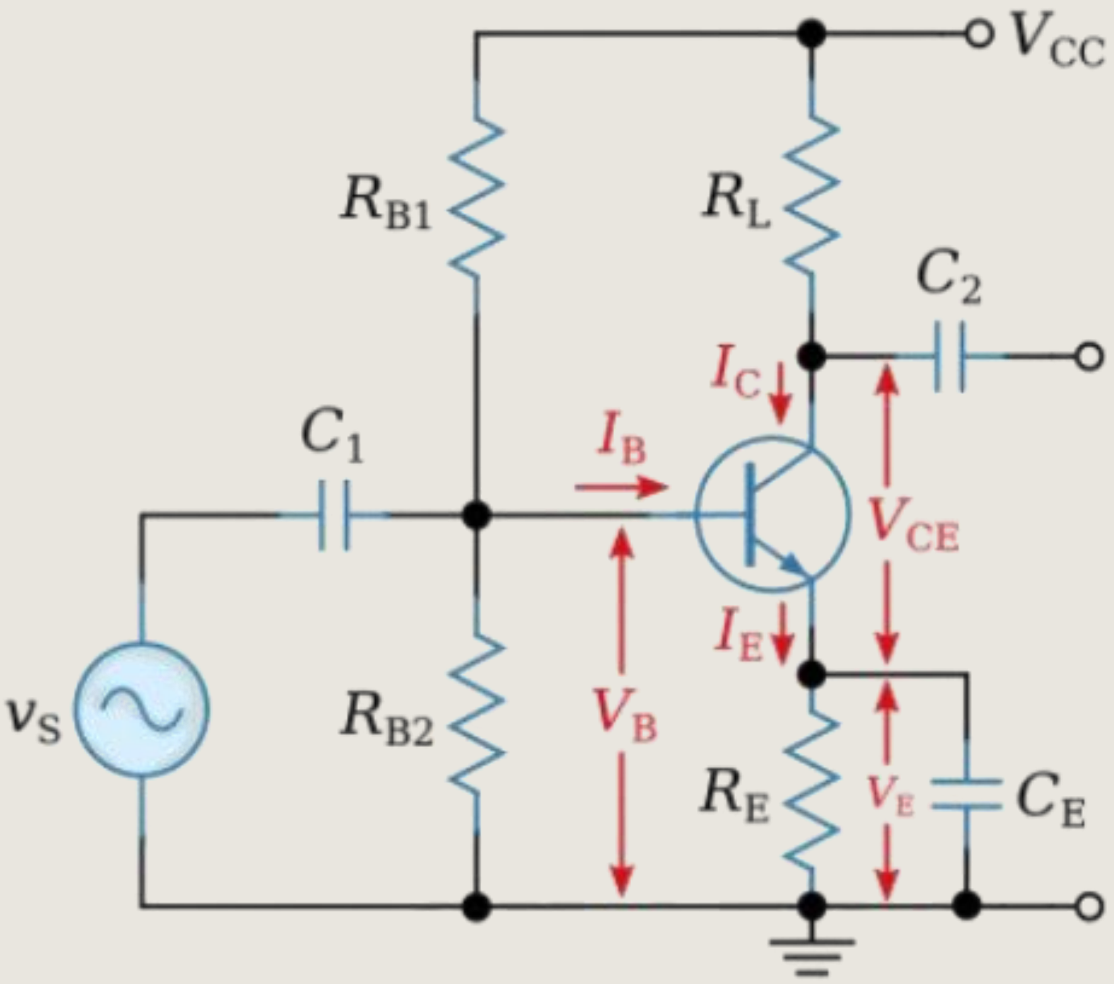

R2
3.3k
R3
3.3k
???
C3
10µ
Q2
BC547B
Q3
BC547B
???
R1
12k
SINE(0 20m 10k)
V2
AC 1 0
.tran 2m

LTSPICE



total.raw
V(n008)
240mV
200mV
160mV
120mV
80mV
40mV
0mV
-40mV
-80mV
-120mV
-160mV
-200mV
-240mV
0.0ms
0.2ms
0.4ms
0.6ms
0.8ms
1.0ms
1.2ms
1.4ms
1.6ms
1.8ms
2.0ms


KEYSIGHT
EDUX1052G
Digital Storage Oscilloscope
50 MHz
1 10.0mV/ 2 100mV/
0.0s 20.00µs/ Stop
-825µV
KEYSIGHT TECHNOLOGIES
Wave Gen
Waveform Sine
Frequency 10.00kHz
Amplitude 20.0mVpp
Offset 0.0V
Settings
Sine, High-Z
Pk-Pk(1): 21.3mV
Pk-Pk(2): 233mV
Min(2): -1.851V
Min(1): -11.6mV
Back
Default Setup
FFT
Help



GAIN STAGE

WORKING PRINCIPLE

- The gain stage consists of a single stage CE Amplifier(common emitter).
- This configuration is chosen as it can handle inputs in the range of hundreds of millivolts.
- It helps in matching high input impedance and moderate output impedance.
- Gain Amplification improves the quality of Audio at speaker.

CALCULATIONS

GAIN STAGE : CE Amplifier

$$\text{Gain} = \frac{g_m R_C}{1 + g_m R_E} \approx \frac{R_C}{R_E} \quad (\text{assuming } g_m R_E >> 1)$$

