Bilkent University

Electrical and Electronics Department

EE313-02 Lab 3 Final Report:

“Single-Supply Push-pull Class-B Power Amplifier”

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Introduction:

This lab’s main aim is designing a single – supply push – pull class – b power amplifier by using 2 different NPN transistors (BC238 and BD135), 2 different PNP transistors (BC308 and BD136) and 1 OPAMP (LM358). Load resistance is 33Ω and supply voltage is 24V. My Bilkent ID in modulo 7 is 6. Therefore, my design should operate with sinusoidal voltages with a gain equal to 26 dB.

Here you can see the circuit’s breadboard implementation **(Figure 1)**:

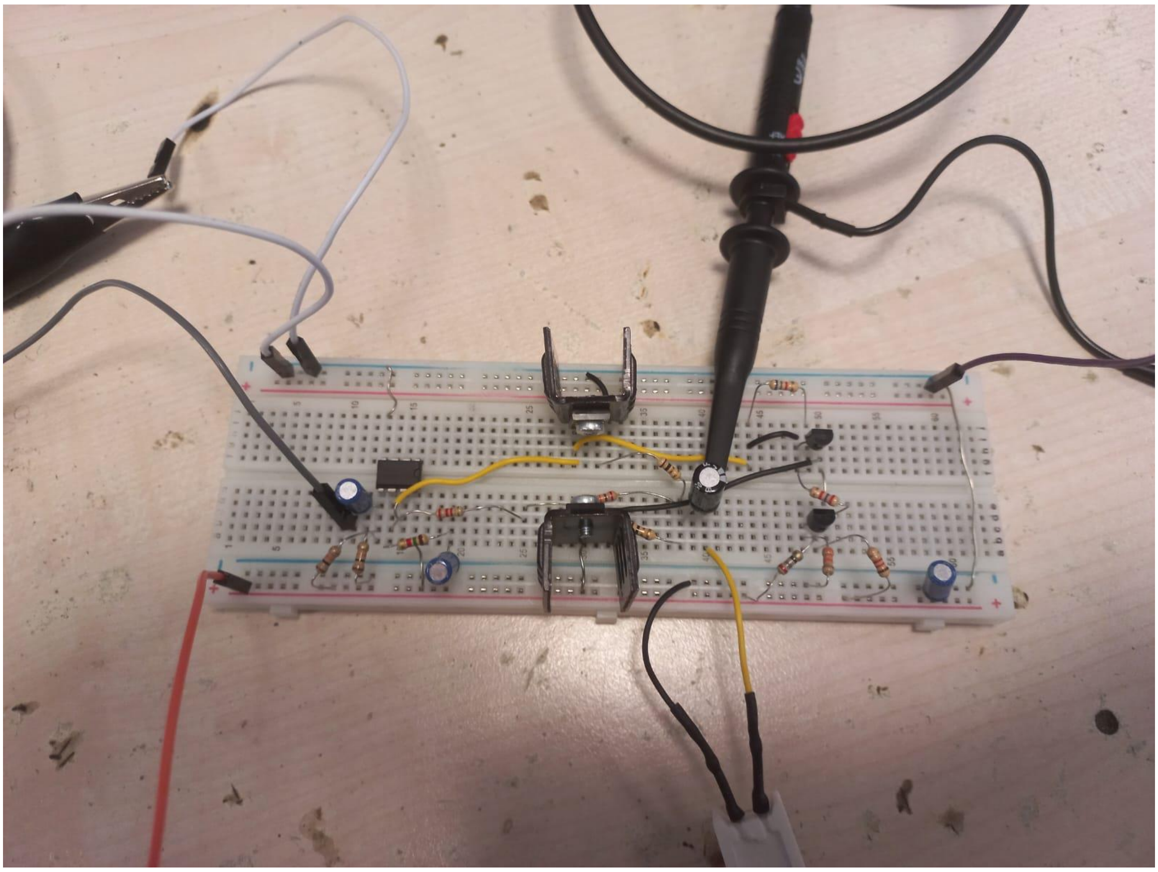

Figure 1: The Breadboard Implementation

Hardware Implementation & Results:

