Bilkent University

Electrical and Electronics Department

EE313-02 Lab 2 Preliminary Report:

“Low-Dropout Voltage Regulator”

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Introduction:

This experiment consisted of two parts: A and B. In part A, we were asked to measure the β value of a pnp-transistor BD136. In part B, we were asked to design a low-dropout (LDO) voltage regulator with an output current of 100mA. We used a zener diode (UMZ5.1N), two op-amp's (LM358) and a power pnp BJT (BD136) in the circuit.

In the lab manual, we were given the following recommended circuit for part B **(Figure 1.1)**:

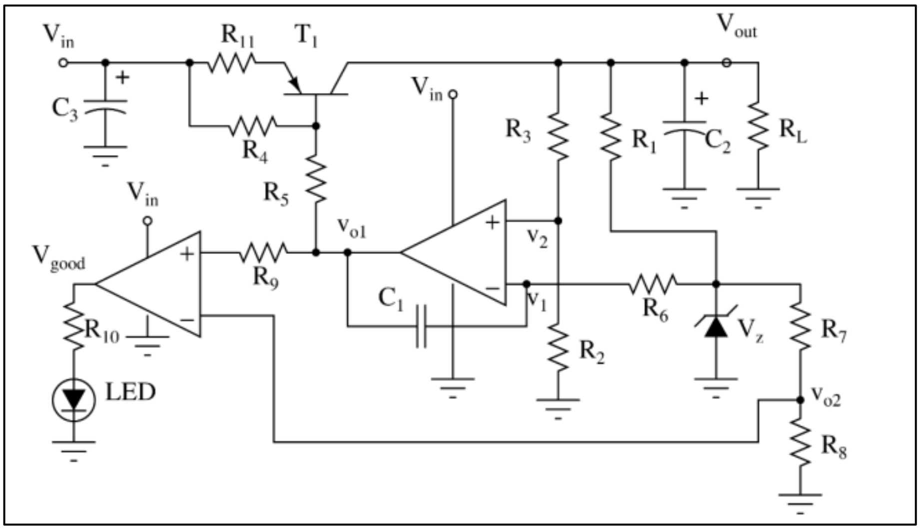


Figure 1.1: The Example Circuit in the Lab Manual for Part B

Simulation&Analysis:

Part A:

In this part of the experiment, we were asked to measure the β value of a pnp-transistor BD136. The mathematical relationship for β is shown in (1).

$$\beta = \frac{I_C}{I_B} \qquad \textbf{(1)}$$

The LTSpice circuit and simulation results for part A **(Figures 2.1&2.2).** The BJT is used in ACT mode. It can be seen that the β value converges to nearly 223 with higher voltages.

