Bilkent University

Electrical and Electronics Department

EE313-02 Lab 3 Preliminary Report:

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

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Fatih Mehmet Çetin - 22201689

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.

Simulation & Analysis:

Here you can see my final circuit for the lab **(Figure 1)**:

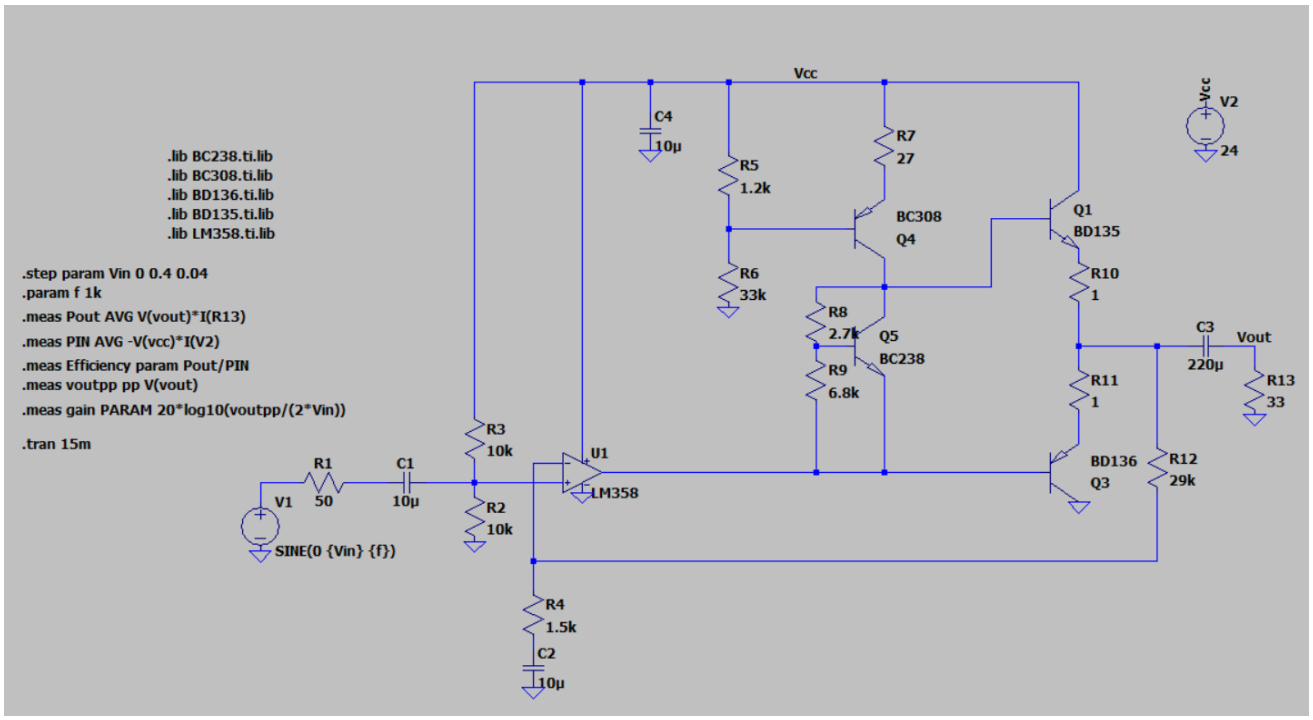

Figure 1: The Amplifier Circuit

Here you can see the output voltage and the currents on the emitters of BD135 and BD136 when Vin is stepped from 0 Volts to 0.4 Volts in 11 steps **(Figures 2 to 4)**:

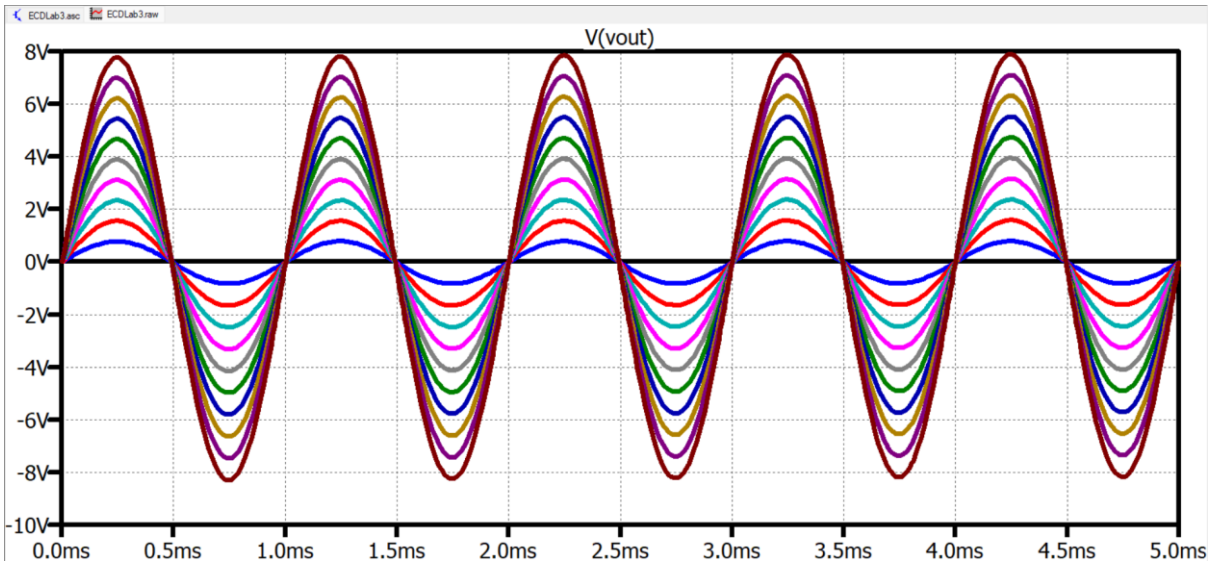

Figure 2: The Output Voltage

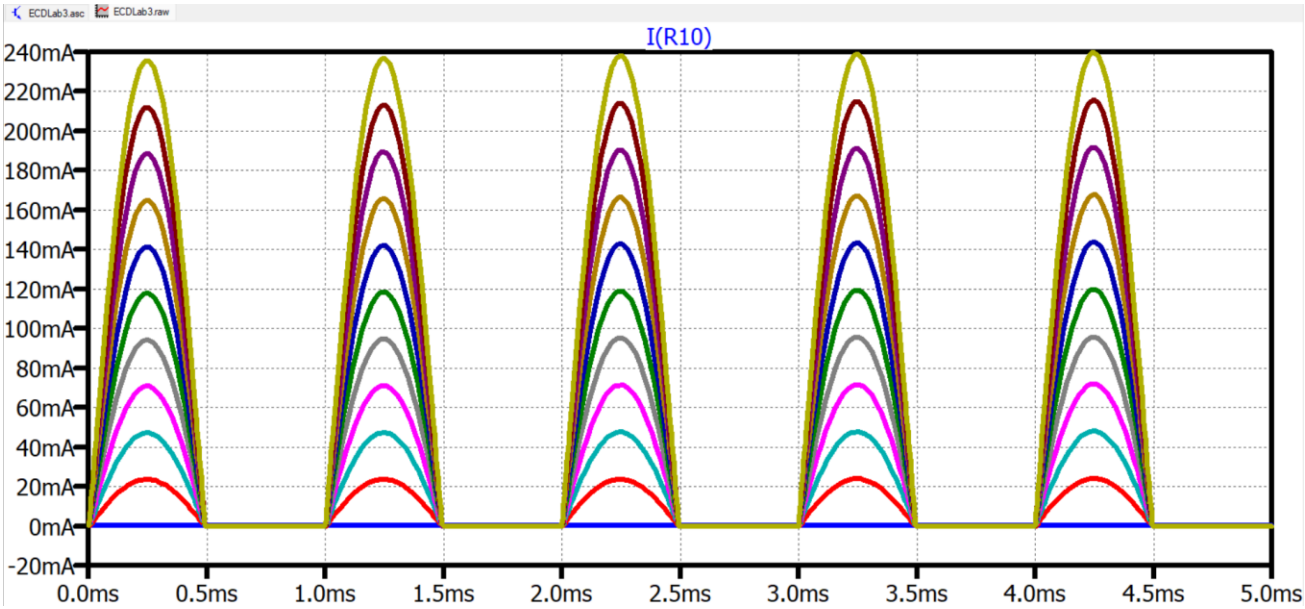

Figure 3: The Current on the Emitter of BD135

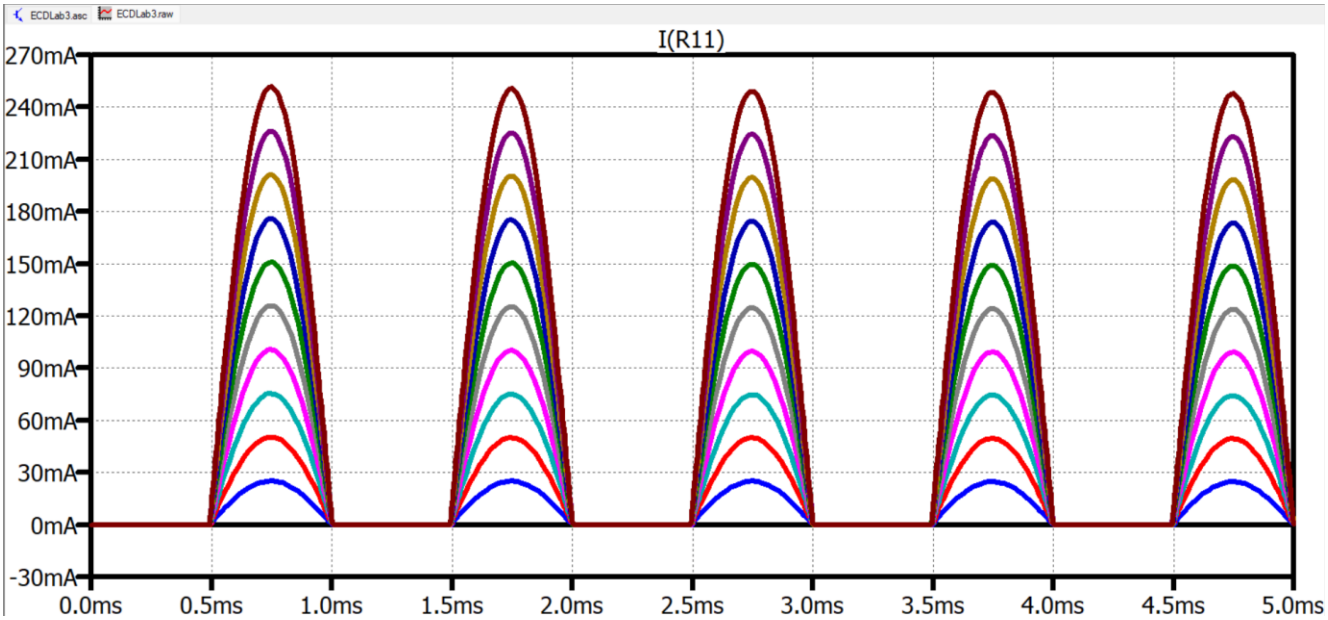

Figure 4: The Current on the Emitter of BD136

Here are the specifications that were given to us in the lab manual **(Figure 5)**:

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 5: The Specification of the Circuit

Now let's dive deep in each criterion:

Criterion 1:

Here you can see the power at the output when the gain is 26dB **(Figures 6 & 7)**. When Vin is 0.4 Volts, the power at the output is 978mW.

Measurement: pout

step	AVG(v(vout)*i(r13))	FROM	TO
1	1.26721e-20	0	0.005
2	0.0097743	0	0.005
3	0.0390972	0	0.005
4	0.0879686	0	0.005
5	0.156413	0	0.005
6	0.244411	0	0.005
7	0.351964	0	0.005
8	0.479073	0	0.005
9	0.625776	0	0.005
10	0.792083	0	0.005
11	0.978179	0	0.005

Figure 6: The Power on the Output

Measurement: gain

step	20*log10(voutpp/(2*vin))
1	inf
2	26.1279
3	26.126
4	26.1302
5	26.1306
6	26.13
7	26.1237
8	26.132
9	26.128
10	26.1319