Here are the specifications required for the circuit which was stated in the lab manual **(Figure 2)**:

Specifications:

1. The amplifier should deliver at least 0.95W power to a 33Ω resistance (16V_{pp} to a 33Ω power resistor) at 1KHz with the chosen gain value.
2. The harmonics (the highest is possibly the third harmonic) at the 0.95W output power level should be at least 40 dB lower than the fundamental signal at 1 KHz.
3. The power consumption at quiescent conditions should be less than 500mW.
4. The amplifier's efficiency (output power/total supply power) should be at least 40% at max power output (0.95W) at 1KHz.
5. The −3dB bandwidth of the amplifier should be at least 150Hz to 15KHz.

Figure 2: The Specifications of the Circuit

Now let’s look at each requirement one by one!

Criteria 1:

Here you can see the output voltage on the 33Ω resistor when the sinusoidal input is $0.4V_{pp}$ **(Figure 3). (1)** shows that the power on the resistor is 0.95W. **(2)** shows the gain is 26dB.

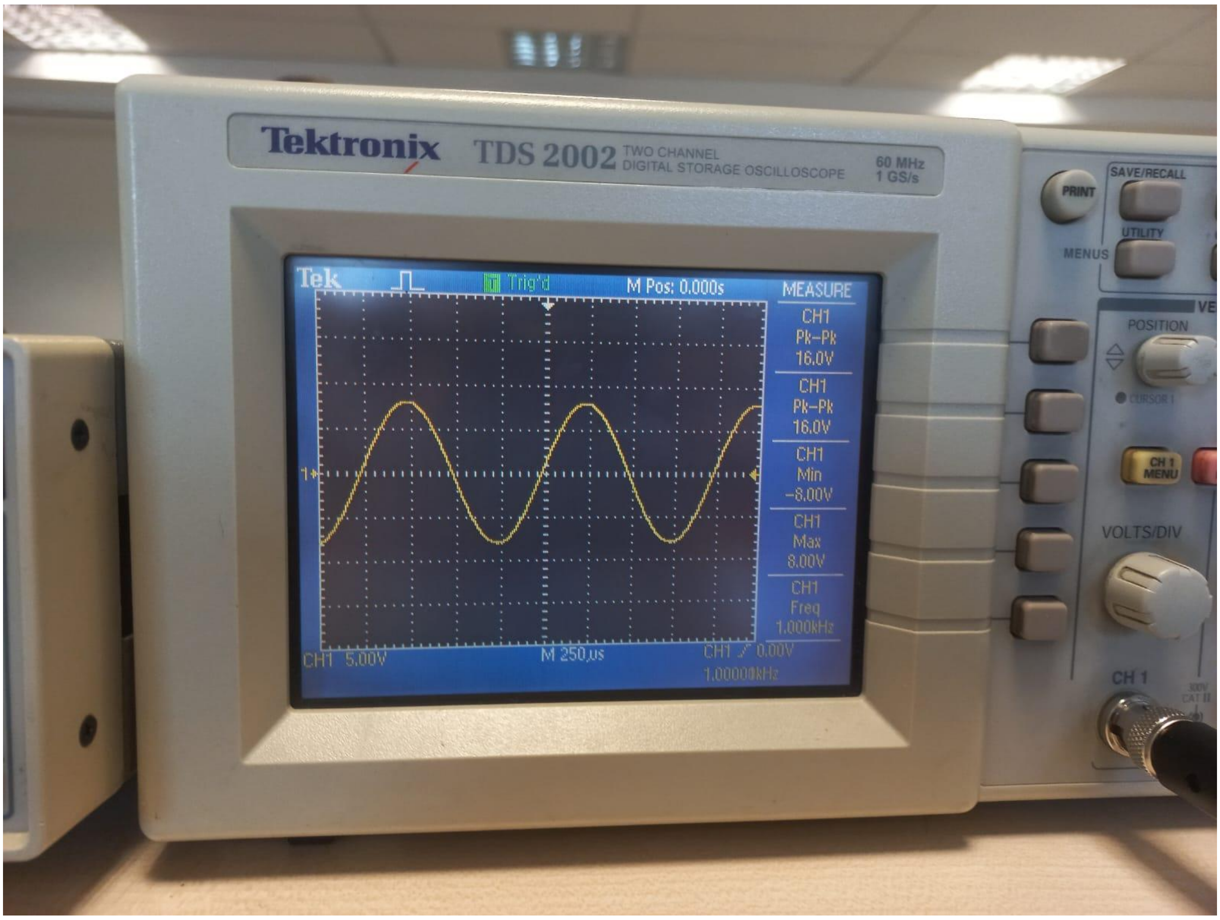

Figure 3: Output Voltage on the 33Ω Resistor

$$P_{out} = \frac{V_{out}^2}{33\Omega} = \frac{V_p^2}{2 \cdot 33\Omega} = \frac{8 \cdot 8}{2 \cdot 33} = 0{,}969\, W \quad \textbf{(1)}$$

$$gain(dB) = 20 \cdot \log\left(\frac{V_{out}}{V_{in}}\right) = 20 \cdot \log\left(\frac{8}{0.4}\right) = 26.02dB \qquad \textbf{(2)}$$

Criteria 2:

Here you can see the difference between the fifth harmonic and the fundamental signal being 51.6dB which is way higher than 40dB **(Figure 4)**:

