AUDIO AMPLIFIER

ELECTRONIC WORKSHOP - 2 PROJECT

Pearl Shah 2022102073
Zainab Raza 2022102013

AUDIO AMPLIFIER DESIGN

Audio amplifiers are widely-used electronic circuits designed to increase the power of an input audio signal, resulting in a louder auditory output. In addition to amplification, they also play a crucial role in refining the quality of the audio by effectively minimizing any unwanted noise present in the input signal.

1.Pre-amp Stage

2.Gain Stage

3.Filter Stage

4.Power Amplifier Stage

TESTING MIC INPUT

19.7mVpp

Pre-Amp Stage

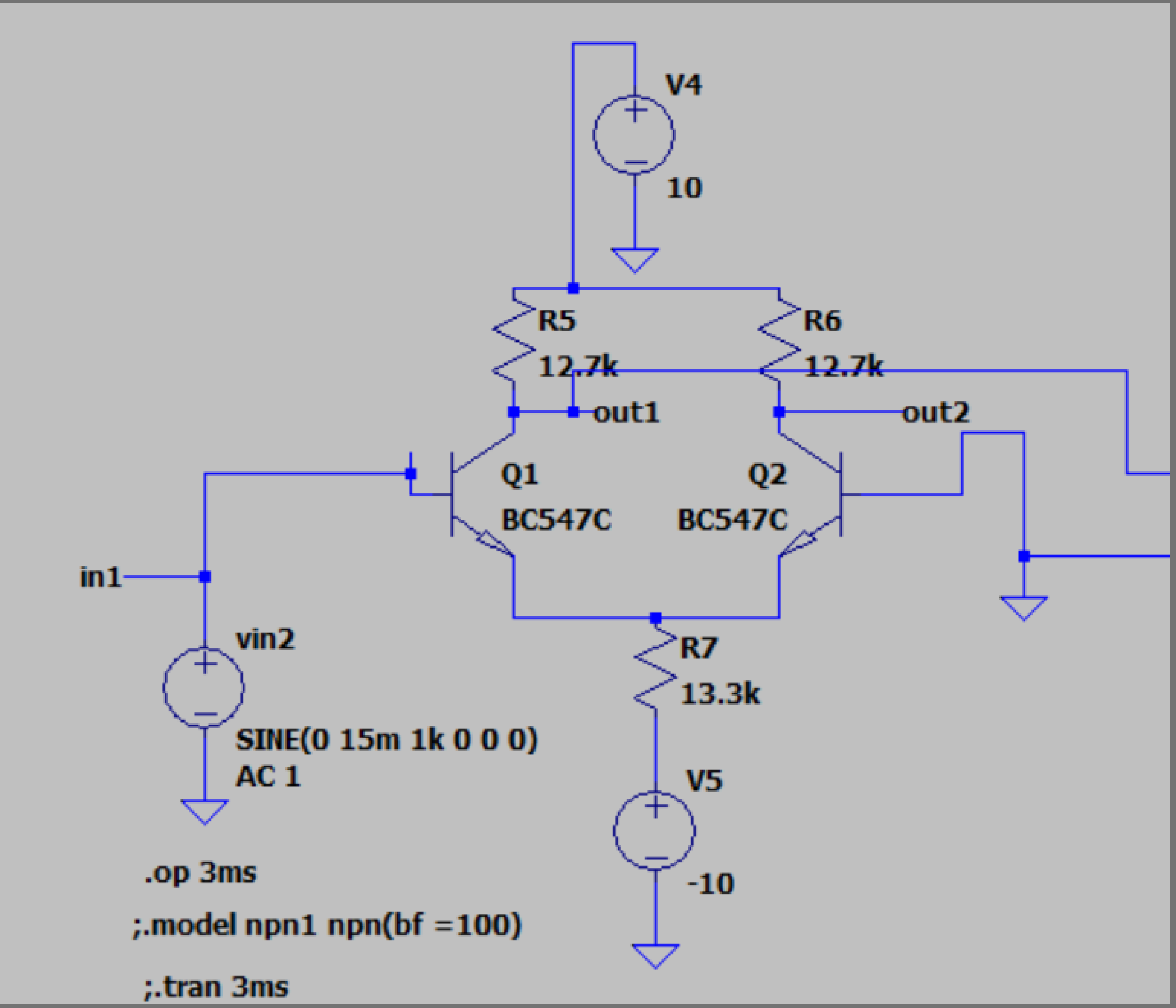
The preamplifier is a circuit designed to boost the strength of our input signal by a modest degree, preparing it for further amplification in the primary stage.

A (SISO) differential amplifier amplifies the difference between a single input signal and a fixed reference voltage, typically ground. It rejects common-mode noise while providing amplification of the desired signal, making it useful in applications requiring precise signal amplification and noise rejection

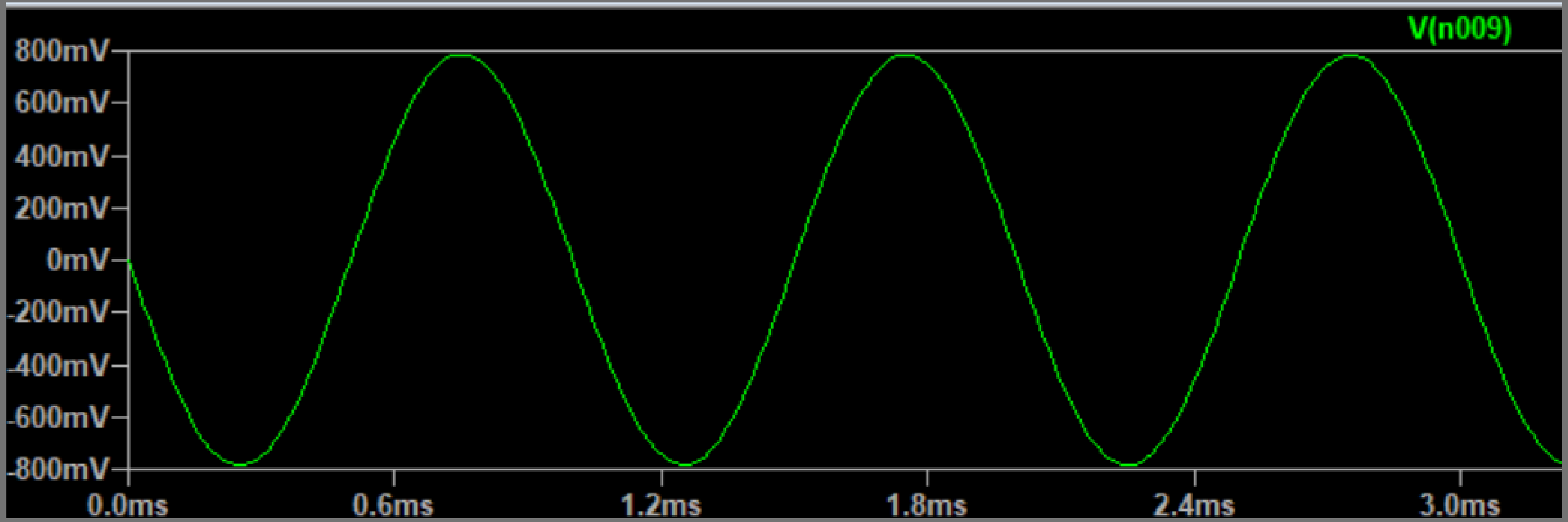
We have used BJT to design our differential amplifier as BJT’s have higher gain range

