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EEE 313 Lab – 4
Wide-Band Amplifier with Feedback

Introduction

In the fourth lab, a wide band amplifier with feedback was designed and implemented on software and hardware that achieves low output impedance and flat gain. There were certain specifications and requirements to be met in order to operate the system as desired.

Purpose

The purpose of the lab was to meet the following specifications in Figure 1 and later achieve certain requirements. The designed and implemented circuit on LTSpice simulation is as in Figure 2.

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: Specifications on the Manual

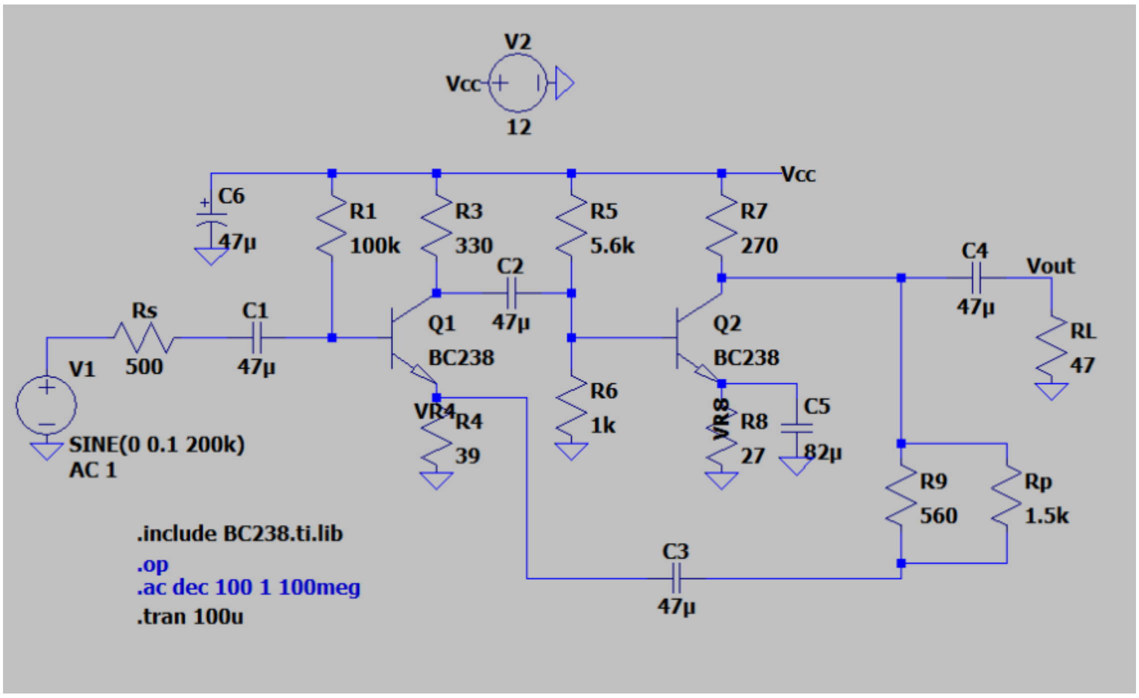

Figure 2: Design on LTSpice

These following requirements were expected from the final circuit and later 2 values were expected to be evaluated and determined accordingly.

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 $R_L=\infty$ while applying the smallest signal of the signal generator. Use EXT SYNC for problem-free oscilloscope measurement.)

Figure 3: Requirements and Desired Values

Methodology and Design

As the requirements were met and the values were determined on simulation, the same circuit was implemented on hardware with the setup in Figures 4 and 5. Later the given requirements were addressed. The DC supply is set to constant 12V while the desired AC signal is sent from the signal generator with changing frequency according to the requirements.

