Bilkent University

Electrical and Electronics Department

EE313-02 Lab 4 Final Report:

“Wide-Band Amplifier with Feedback”

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Introduction:

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

Hardware Implementation & Results:

Here you can see the hardware implementation of the circuit **(Figure 1)**. Beware that I used a small portion of the breadboard and obtained from using long jumper wires. This is because Maxwell's equations might take over the circuit theory in such high frequency cases.

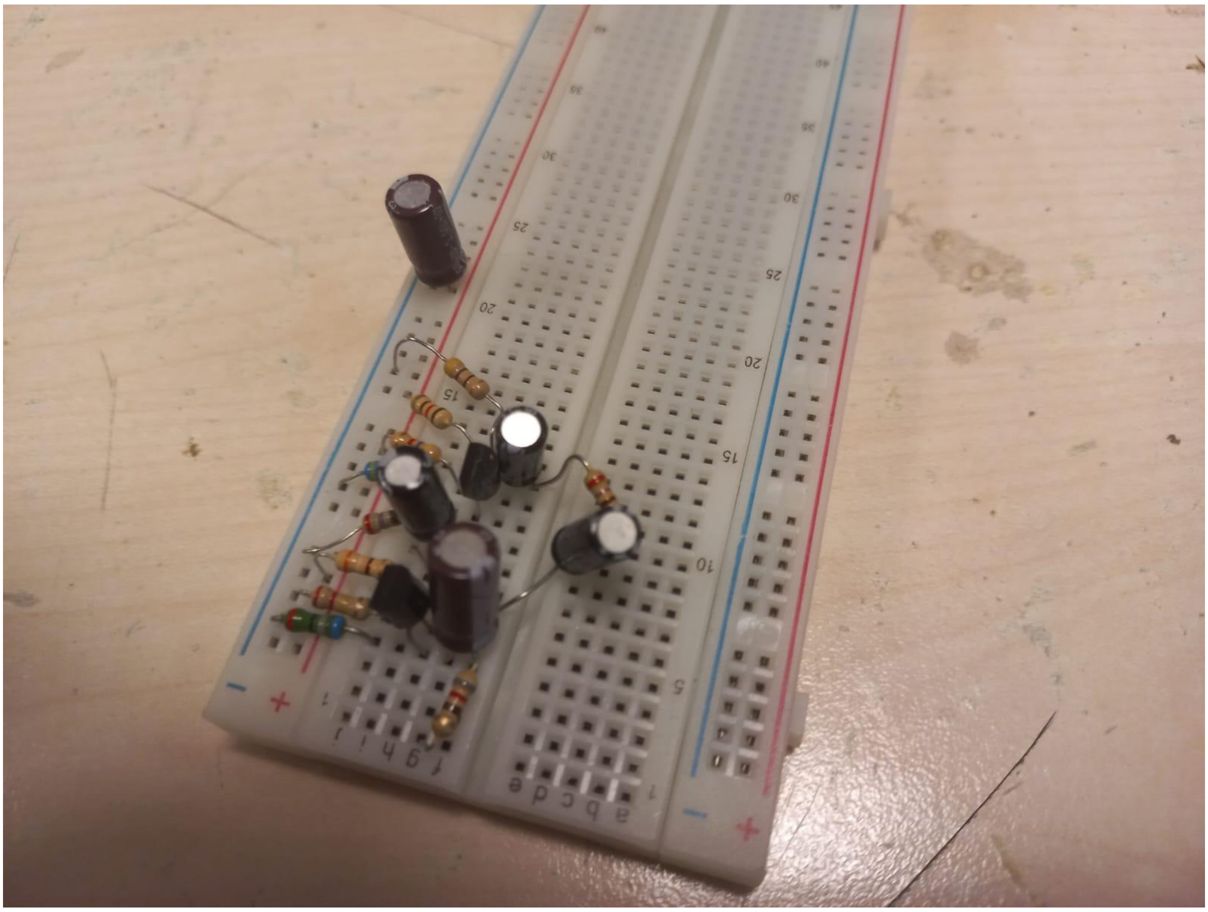

Figure 1: The Circuit Implemented on a Breadboard

Here are the specifications that were given to us in the lab manual **(Figure 2)**.