SIMULATION

CIRCUIT



RESULT



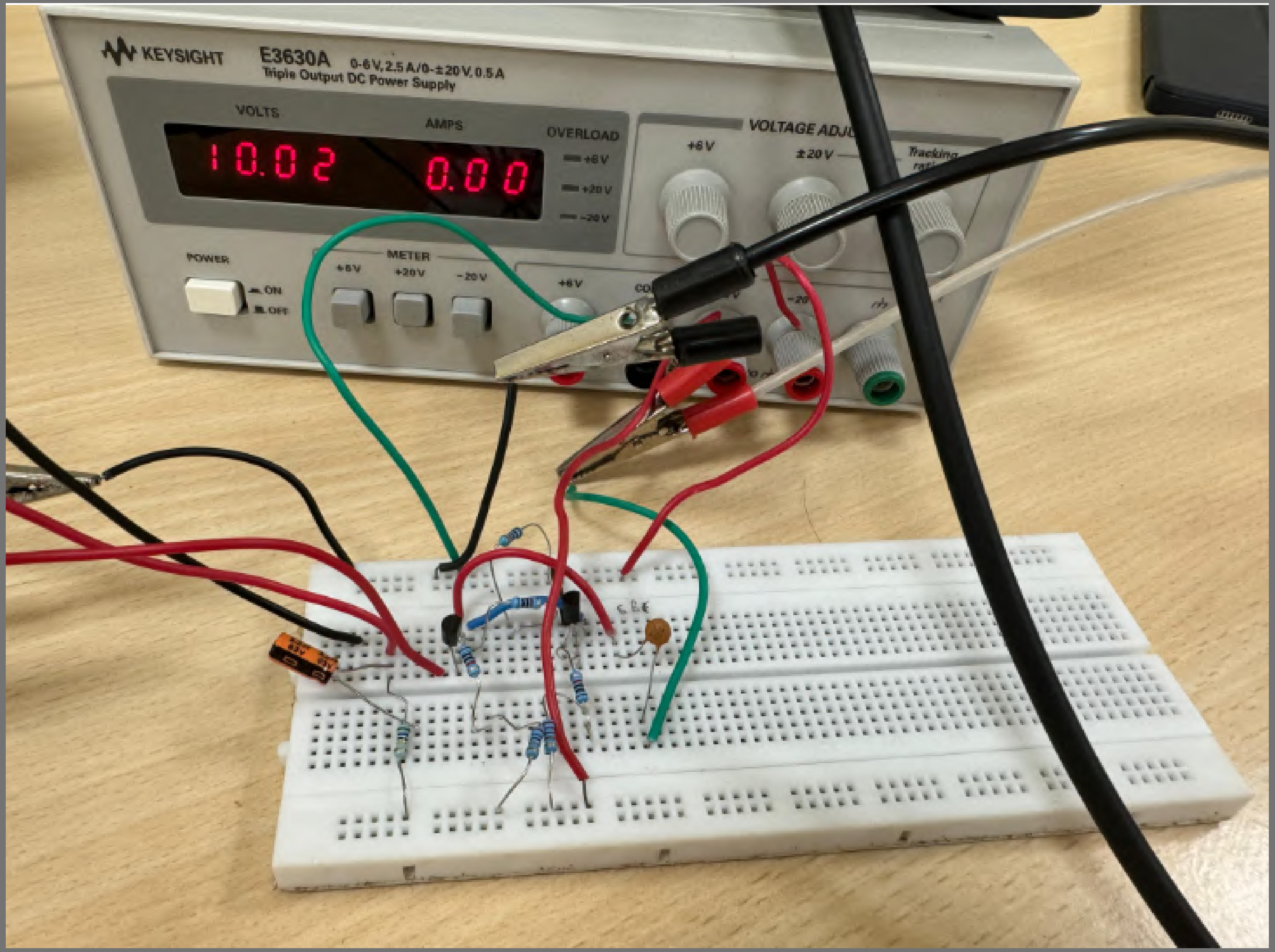
Input Voltage : 10mV

Output Voltage : 800 mV

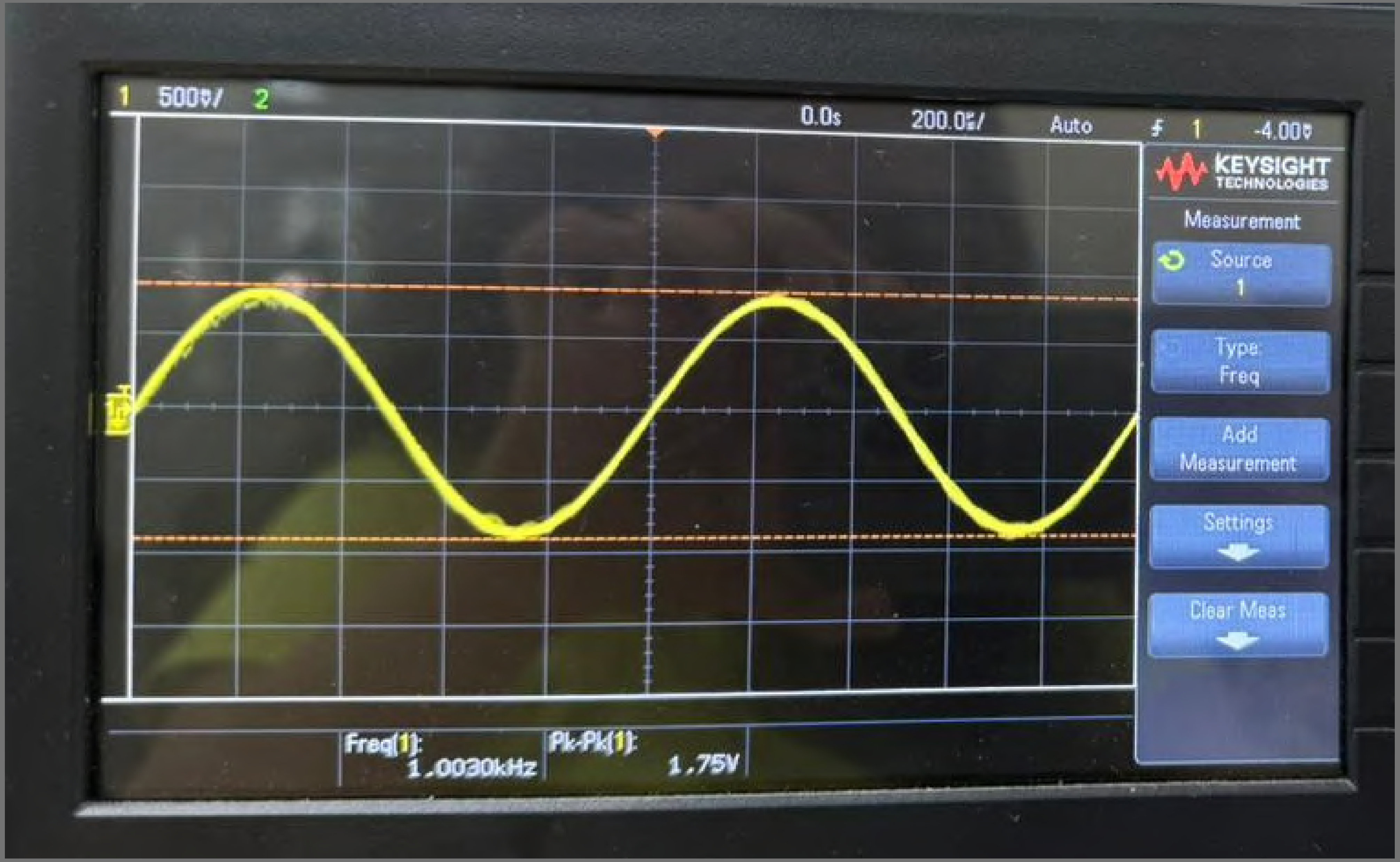
Gain : V(out) / V(in) = 80

HARDWARE

CIRCUIT



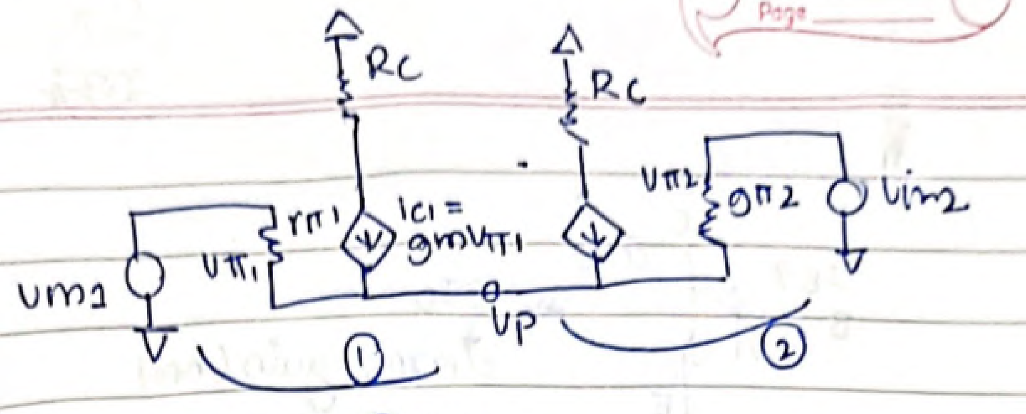
RESULT



Input Voltage : 20mVpk   Output Voltage : 1.75 pkV

Gain : V(out) / V(in) = 87.5

CALCULATIONS



KLL ① :-

$V_{in1} - V_{\pi 1} = V_p$

$V_{in1} - V_{in2} = V_{id}$

$V_{in1} = V_{id}/2$ & $V_{in2} = -\frac{V_{id}}{2}$

as P point acts as virtual ground.

KVL ② :-

$V_{in2} - V_{\pi 2} = V_p$

$V_{id} = V_{\pi 1} - V_{\pi 2}$

$g_{m1} V_{\pi 1} + g_{m2} V_{\pi 2} + \frac{V_{\pi 1}}{r_{\pi 1}} + \frac{V_{\pi 2}}{r_{\pi 2}} = 0$

Assume perfect transistor so

$g = g_{m1} = g_{m2}$

$r_{\pi 1} = r_{\pi 2} = r_\pi$

$(V_{\pi 1} + V_{\pi 2})(g_m + \frac{1}{r_\pi}) = 0$

$(-2V_P)(g_m + \frac{1}{r_\pi}) = 0$

$V_{in1} - V_{\pi 1} = V_P = V_{in2} - V_{\pi 2}$

(single input) $V_{in2} = 0$, $V_P = -V_{in2}$

$V_{in1} = V_{\pi 1} - V_{\pi 2}$

$V_{o1} - V_{o2} = -g_m V_{\pi 1} R_C + g_m V_{\pi 2} R_C$

$- g_m R_C (V_{in1} - V_{in2})$

$\frac{V_{o1} - V_{o2}}{V_{in} - V_{in2}} = -\frac{g_m R_C}{2}$ $\frac{-140}{\cancel{80}} = -22ms \cdot R_C$

$-140 = \frac{g_m R_C}{2} = \frac{22}{2} \cdot R_C$ $\boxed{R_C = 12.72}$

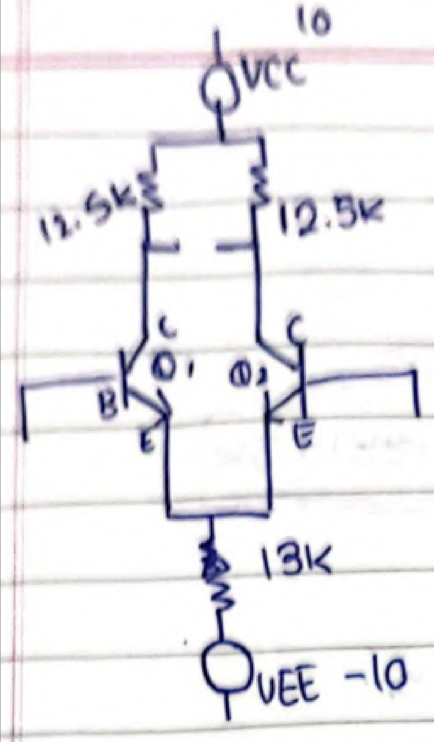
$A_{vd} = \frac{-R_C}{1/g_m + R_E} = -140 = 12.7/(1/22) + R_E$

$-140 = \frac{-12.7}{\frac{1}{\cancel{20}\ 22ms} + R_E}$

$\cancel{-140}$ $-6.3 - 140R_E = -12.7$

$R_E = 0.135$

$\boxed{R_E = \cancel{13k}\ 13.5K}$



$I_{CQ} = \beta \left(\frac{V_{EE} - V_{BE}}{R_B + 2(1+\beta)R_E} \right)$

$V_{CEQ} = (V_{CC} + V_{EE}) - I_{CQ}(R_C + 2R_E)$

$r_\pi = \frac{\beta V_T}{I_{CQ}}$ $(V_T = 25mV)$

$A_d = \frac{\beta R_C}{R_B + r_\pi}$

$A_{cm} = \left| \frac{R_C}{2R_E} \right|$

$I_{BQ} = \frac{10 - 0.7}{2(1+\beta) \times 13}$

$\frac{10 - 0.7}{2(1+110)\cancel{40}13} = \frac{0.3}{200 \times 13}$

$= \cancel{0.0032}$ $= 0.0035$

$I_{CQ} = 0.0032 \times \cancel{110}\ 100$

$= \cancel{0.354}$ $\cancel{35}$

$= \cancel{\times 10^{-6}}$ $0.35 mA$

$V_{CEQ} = 10 + 10 - 0.354 \times 10^{-3} (12.5 + 2 \times 13)$

$= 20 - 13.629 = 6.371$

$r_\pi = 100 \times 26 \times 10^{-3} / 0.35 \times 10^{-3} = 7.42$

$A_d = 100 \times 12.5 / 7.42 = 160$

Becomes 80 for single output

GAIN STAGE

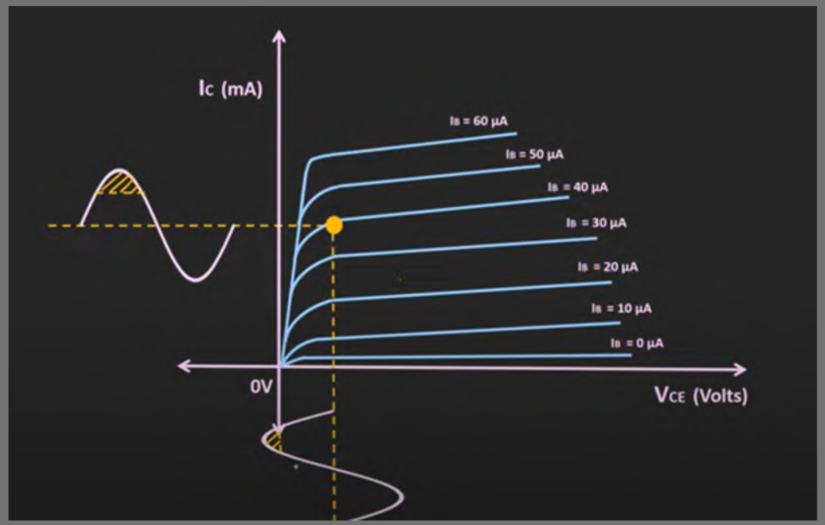
COMMON EMMITER AMPLIFIER

A common emitter amplifier is a type of bipolar junction transistor (BJT) amplifier configuration that amplifies input voltage signals applied between the base and emitter terminals