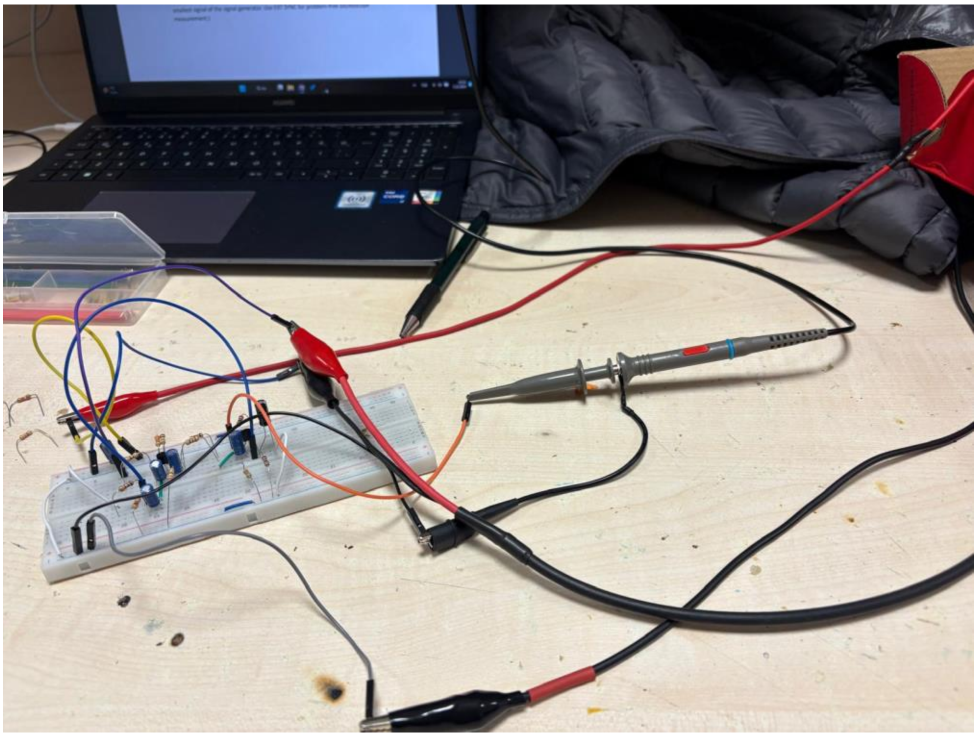

Figure 4: Hardware Setup

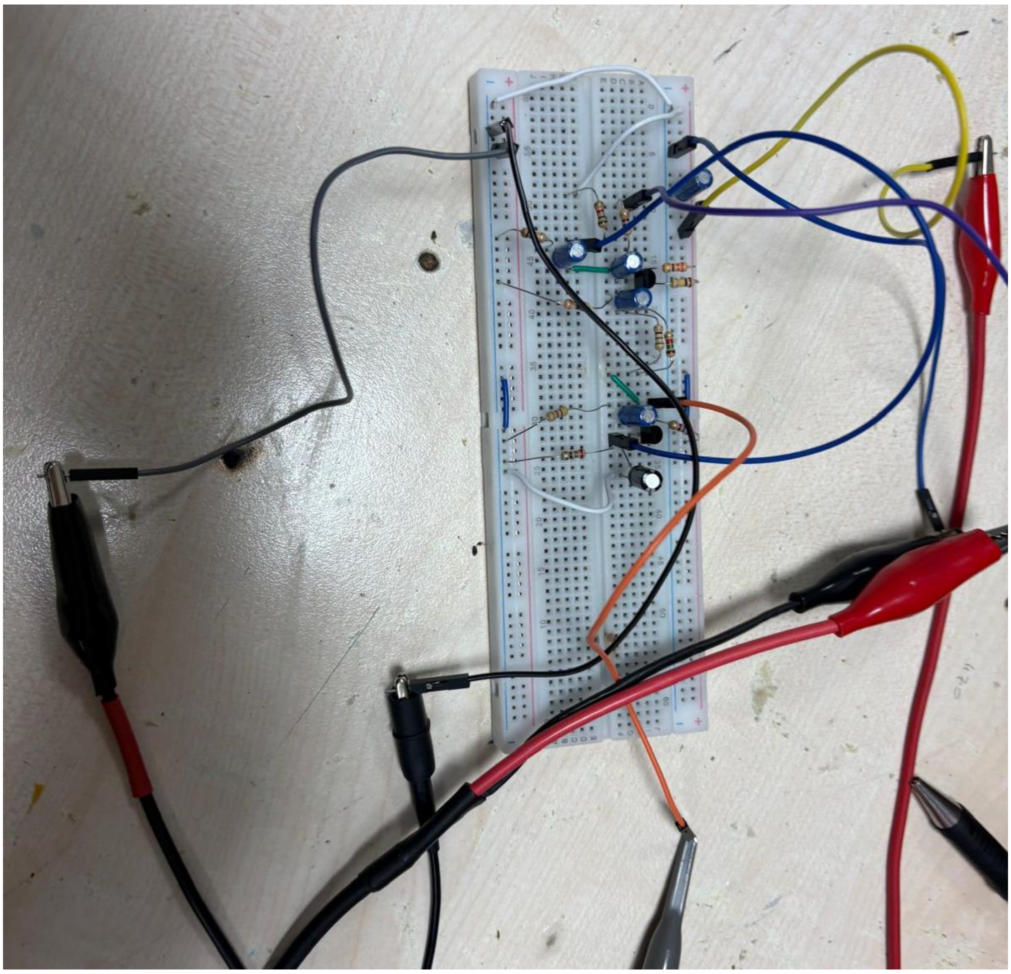

Figure 5: Hardware Design

Figure 6: Inputs From Sources

Requirements to be addressed:

REQUIREMENT 1

1. The current consumption is less than 70mA

Figure 7 demonstrates the current consumption of the circuit from directly the DC supply, the AMPS value is expected to be below 0.07 (below 70 mA).

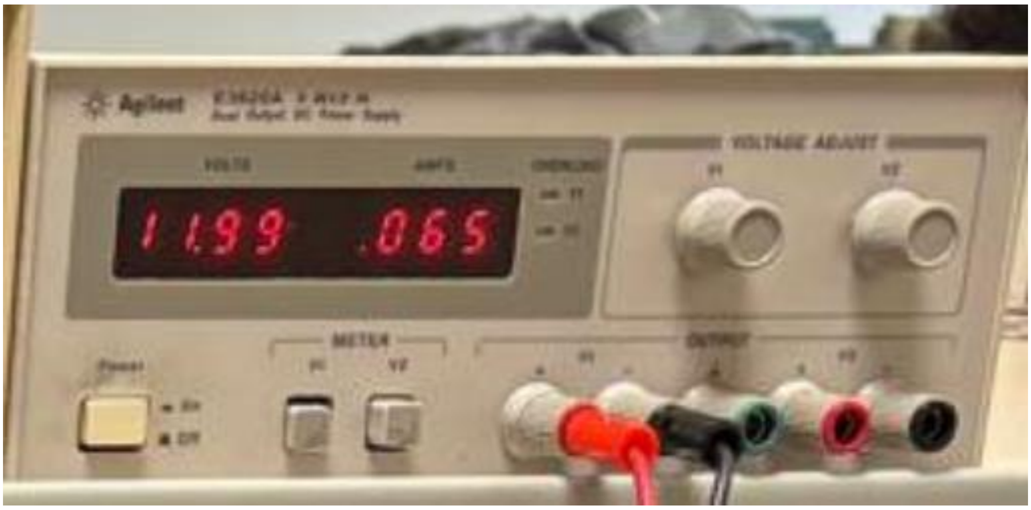

Figure 7: Current Consumption

The current consumption is 65 mA (<70 mA), satisfying the given requirement. The setup is unchanged (same inputs and unchanged circuit) and the setup consumes current at the desired level.