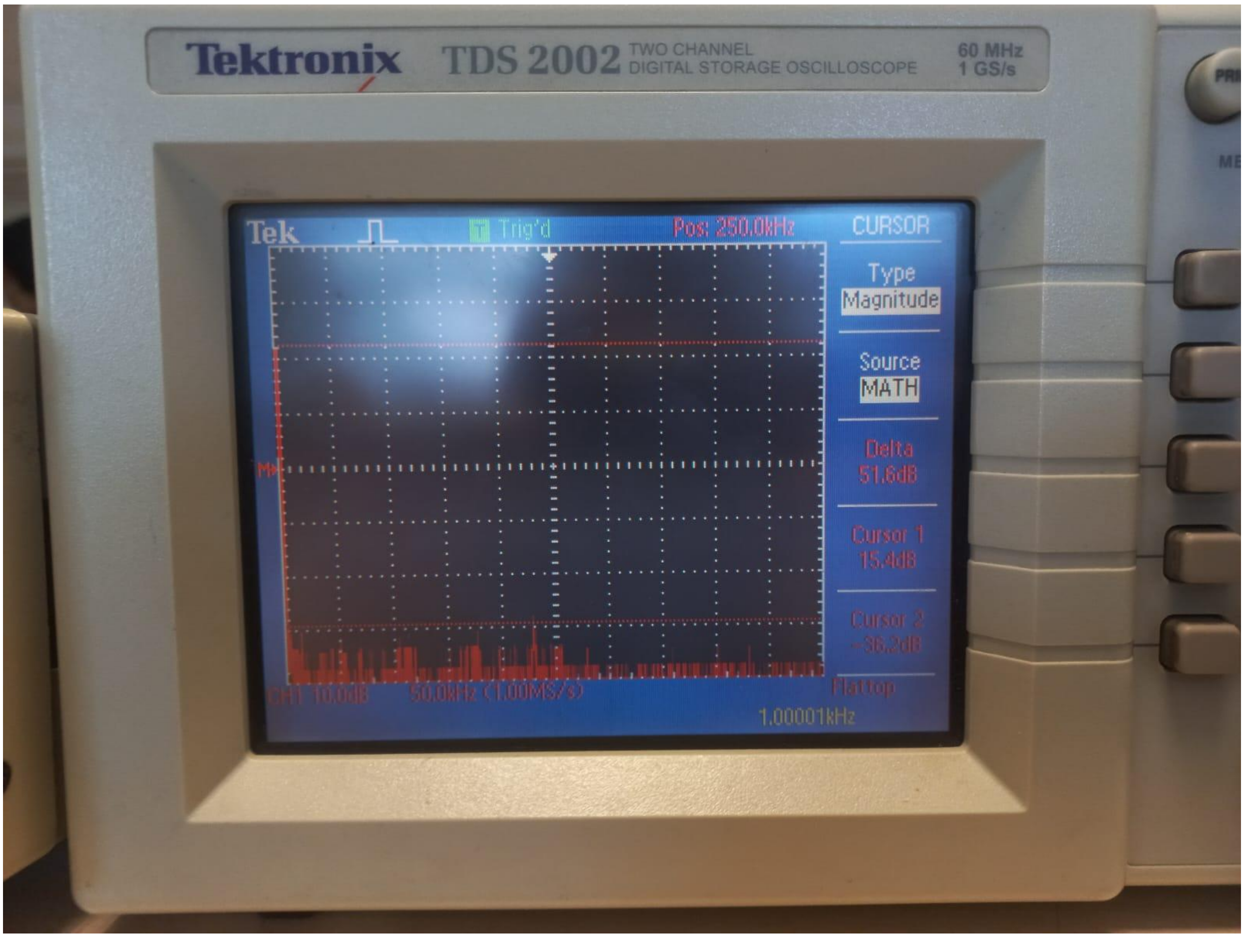

Figure 4: The Harmonics Difference Being 40 dB lower than the fundamental signal

Criteria 3:

Here you can see the current drawn from the DC power source being 8mA **(Figure 5)**: **(3)** shows the input power being 192mW which is well under 500mW.

$$P_{in} = V_{in} \cdot I_{source} = 24V \cdot 0{,}008mA \ = \ 192mW \quad \textbf{(3)}$$

Figure 5: The DC Supply Current being 8mA in Quiescent Conditions

Criteria 4:

Here you can see the output current being 85mA when the output power is 0.95 Watts **(Figure 6)**. **(4)** shows the efficiency calculations.

$$\eta = \frac{P_{out}}{P_{in}} = \frac{0.969mW}{24V \cdot 85mA} = \frac{0.969mW}{2.04W} = 47{,}5\% \quad \textbf{(4)}$$