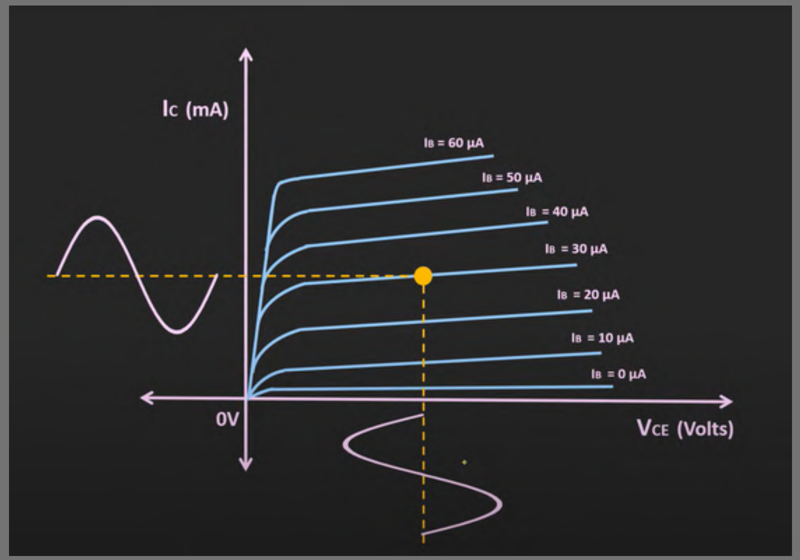
WHY CE COMPARED TO CS ?

We initially used CS amplifier (MOSFET) but operating area of mosfet is very small and hence finding the perfect operating point is difficult so we switched to bjt which has larger operating area

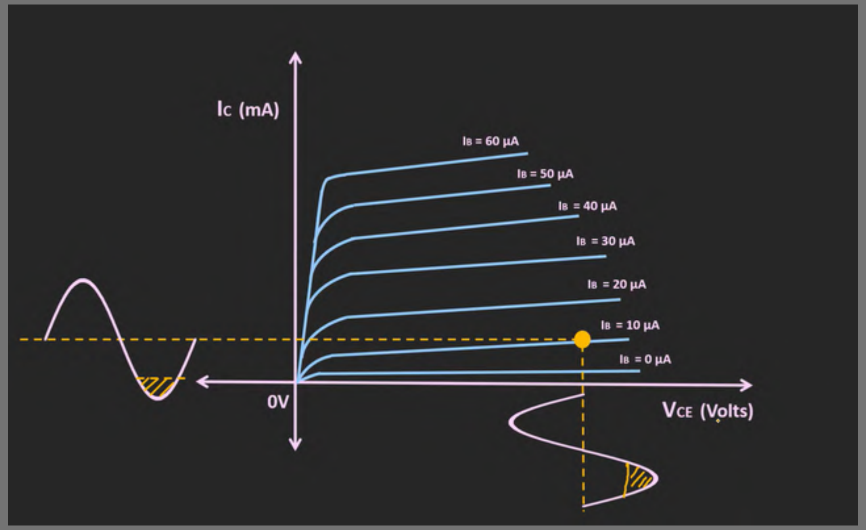
OPERATING REGION FOR MOSFET



TOWARDS LEFT - FALLING OUT OF OPERATING REGION



IDEAL BIAS POINT



TOWARDS RIGHT - FALLING OUT OF OPERATING REGION

GAIN STAGE

BUFFER BETWEEN STAGES

Adding a buffer between pre-amp and CE-amplifier
to do impedence matching between the 2 stages

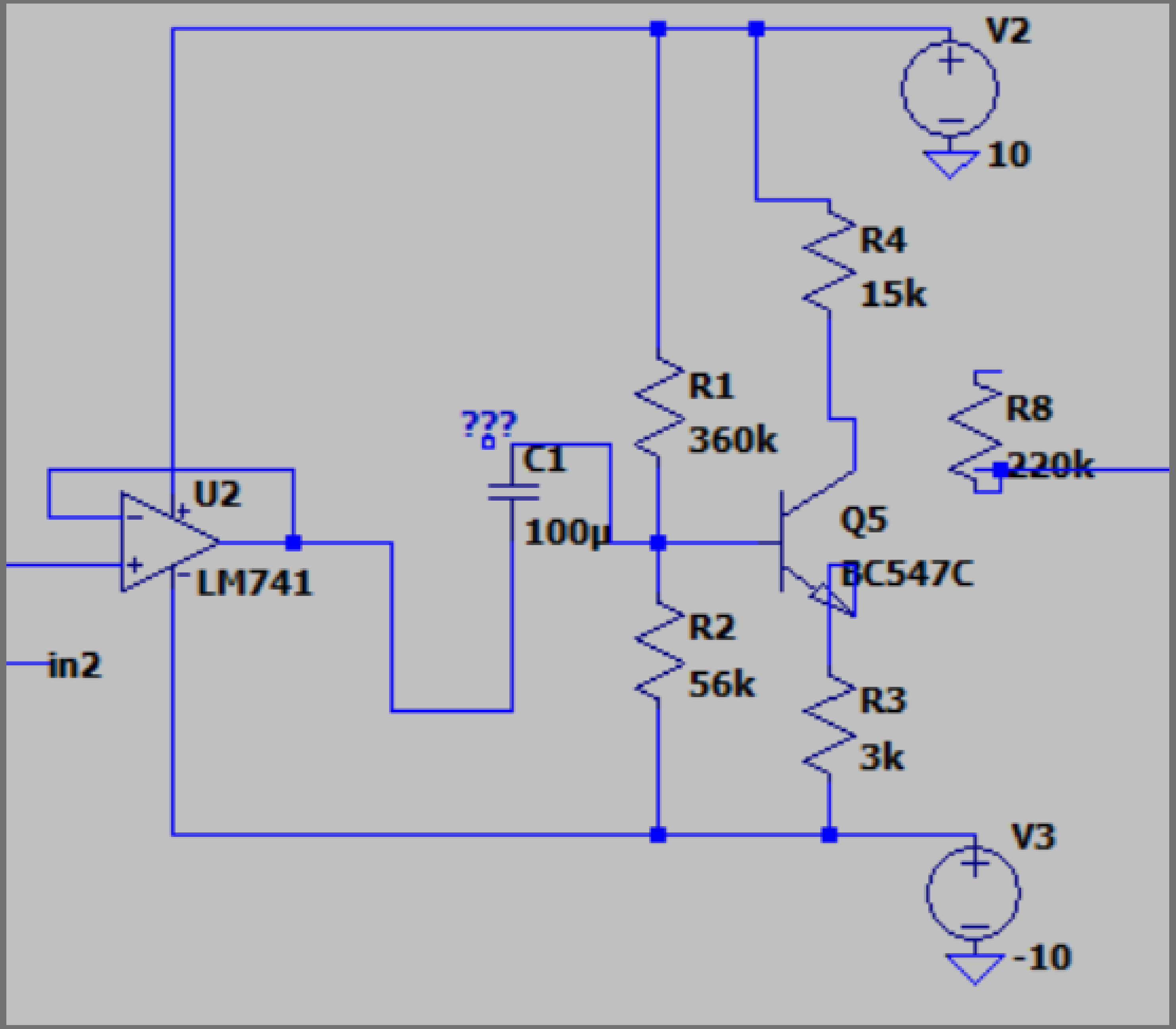
We used an opamp to create a buffer by configuring it in a non-inverting unity gain configuration

In this setup, the op-amp operates with a feedback loop that ensures the output voltage precisely matches the input voltage

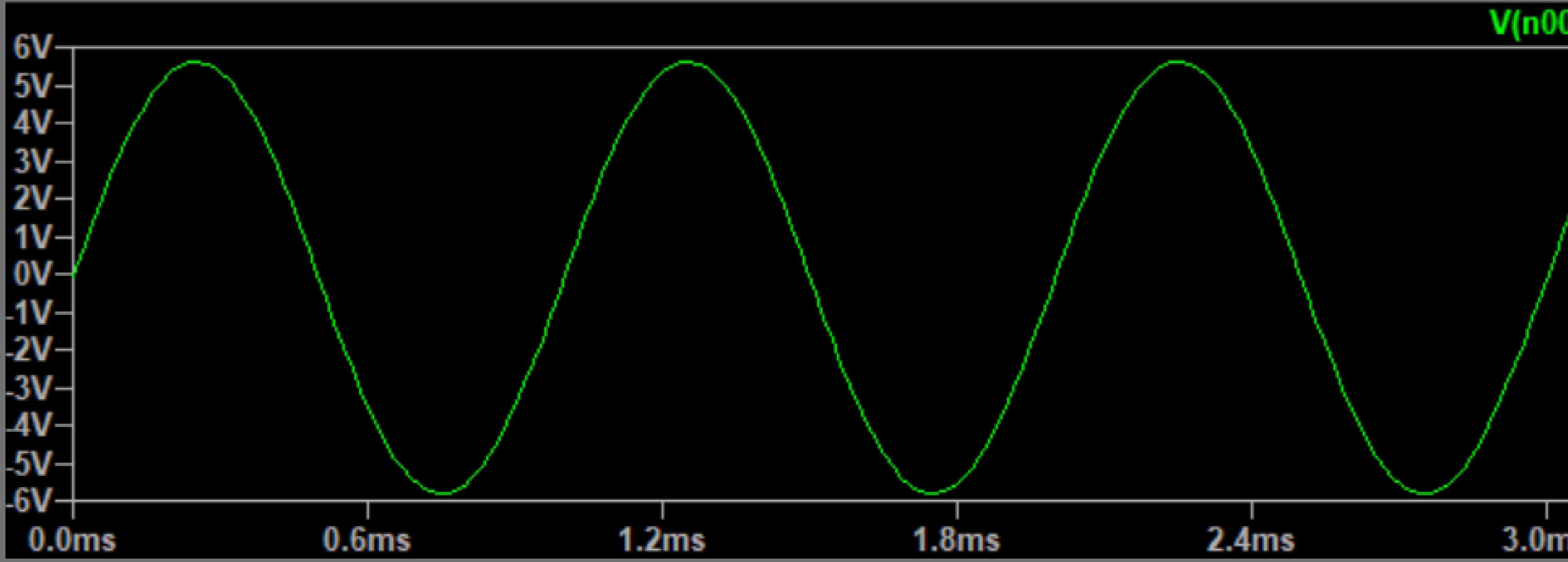
The ideal opamp has infinite input impedence and 0 output impedence

