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Date: 03.03.2024

EE313-Electronic Circuit Design
Lab2 Preliminary
Low-Dropout Voltage Regulator

Preliminary Work

In this lab, we will focus on designing a Low-Dropout Voltage Regulator. A Low-Dropout Voltage Regulator (LDO) is a type of voltage regulator used in electronic circuits to provide a stable output voltage from a varying input voltage while minimizing the voltage drop between the input and output.

1) Finding β of the pnp Transistor

In this lab we're working with BD136 pnp transistor. First, I design a very simple circuit to observe β of the pnp transistor (Figure 1.1). To do that with trial and error, changing the voltage and resistances I reached a linear region of the transistor, with the help of the cursor I checked Vc, Ve, Vb values then made sure that my transistor is not saturated (Figure 1.2 and 1.3). Then, with the formula below (Eq. 1) I derive the β (Ic stands for collector current and Ib stands for base current of the BJT) :

$$Ic = \beta Ib \qquad \text{(eq. 1)}$$

In order to check whether bjt is in its linear region, Vce and Vbe values should satisfy below values based on the pnp model :

Vbe ≈ -0.7 Volts

Vce ≈ 0.2 Volts

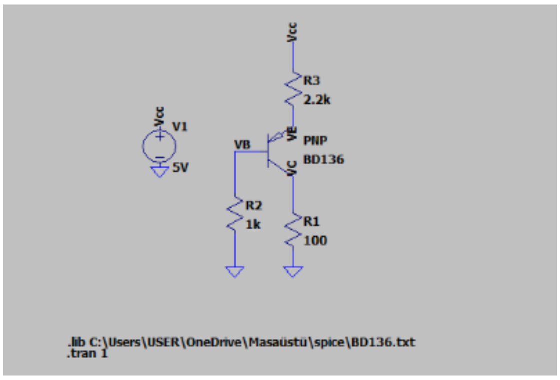

Figure 1.1 : pnp Transistor Circuit

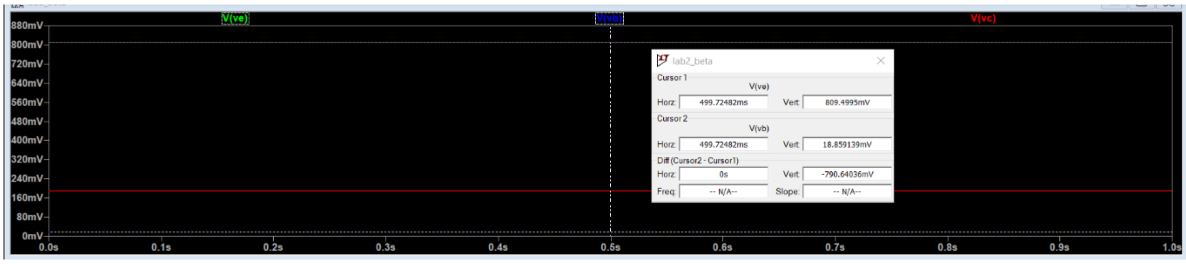

Figure 1.2 : Vbe= -0.79V calculated (≈0.7V)

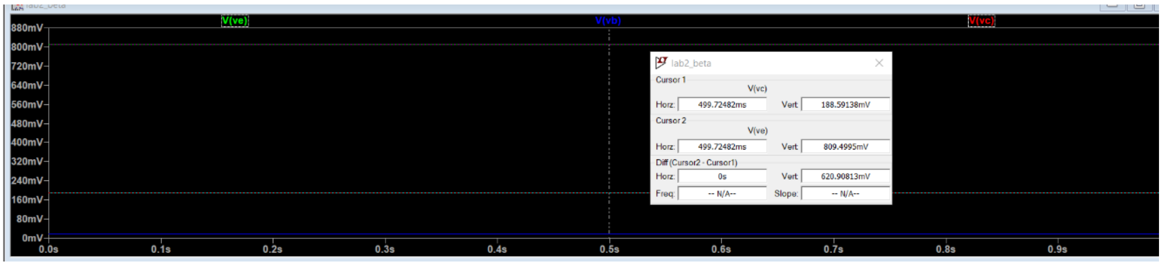

Figure 1.3 : Vce= 620.91mV calculated (> 0.2)

After making sure that we are in the linear region, we check the ratio between Ib and Ic (β):