11	26.1307

Figure 7: The Gain of the Circuit

Criterions 3 & 4:

Here you can see the power at the input, output and the efficiency of the circuit **(Figure 8)**. As expected in criterion 3, the input power -when Vin is zero- is 197mW and it is well below 500mW. As expected in criterion 4, the efficiency is 49.6% and it is well above 40% when the power at the output is 950mW.

Measurement: pout

step	AVG(v(vout)*i(r13))	FROM	TO
1	1.26721e-20	0	0.005
2	0.0097743	0	0.005
3	0.0390972	0	0.005
4	0.0879686	0	0.005
5	0.156413	0	0.005
6	0.244411	0	0.005
7	0.351964	0	0.005
8	0.479073	0	0.005
9	0.625776	0	0.005
10	0.792083	0	0.005
11	0.978179	0	0.005

Measurement: pin

step	AVG(-v(vcc)*i(v2))	FROM	TO
1	0.19751	0	0.005
2	0.37437	0	0.005
3	0.551975	0	0.005
4	0.729542	0	0.005
5	0.907059	0	0.005
6	1.08453	0	0.005
7	1.26194	0	0.005
8	1.43932	0	0.005
9	1.6167	0	0.005
10	1.79394	0	0.005
11	1.97124	0	0.005

Measurement: efficiency

step	pout/pin
1	6.41591e-20
2	0.0261087
3	0.0708314
4	0.120581
5	0.172439
6	0.22536
7	0.278906
8	0.332846
9	0.387069
10	0.441532
11	0.496225