REQUIREMENT 2

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.

The output voltage on RL is as in Figure 8 with frequency set to 200 kHz. The changing outputs as the frequency is changed through 2 kHz, 200 kHz and 2 MHz is as in the following figures. The peak to peak voltages are expected to be near 2V on RL to observe that the bandwidth expands the given range.

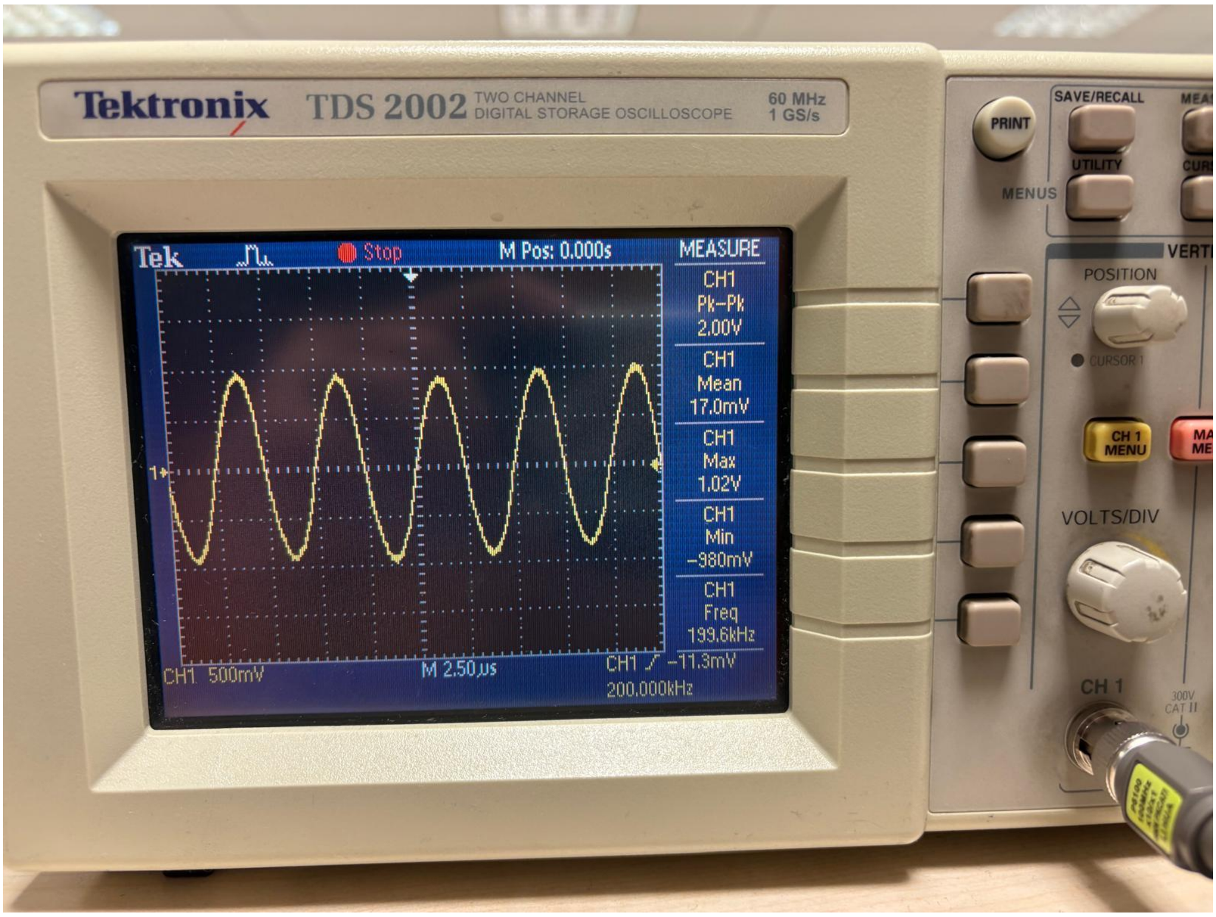

Figure 8: Peak to Peak Voltage is 2V for Frequency 200 kHz

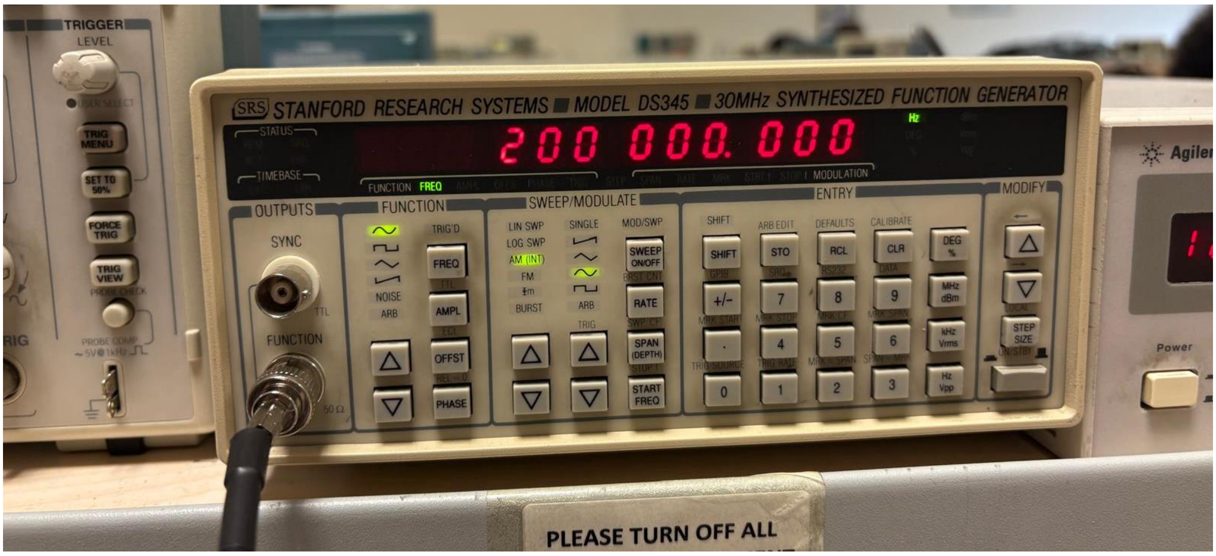