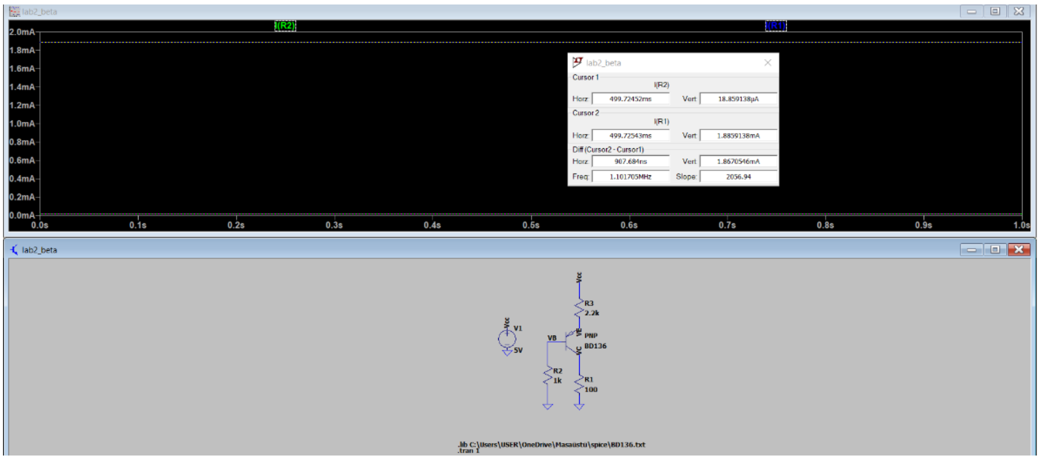

Figure 1.4 : Ic = 18.86µA, Ib= 1.886 mA

$$Ic = \beta Ib$$

18.86 µA = 100 ×1.886mA

$$\beta = 100$$

2) Designing a Low-Dropout Voltage Regulator

Lowdropout (0.7V max) voltage regulator with an output current of 100mA. A green LED sho uld turn on if the regulator output is good. Use a power pnp BJT (BD136) to regulate the volt age, an OPAMP (LM358) to provide the feedback and a Zener diode as the voltage reference. Select an output voltage of 7V, 8V, 9V, 10V, 11V, or 12V.

Initially, I picked a zener diode voltage available in the lab which is 8.2V (BZX84C8V2L). I selected output voltage as between 11 and 12V.

Specification:

1.Line regulation: When Vin is between Vout+0.7 to Vout+6, the output voltage, Vout, chang es by no more than 10mV when the output current is 20mA (RL=Vout/0.02).

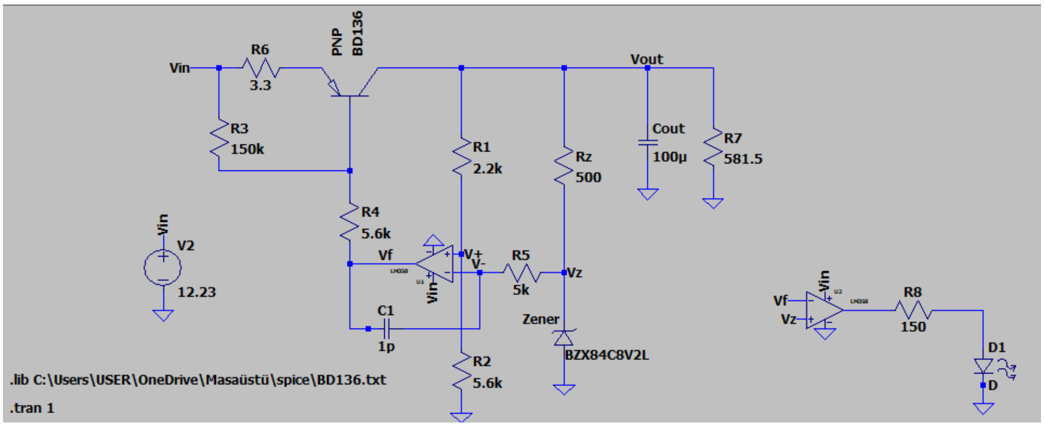

Figure 2.1 : Circuit of Specification 1

- As seen here, Vin = Vout+0.6, Vout changes by no more than 10mV when the output current is 20mA.
- Also RL= R7 is selected from RL=Vout/0.02 >> 11.629738/0.02 ≈ 581.5Ω (However, in experimental this value will be probably 560Ω)

Vf is not 0V, about 9.77V (Vf< Vin-2V), so our opamp is working in its linear region, so we can continue our design:

Figure 2.2 : 9.77V (Vf < Vin-2V), 9.77V < 10.33

Vout doesn't change more than 10mV as seen via cursors when Vin= Vout +0.6 and Vin= Vout +0.7:

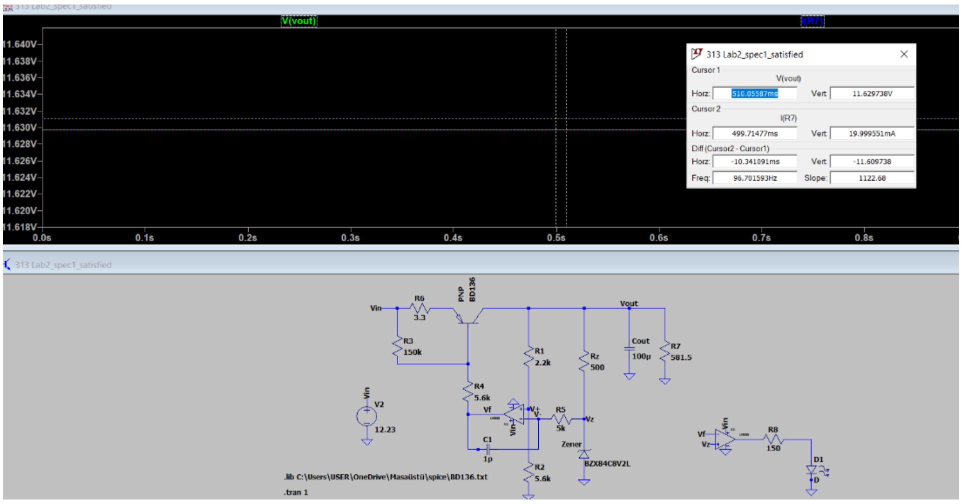

Figure 2.3 : Vout =11.62974V in both cases when Vin is 12.33V and Vin = 12.23V, Iout=19.999551mA

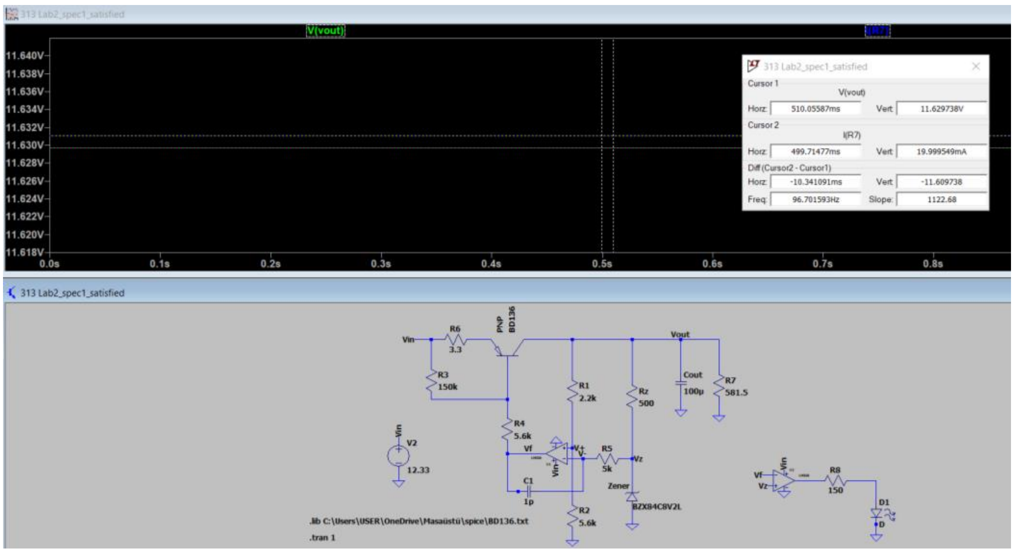

Figure 2.4: Vin= 12.33, Iout=19.99955mA

How to decide resistors R1 and R2:

From the formula below Vout value is derived:

$$V_{out} = V_z \frac{R_1 + R_2}{R_2}$$

$$8.3492V \times \frac{(5.6k+2.2k)}{5.6k} \approx 11.62924V\ V$$

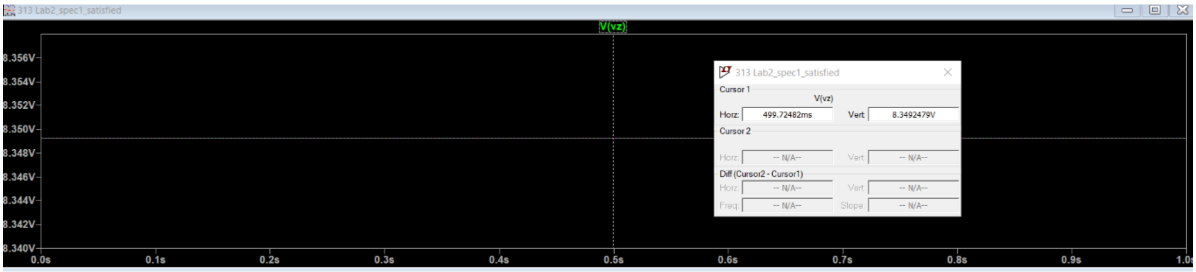

Figure 2.5 : Vzener= 8.3492V , Vout= 11.6297

Specification:

2.Load regulation: When Vin=Vout+2, the output voltage, Vout, changes no more than 50mV when
the output current changes between 5mA and 100mA (RL is varied between Vout/0.005 to V out/0.1).

