Bilkent University

Electrical and Electronics Department

EE313-02 Lab 4 Preliminary Report:

“Wide-Band Amplifier with Feedback”

01/12/2024

Fatih Mehmet Çetin - 22201689

Introduction:

This lab’s main aim is designing a two-stage amplifier with feedback to achieve a low output impedance and a flat gain.

Simulation & Analysis:

Here are some specifications which were given to us in the lab manual **(Figure 1)**:

Specifications:

Source impedance: 500Ω

Load impedance: 47Ω

Mid band voltage Gain: 20 dB±0.5dB

Bandwidth (−3dB): at least 2KHz to 2MHz (by CNTL-Click in AC analysis)

Supply voltage: 12V (single supply)

Maximum current consumption: 70mA from the supply voltage

Undistorted peak-to-peak output voltage: $2V_{pp}$ at 200KHz.

Distortion at the output: Harmonics less than −30dBc at 200KHz $2V_{pp}$ output voltage (the difference between the fundamental and the highest harmonic in FFT window)

Figure 1: The Specifications of the Circuit

Here you can see my final circuit for this lab **(Figure 2)**. As you can see the source impedance is 500Ω, the load impedance is 47Ω. The DC supply voltage is 12 Volts.

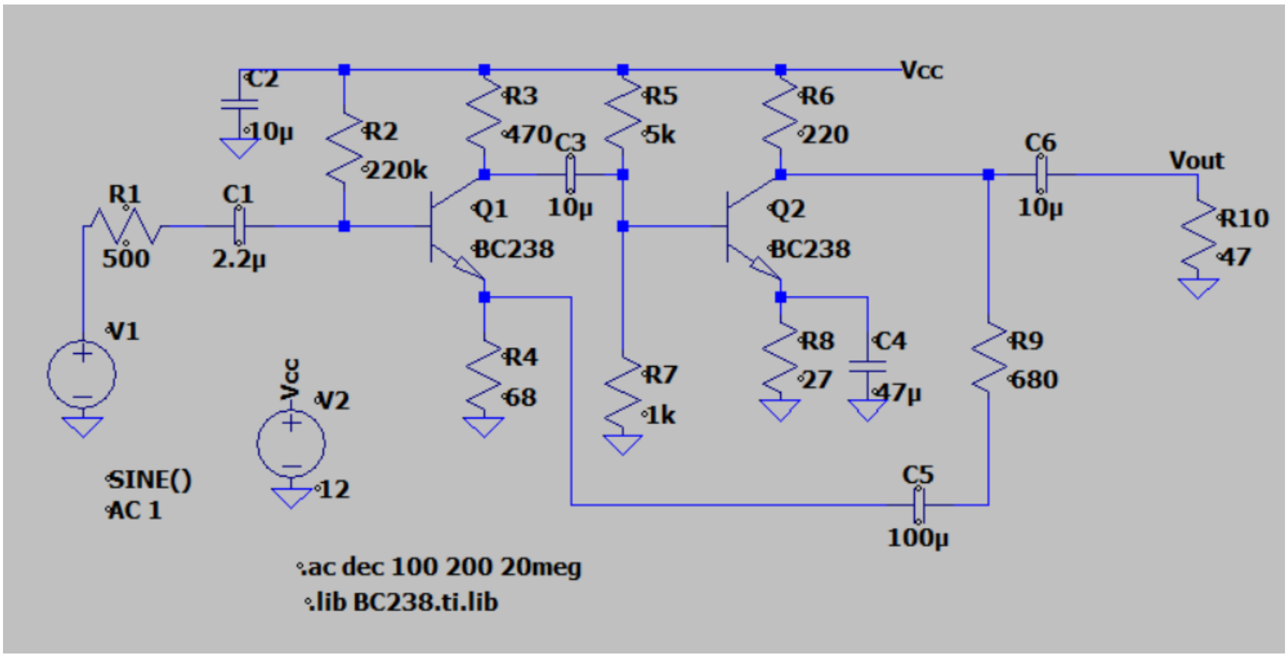

Figure 2: The Final Circuit

Here are the output voltage plots when the input voltage is 0.2 Vpp and has a frequency of 200kHz **(Figures 3.1 & 3.2)**. You can see that the output voltage is nearly 2Vpp at these conditions.

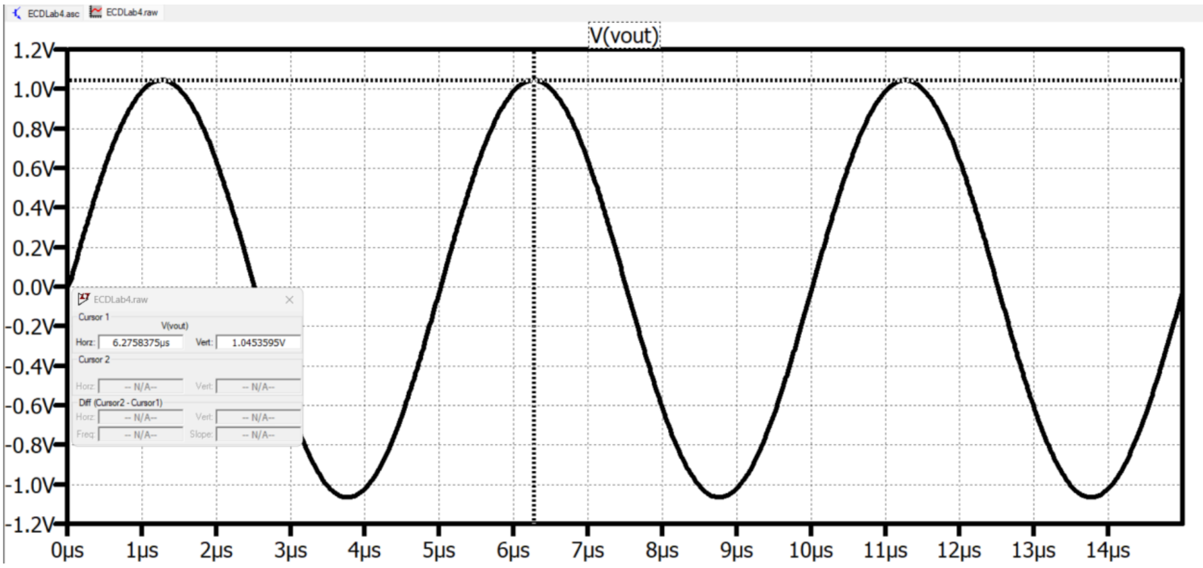

Figure 3.1: The Output Voltage being nearly 2Vpp when the input is 0.2Vpp 200kHz.