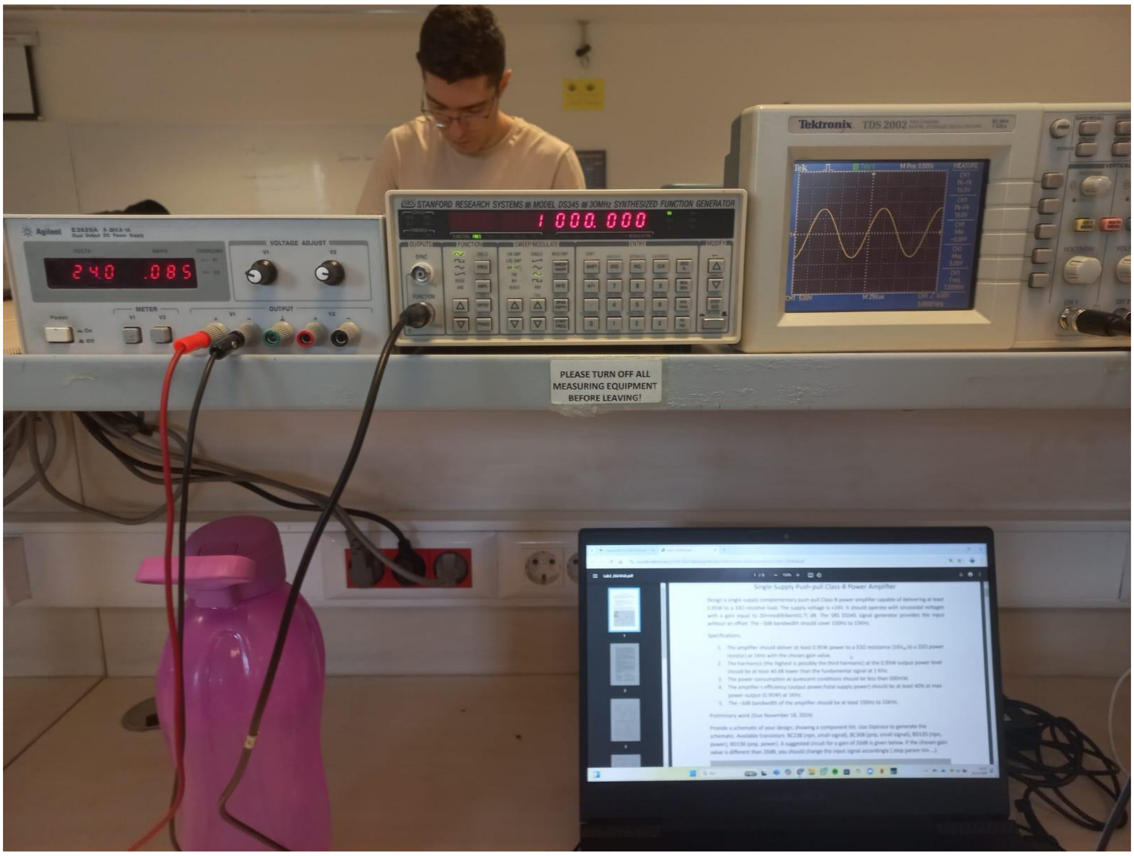

Figure 6: Output Current being 85mA at 0.95W output power on the load resistor

Criteria 5:

Here you can see the output peak voltages at 150Hz and 15kHz **(Figures 7&8)**. **(5 & 6)** show the gain in these conditions. At both of the frequencies the gain is above the –3dB limit (23dB).

$$gain(dB) = 20 \cdot \log\left(\frac{6.3}{0.4}\right) = 23.94dB \quad ; f = 15kHz \qquad \textbf{(5)}$$

$$gain(dB) = 20 \cdot \log\left(\frac{7.9}{0.4}\right) = 25.91dB \quad ; f = 15kHz \qquad \textbf{(6)}$$