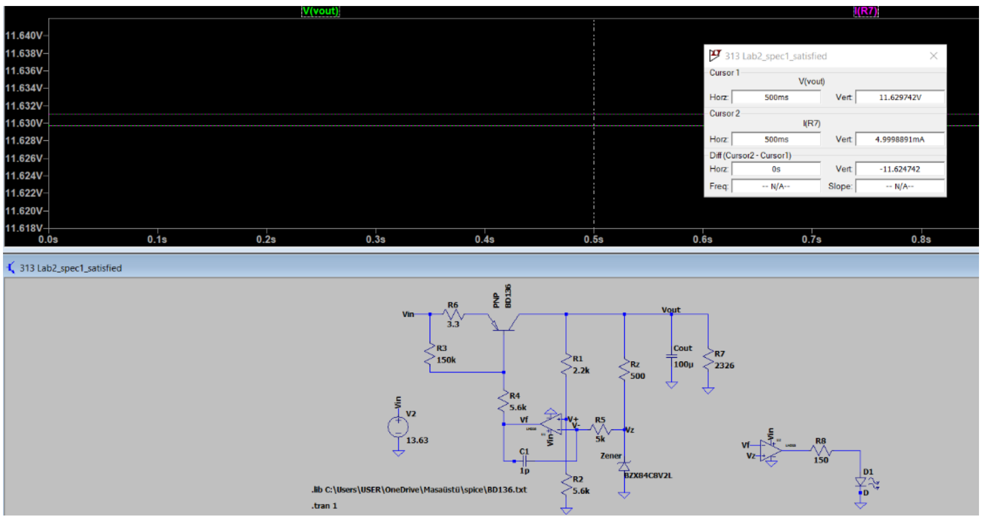

Figure 3.1 : Circuit of Specification 2, Vin=Vout+2 = 13.63 when RL = Vout/0.005 =2.3k Iout=4.99mA

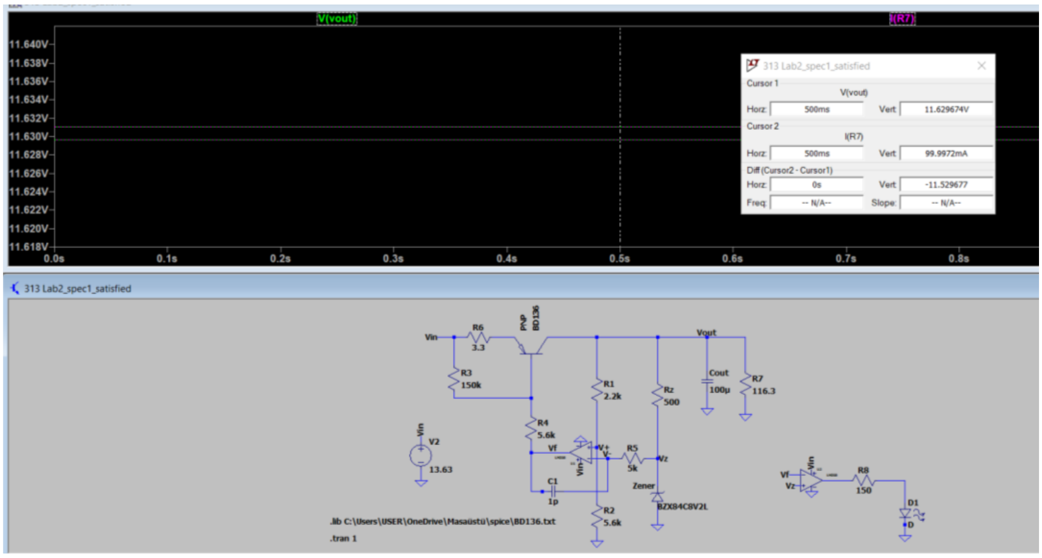

Figure 3.2 : Vin=Vout+2 = 13.63 when RL = Vout/0.1 =116.3, Iout=99.997mA

- Also RL= R7 is selected from RL=Vout/0.1= 116.3Ω (However, in the experimental this value will be probably 100Ω or 120 Ω, this is just for lowering the software error).