Show that

1. The current consumption is less than 70mA
2. The bandwidth is at least 2KHz-2MHz while the mid-band gain is 20dB±0.5dB (measure at 2KHz, 200KHz and 2MHz). Adjust the signal generator to 50mV peak (meaning it generates 200mV peak-to-peak) and insert a 470Ω resistor in series with the signal generator to simulate R_S=500Ω. The output voltage across R_L=47Ω should be 2V peak-to-peak.
3. The harmonic content of the output voltage is better than −30dBc at 200KHz.

Determine

4. The small-signal input impedance of the amplifier at 200KHz (with R_L=47Ω, adjusted value of R_S until the voltage gain drops to half its value compared to R_S=0)
5. The small-signal output impedance of the amplifier at 200KHz (with R_S=500 Ω, adjusted value of R_L until the voltage gain drops to half its value compared to R_L=∞ while applying the smallest signal of the signal generator. Use EXT SYNC for problem-free oscilloscope measurement.)

Figure 2: The Specifications of the Circuit

Now, let's dive deep in each specification one by one.

Specification 1:

Here you can see the current consumption of the circuit being 58mA when the input is 0.1V 200kHz sinusoidal wave **(Figure 3)**:

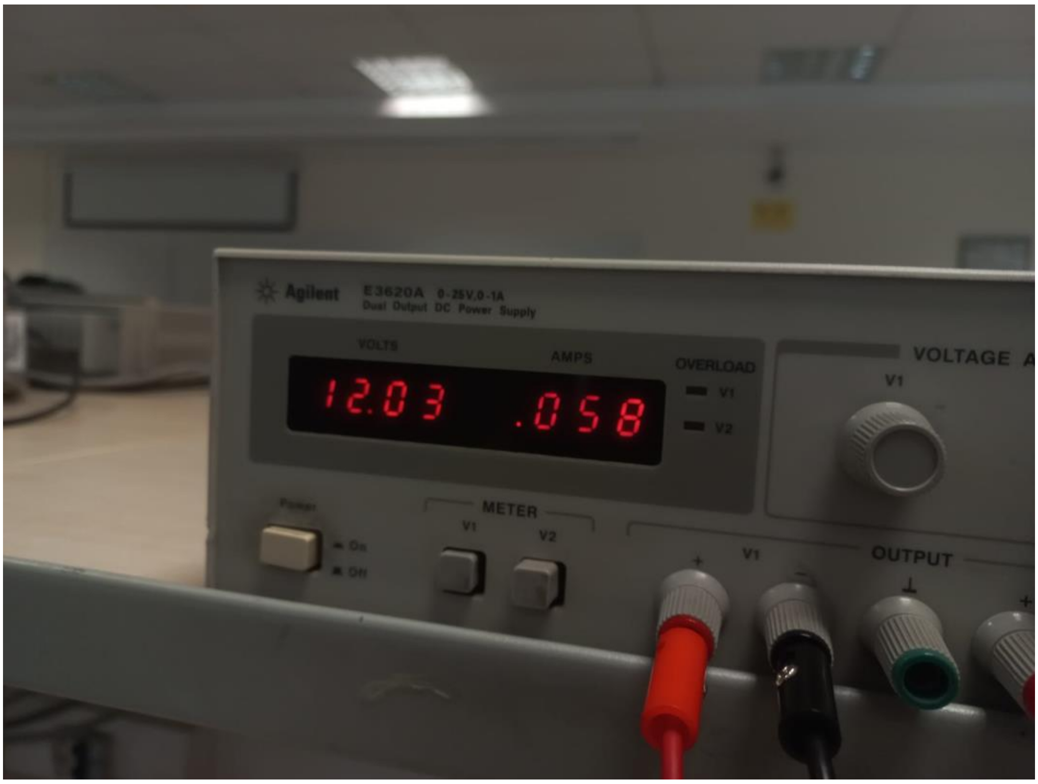

Figure 3: The Current Consumption is 58mA

Table I shows the experimental and simulation values for the current consumption at 0.1V 200kHz sinusoidal input:

TABLE I

Simulation Result	Experimental Result	Error
58.4mA	58mA	-0.69%

Specification 2:

Here you can see the outputs at 0.1 Vpp input level for each frequency (2kHz, 200kHz, 2MHz) **(Figures 4.1 to 4.3)**:

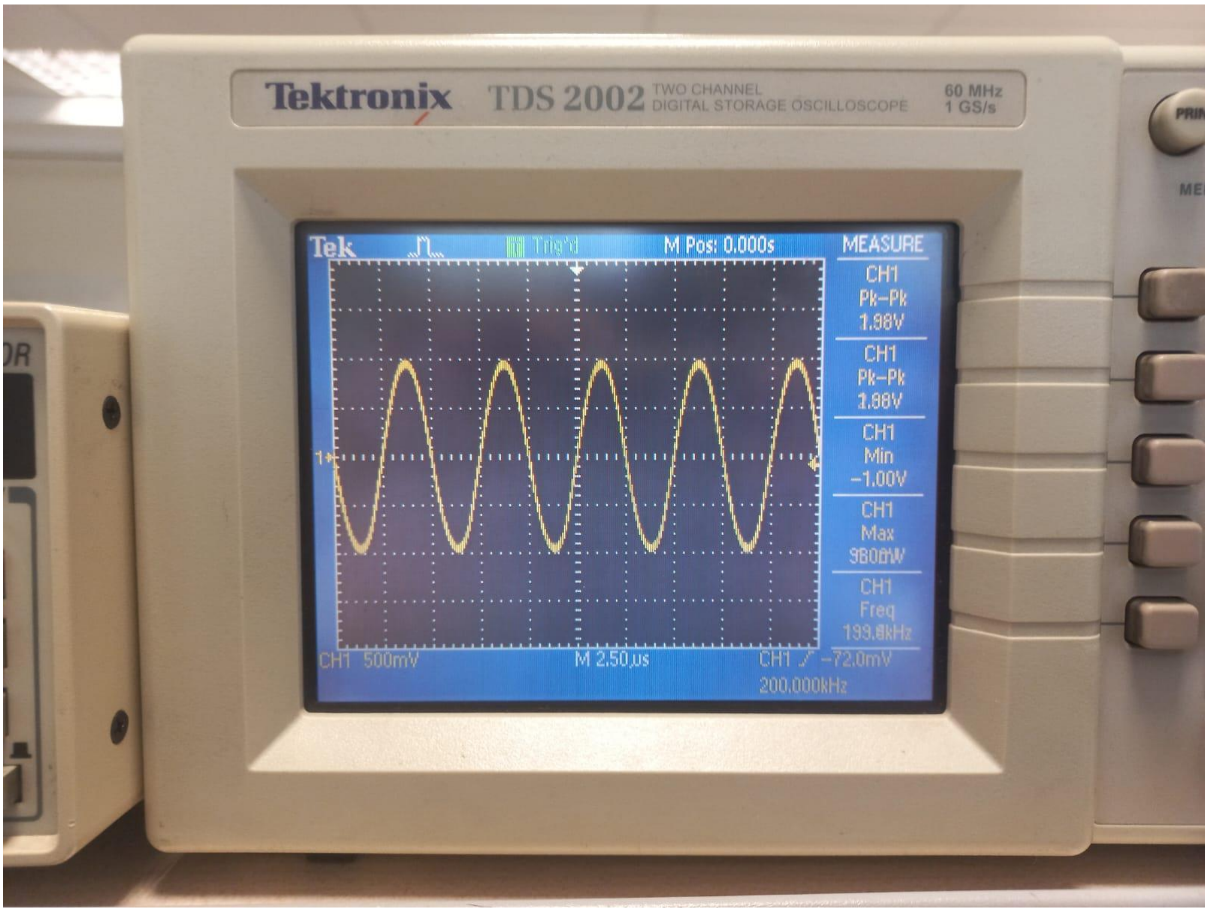

Figure 4.1: Output is 1.98 Vpp at 200kHz Input Frequency

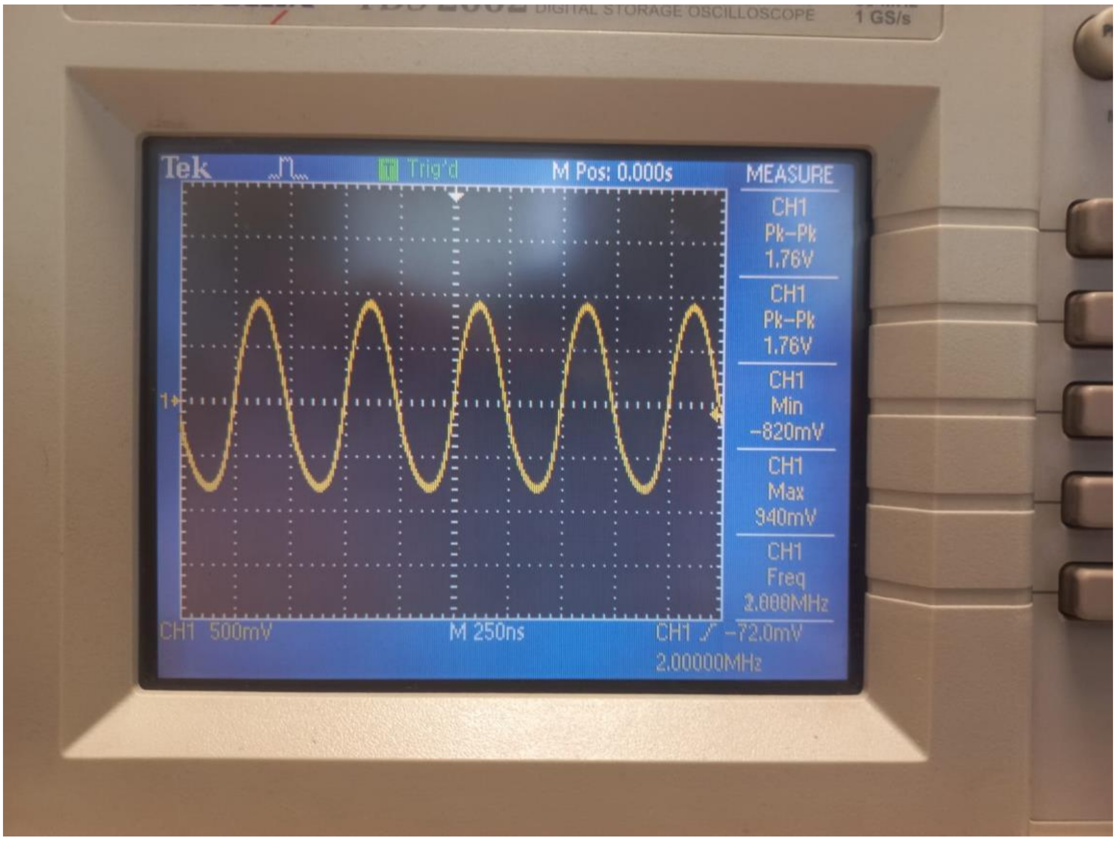

Figure 4.2: Output is 1.76 Vpp at 2MHz Input Frequency