Figure 8: The efficiency of the Circuit, Pin and Pout

Criterion 5:

Here you can see the gain of the amplifier and the output voltage when the frequency is 150Hz, 1.5kHz and 15kHz **(Figure 9)**. As expected, the gain at 150Hz and 15kHz is well above the –3dB(23dB) limit.

```
.step f=150
.step f=1500
.step f=15000


Measurement: voutpp
  step             PP(v(vout))          FROM                 TO
     1             15.2549              0                    0.005
     2             16.1768              0                    0.005
     3             15.1828              0                    0.005

Measurement: gain
  step             20*log10(voutpp/(2*vin))
     1             25.6064
     2             26.116
     3             25.5653
```

Figure 9: The Gain and Vout when Frequency Changes

Criterion 2:

Here is the FFT analysis of Vout when Vin is 0.4 Volts **(Figures 10 & 11)**. The highest harmonic is the fifth harmonic at 5kHz. The difference in dB is 58.08dB which is well above 50dB as expected.

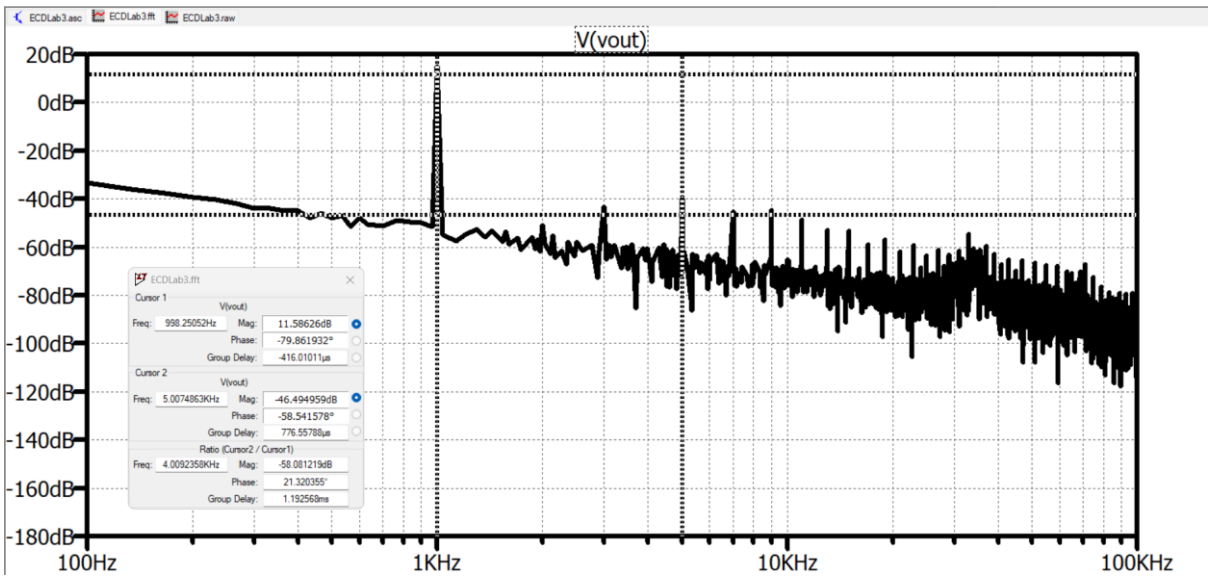

Figure 10: The FFT Analysis of Vout

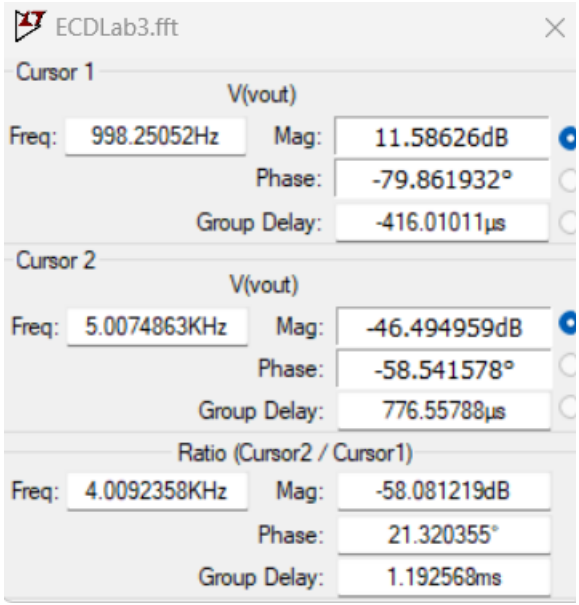

Figure 11: The Difference between the Fundamental Signal and Highest Harmonic being 58.08dB

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 design and the simulation were complete. All the criteria were met. The lab was a total success.