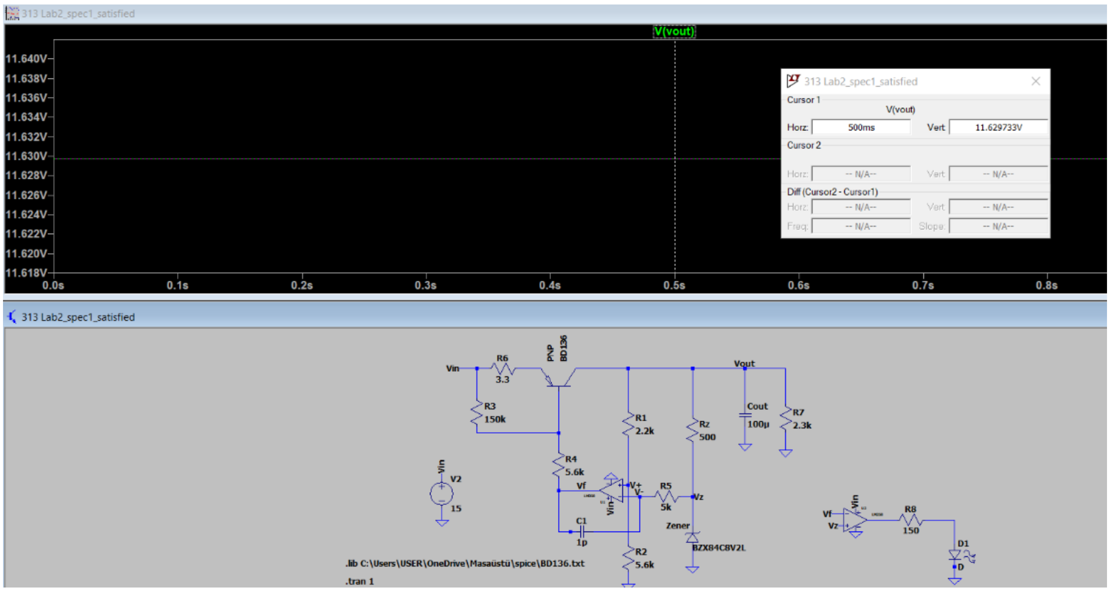

Figure 3.3 : Vin=15V when RL = Vout/0.005 =2.3k, Vout =11.629733V

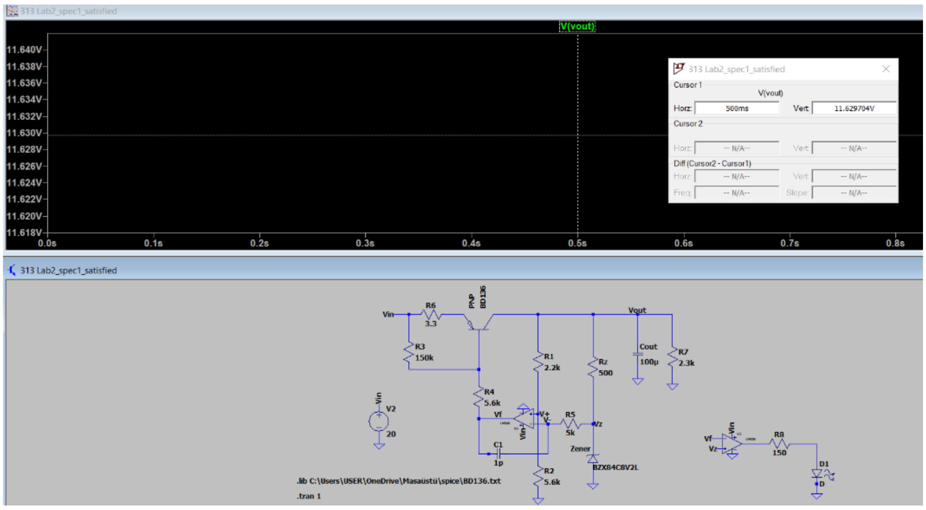

Figure 3.4 : Vin=20V when RL = Vout/0.005 =2.3kΩ, Vout =11.629704V

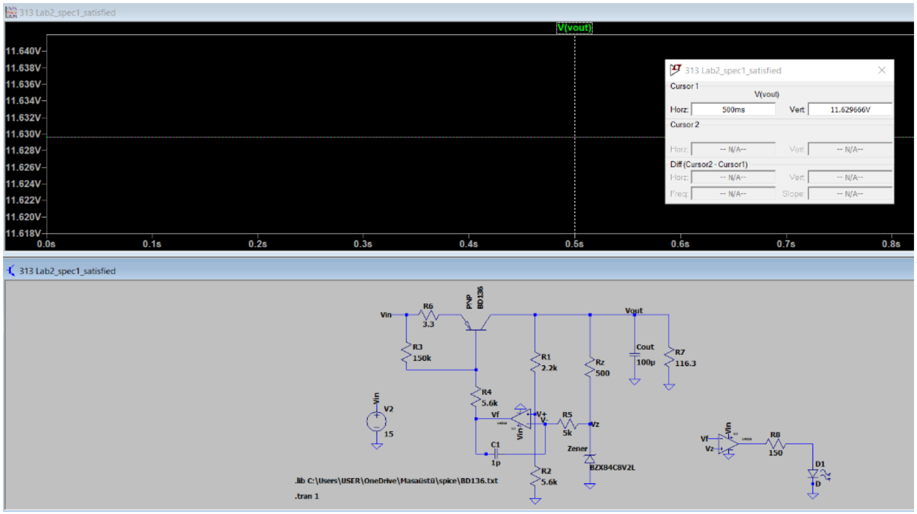

Figure 3.5 : Vin=15V when RL = Vout/0.1 =116.3Ω, Vout =11.629666V

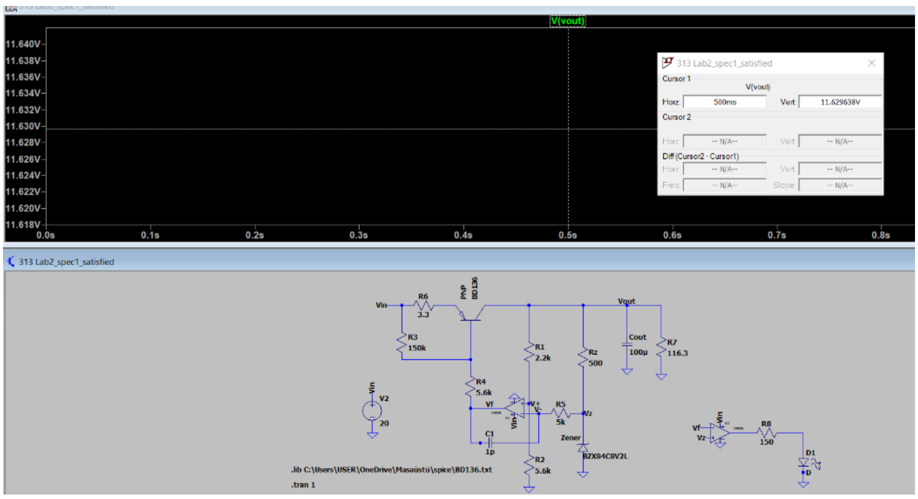