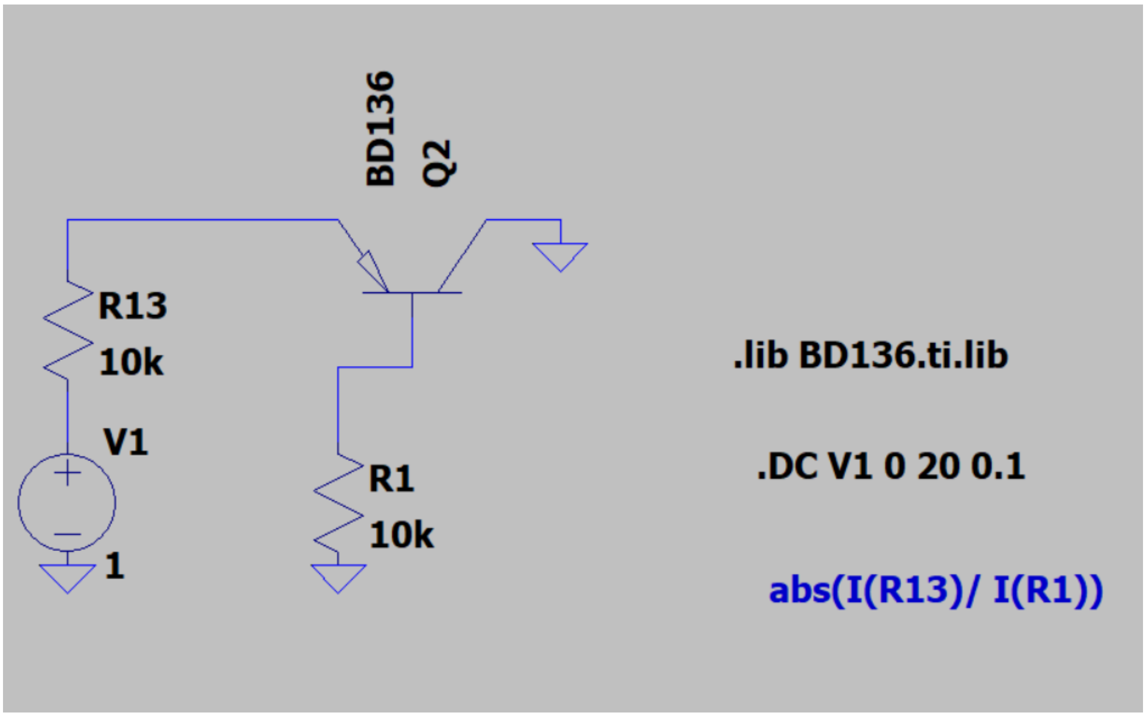


Figure 2.1: The LTSpice Circuit for β Analysis

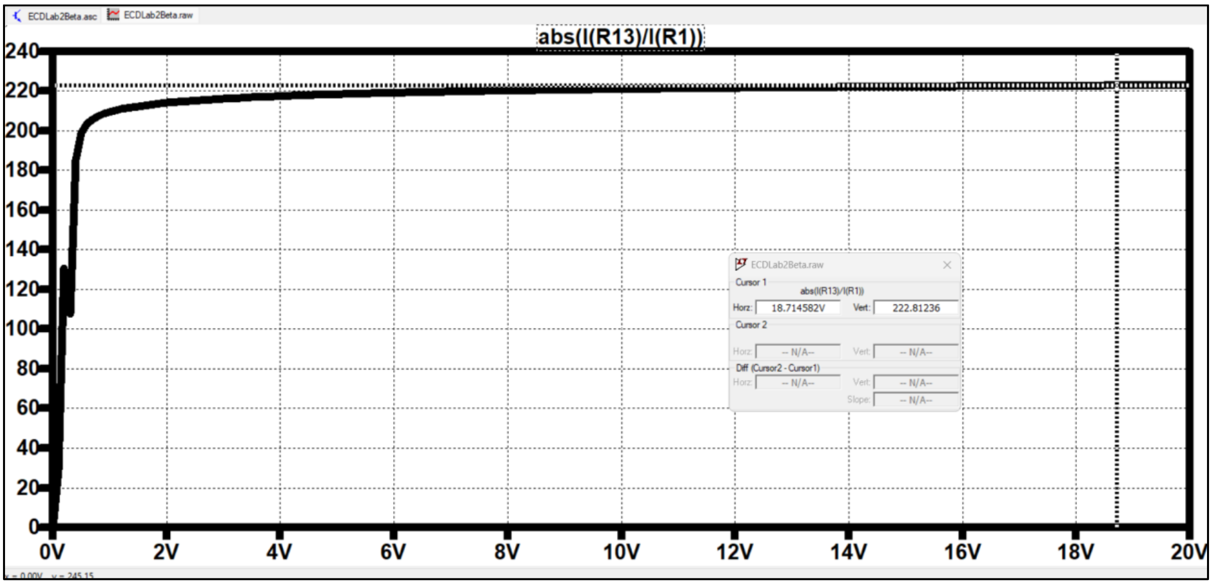


Figure 2.2: The LTSpice Simulation for β with respect to different voltage values

Part B:

In part B, we were asked to design a low-dropout (LDO) voltage regulator with an output current of 100mA. We used a zener diode (UMZ5.1N), two op-amp's (LM358) and a power pnp BJT (BD136) in the circuit.

Since my Bilkent ID number is equal to 3 in modulo 6, my desired output voltage was 10.5 Volts. Here is the overall circuit I used for the part B of the experiment **(Figure 2.3)**:

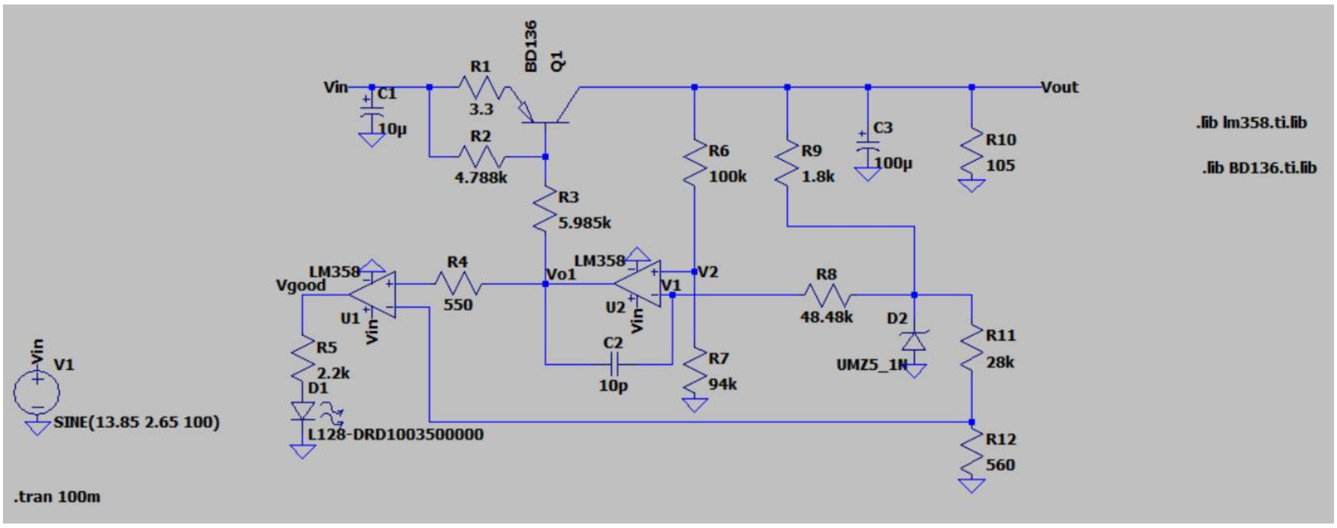


Figure 2.3: The overall circuit I used for the part B of the experiment

There are 3 requirements that the circuit should meet. These were given in the lab manual **(Figure 2.4)**:

Specifications:

1. Line regulation: When V_{in} is varying between V_{out}+0.7 to V_{out}+6 at 100Hz, the output voltage, V_{out}, changes by no more than 20mV when the output current is 100mA (R_L=V_{out}/0.1).
2. Load regulation: When V_{in}=V_{out}+2, the output voltage, V_{out}, changes no more than 20mV when the output current changes between 0mA and 100mA at 100Hz. (In LTSpice, you can connect a sinusoidal current source at the output varying between 0 and 100mA.)
3. 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 2.4: The Requirements the Circuit should Meet

Criterion 1: Line regulation: When Vin is varying between Vout+0.7 to Vout+6 at 100Hz, the output voltage, Vout, changes by no more than 20mV when the output current is 100mA.

Here are three graphs **(Figures 2.5 to 2.7)**. First of them shows the relationship between Vin and Vout. The second one shows Vout in a more detailed fashion. We can clearly see that our voltage regulator works well, and it satisfies the criterion since Vout is clearly within the 20mV limits. The third and final graph for this criterion shows us that output current is oscillating around 100mA as expected.

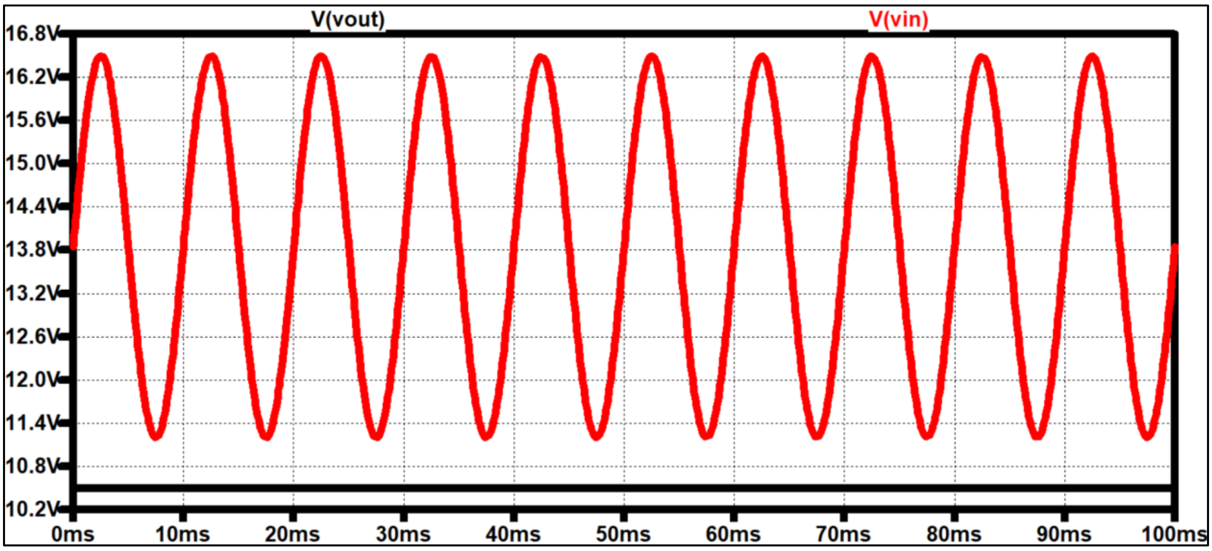


Figure 2.5: The relationship between Vin (Red) and Vout (Black)