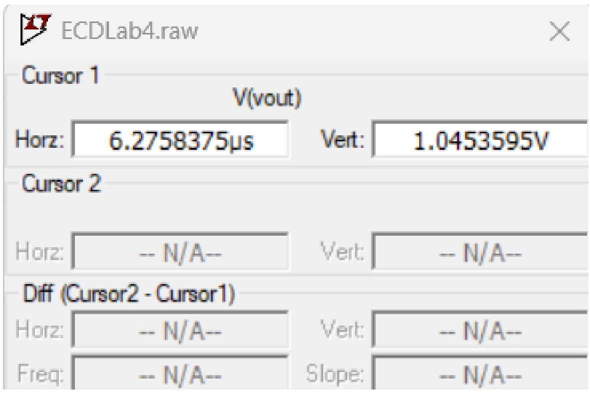

Figure 3.2: The Output voltage is 2.09 Vpp

Now I will show each of these 3 steps one by one **(Figure 4)**.

Show that

1. The current consumption is less than 70mA
2. The small-signal bandwidth is at least 2KHz-2MHz while the mid-band gain is 20dB±0.5dB (by AC analysis)
3. The harmonic content of the output voltage is better than −30dBc with 0.1V peak input signal at 200KHz.

Figure 4: Three Requirements the Circuit Should Meet

Condition 1:

Here you can see the current consumption of the circuit from the power source **(Figure 5)**. As you can see, the current does not exceed 62.4mA which is well under the 70mA limit.

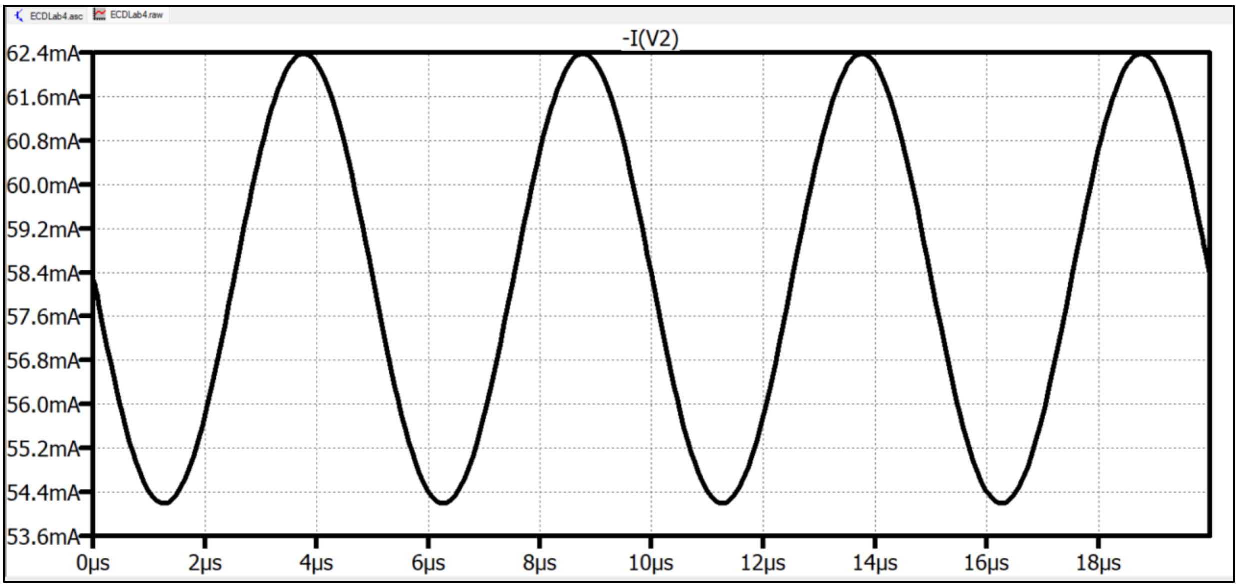

Figure 5: The Current Drawn from the 12V DC power source

Condition 2:

To meet this condition, I applied an AC analysis to the circuit. Here is the new circuit and the results **(Figures 6.1 to 6.4)**. As you can see the mid-band gain is at max 20.39dB which is within the limits. Also, the Mid-band gain does not drop below 19.5dB at 2kHz and 2MHz.