$$55 \approx \frac{18k}{330} = \frac{R_C}{R_E}$$

$$\text{Total cumulative gain} = 55 \cdot (11) \approx 550 \geq 500$$

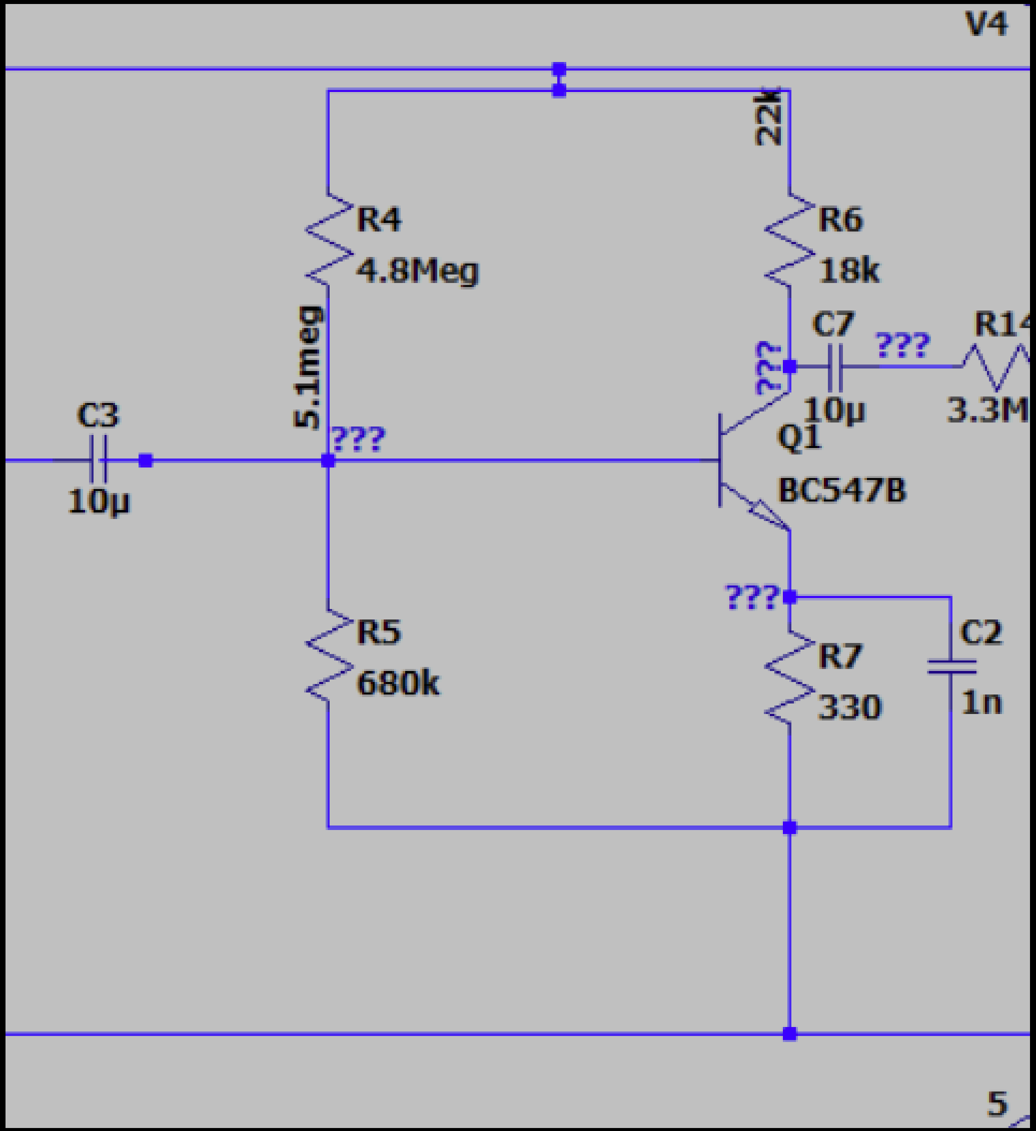
$$V_{in} = V_B$$

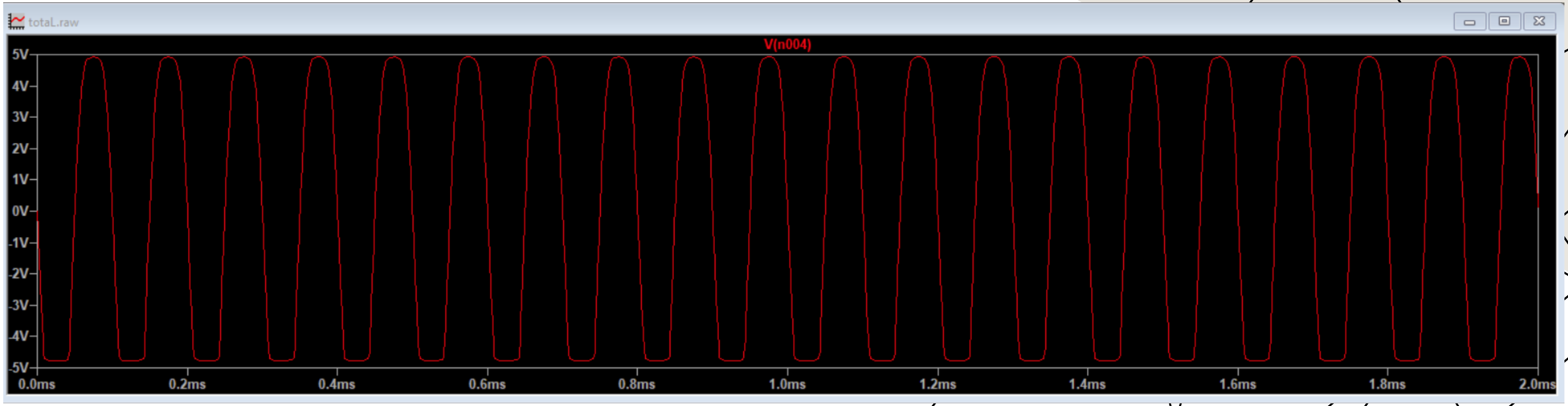
$$I_C = I_s e^{\frac{V_B - V_E}{V_T}} \qquad I_C \propto V_{in}$$