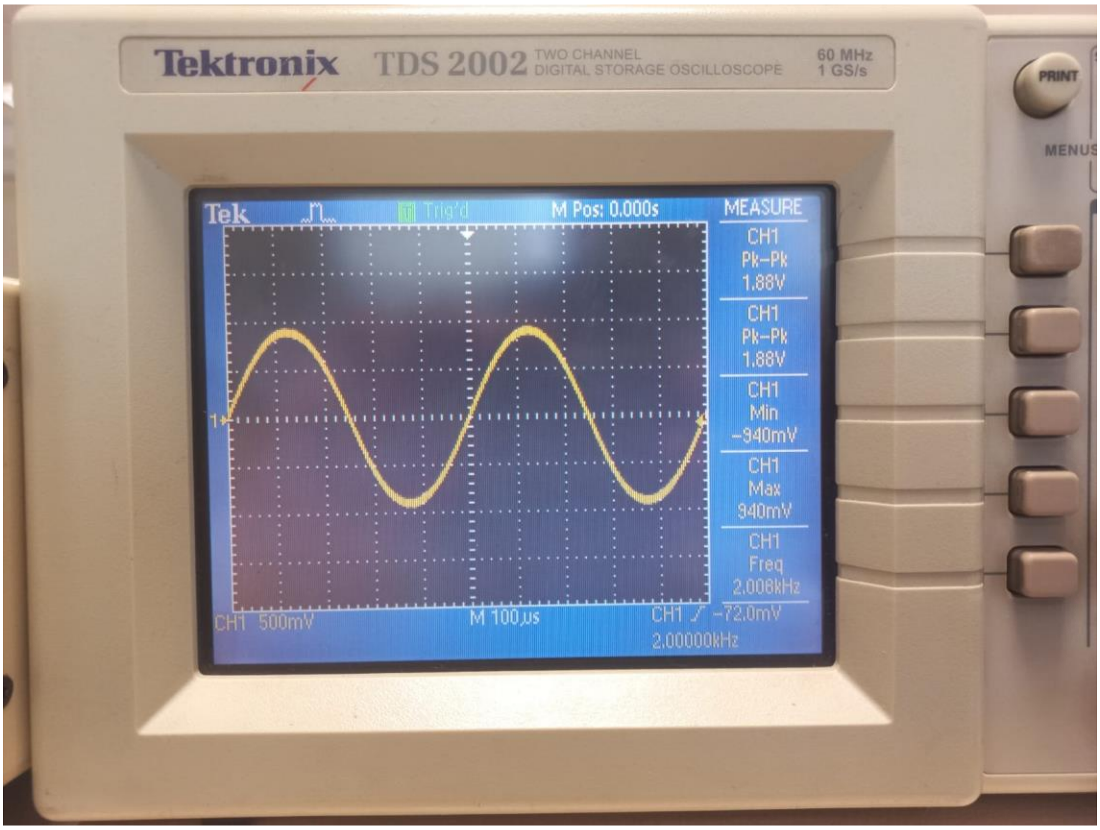

Figure 4.3: Output is 1.86 Vpp at 2kHz Input Frequency

Table II shows the differences between experimental and simulation data for the output voltage and gain for different frequencies. **(1)** shows the relationship between output & input voltages and gain.

TABLE II

Frequency	Experimental Output Voltage (Vpp)	Experimental Gain (dB)	Simulation Gain (dB)	Error
2kHz	1.86V	19.36	20.10	-3.68%
200kHz	1.98V	19.91	20.37	-2.26%
2MHz	1.76V	18.89	20.33	-7.08%

$$Gain\ (dB) = 20 \cdot \log\left(\frac{V_{out}}{V_{in}}\right) \qquad \textbf{(1)}$$

Specification 3:

Here you can see the harmonic content of the 200kHz input signal. The difference between the main signal (at 200kHz) and the second harmonic (at 400kHz) is 31.2dB.