Figure 3.6 : Vin=20V when RL = Vout/0.1 =116.3Ω, Vout =11.629638V

Specification:

3. An output short circuit current of smaller than 250mA when Vin=Vout+0.7

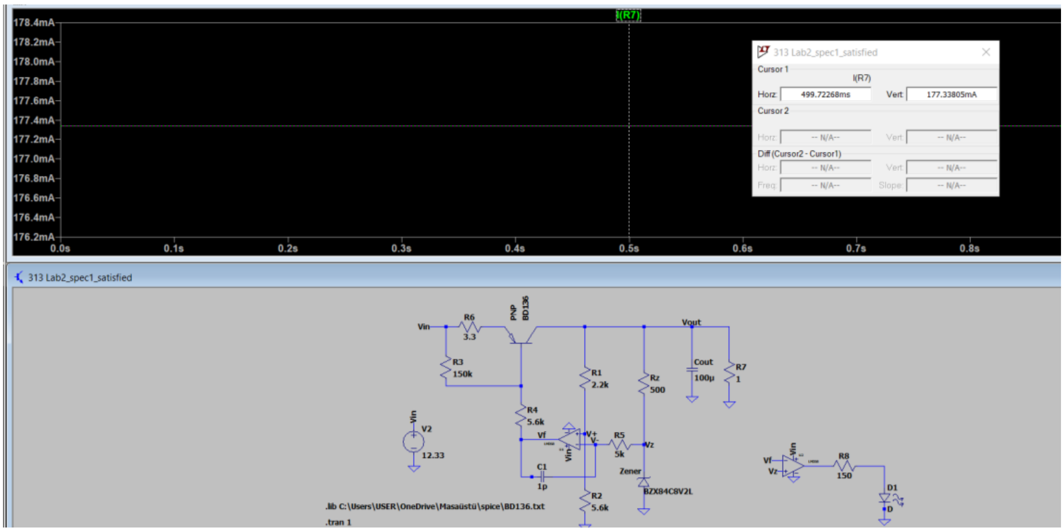

Figure 4 : Iout ≈ 177.34mA

Specification:

4.A green LED should turn on if the regulation is achieved. Otherwise, it should turn off, for example, because the input voltage is too low or the output current is too high.