Figure 9: Input Frequency is 200 kHz

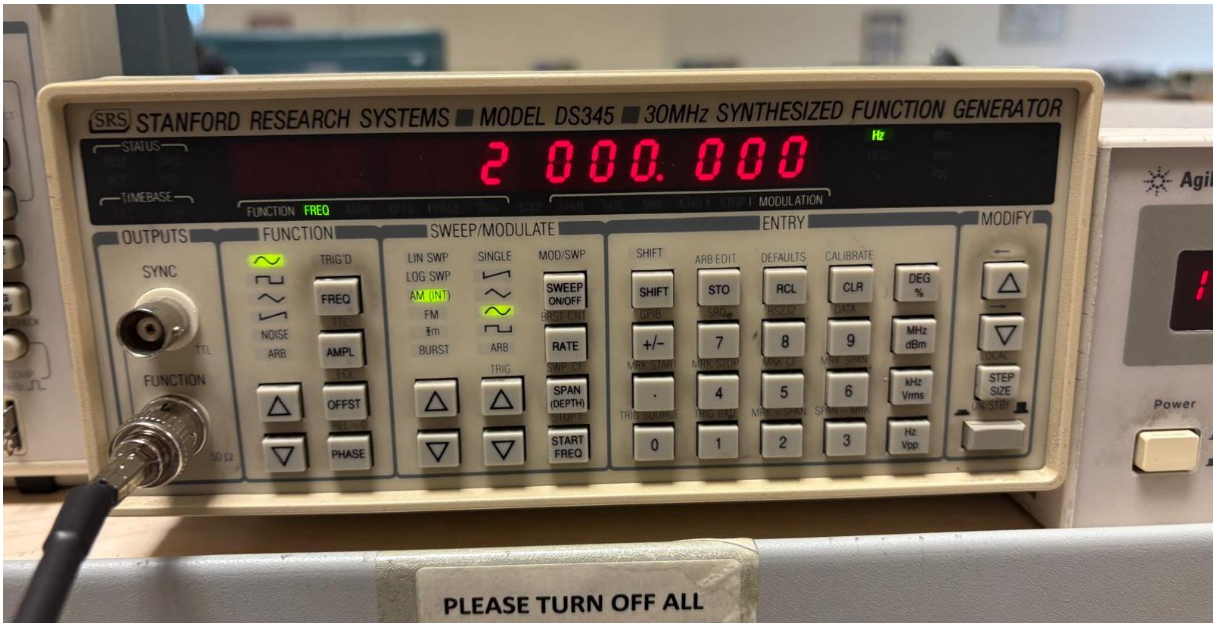

Figure 10: Input Frequency is Changed to 2 kHz

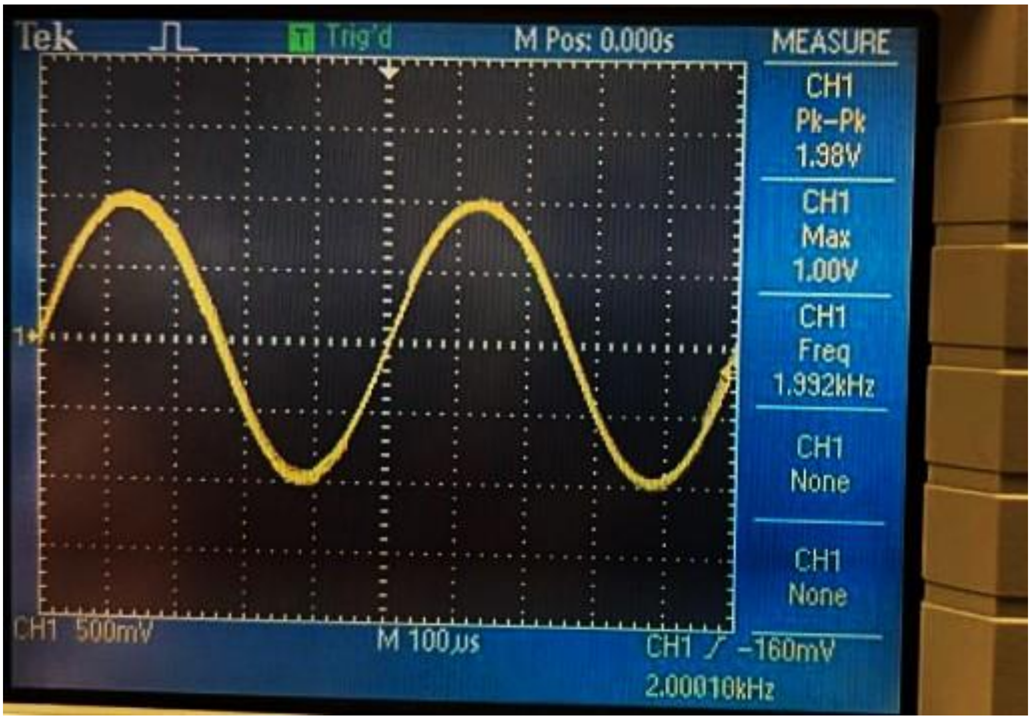

Figure 11: Peak to Peak Voltage is 1.98V for Frequency 2 kHz

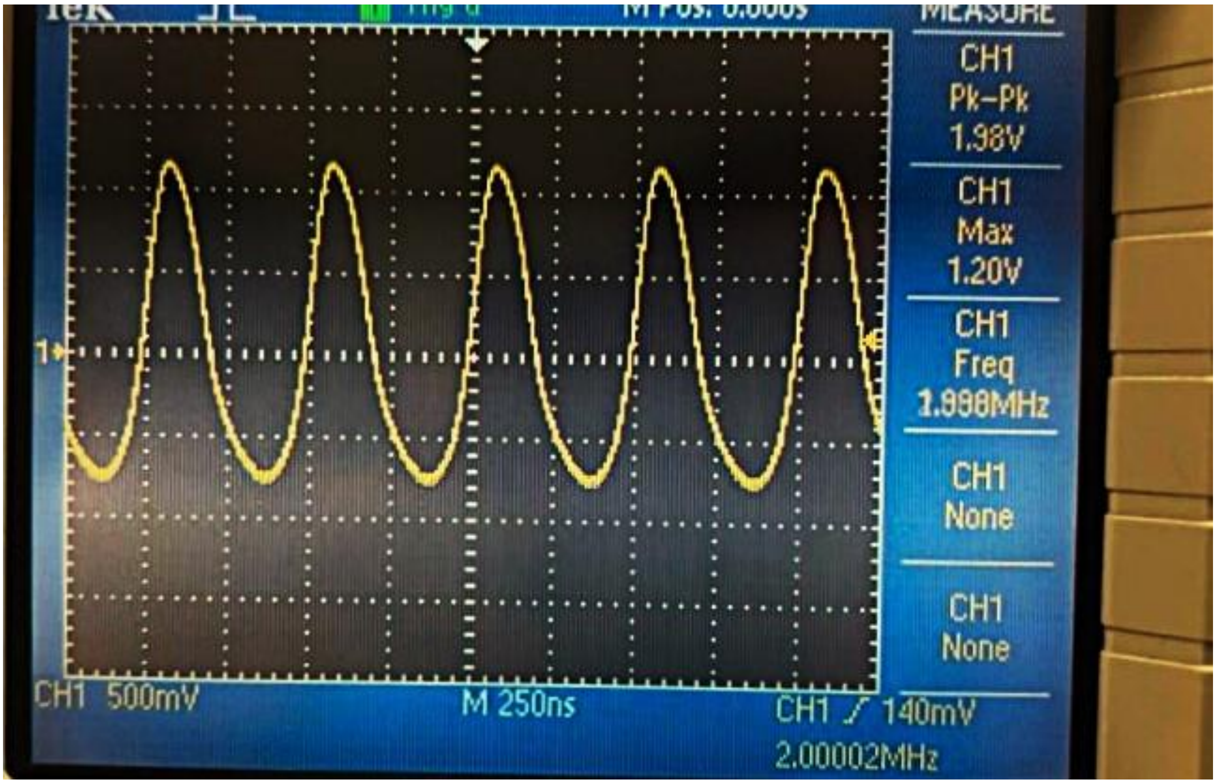

Figure 12: Peak to Peak Voltage is 1.98V for Frequency 2 MHz

Input Frequency	2 kHz	200 kHz	2 MHz
Peak to Peak Output Voltage	1.98V	2V	1.98V
Error Rate	10%	0%	8%

Table 1: Results for Requirement 2

As in Table 1, the peak to peak voltages are exactly or near 2V satisfying the given requirement of having 2Vpp for these input frequencies to successfully determine that the bandwidth surpasses the range of 2 kHz to 2 MHz. The gains for the frequencies are 1.99 dB, 20 dB and 1.99 dB, satisfying this requirement.

REQUIREMENT 3

3. The harmonic content of the output voltage is better than −30dBc at 200KHz.

With the input frequency set back to 200 kHz, the output voltage is inspected through the FFT function of the oscilloscope as in Figures 13-14.