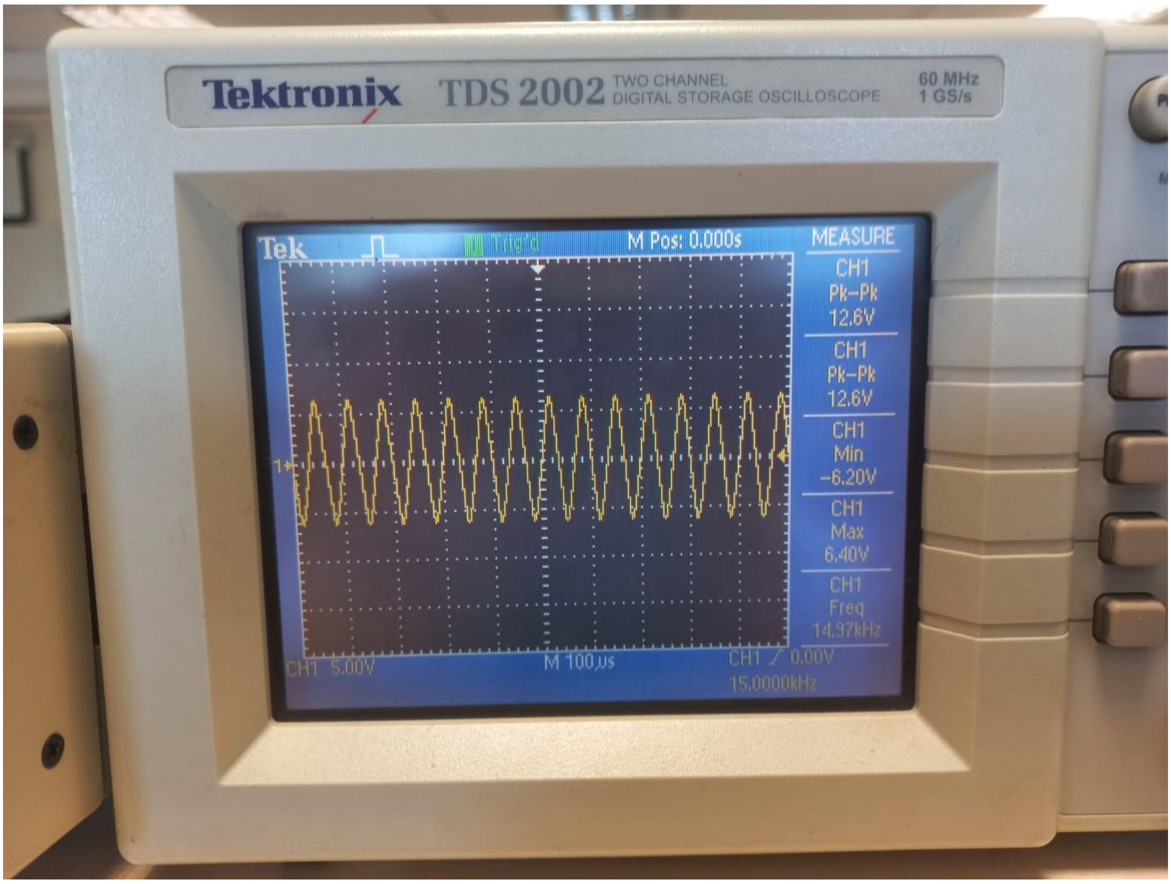

Figure 7: Output Voltage is 12.6 Volts when input frequency is 15kHz.