SIMULATION

CIRCUIT



RESULT AFTER 2 STAGES



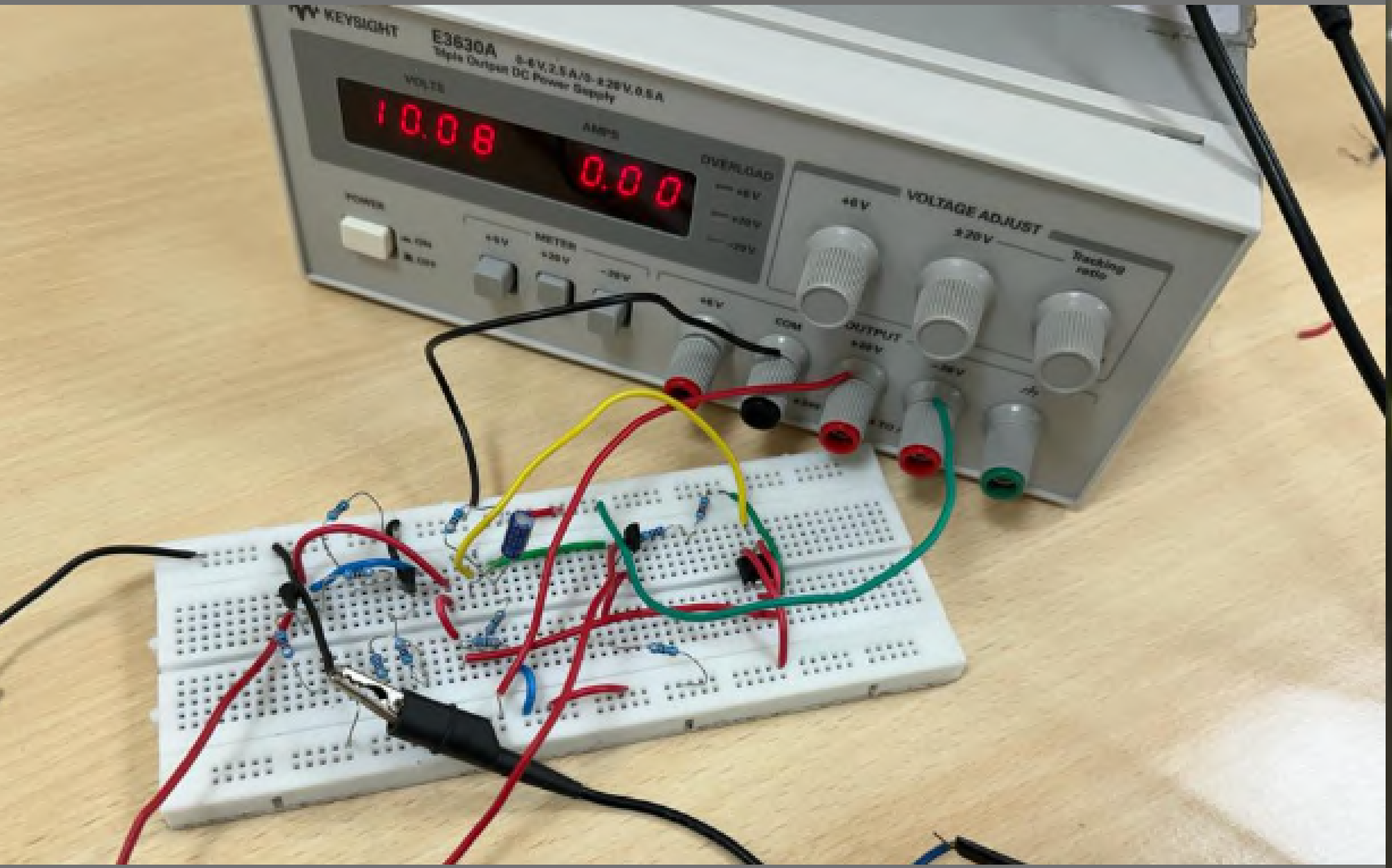
Input Voltage : 15mV

Output Voltage : 6V

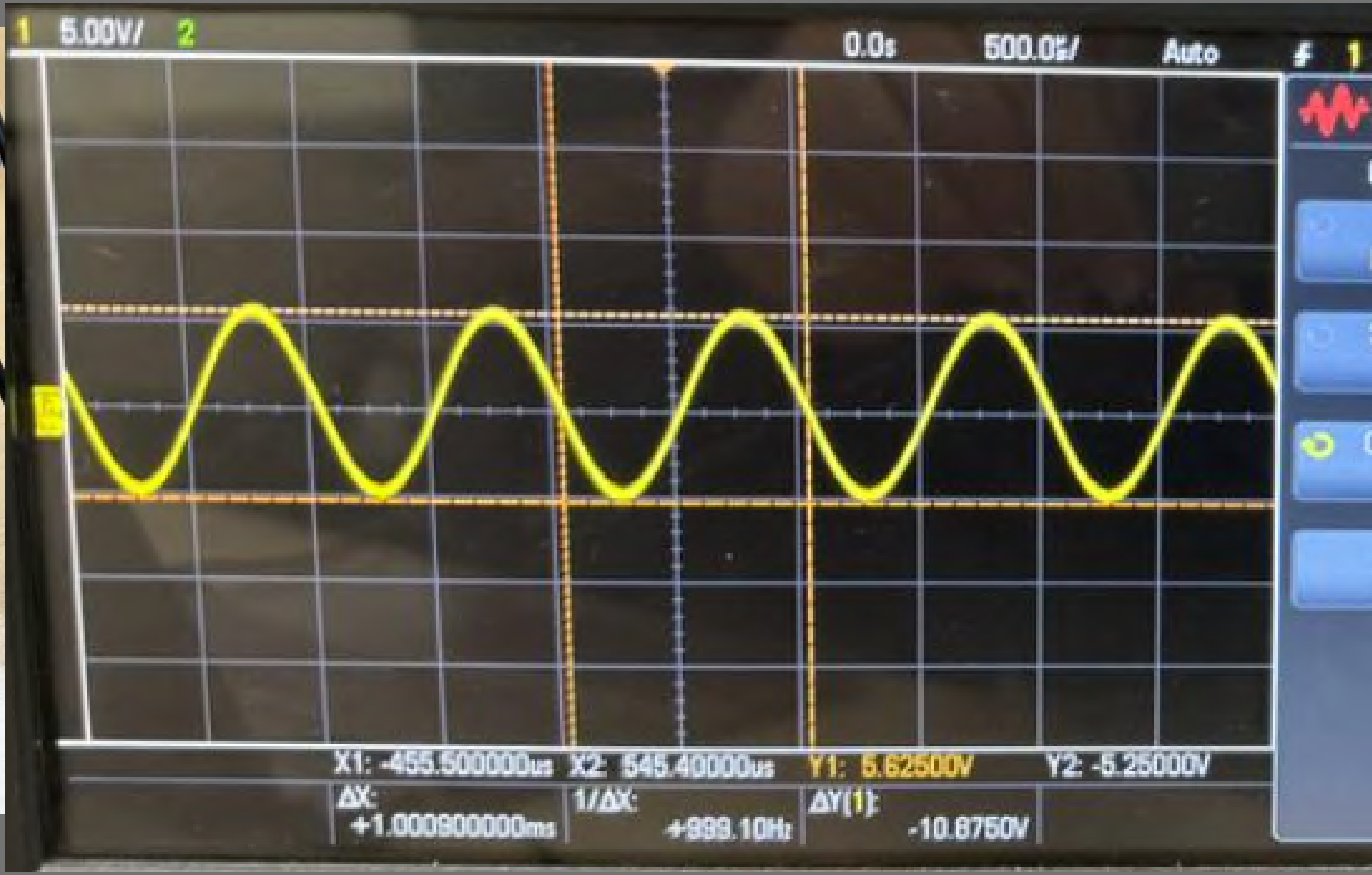
Gain : V(out) / V(in) = 400

HARDWARE

CIRCUIT



RESULT



Input Voltage : 30mVpp   Output Voltage : 10.8 Vpp

Gain : V(out) / V(in) = 360

FILTER STAGE

BAND-PASS FILTER

To ensure our amplifier outputs signals only within the audible frequency range while suppressing any frequencies outside this range, we'll implement an active bandpass filter

This stage helps us eliminate the unwanted noise added in the previous stage of the system and improves the overall tone.

Achieving this involves combining a high-pass filter and a low-pass filter in series, with an op-amp inserted between them to serve as a buffer.