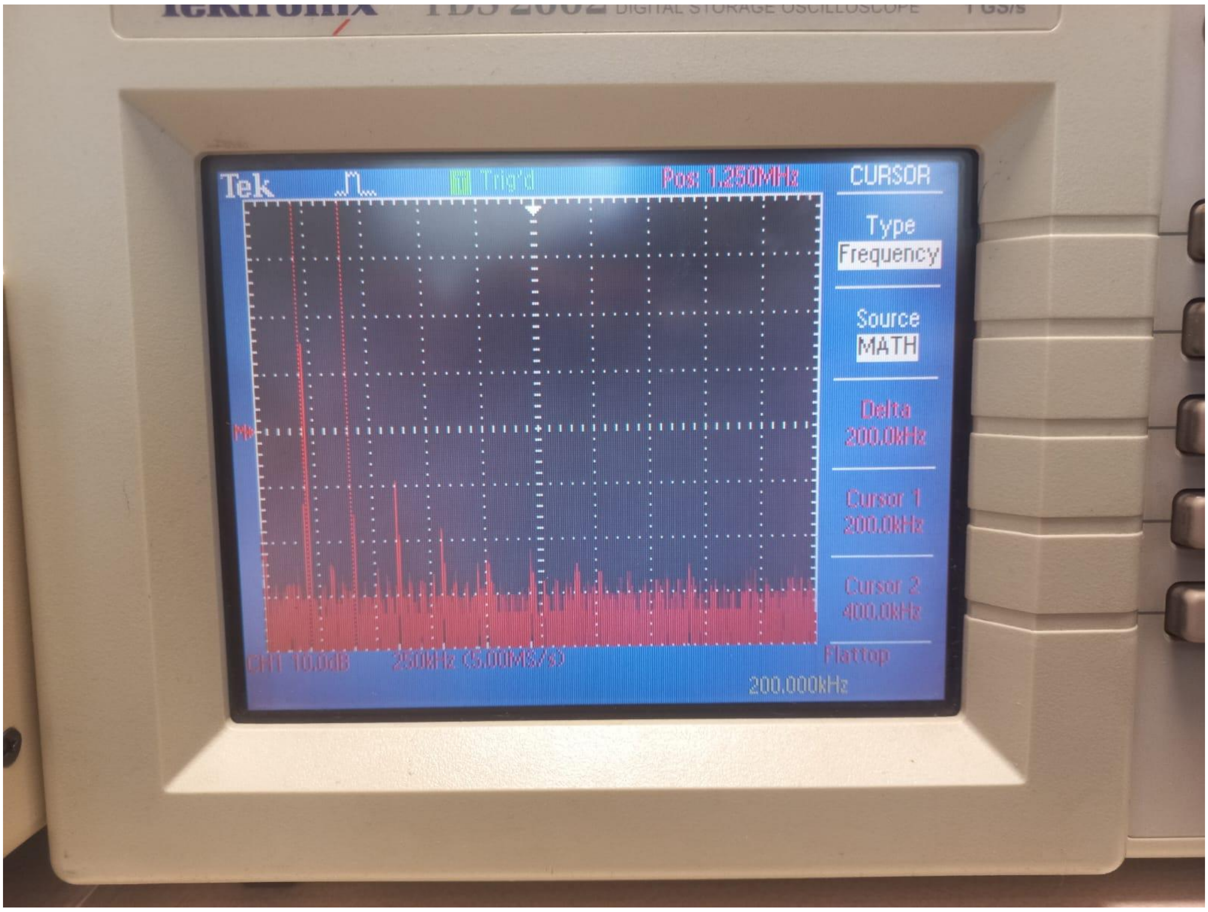

Figure 5.1: The 200kHz and 400kHz Harmonics by Cursors

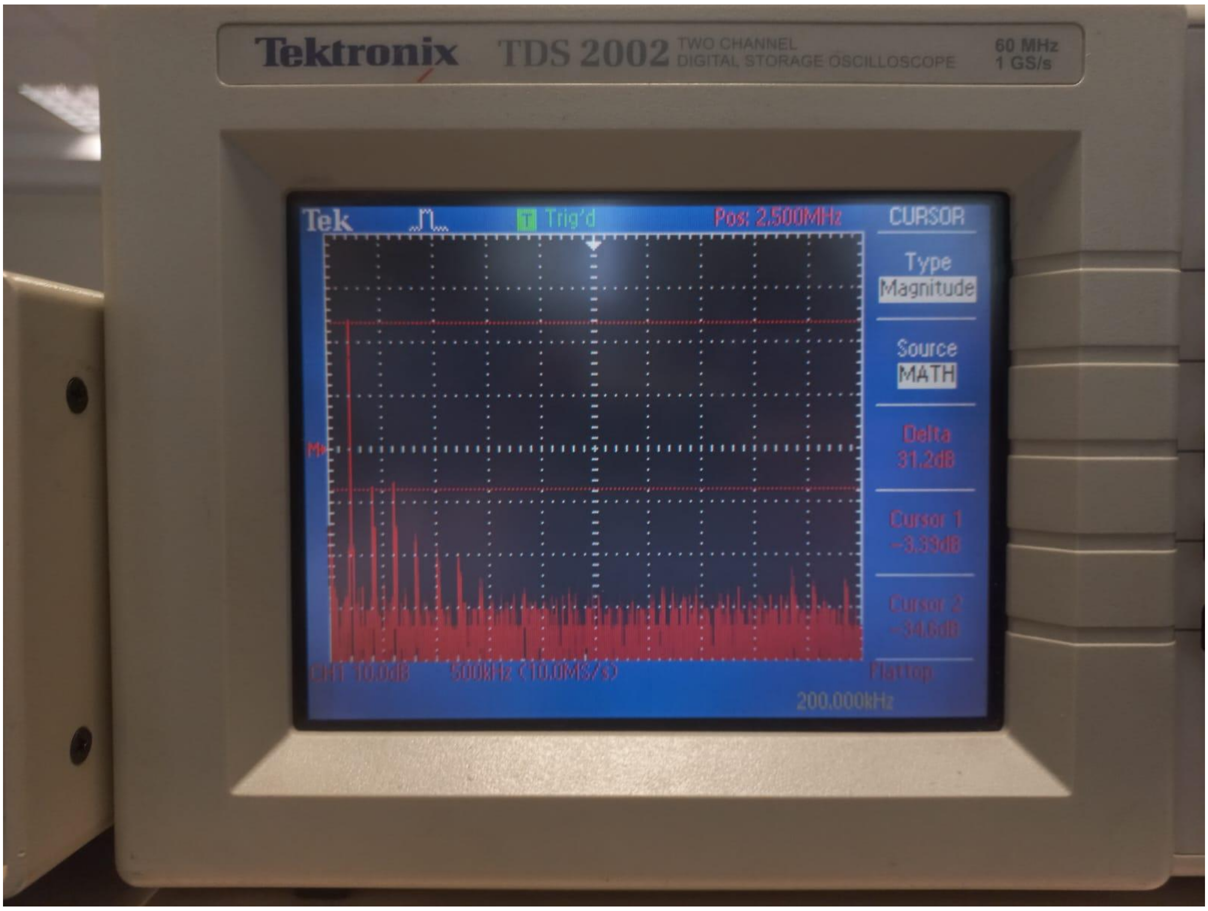

Figure 5.2: The 200kHz and 400kHz Harmonics Magnitude Difference being 31.2dB

Table III shows the difference between experimental and simulation data for the difference of the magnitude of the biggest harmonic and the main signal:

TABLE III

Experimental Data	Simulation Data	Error
31.2dB	48.4dB	-35%

Specifications 4&5:

I calculated the small signal input impedance of the circuit as 47kΩ. The output voltage dropped from 2.04Vpp (when input resistor is shorted) to 1.02Vpp when the input impedance was 47kΩ. But beware that even though I calculated the 2.04Vpp as the output voltage when Rs is shorted, the input impedance was actually 50Ω because of the impedance of the signal generator. In my LTSpice simulations, the input impedance being 50Ω and 0Ω does not make a huge difference in terms of output voltage. Therefore, I approximate the output voltage at 0Ω input resistance as 2.04V when the input resistance for that measurements is actually 50Ω.

In a similar fashion, I calculated the small signal output impedance of the circuit as 3.3Ω. The output voltage dropped from 2.16Vpp (when the output resistor is open-circuited) to 1.08Vpp when the output impedance was 3.3Ω.