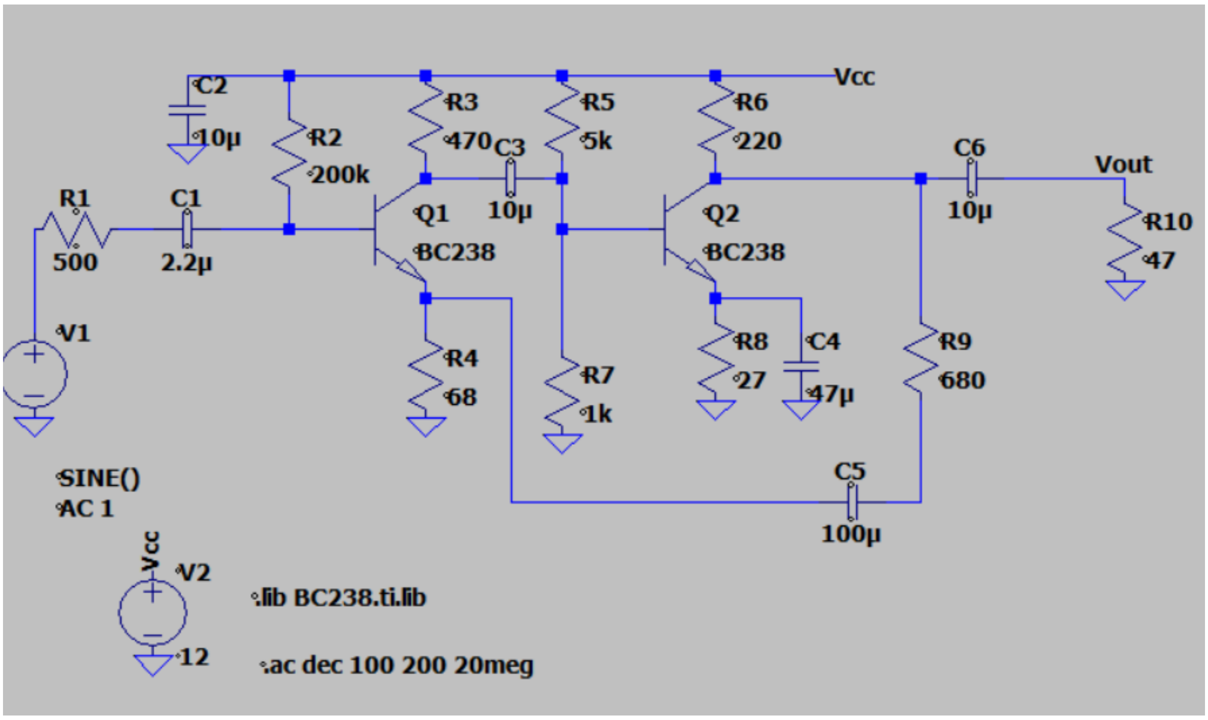

Figure 6.1: The AC Analysis Circuit

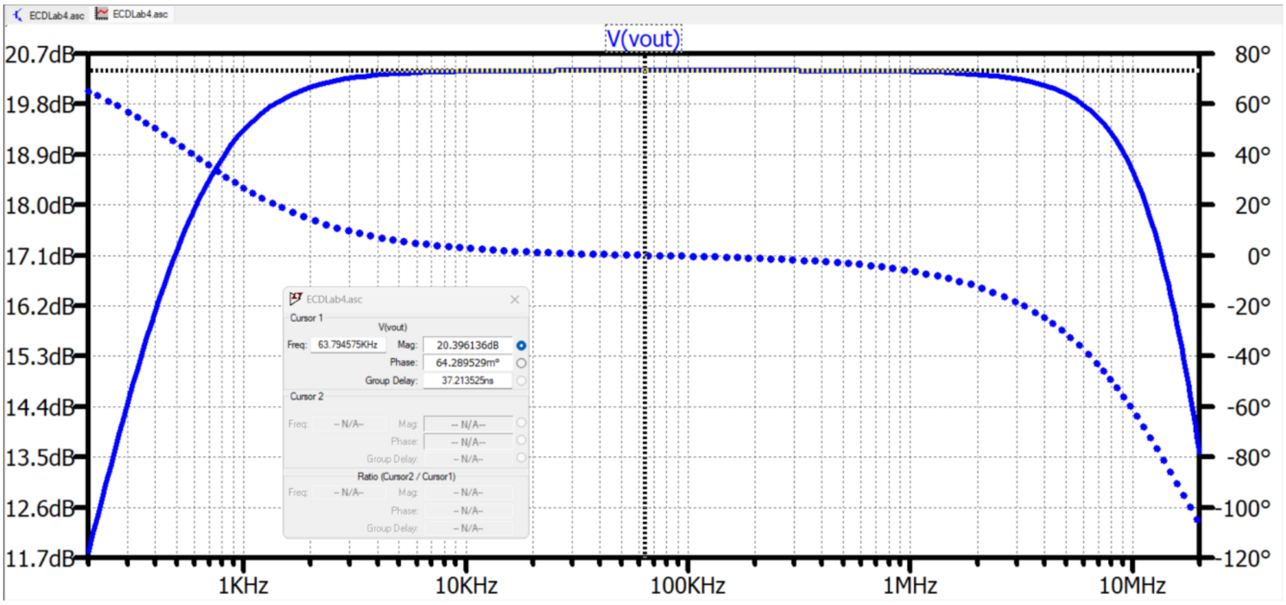

Figure 6.2: The Gain vs Frequency Plot

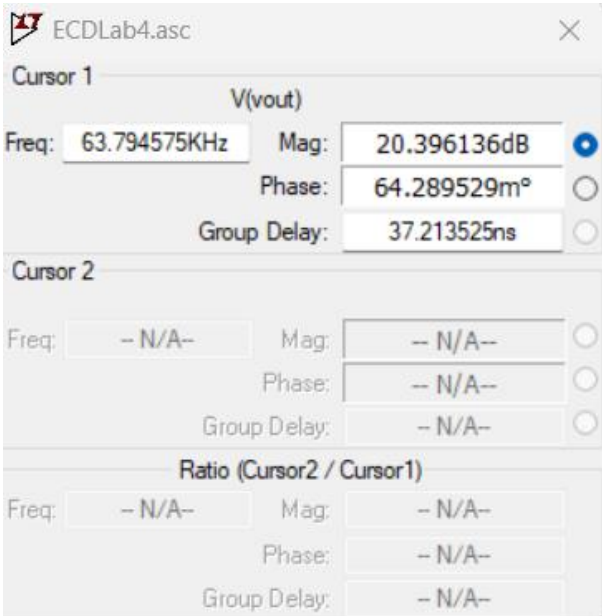

Figure 6.3: The Gain being maximum 20.39dB at the Wide-Band

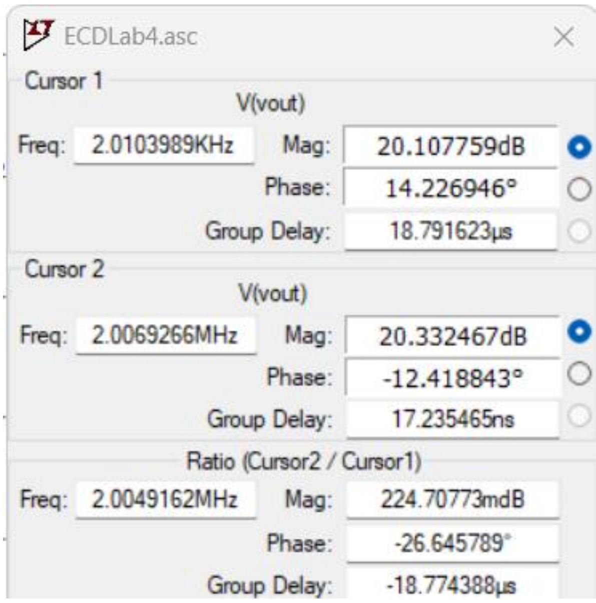

Figure 6.4: The Gain being 20.10dB at 2kHz and 20.33dB at 2MHz

Condition 3:

FFT analysis was applied to Figure 3.1 with 100 periods and the following graph was obtained **(Figures 7.1 & 7.2)**. As you can see, the difference between the main signal and the highest harmonic is 48dB, which is well above the minimum limit.

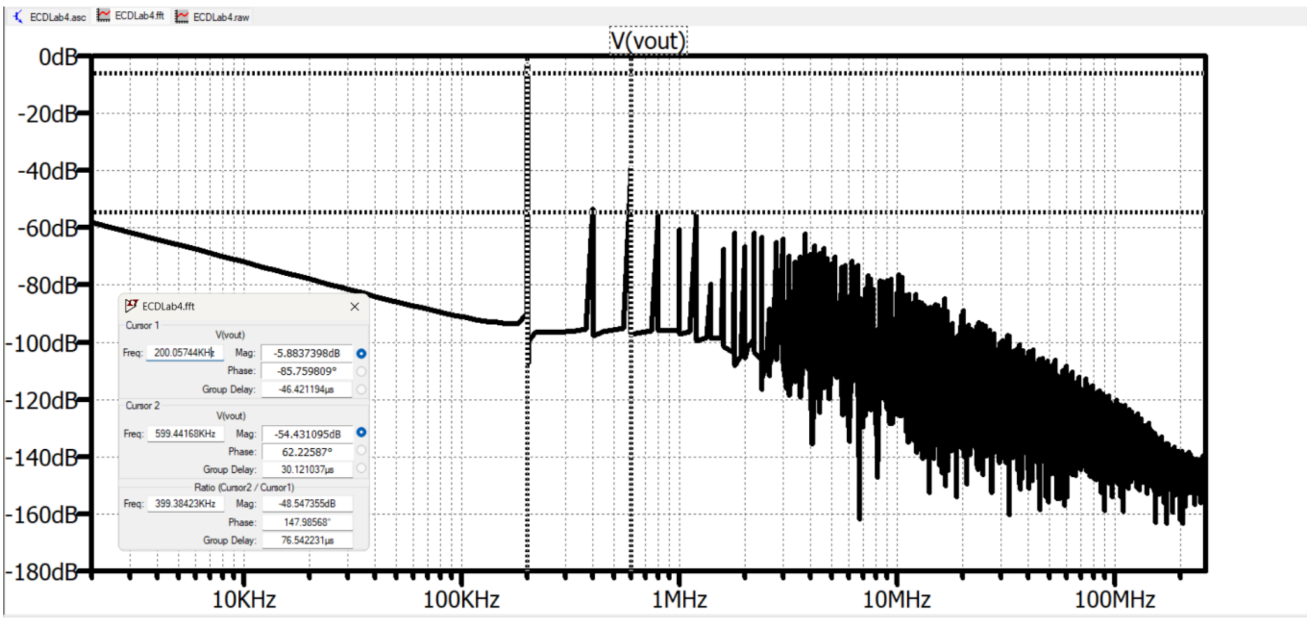