1/ (2 π R C) to decide upper and lower bound frequency

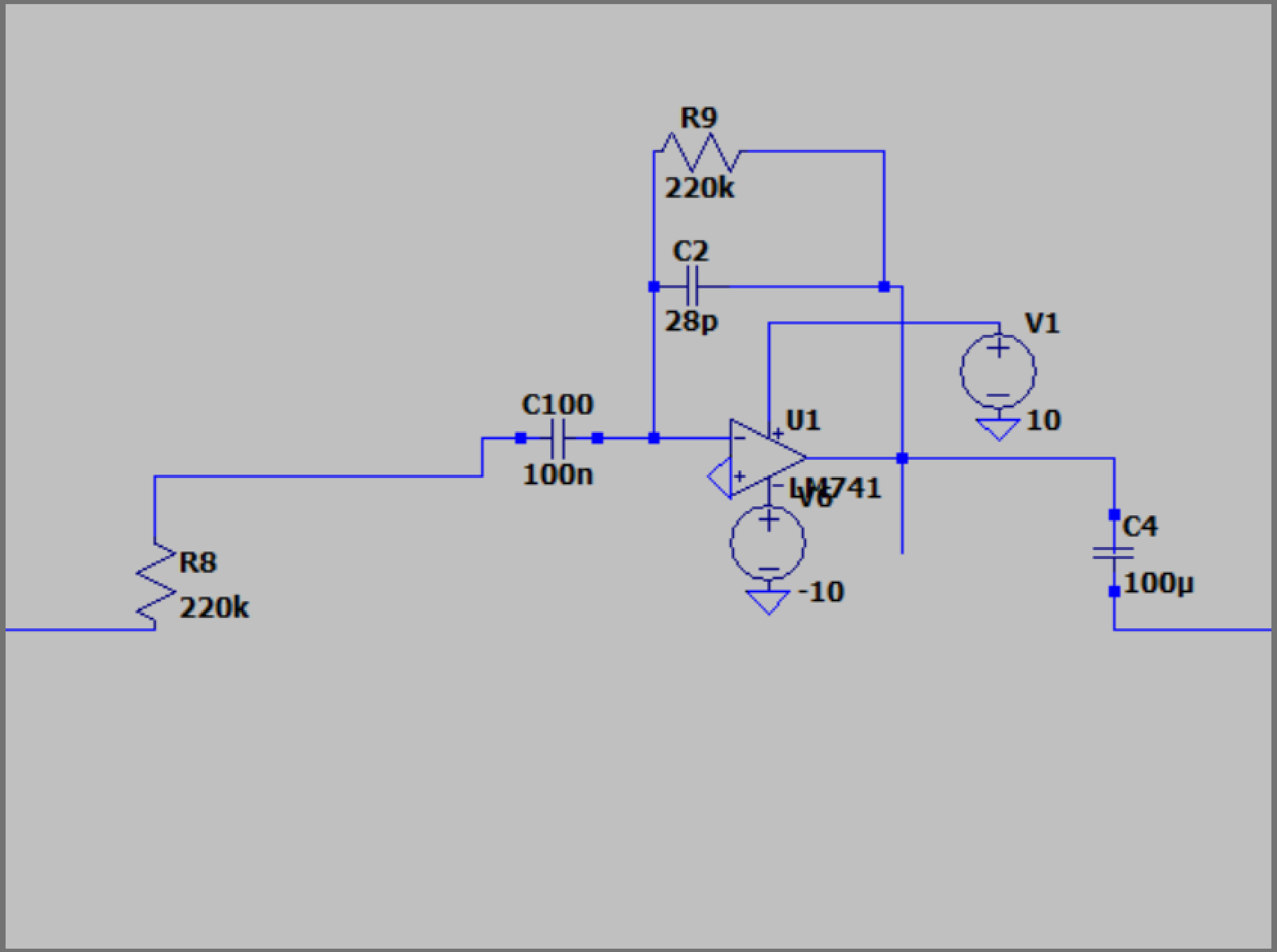
Transfer Function : $\text{Bandpass:} \quad H(s) = \dfrac{Ks}{s^2 + bs + a}$

$$H(j\omega) = \frac{K}{j\omega + b + \frac{a}{j\omega}} = \frac{K}{j\omega + b - \frac{ja}{\omega}}$$

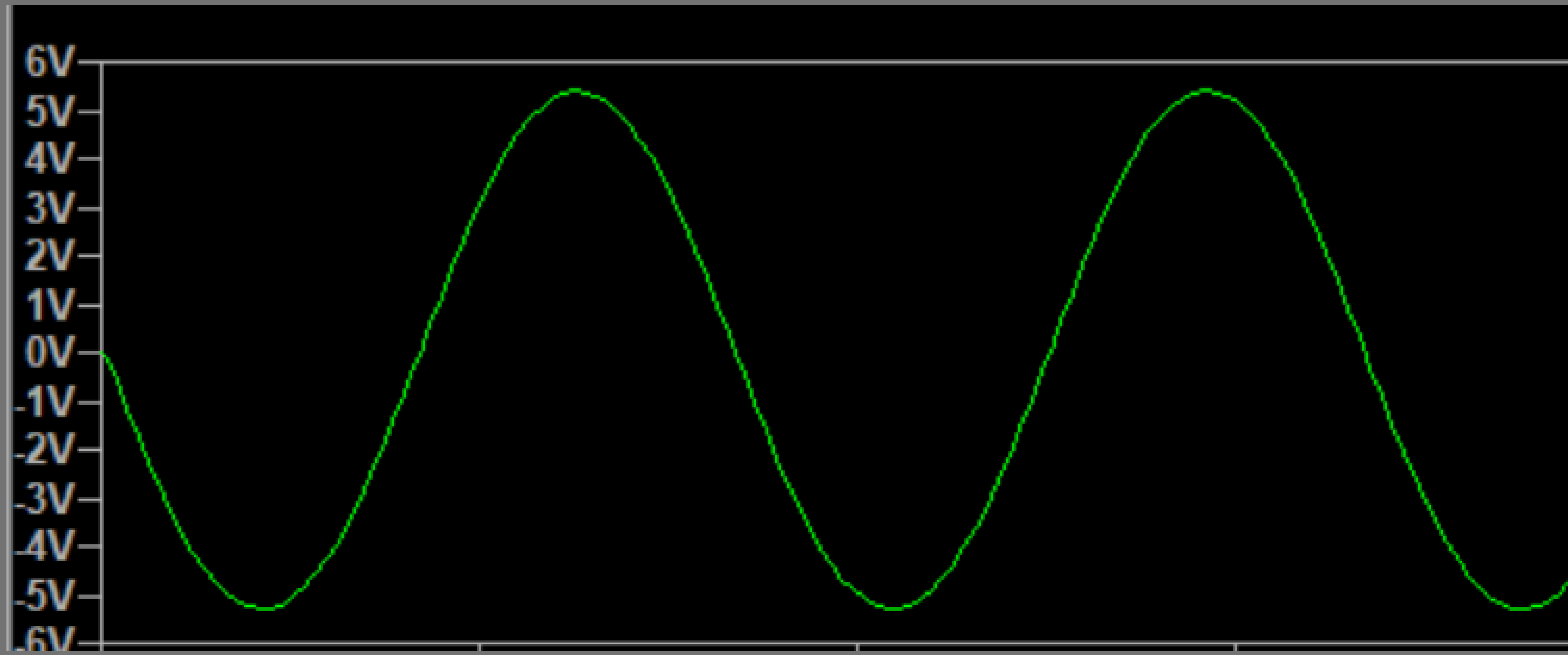
At ω = 0 and ω = ∞, equation reduces to 0
when ω = a/ω or ω2 = a, H = K/b, this describes a filter that attenuates low and high frequencies and passes midband frequencies