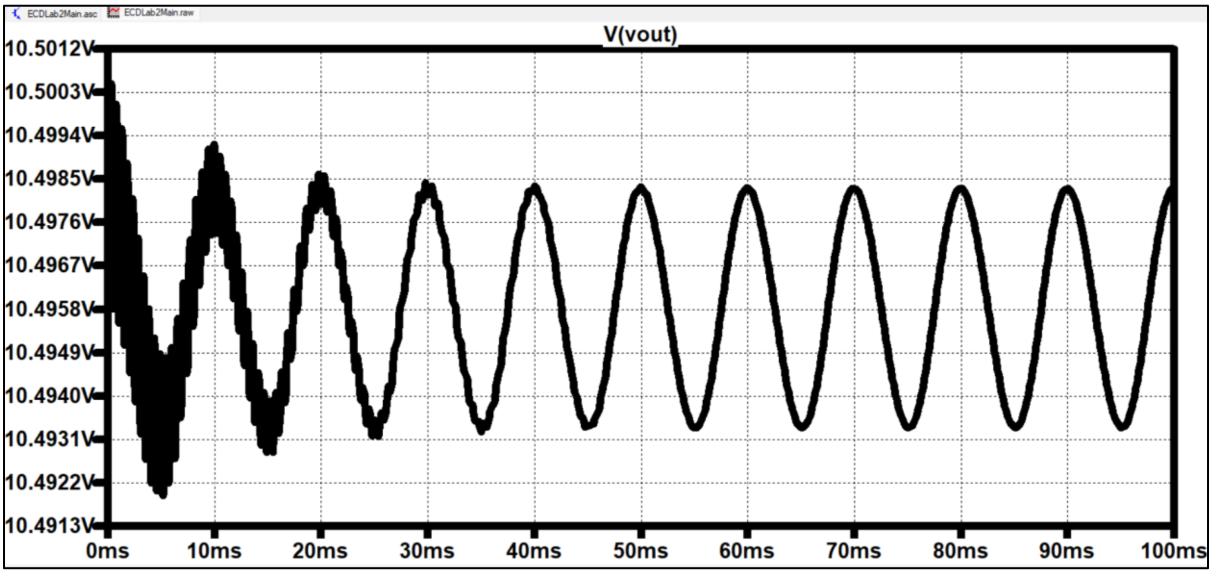


Figure 2.6: Vout being in the limits (10.48V-10.52V)