Figure 7.1: The FFT of the Output Voltage

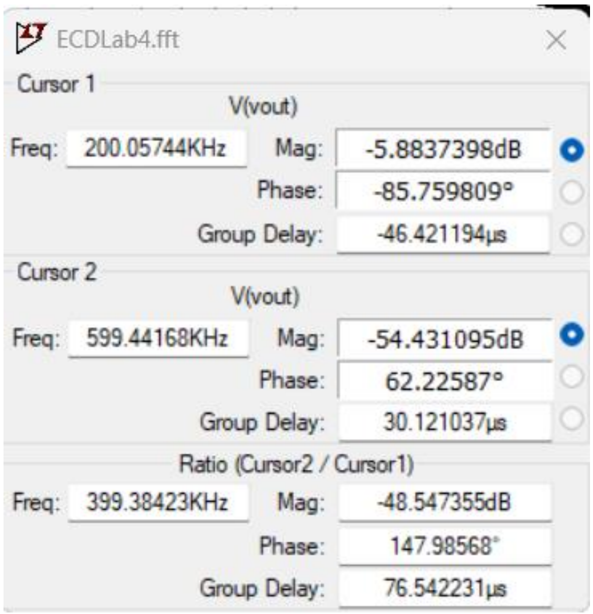

Figure 7.2: The difference between the main signal and the highest harmonic being 48dB

Now let’s check one by one 3 other measurements that we should determine according to the lab manual **(Figure 8)**:

Determine

4. The small-signal input impedance of the amplifier at 200KHz (the adjusted value of R_S in AC analysis until the voltage gain drops by 6dB compared to R_S=0)
5. The small-signal output impedance of the amplifier at 200KHz (the adjusted value of R_L in AC analysis until the voltage gain drops by 6dB compared to $R_L=\infty$)
6. The phase margin of the open-loop system.