SIMULATION

CIRCUIT



RESULT AFTER 3 STAGES



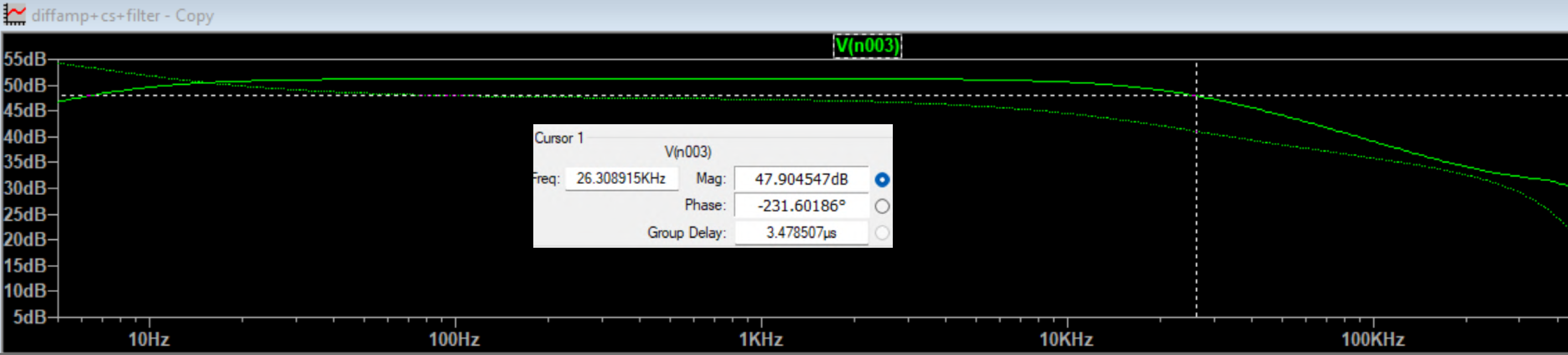
Input Voltage : 15mV

Output Voltage : 5.5V

Gain : V(out) / V(in) = 366

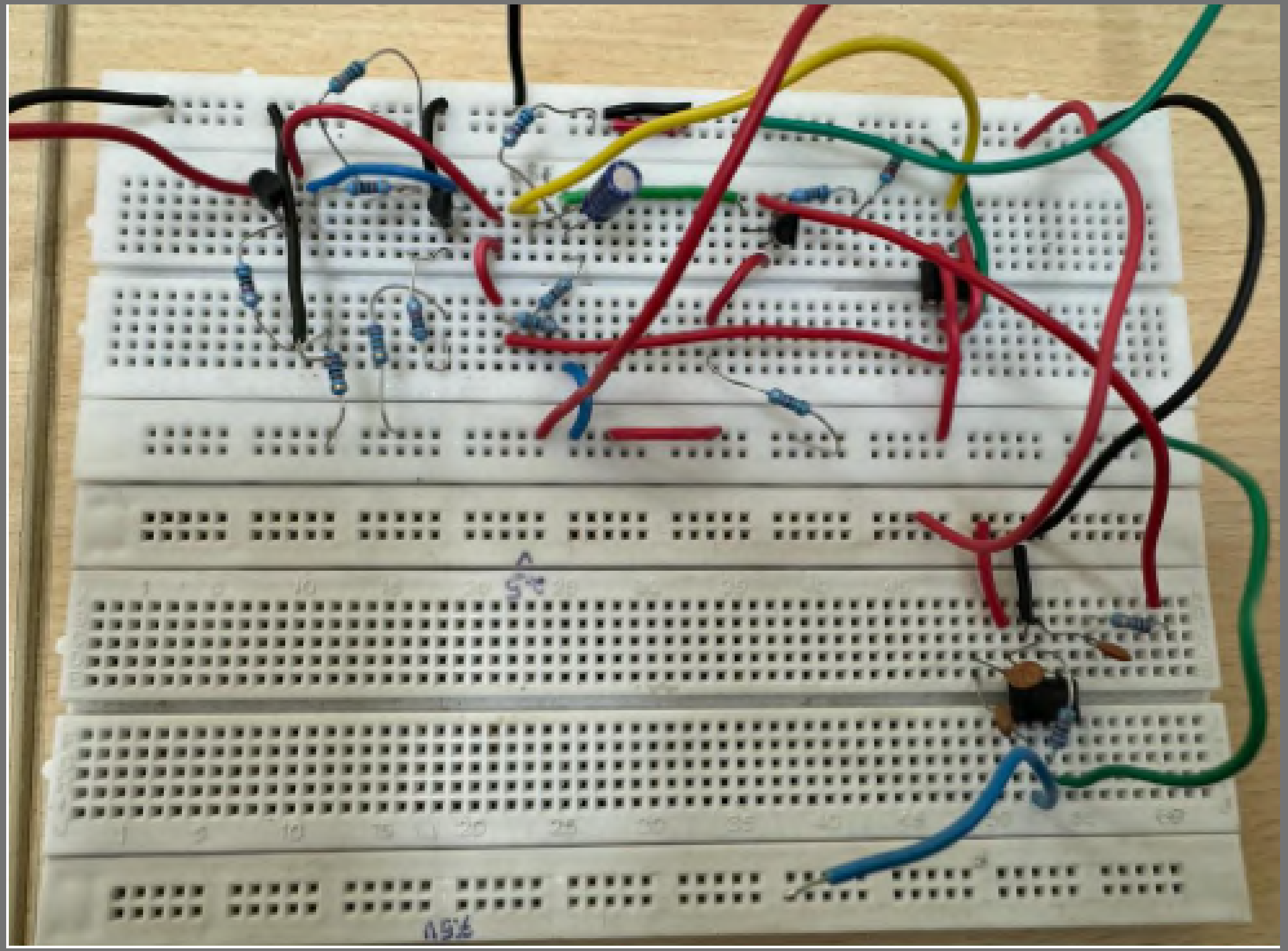
SIMULATION

BODE PLOT

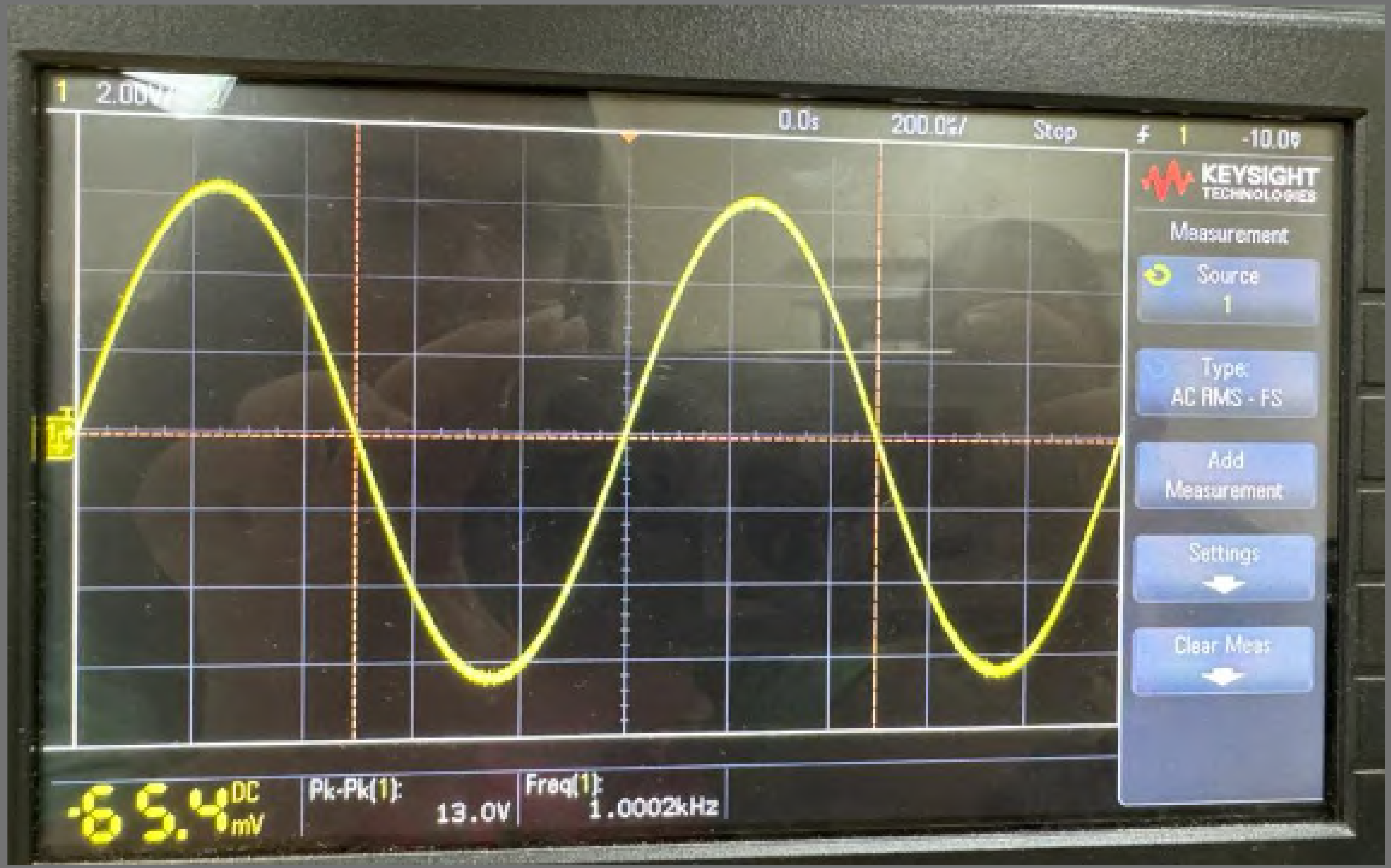


HARDWARE

CIRCUIT



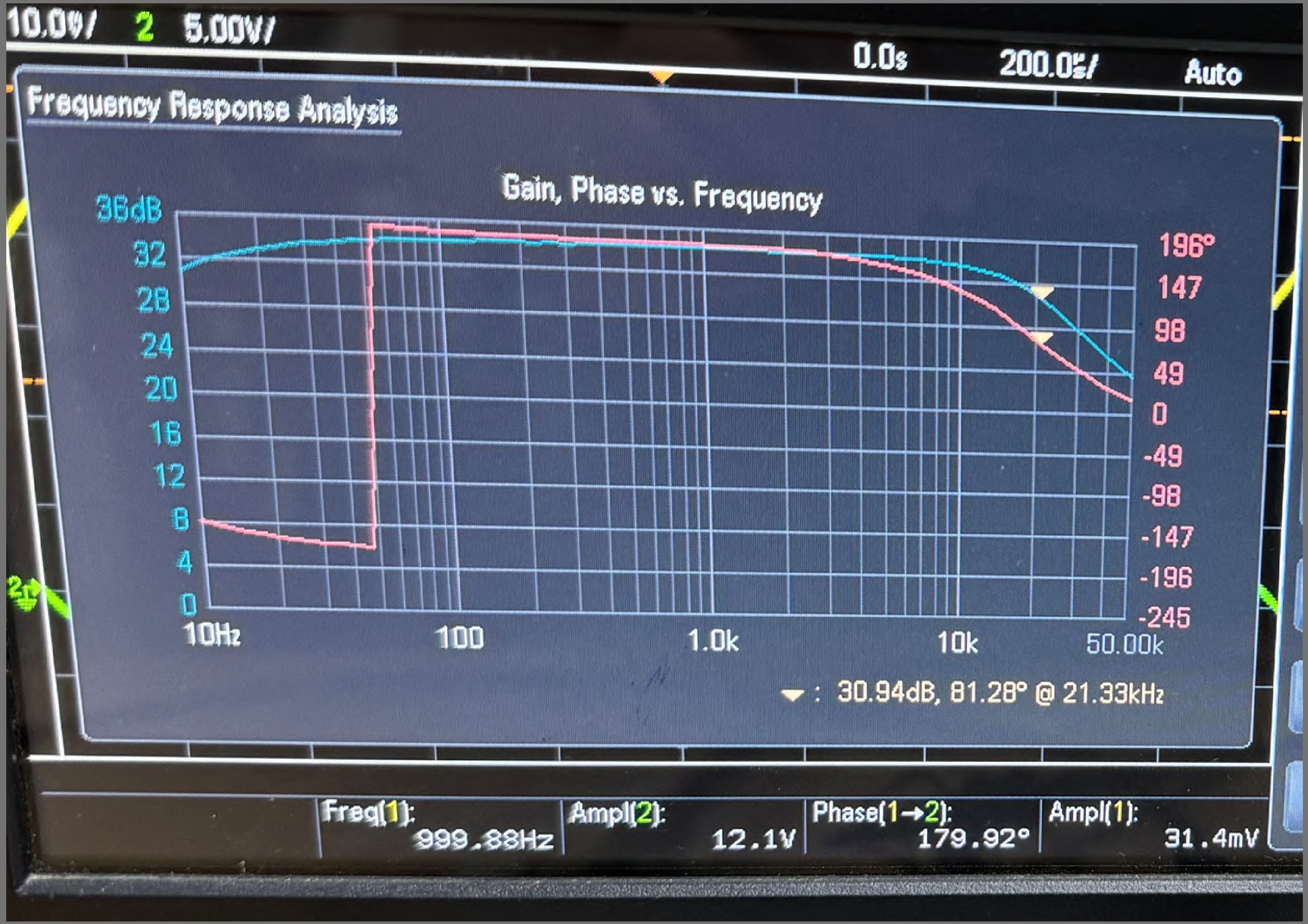
RESULT AFTER 3 STAGES (VDD=12V)



Input Voltage : 30 mVpp
Output Voltage : 13Vpp
Gain : V(out) / V(in) = 433

SIMULATION

BODE PLOT



$$f_c = \frac{1}{2\pi RC}$$

1/ (2 * 3.14 * 220k * 100n) = 7.23Hz

1/ (2 * 3.14 * 220k * 28p) = 25kHz

POWER AMPLIFIER STAGE

The power amplifier, fed by both the pre-amplifier and filter stage, primarily serves to boost the power level of a weaker audio signal. We use Class AB power amplifier