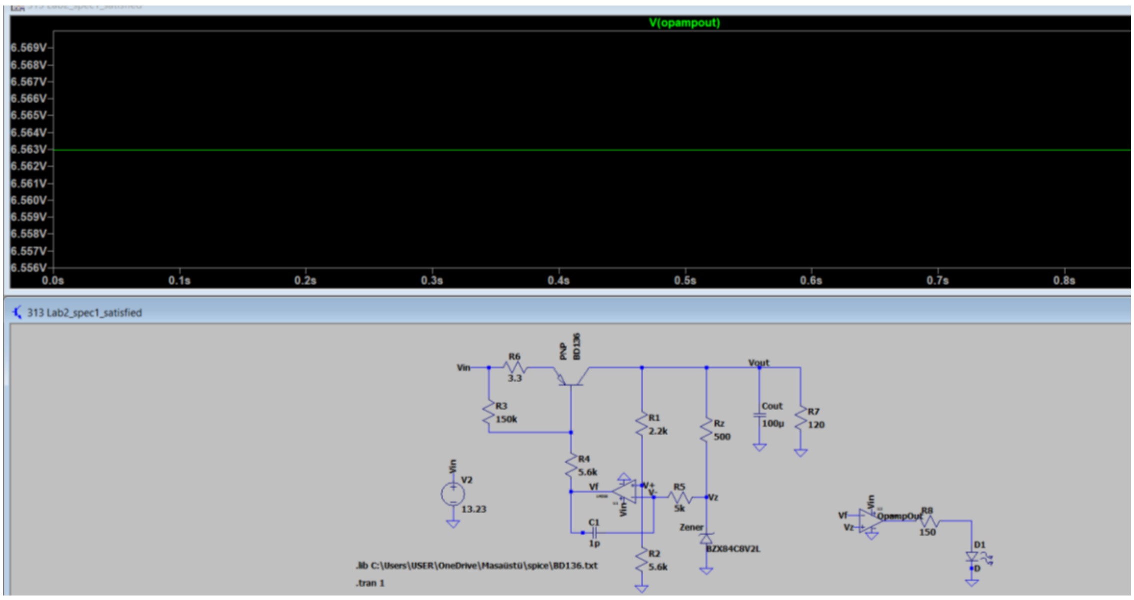

Figure 5.1 : The output of the last opamp is approximately 6.56V, so LED is ON, as we know LED turns on 1.7V