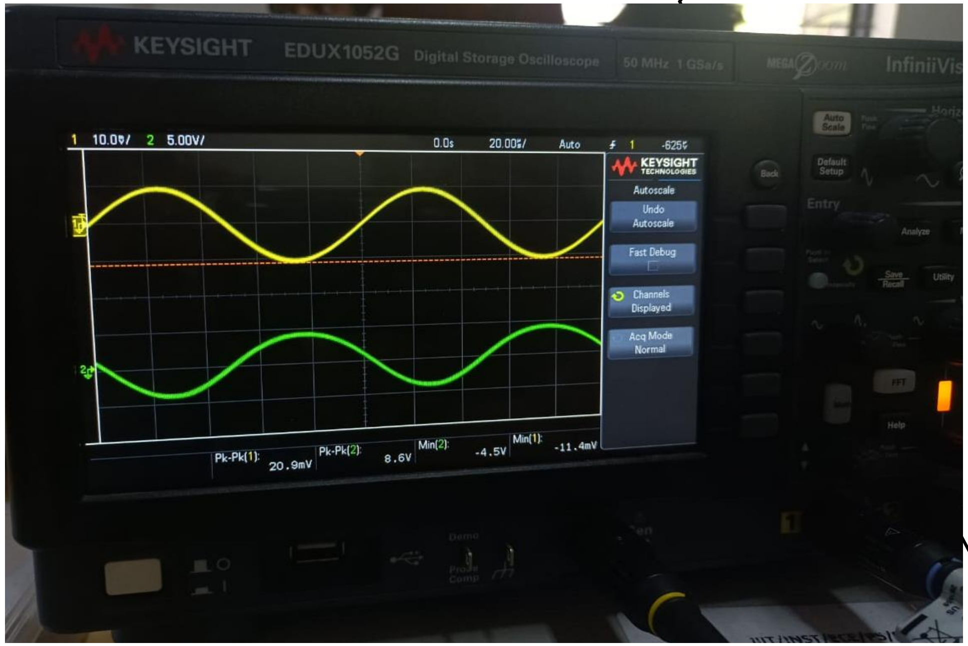
$$V_{out} = V_{DD} - I_C R_C$$

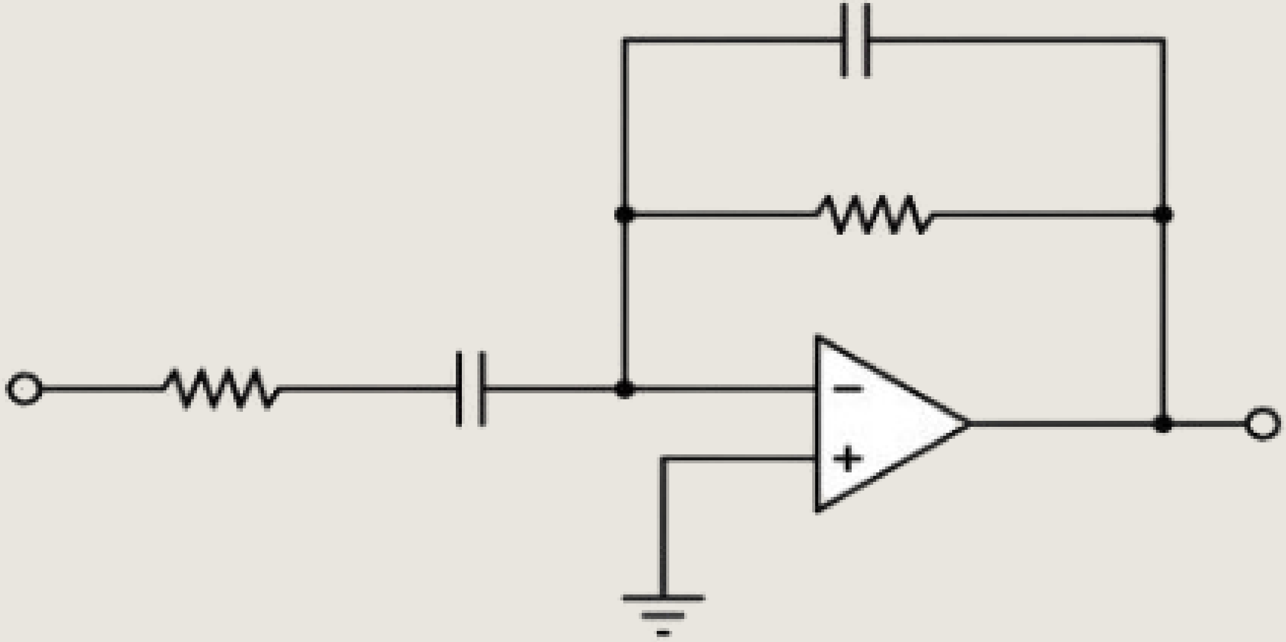
$$= \propto \frac{1}{I_C}$$

$$V_{out} \propto \frac{1}{V_{in}} \quad (\text{phase shift of } 180^\circ)$$


V4
22k
R4
4.8Meg
R6
18k
5.1meg
C7
???
R14
3.3M
C3
???
10µ
Q1
10µ
BC547B
???
R5
680k
R7
330
C2
1n
5


total.raw
V(n004)
5V
4V
3V
2V
1V
0V
-1V
-2V
-3V
-4V
-5V
0.0ms
0.2ms
0.4ms
0.6ms
0.8ms
1.0ms
1.2ms
1.4ms
1.6ms
1.8ms
2.0ms


KEYSIGHT
EDUX1052G Digital Storage Oscilloscope
Autoscale
Undo Autoscale
Fast Debug
Channels Displayed
Acq Mode Normal
Pk-Pk(1): 20.9mV
Pk-Pk(2): 8.6V
Min(2): -4.5V
Min(1): -11.4mV



ACTIVE BANDPASS FILTER

WORKING PRINCIPLE

- Here we have designed an active bandpass filter which is inverting in nature.
- We have designed a bandpass filter because the audio should only be audible if it lies the human hearing range.
- Filter stage removes the unnecessary Interference of noise signals and also improving the overall efficiency of the audio signal which leads to better sound quality.
- The Band pass filter consists of a low pass filter and a high pass filter.
- Active filter can be cascaded without loading and impedance matching issues.
- Although the signals out of Range are not audible they still interfere with the signal quality therefore removing them becomes essential.
- The HPF should pass signals whose frequency is above 2kHz and LPF should pass signals whose frequency is below 20kHz.