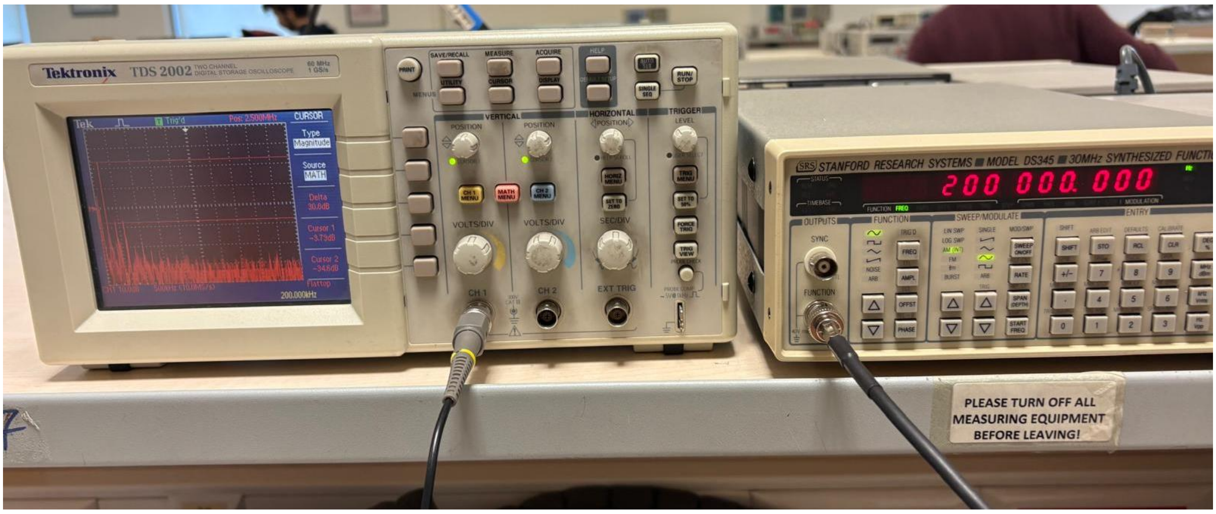

Figure 13: Observing at 200 kHz

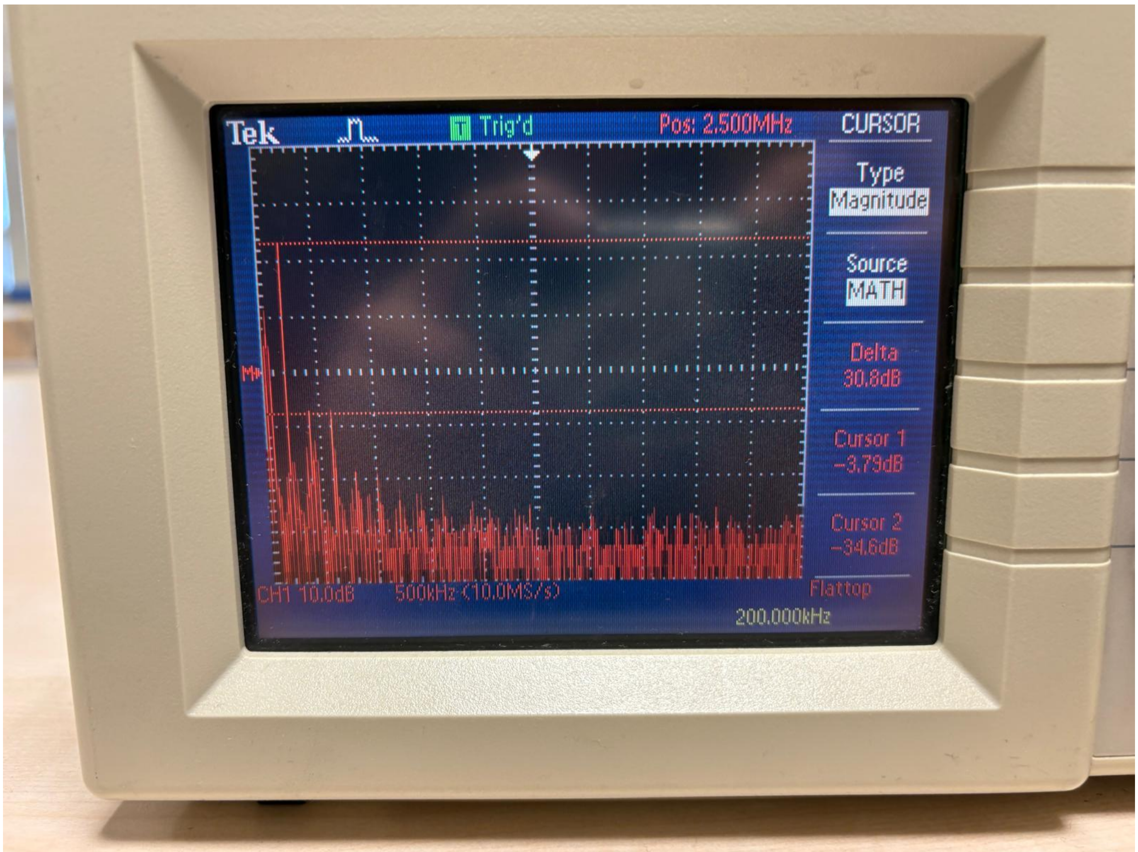

Figure 14: Output of FFT

The spikes at the first and third harmonics are evaluated and the difference between them is desired to be above 30 dB. The found difference is 30.8 dB (>30dB), meaning that harmonic content of the output voltage is better than -30dBc, satisfying the given requirement at 200 kHz.

VALUE TO DETERMINE – 1

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)

The value of the source resistor is changed from zero to a desired value to determine the small signal input impedance of the amplifier at 200 kHz. The first gain found at Rs=0 is expected to be half of it with the new impedance.