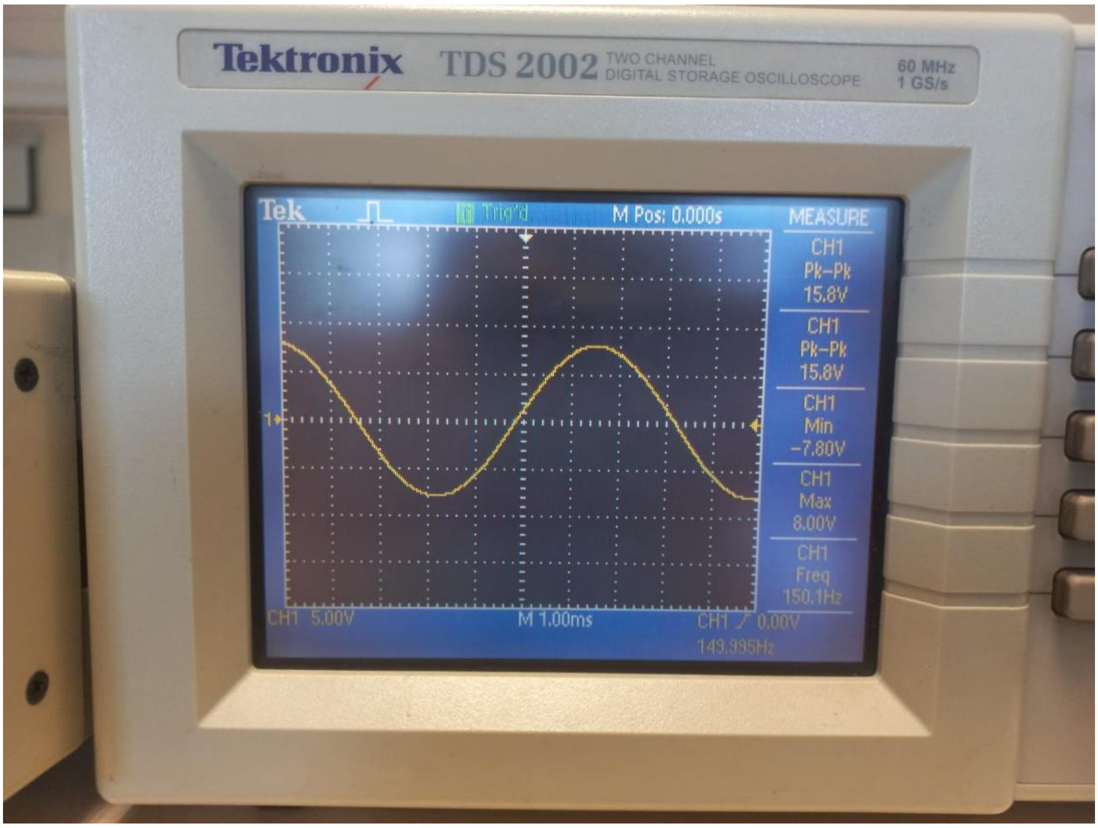

Figure 8: Output Voltage is 15.8 Volts when input frequency is 150Hz.

Here you can see the frequency-gain plot when the output power on the load resistor is 