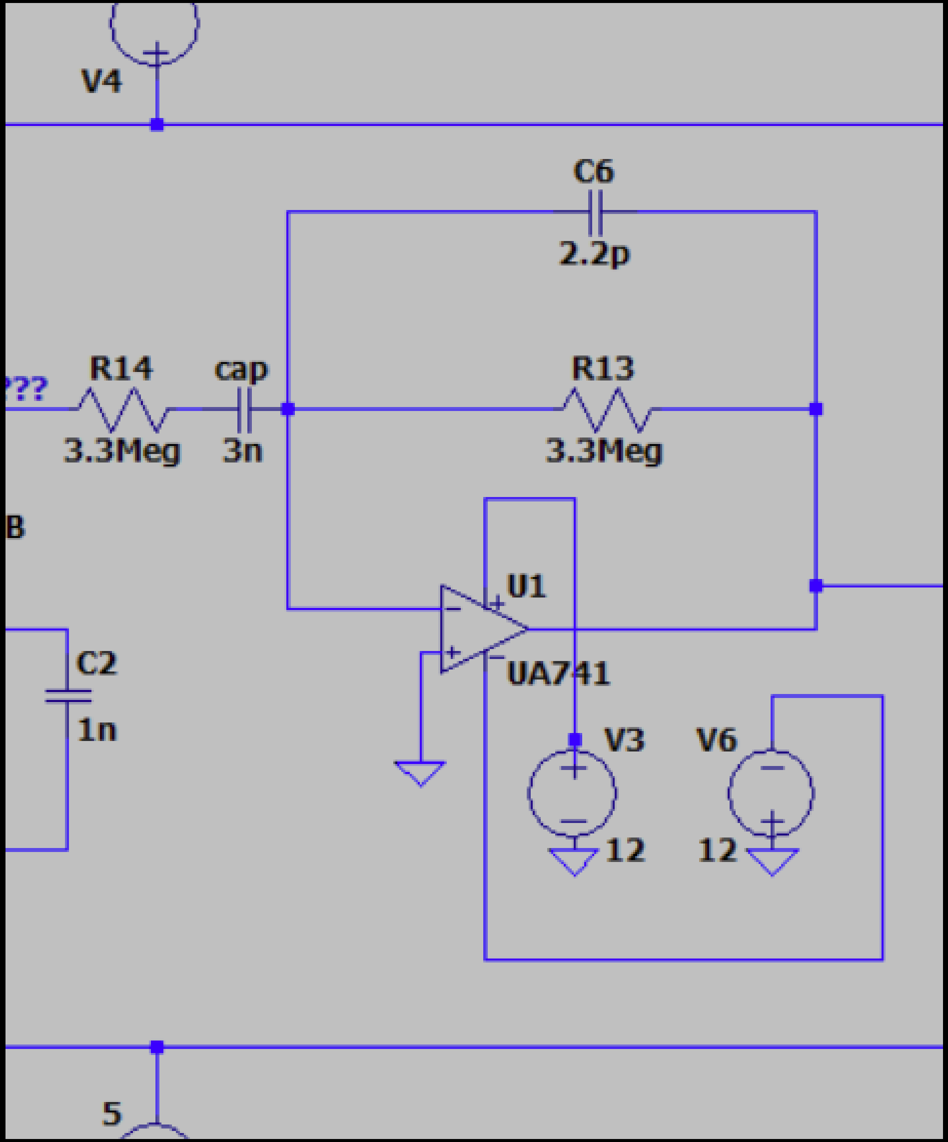
CALCULATIONS

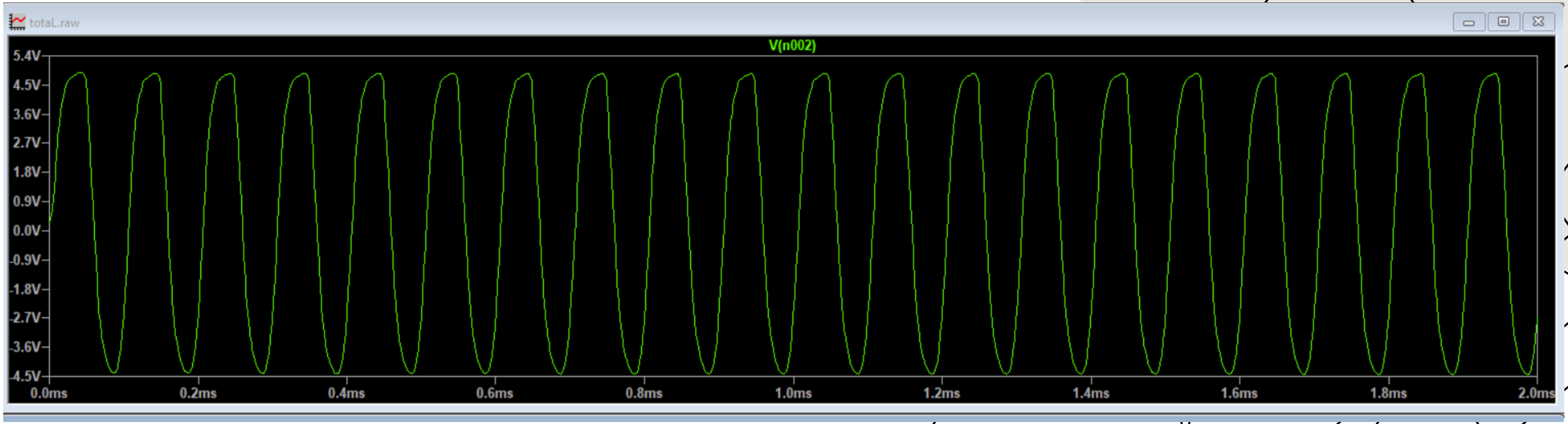
$$f_L = \frac{1}{2 \cdot \pi \cdot R \cdot C_1}$$

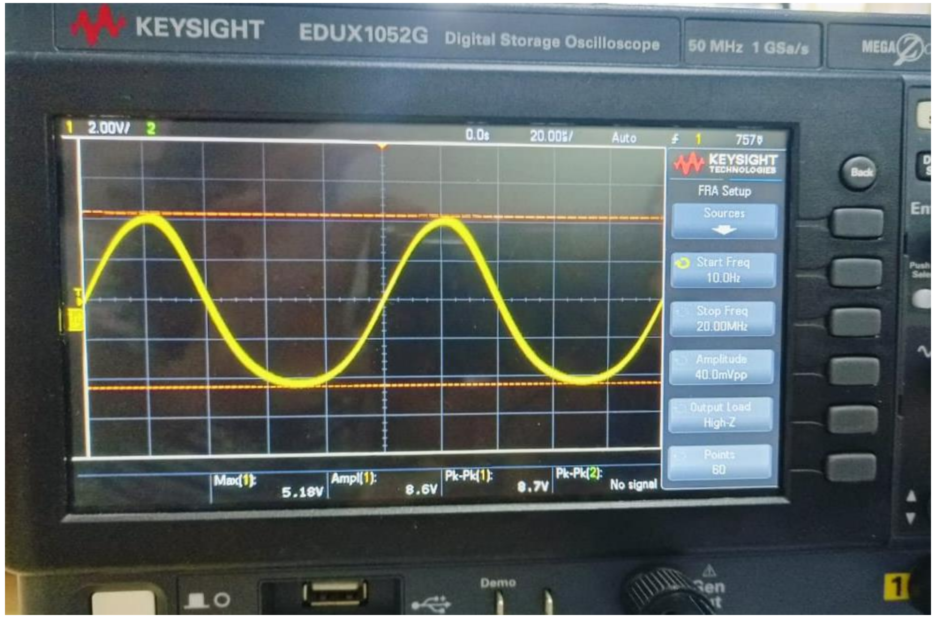
$$\frac{1}{2 \cdot \pi \cdot 3.3 \cdot 10^6 \cdot 3 \cdot 10^{-9}} = 16.07625688$$