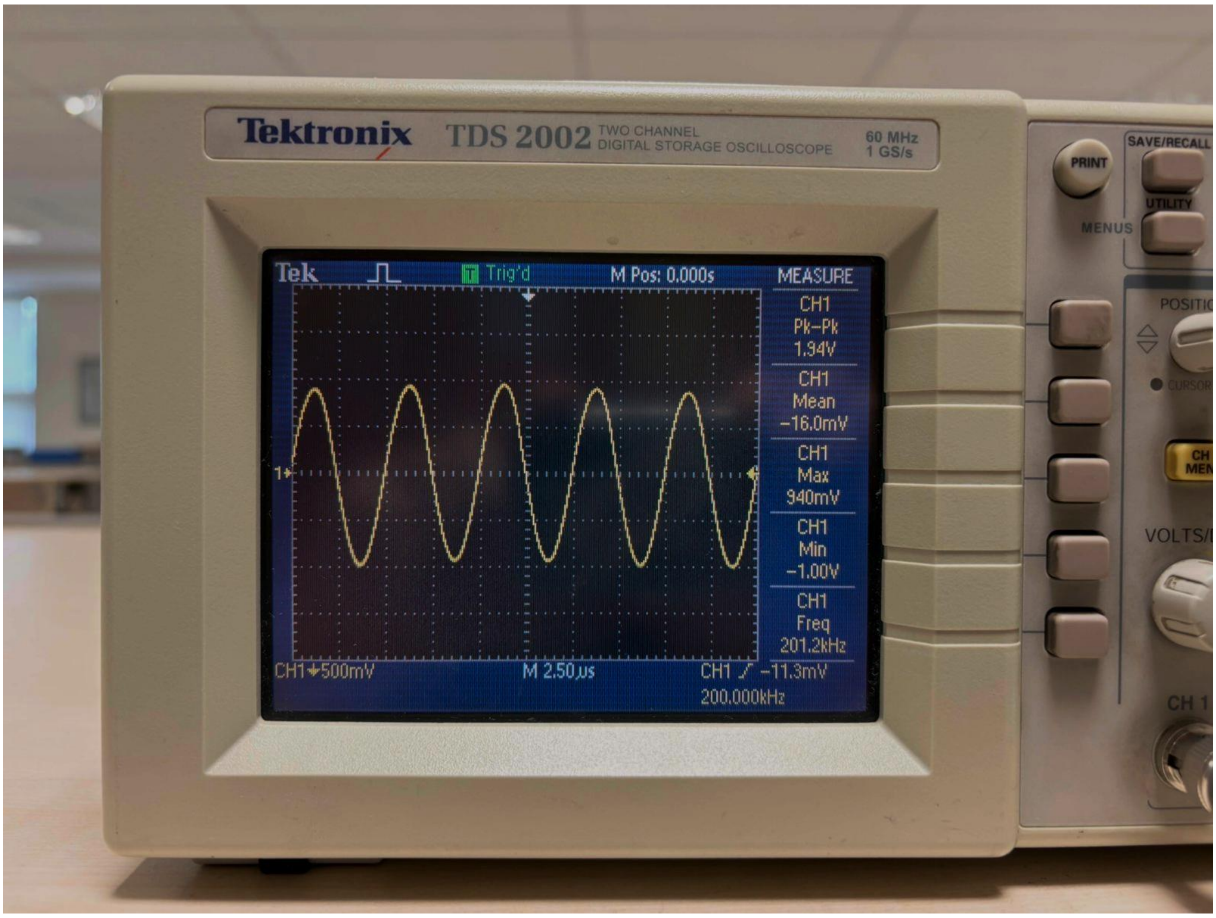

Figure 15: Output Voltage for 200 kHz and Rs=0

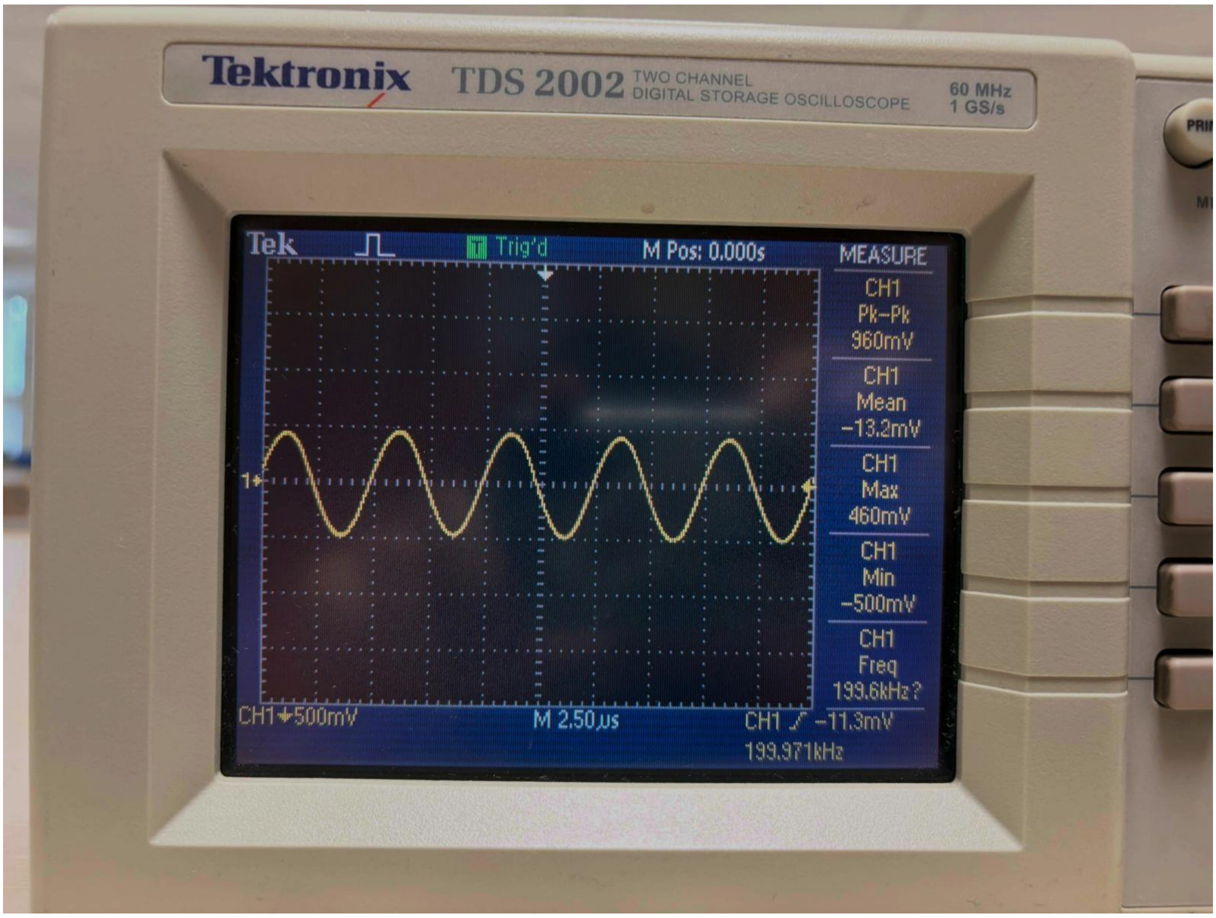

Figure 16: Output Voltage for 200 kHz and Rs=27k

As the source resistance is changed from 0 to 27 kΩ, the output voltages changes to half of the initial value, 1.94V to 0.96V. This implies the gain also drops to half of the initial value, meaning that the desired Rs = 27 kΩ.