0.95Watts and the efficiency-input voltage plot for changing input voltages **(Figures 9&10)**:

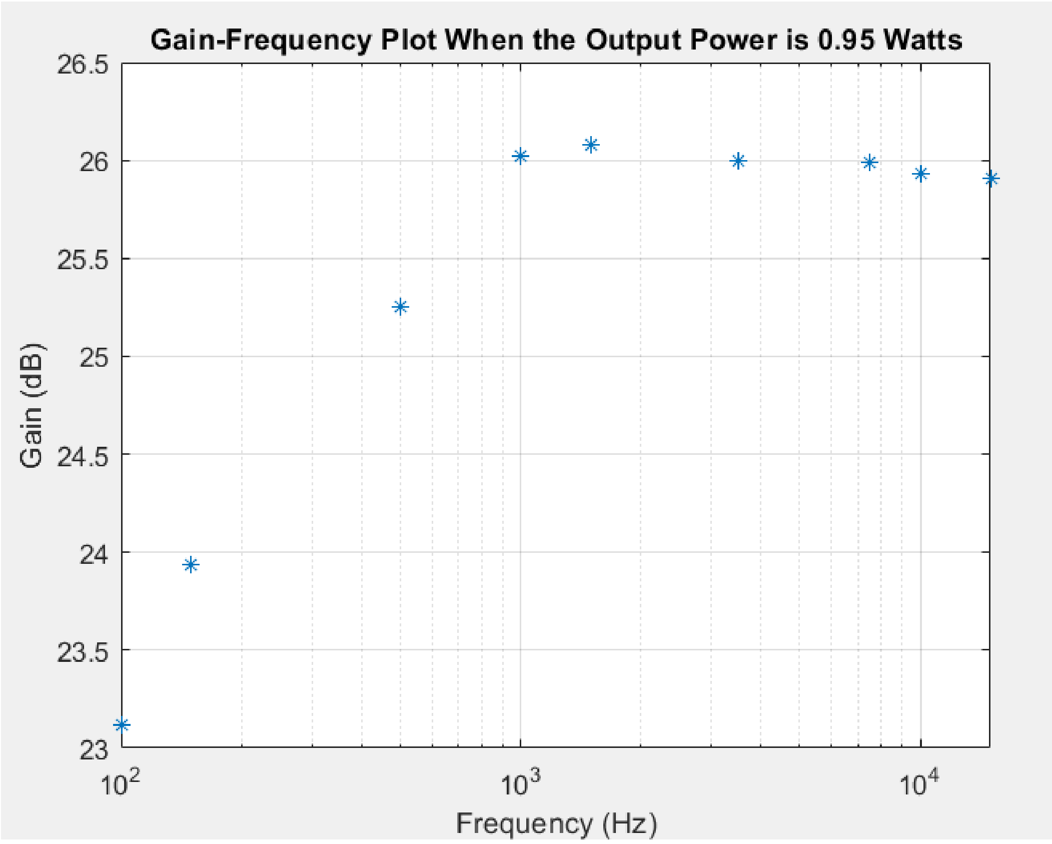

Figure 9: Gain-Frequency Plot when the Output Power is 0.95 Watts.