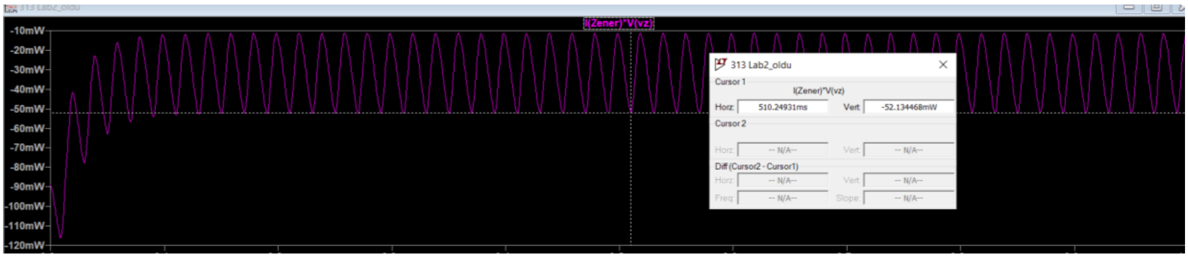

Figure 5.2 : Zener won't dissiaptes more than 100mW as expected, dissipates 52mW

Thermal Analysis

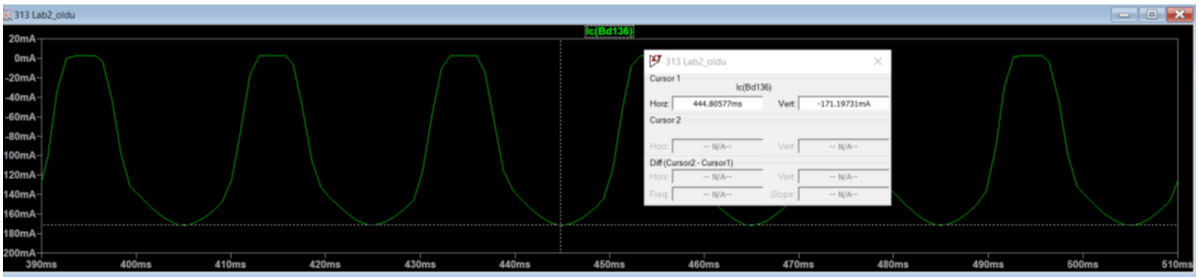

Figure 6.1 : Ic= 171mA measured

VCE calculated from the difference Vc and Ve = Vce =2.53V

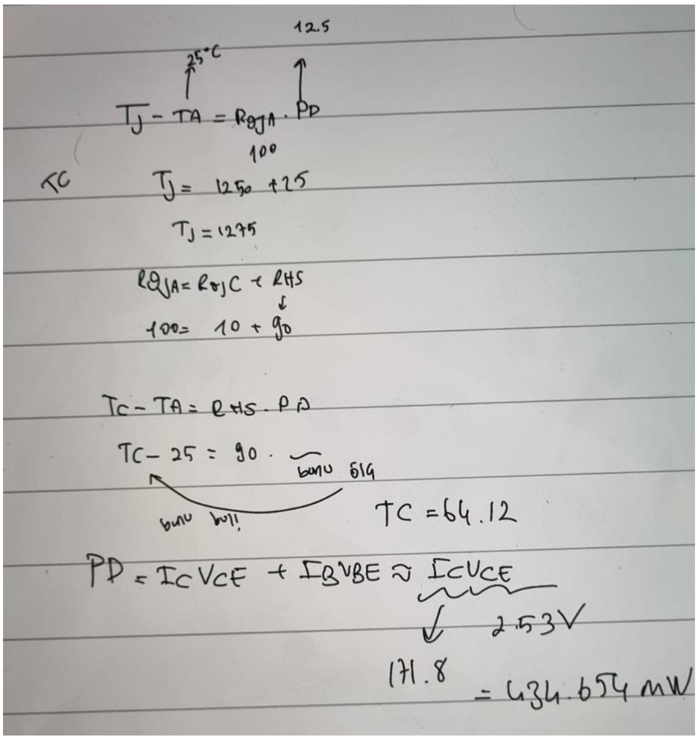

Figure 6.2 : PD= 434.65 mW measured, therefore Tc is about 64°C

#	Name	RefDes	Value
1	CAP100	C1	1p
2	CAP250RP	Cout	100u
3	LED	D	
4	BD136	PNP	
5	CFR25SJR-52-100K	R1, R2, R3, R4, R5, R6, R7, R8, Rz	2.2k, 5.6k, 150k, 5.6k, 5k, 3.3, 1116.3, 150, 500
6	LM358N	U1, U2	LM358
7	BZX84C8V2LT1G	Zener	8.2V

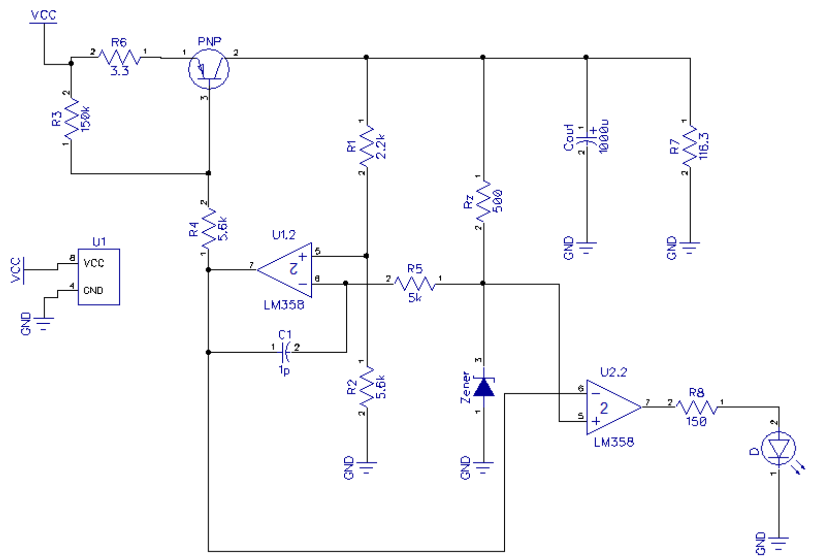

Figure 7: Diptrace Schematic and Component List

Note: The reason why I misunderstood some concepts of this lab, I needed to change my preliminary lab report. So, I submitted my report after the experimental session again!!

REFERENCES:

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- https://moodle.bilkent.edu.tr/2023-2024-spring/pluginfile.php/77721/mod_resource/content/1/LDOAnalysis.pdf
- https://moodle.bilkent.edu.tr/2023-2024-spring/pluginfile.php/82714/mod_resource/content/2/HintsForLab2.pdf
- https://moodle.bilkent.edu.tr/2023-2024-spring/pluginfile.php/81407/mod_resource/content/1/ZenerDiodeList.txt
- Data sheet of BD146