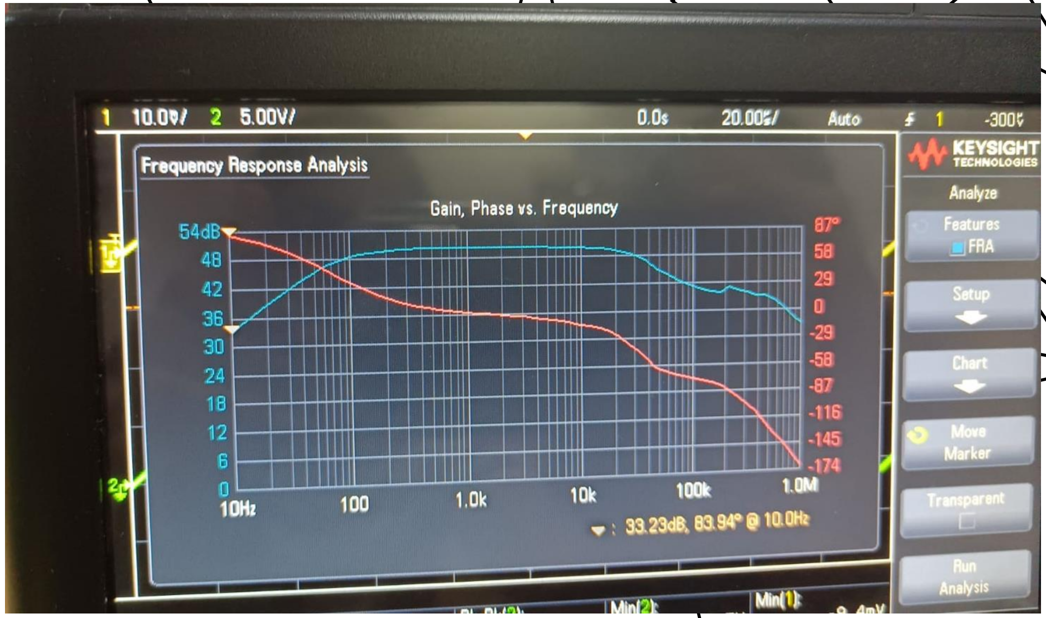
$$f_H = \frac{1}{2 \cdot \pi \cdot R \cdot C_2}$$

$$\frac{1}{2 \cdot \pi \cdot 3.3 \cdot 10^6 \cdot 2.2 \cdot 10^{-12}} = 21922.16847$$

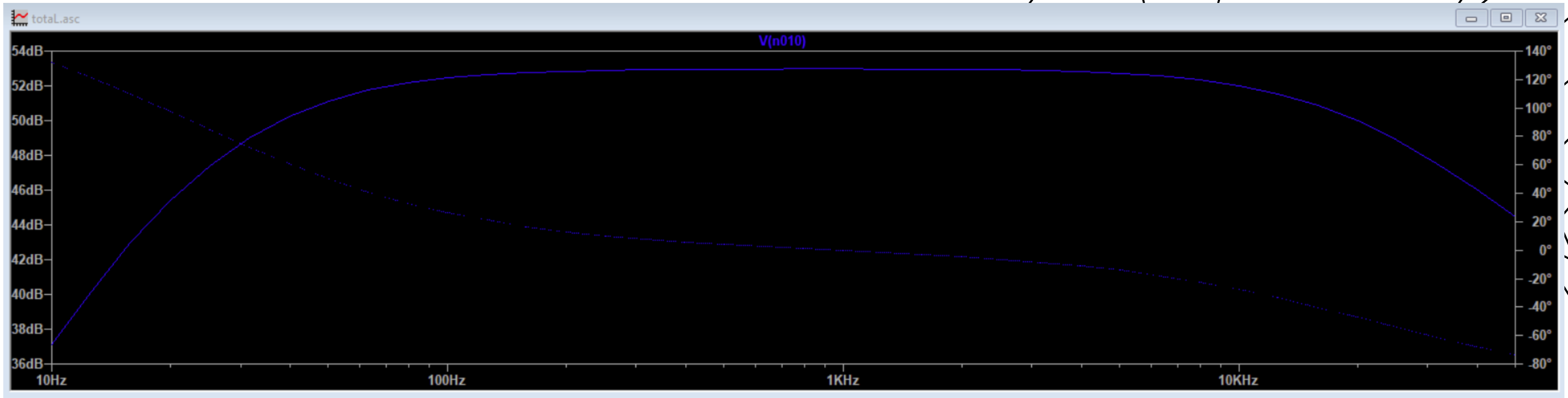

V4
C6
2.2p
R14
3.3Meg
cap
3n
R13
3.3Meg
B
U1
UA741
C2
1n
V3
V6
12
12
5


total.raw
V(n002)
5.4V
4.5V
3.6V
2.7V
1.8V
0.9V
0.0V
-0.9V
-1.8V
-2.7V
-3.6V
-4.5V
0.0ms
0.2ms
0.4ms
0.6ms
0.8ms
1.0ms
1.2ms
1.4ms
1.6ms
1.8ms
2.0ms