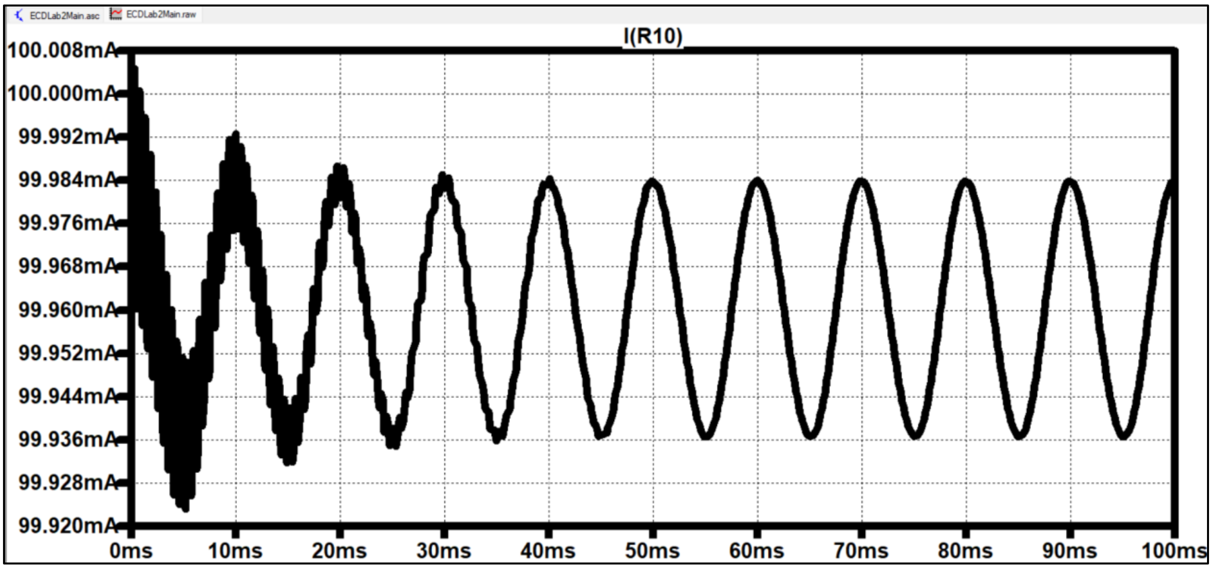


Figure 2.7: The current on the load resistor being around 100mA with 8mA perturbation

Criterion 2: Load regulation: When Vin=Vout+2, the output voltage, Vout, changes no more than 20mV when the output current changes between 0mA and 100mA at 100Hz.

To satisfy this criterion, we should alter the circuit. Here is the altered circuit which is used in this part of the experiment **(Figure 2.8)**:

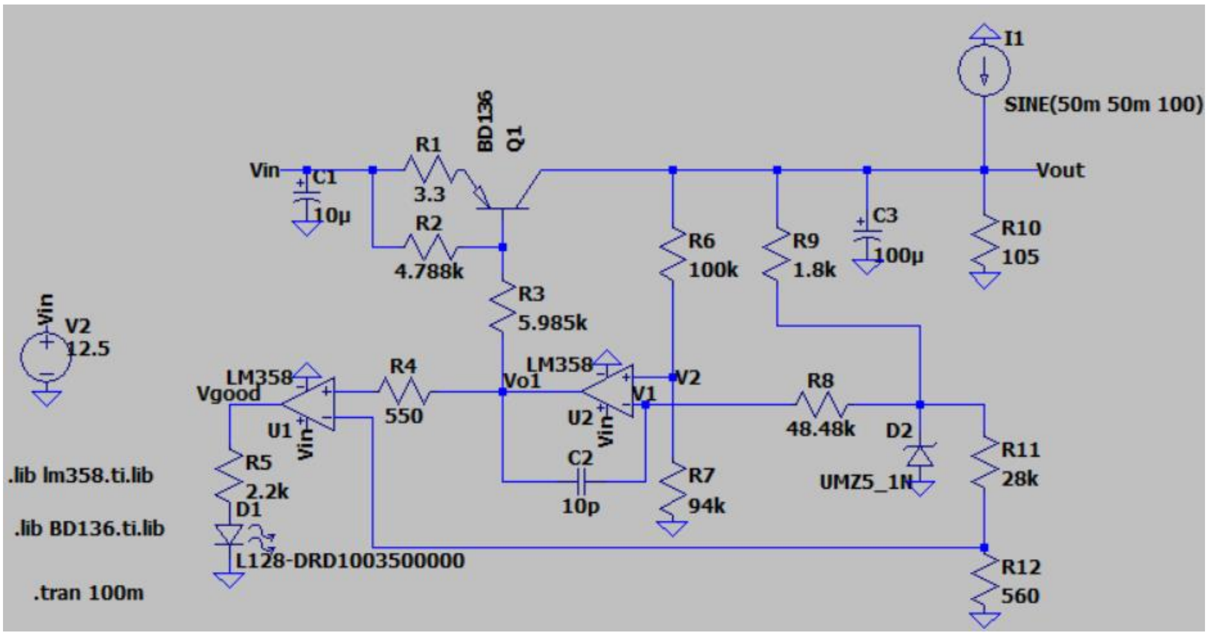


Figure 2.8: The altered circuit for this part of the experiment

Here are two graphs for this criterion **(2.9&2.10)**. First of them shows Vout. The second one shows the output current varying between 0 and 100mA. As expected, the output voltage does not exceed 20mV difference from 10.5 Volts.