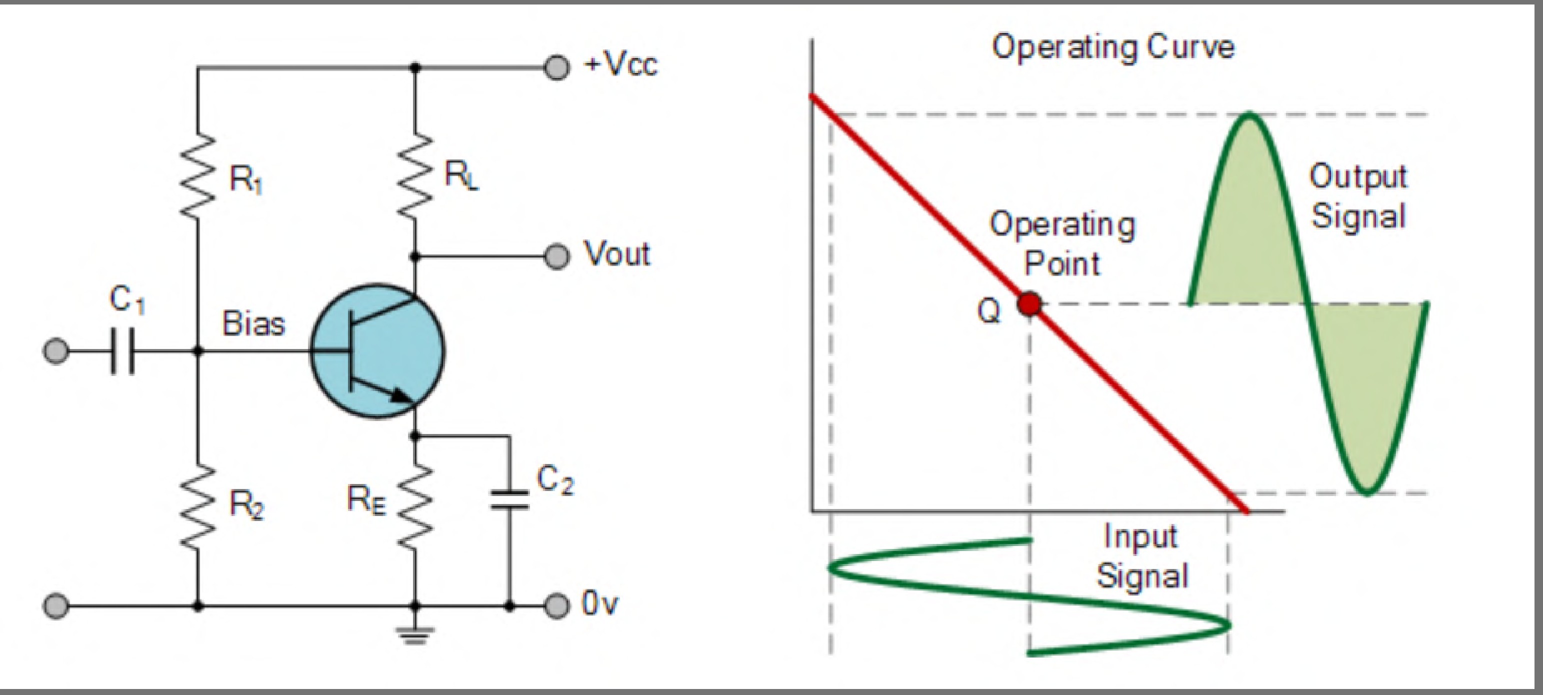
WHY CLASS AB IS USED ?

Class-A Amplifier: output transistors conduct throughout the entire cycle of the input signal. This results in low distortion but low efficiency as the transistors are always conducting, even when there is no signal.

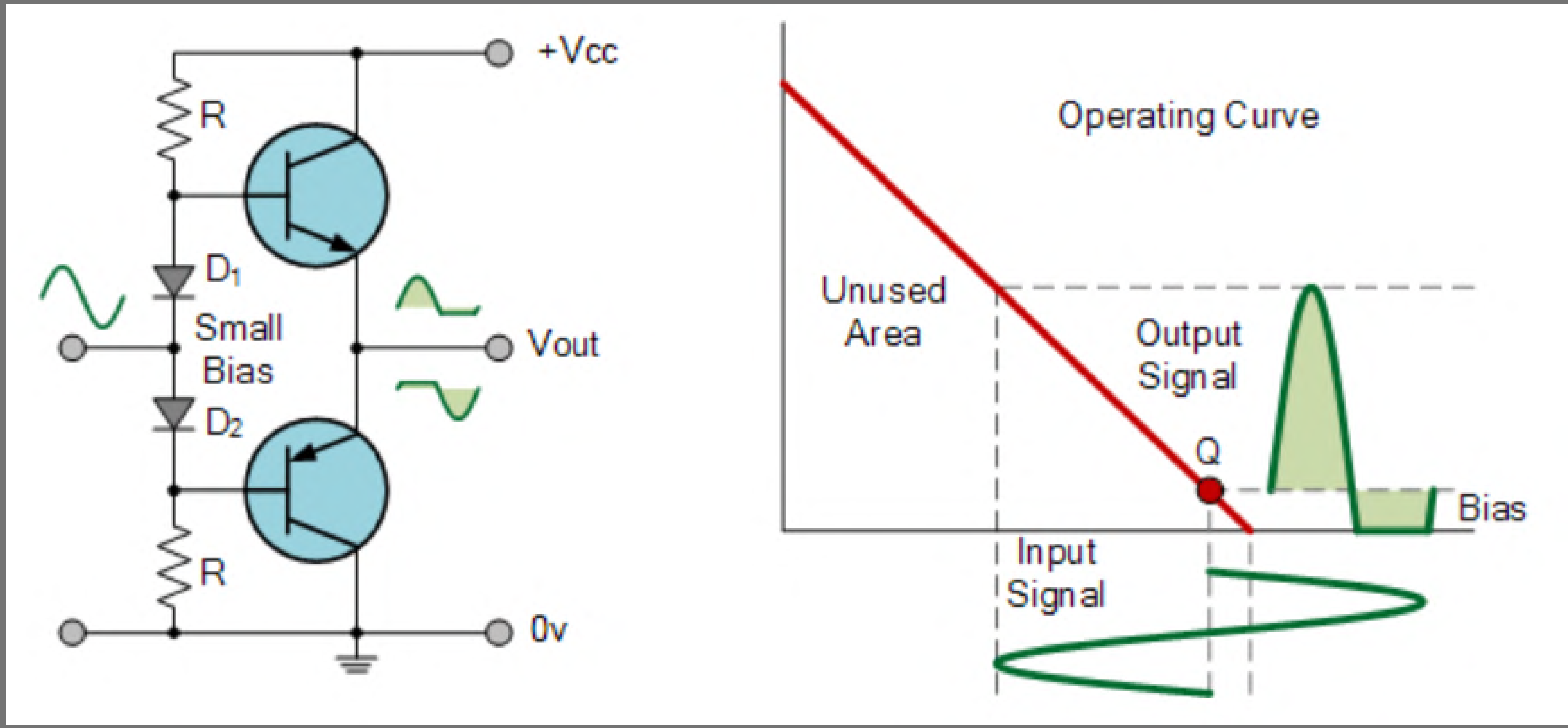
Class-B Amplifier: divides the input signal cycle between two transistors. While this improves efficiency, it introduces crossover distortion at the transition points, where one transistor turns off and the other turns on.

Class-AB Amplifier: combines features of both Class-A and Class-B amplifiers. They operate with both output transistors conducting slightly, reducing crossover distortion compared to Class-B amplifiers while offering better efficiency than Class-A amplifiers. This balanced approach results in improved linearity and efficiency, making Class-AB the best choice.