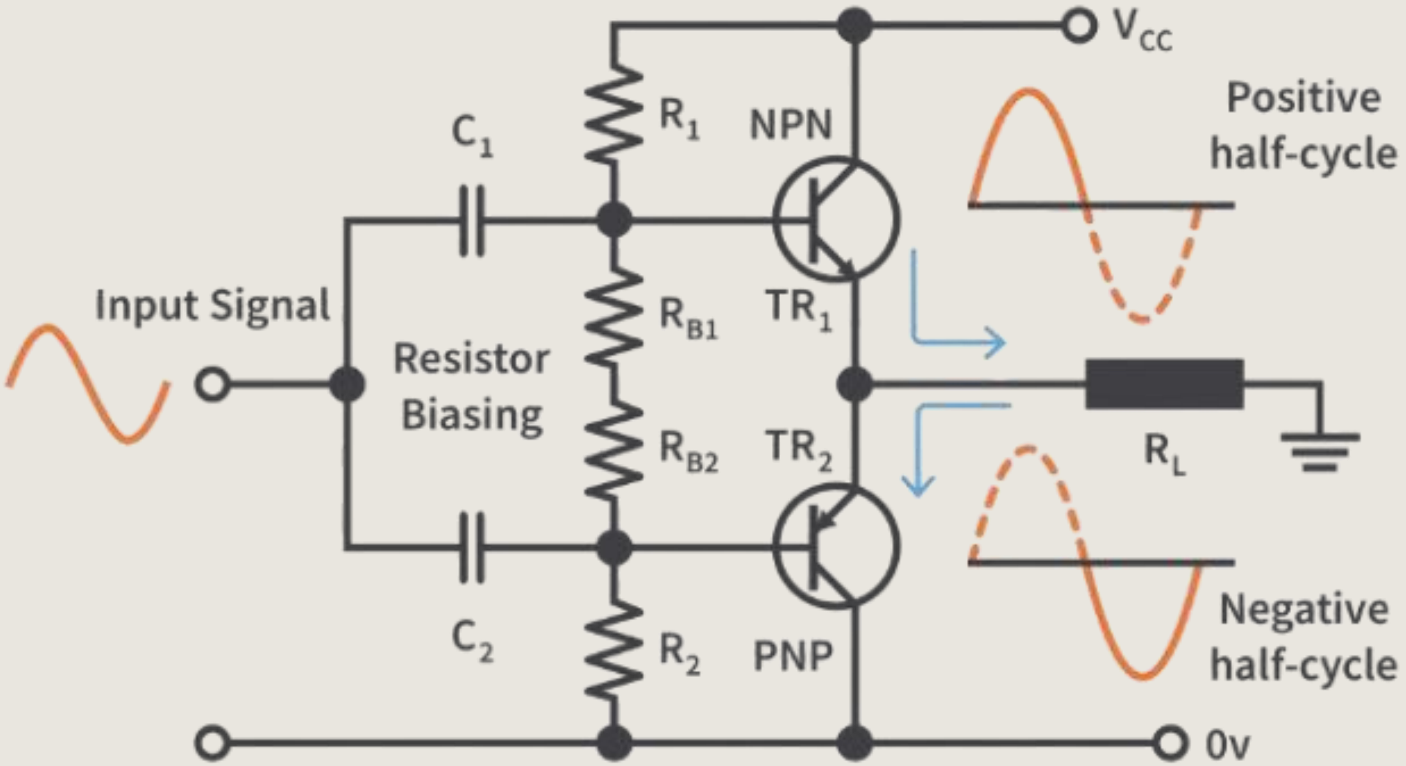

KEYSIGHT EDUX1052G Digital Storage Oscilloscope
50 MHz 1 GSa/s
FRA Setup
Sources
Start Freq
10.0Hz
Stop Freq
20.00MHz
Amplitude
40.0mVpp
Output Load
High-Z
Points
60
Max(1): 5.18V
Ampl(1): 8.6V
Pk-Pk(1): 8.7V
Pk-Pk(2): No signal


Frequency Response Analysis
Gain, Phase vs. Frequency
54dB
48
42
36
30
24
18
12
6
0
87°
58
29
0
-29
-58
-87
-116
-145
-174
10Hz
100
1.0k
10k
100k
1.0M
33.23dB, 83.94° @ 10.0Hz
Analyze
Features
FRA
Setup
Chart
Move Marker
Transparent
Run Analysis

AC ANALYSIS



total.asc
V(n010)
54dB
52dB
50dB
48dB
46dB
44dB
42dB
40dB
38dB
36dB
140°
120°
100°
80°
60°
40°
20°
0°
-20°
-40°
-60°
-80°
10Hz
100Hz
1KHz
10KHz



POWER AMPLIFIER

TYPES OF POWER AMPLIFIERS

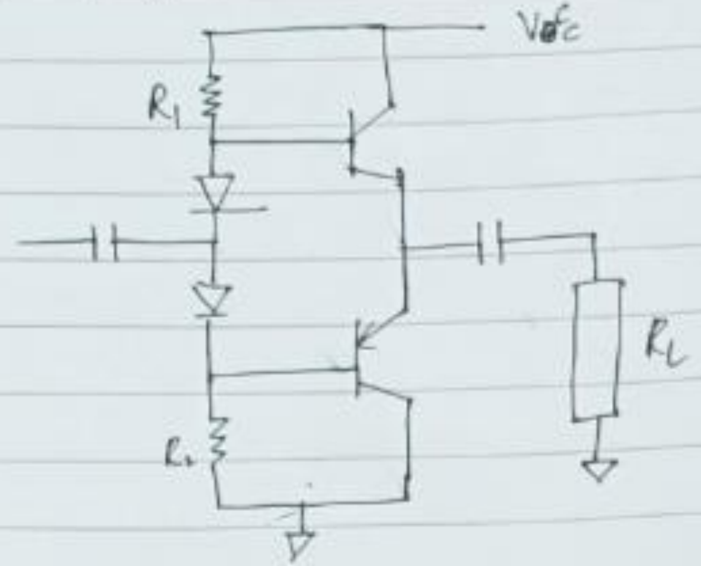
- **Class A amplifier**: The biasing conditions in class A power amplifier are such that the collector current flows for the entire AC signal applied.
- **Class B amplifier**: The biasing conditions in class B power amplifier are such that the collector current flows for the half cycle of input AC signal applied.
- **Class AB amplifier**: The class AB power amplifier is one which is created by combining both class A and class B in order to have all the disadvantages of both the classes and to minimize the problems they have.

WORKING PRINCIPLE

- Here for the power amplifier stage , we have used class AB emitter – follower configuration.
- It provides sufficient power to an output load to drive other power device.
- It is chosen as it gives low cross-over distortion.
- In previous stages, the voltage has been amplified .The current is yet to be amplified as the signal at the output needs certain threshold amount of power to be able to drive the speaker.
- It provides a low output resistance in order to avoid loss of gain and to maintain linearity (to minimize harmonic distortion).