Figure 8: Conditions 4, 5 and 6

Condition 4:

To measure the small-signal input impedance of the amplifier at 200kHz, I gradually incremented Rs until the gain at 200kHz was 14.45dB -6dB lower than the initial value of the gain when Rs is zero, 20.45dB. The gain was 14.25dB when the input resistance was 69kΩ. So, small-signal input impedance of the circuit is nearly 69kΩ. Here you can see the gain plots when Rs is 69kΩ and shorted: **(Figures 9.1 to 9.4)**

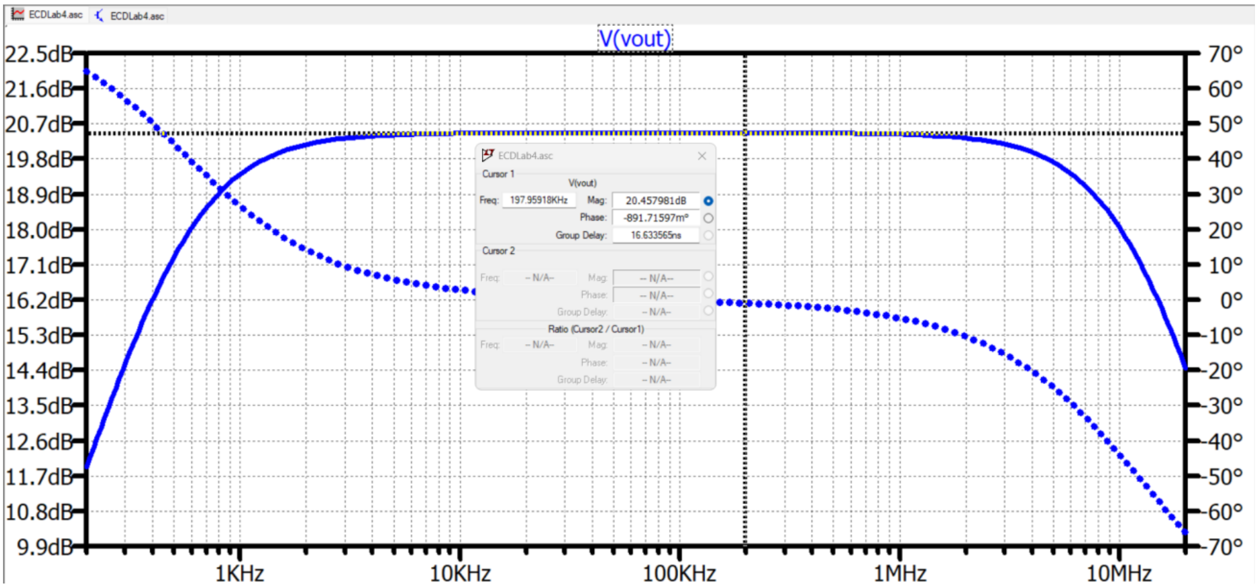

Figure 9.1: The AC Analysis when Rs is Shorted

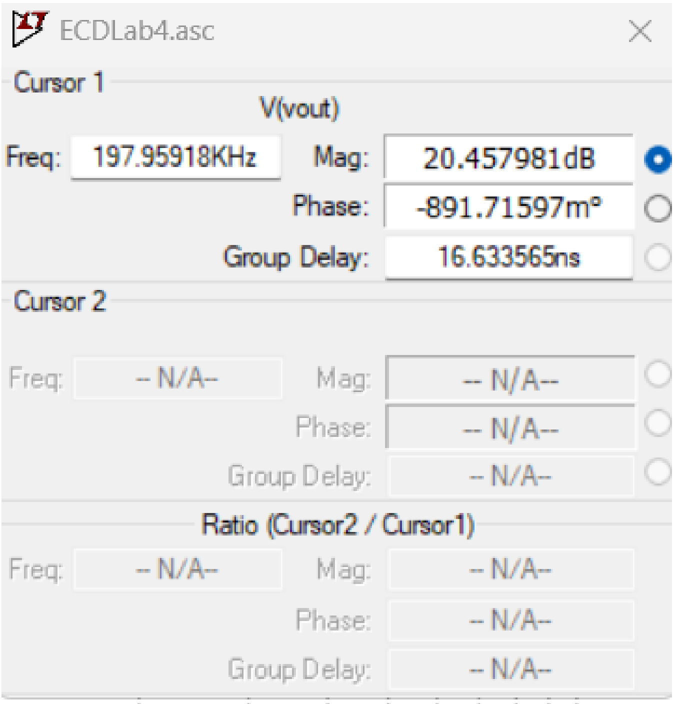

Figure 9.2: The Gain is 20.45dB when Rs is Shorted