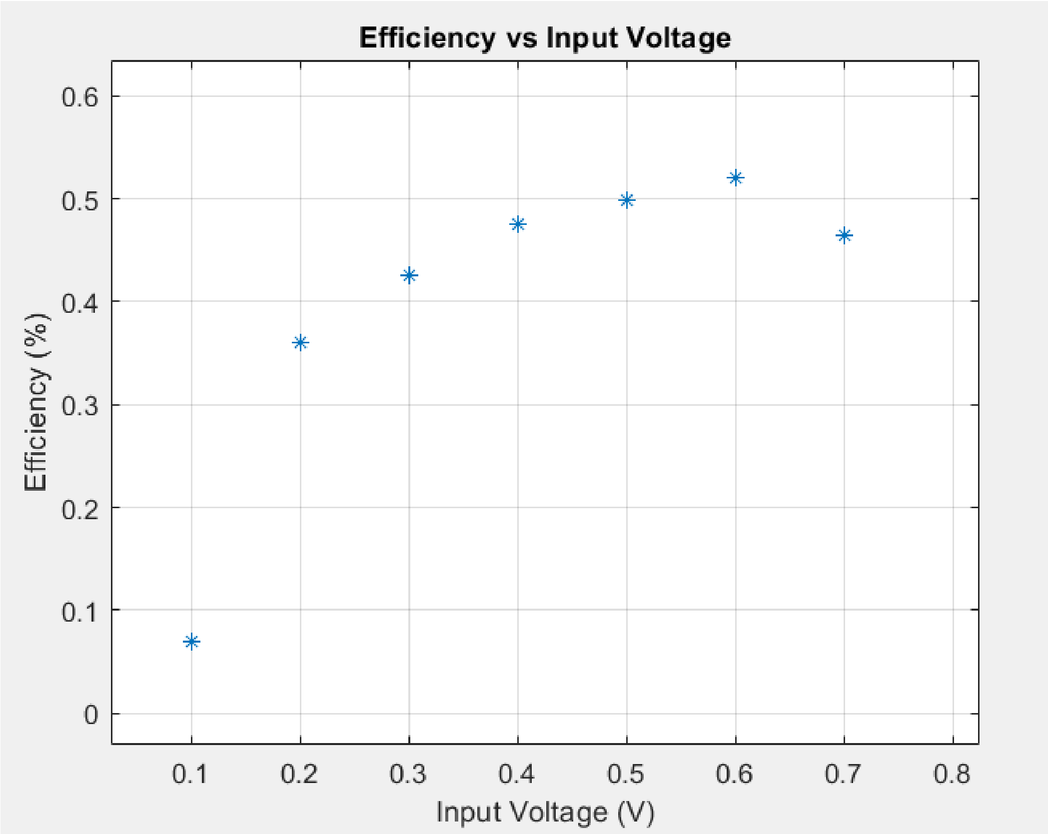

Figure 10: The Efficiency vs. Input Voltage Plot

Conclusion:

This lab's main aim was designing a single – supply push – pull class – b power amplifier by using 2 different NPN transistors (BC238 and BD135), 2 different PNP transistors (BC308 and BD136) and 1 OPAMP (LM358). Load resistance was 33Ω and supply voltage was 24V. My Bilkent ID in modulo 7 was 6. Therefore, my design should have operated with sinusoidal voltages with a gain equal to 26 dB.

The hardware implementation was complete. All the criteria were met. The lab was a total success.