CALCULATIONS

POWER AMP



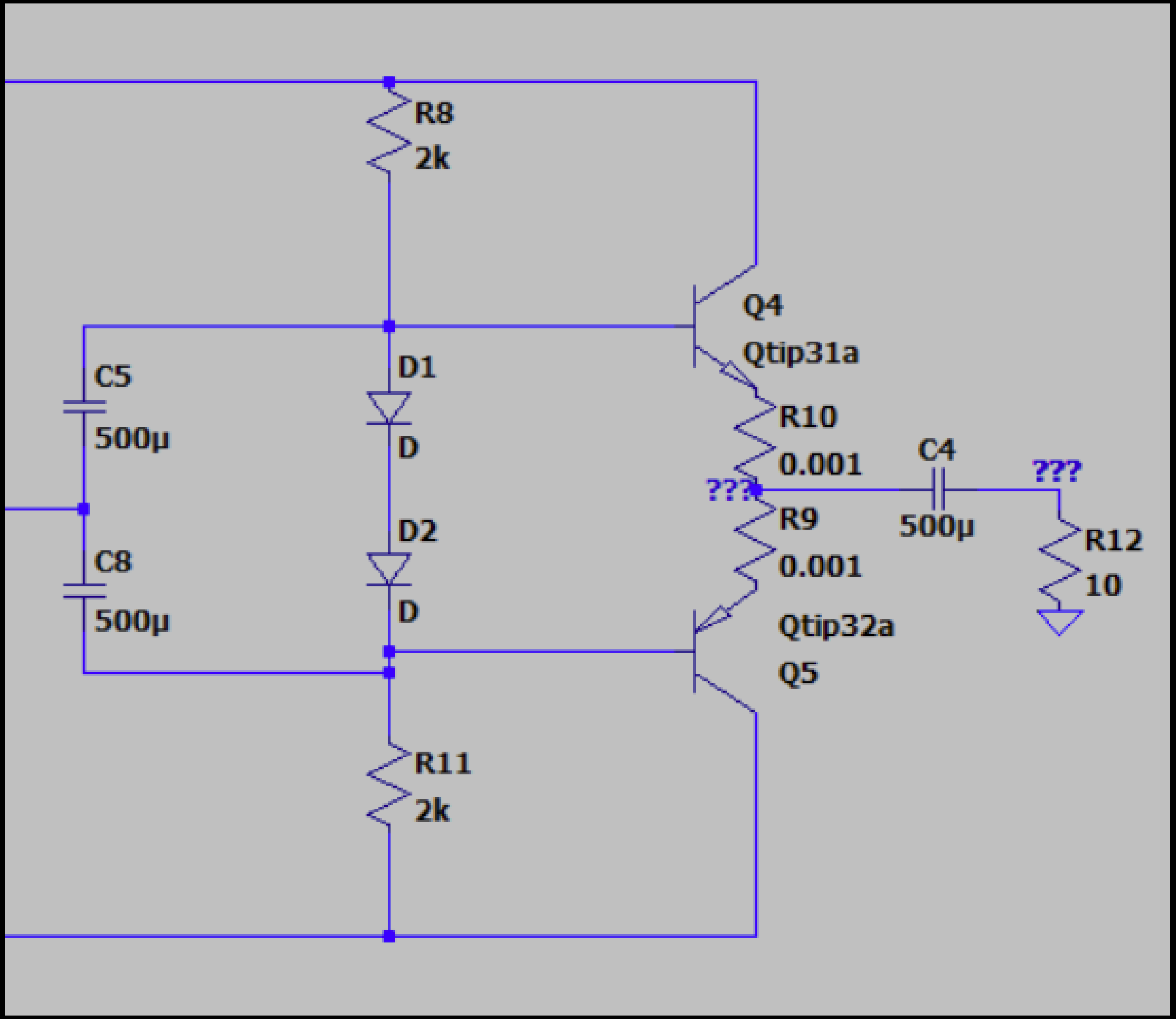
$$I_d = \frac{V_{CC} - 1.4}{R_1 + R_2} = \frac{3.6}{R_1 + R_2}$$

$I_d \approx 1\,mA$
(assume)