Please remember that a –6dB loss in gain corresponds to a decrease to half in the output voltage when input Vpp remains constant. Table IV shows the experimental and simulation data for the small signal input & output impedances

TABLE IV

	Experimental Data	Simulation Data	Error
Small Signal Input Impedance	47kΩ	69kΩ	-31.88%
Small Signal Output Impedance	3.3Ω	7.2Ω	-54.16%

Here you can see the frequency-gain plot of my circuit **(Figure 6)**:

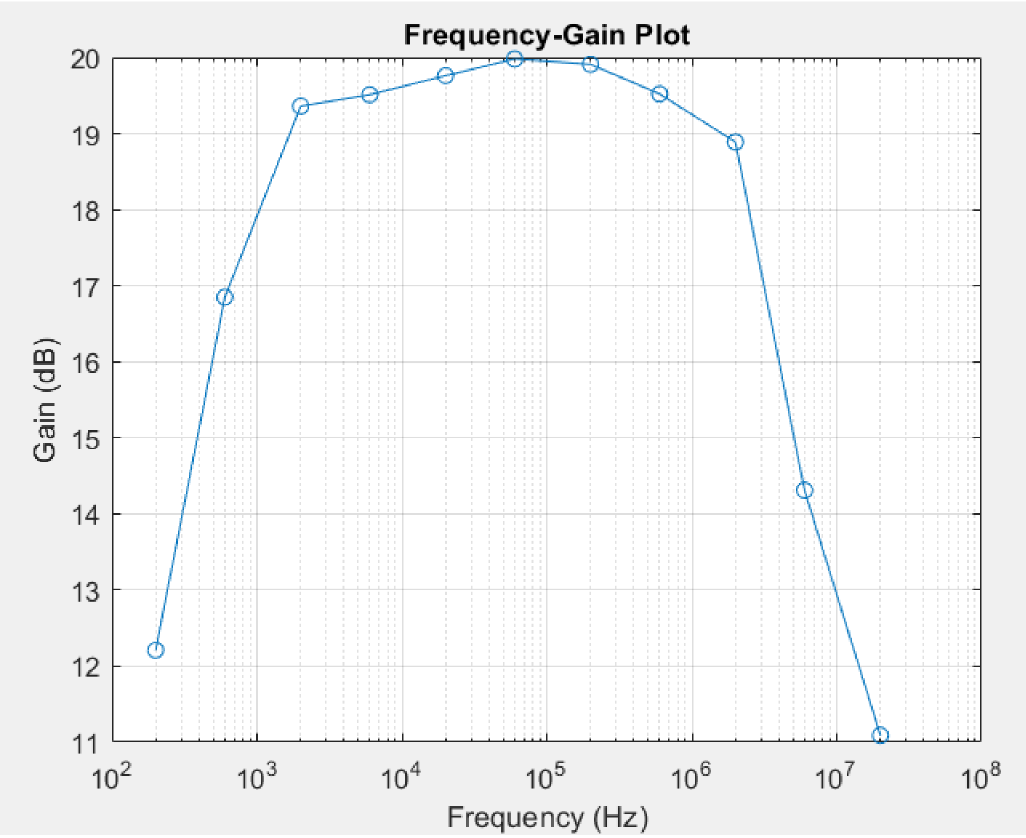

Figure 6: The Frequency-Gain Plot of the Circuit

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 lab was a total success. The circuit was successfully assembled and implemented on a breadboard. Every single criterion was met.

Nevertheless, I obtained huge error margins reaching up to 50% when calculating the small signal input & output impedances. The reason for that might be the hardware limitations such as some connection issues, resistor & capacitor values slightly changing. But I believe the main reason is the high frequency we are working on. In real life, radiation happens at an innegligible rate at high frequencies, this breaks the circuit theory to some extent.

The lab was very difficult to successfully achieve in my opinion. I had a hard time trying to acquire the desired gain in such a wide-band. I personally observed what my EE351-Electromagnetics instructor always kept telling us through the lectures –Maxwell's equations break circuit theory at high frequencies- in a somewhat exhausting and a frustrating way. Despite everything, I believe this lab was very helpful for the course and enjoyable as a student.