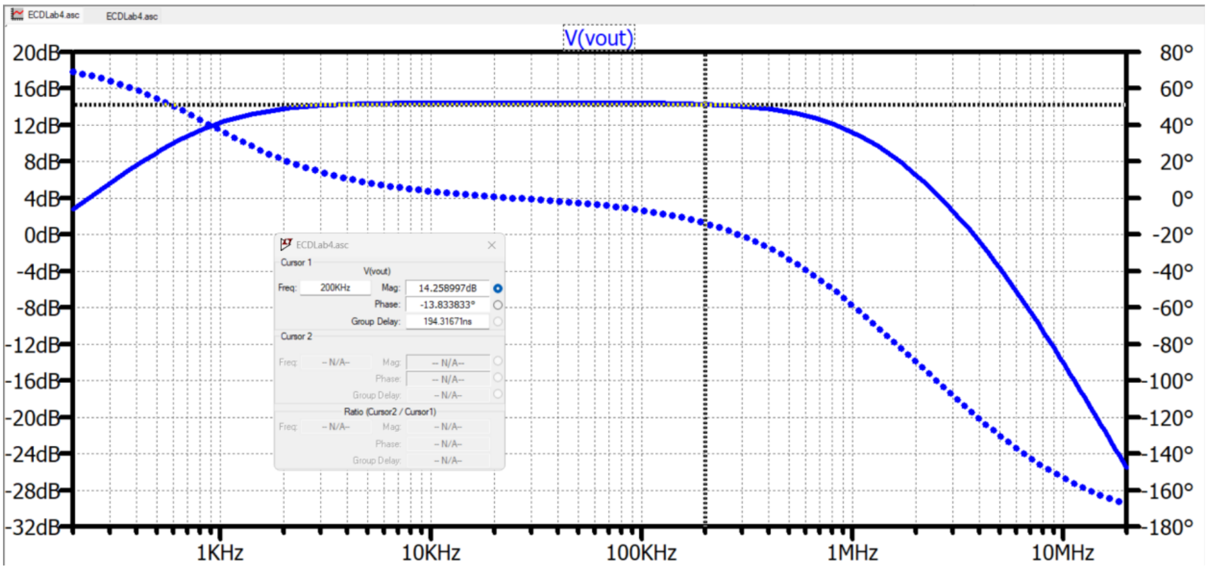

Figure 9.3: The AC Analysis when Rs is 69kΩ

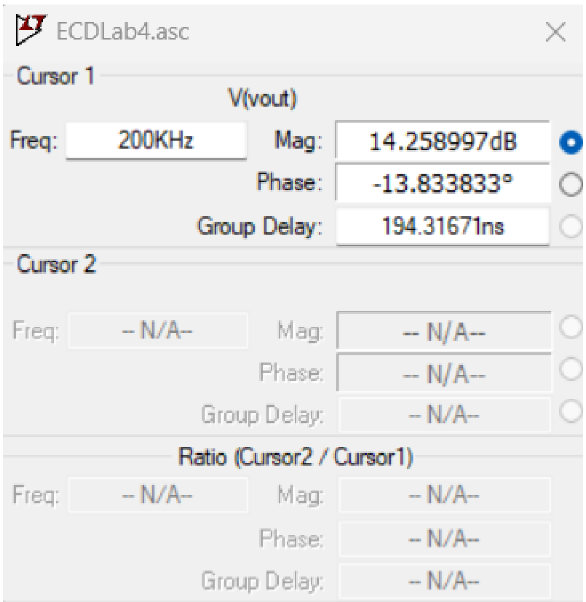

Figure 9.4: The Gain is 14.25dB when Rs is 69kΩ

Condition 5:

To measure the small-signal output impedance of the amplifier at 200kHz, I gradually decremented Rl until the gain at 200kHz was 15.68dB -6dB lower than the initial value of the gain when Rl is open-circuited, 21.68dB. The gain was 15.46dB when the output resistance was 7.2Ω. So, small-signal input impedance of the circuit is nearly 7.2Ω. Here you can see the gain plots when Rl is 7.2Ω and open-circuited **(Figures 10.1 to 10.4)**:

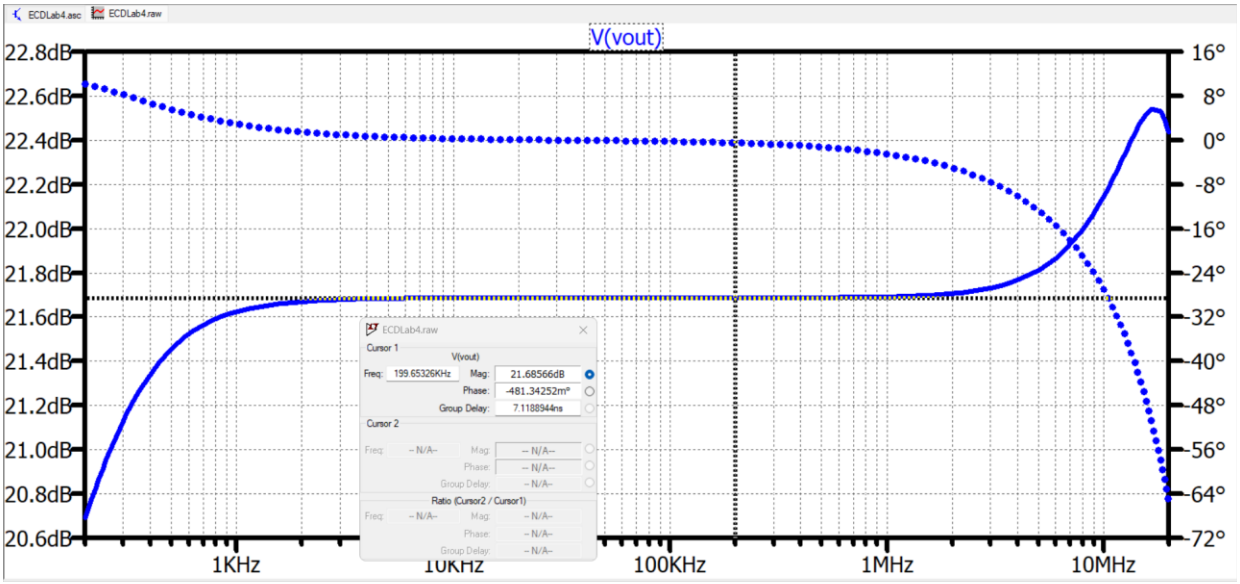

Figure 10.1: The AC Analysis when Rl is Open Circuit

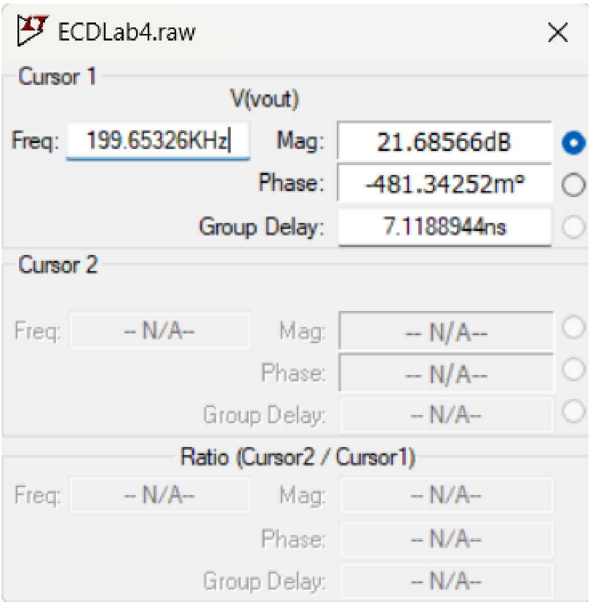

Figure 10.2: Gain is 21.68dB when Rl is open-circuit

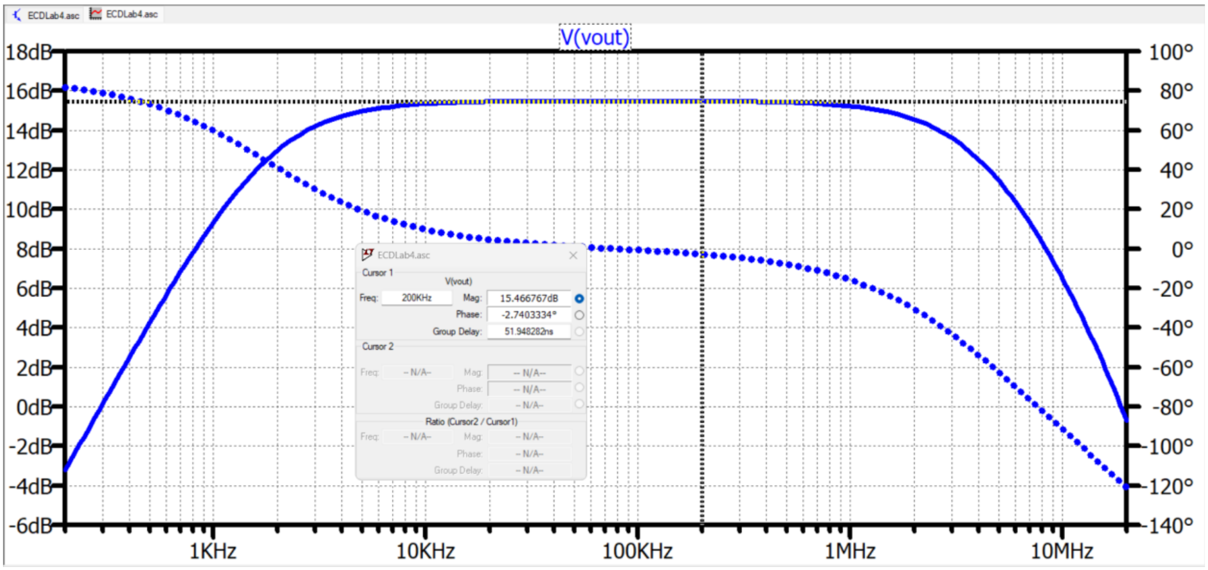

Figure 10.3: The AC Analysis when Rl is 7.2 Ohms

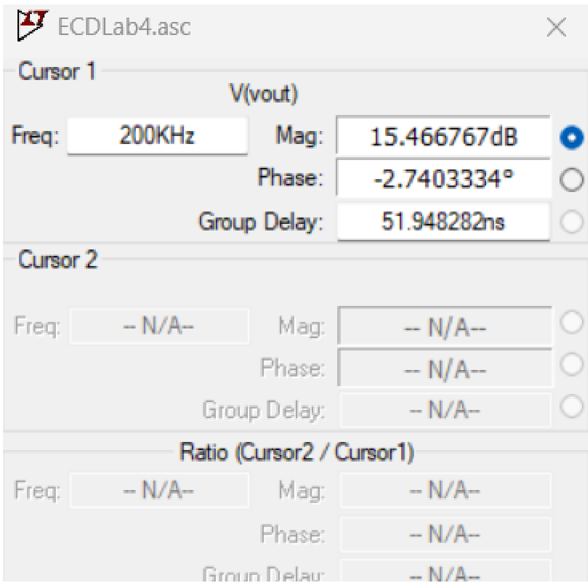

Figure 10.4: Gain is 15.46dB when Rl is 7.2 Ohms

Condition 6:

To measure the phase margin of the open loop system, I changed and used this circuit **(Figure 11)**. Here are my results **(Figures 12.1 & 12.2)**. The phases are above the -360° instability limit. No problem with phase shifts.