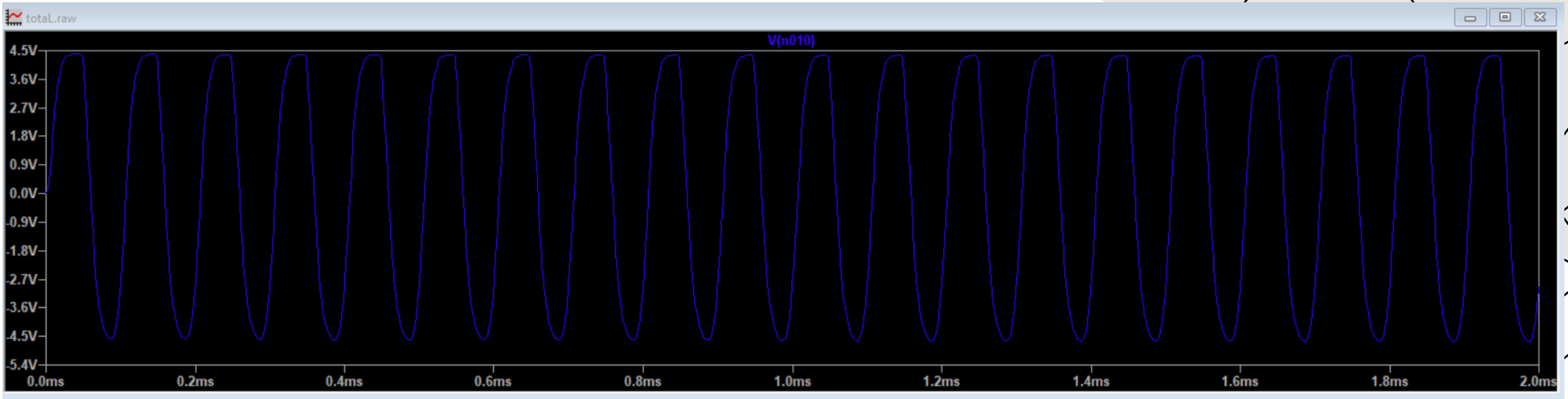
$$2R_1 = \frac{3.6}{1\,mA}$$

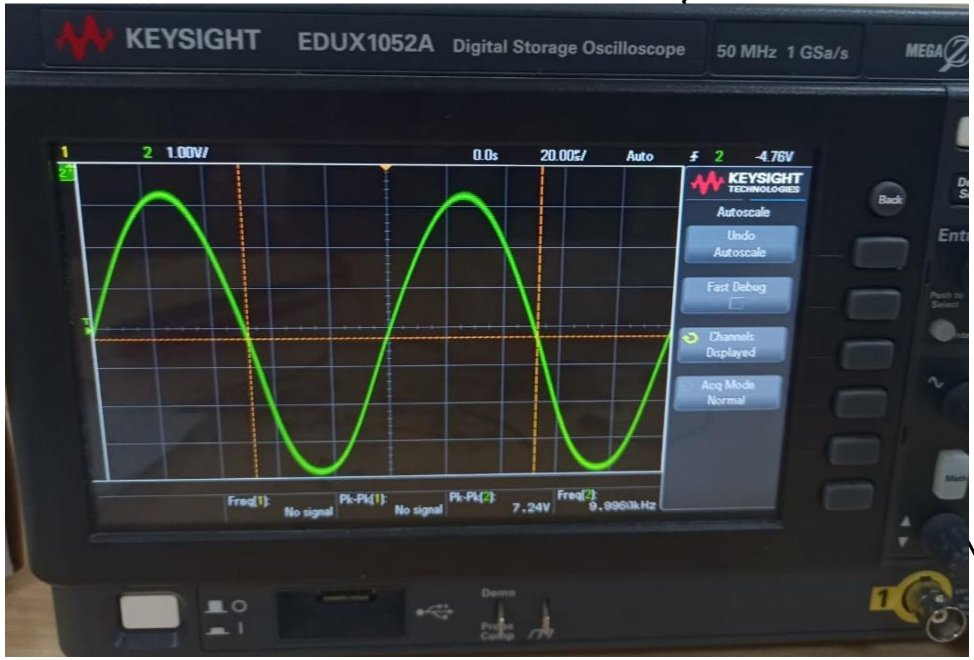
$$R_1 = R_2 = 1.8k \approx 2k$$

$I_d \approx 1\,mA$ for 0.7 drop across diode & to turn both transistors ON

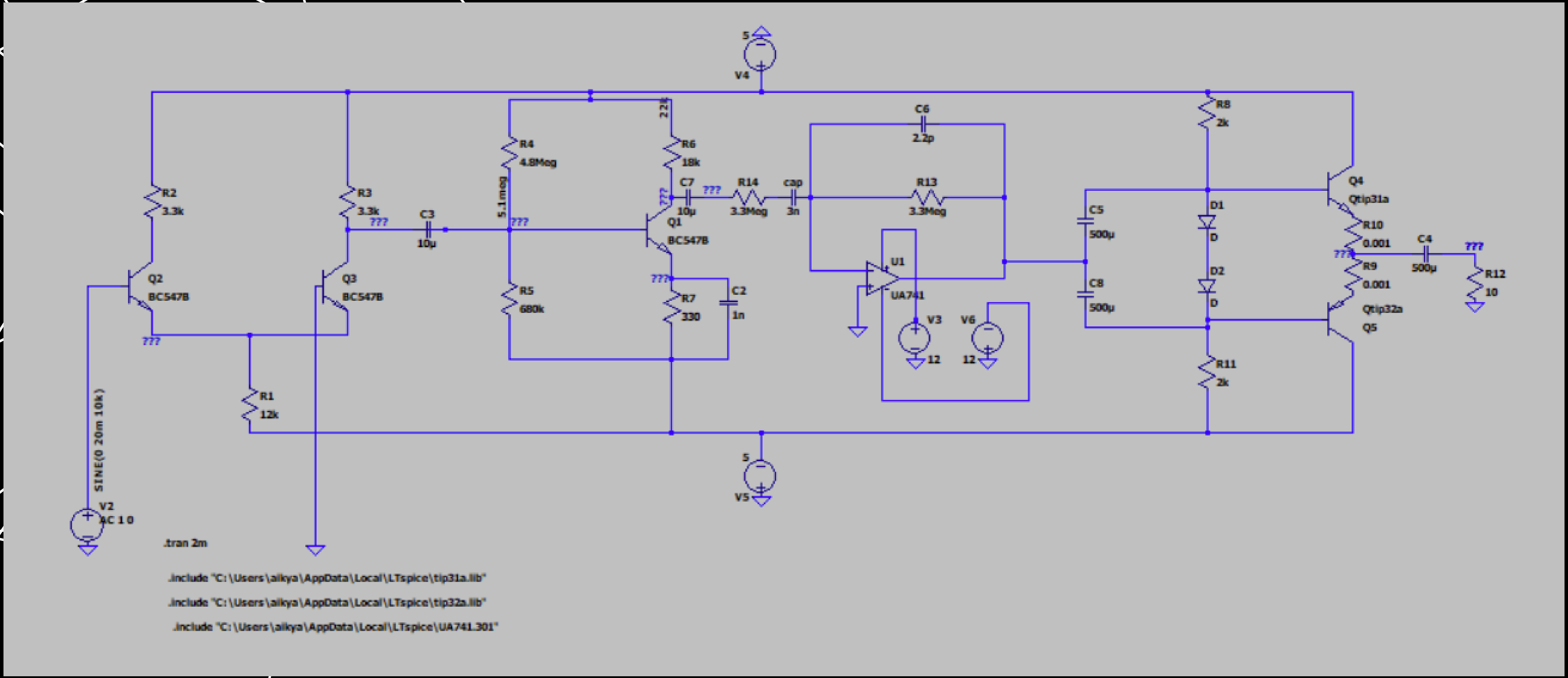


R8
2k
Q4
Qtip31a
C5
500µ
D1
D
R10
0.001
C4
500µ
???
???
R9
0.001
R12
10
C8
500µ
D2
D
Qtip32a
Q5
R11
2k


total.raw
V(n010)
4.5V
3.6V
2.7V
1.8V
0.9V
0.0V
-0.9V
-1.8V
-2.7V
-3.6V
-4.5V
-5.4V
0.0ms
0.2ms
0.4ms
0.6ms
0.8ms
1.0ms
1.2ms
1.4ms
1.6ms
1.8ms
2.0ms


KEYSIGHT
EDUX1052A Digital Storage Oscilloscope
50 MHz 1 GSa/s
Autoscale
Undo Autoscale
Fast Debug
Channels Displayed
Acq Mode Normal
Pk-Pk(2): 7.24V

FINAL CIRCUIT



FINAL OUTPUT