VALUE TO DETERMINE – 2

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 $R_L=\infty$ while applying the smallest signal of the signal generator. Use EXT SYNC for problem-free oscilloscope measurement.)

First, the load resistor is removed from the circuit to create an open circuit (RL=∞), and later the new RL value that halves the voltage gain is found where 0.01V minimal input is applied. The changing output voltages can be observed in Figures 17-18.

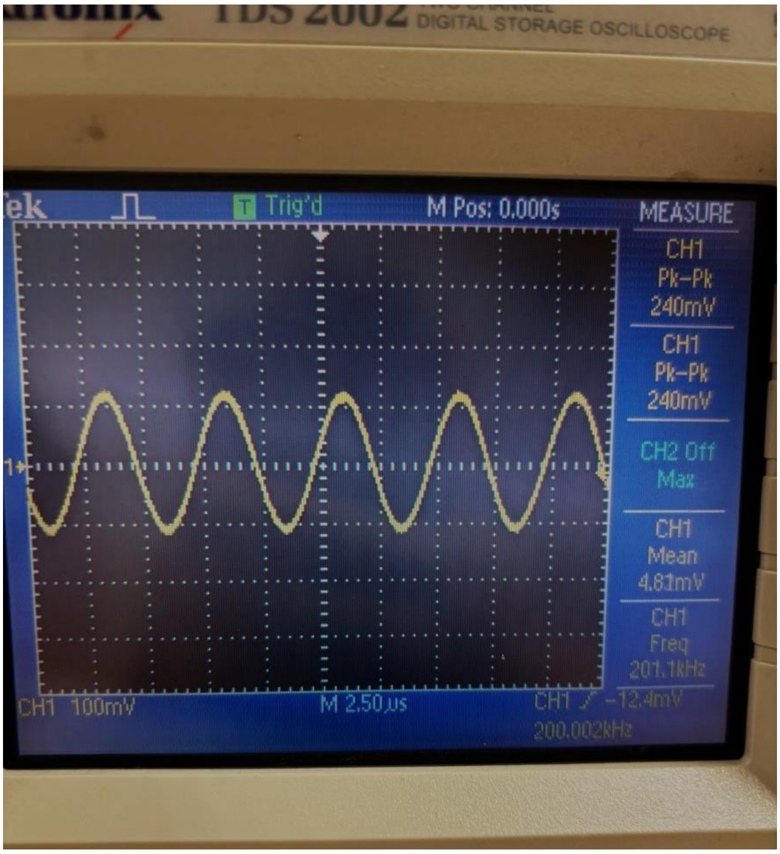

Figure 17: RL = ∞, Output Voltage is 240 mV Pk-Pk

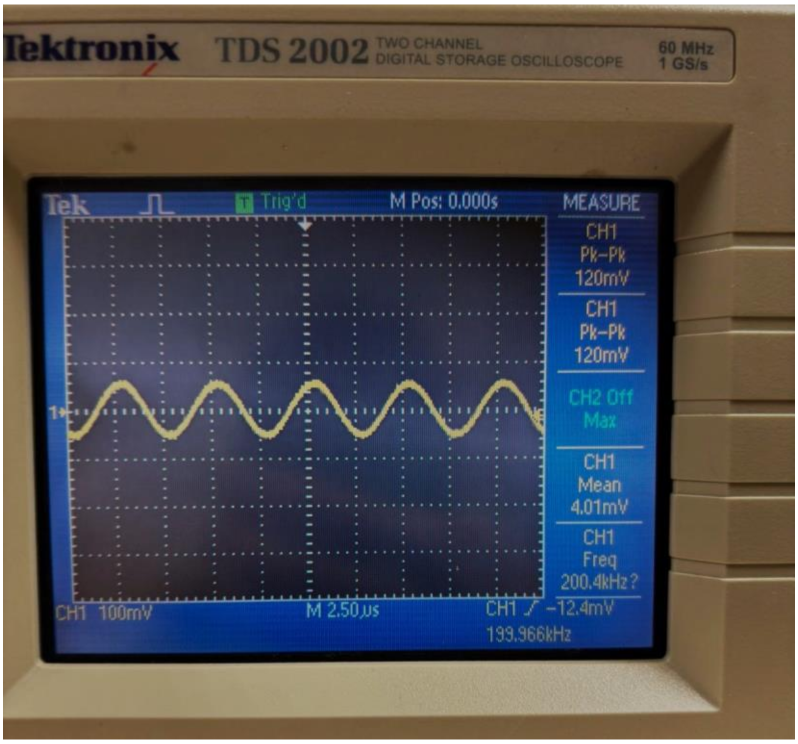

Figure 18: RL = 10 Ω, Output Voltage is 120 mV Pk-Pk

As the load resistance is changed from RL=∞ (open circuit) to 10 Ω, the output voltage is halved from 240 mV to 120 mV (smallest possible input is applied from the signal generator), meaning that the gain is also halved. The resistance satisfying the gain drop to half is for this reason 10 Ω.

Conclusion

In the fourth lab, the students designed a wide band amplifier with a desired kind of feedback by satisfying three requirements. The final circuit was then inspected to determine two values. All requirements were satisfied and this lab was useful in terms of totally grasping amplifiers using BJTs.