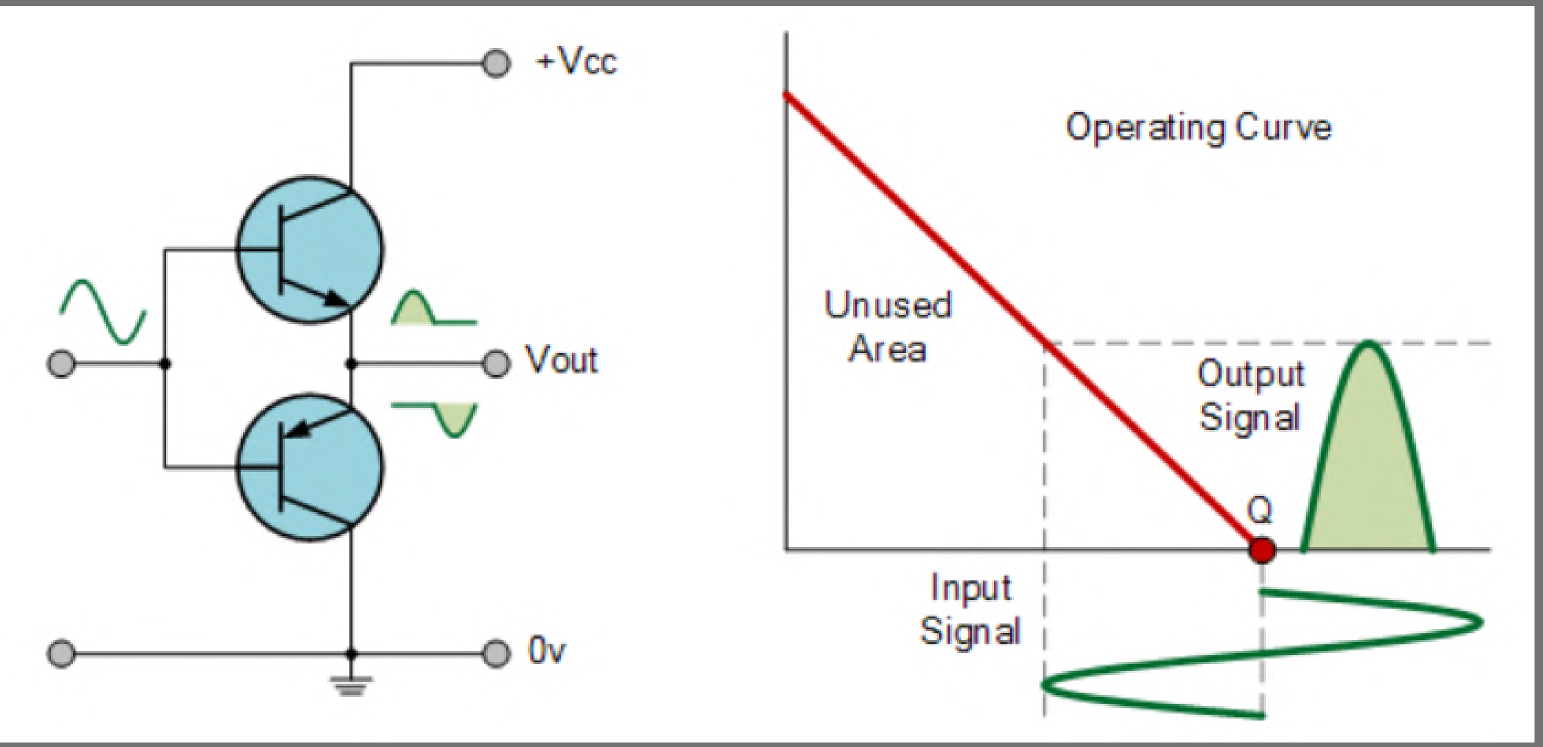
Class A



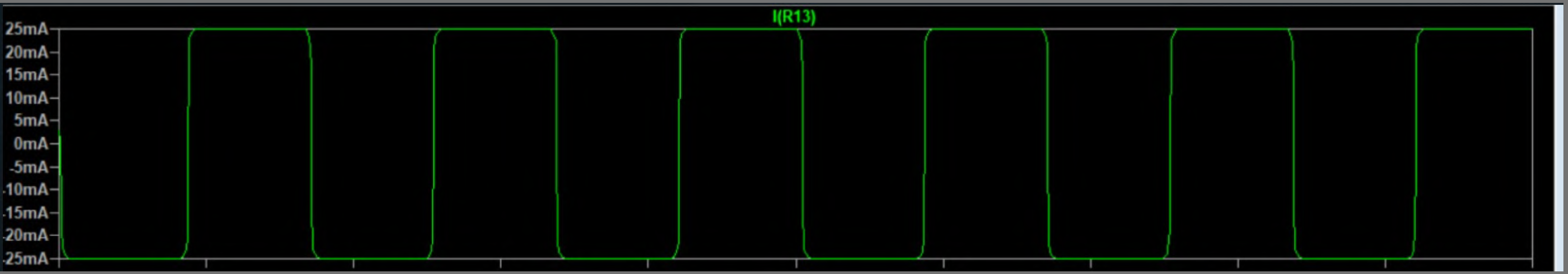
Class AB



Class B

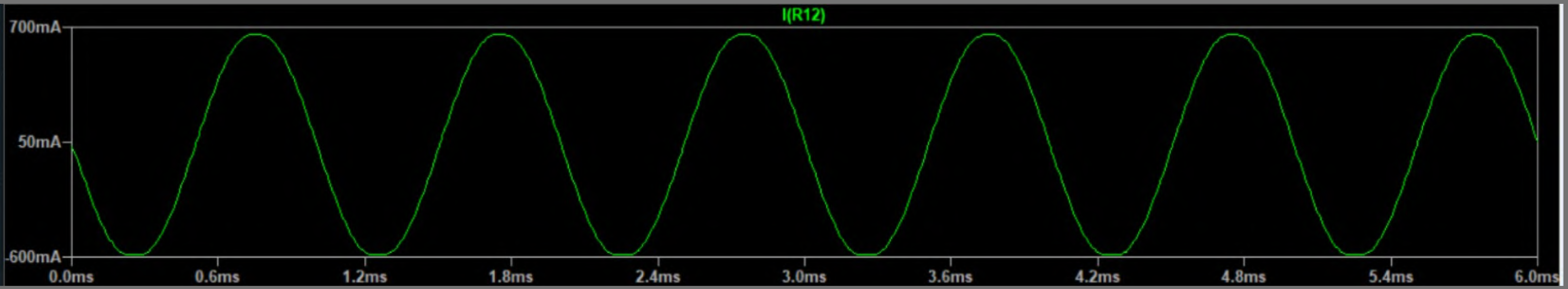


Current before Power Amplifier



50mVpp

Current after Power Amplifier

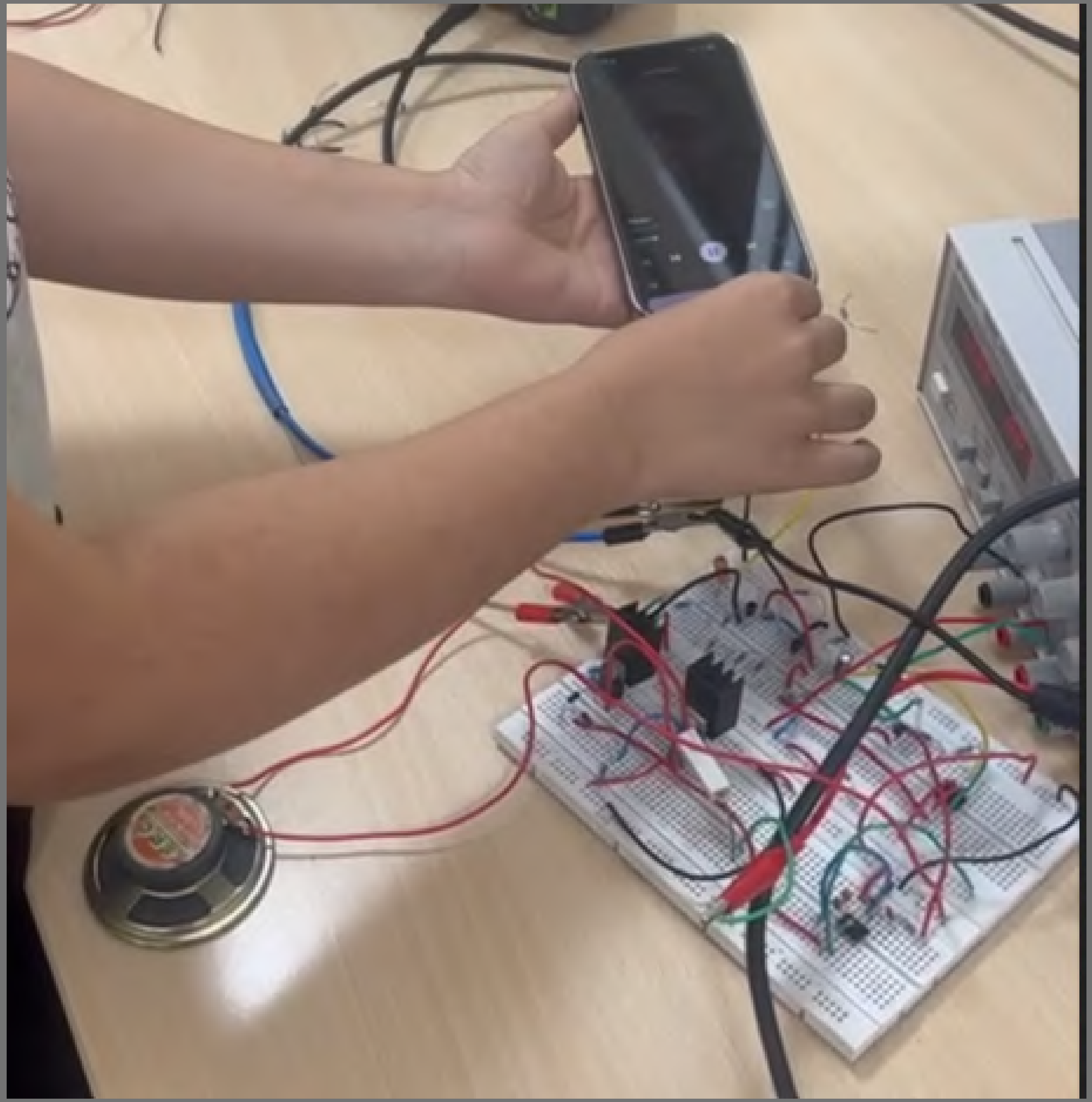


1300mVpp

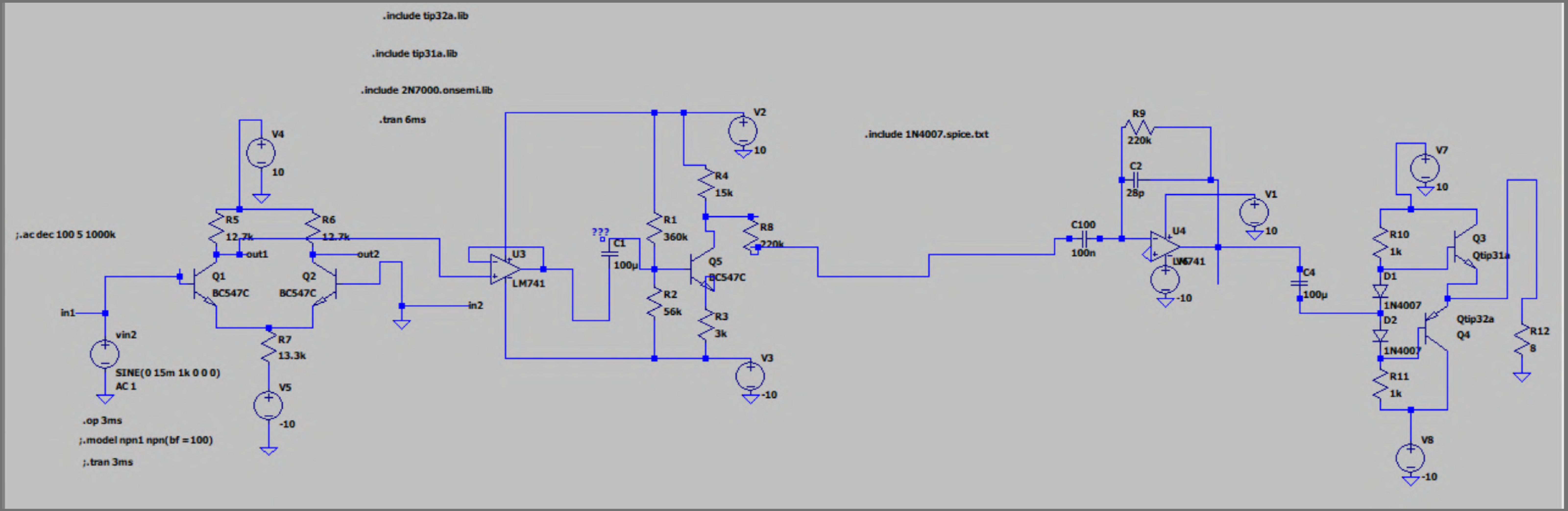
Therefore , Current gets amplified after using power amplifier

Final Circuit

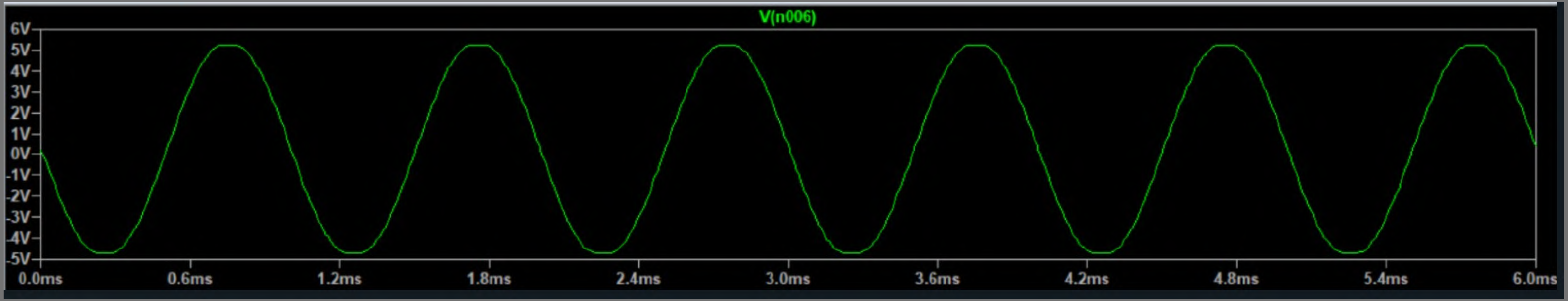
The power amp output is then used and a load resistance is applied so that excessive current doesn't flow through the Q-tips. We get the final circuit and a total gain of about 430 .



Simulation



Result



11Vpp

Hardware Results

link to working of our circuit :

https://drive.google.com/file/d/1Z2dTJs6QuSHeNsl6QInivUGPlxvtooMz/view?usp=drivesdk

We get an amplified audio
and we can properly
amplify music