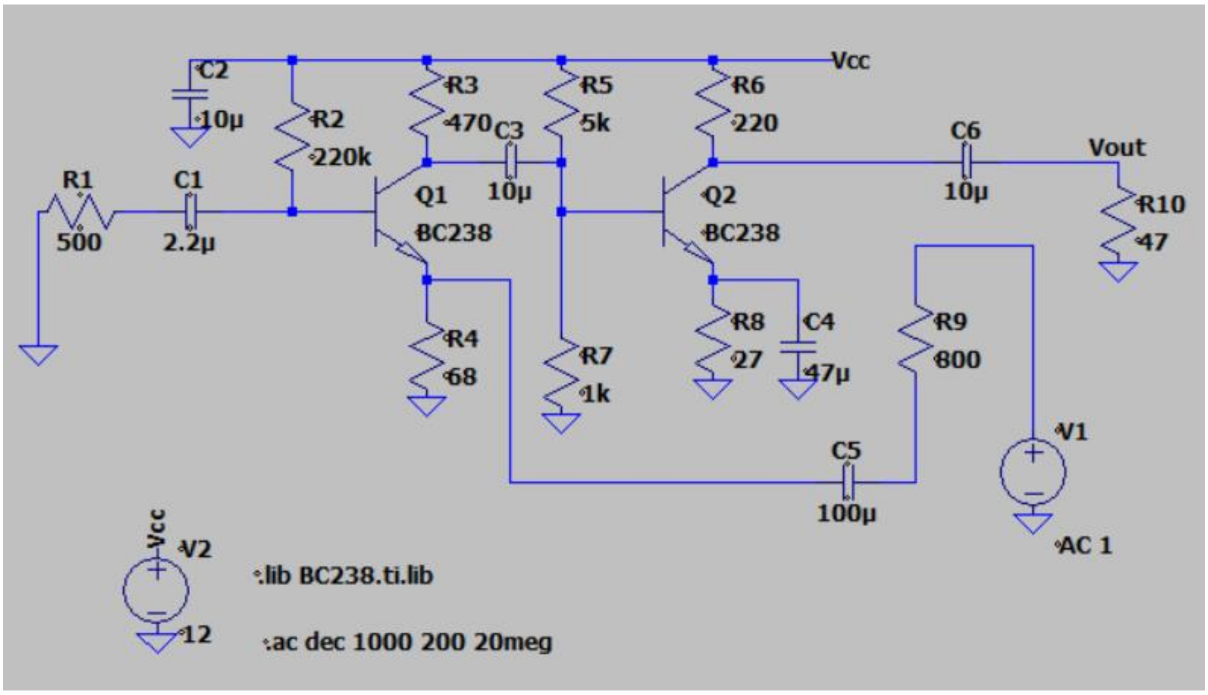

Figure 11: The New Circuit

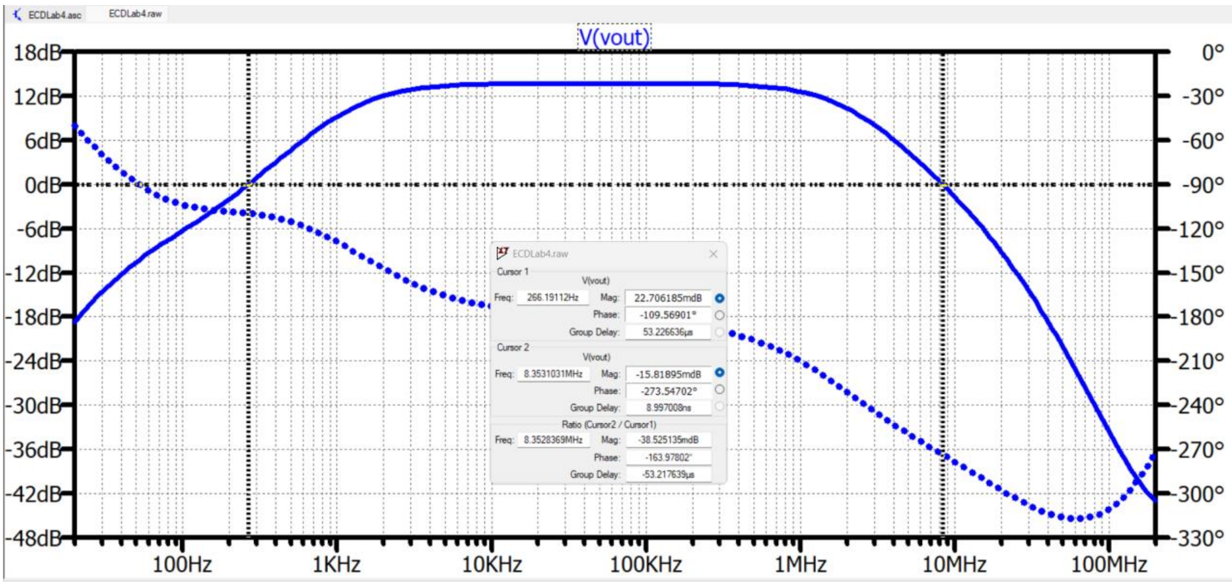

Figure 12.1: The Gain Plot

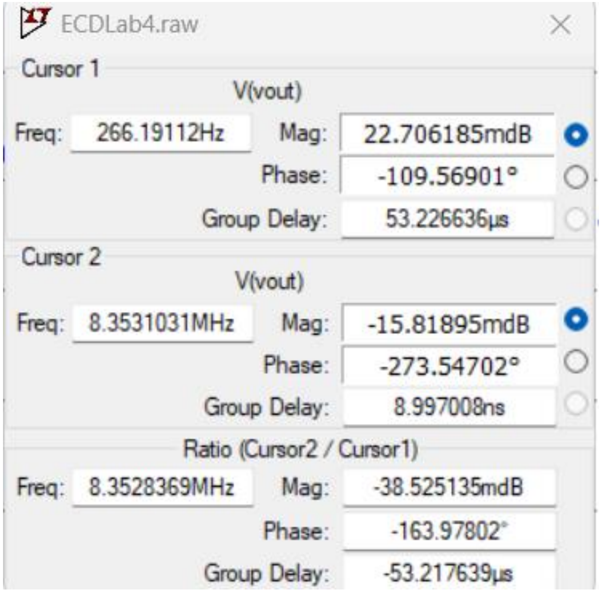

Figure 12.2: The Phase at 266Hz (0dB) is –109°; The Phase at 8.35MHz (0dB) is –273°.

Conclusion:

This lab's main aim was designing a two-stage amplifier with feedback to achieve a low output impedance and a flat gain.

The software part was successful. All the specifications and requirements were met.