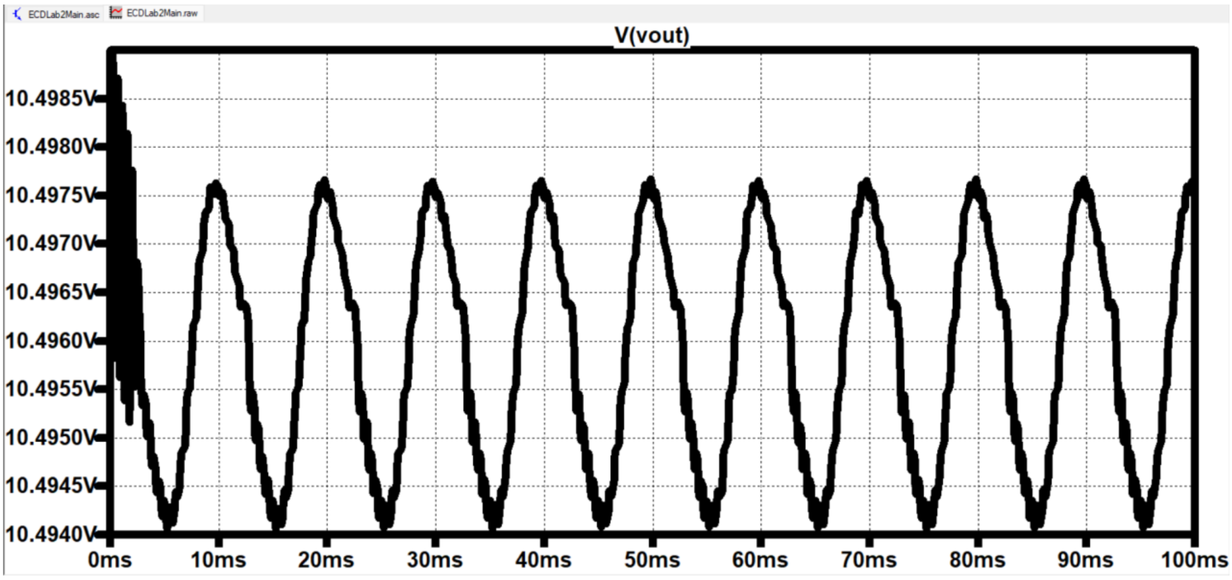


Figure 2.9: Vout being in the limits (10.48V-10.52V)

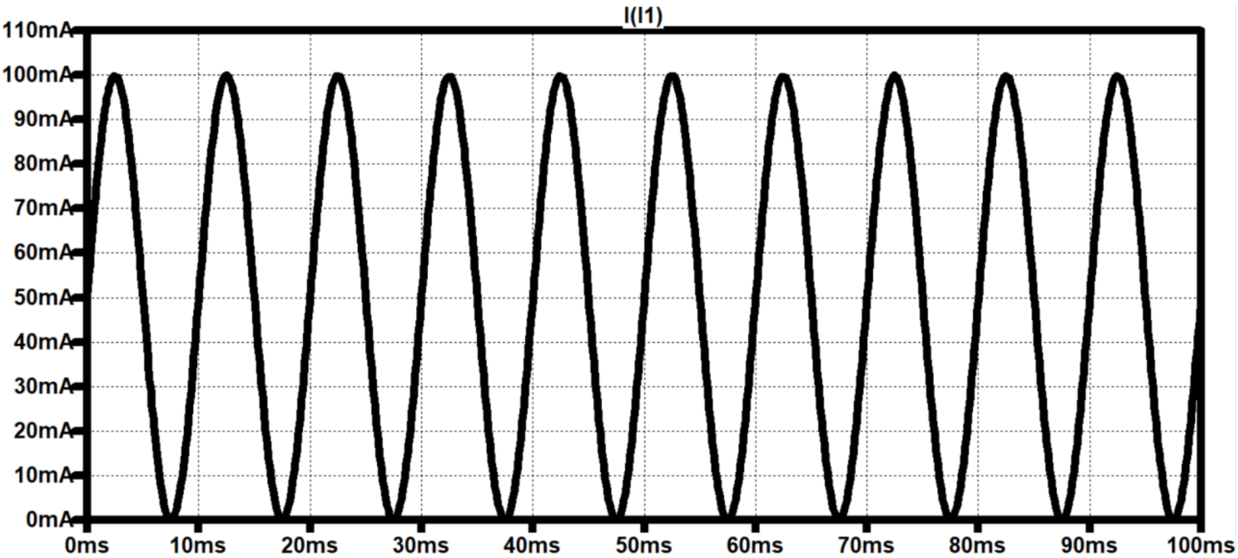


Figure 2.10: The output current varying between 0 and 100mA

Criterion 3: 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.

This criterion means that a green LED should light when there is voltage regulation, if the input voltage is not high enough for the regulation to be performed, then the current on the LED should go low. Here you can see a detailed graph which contains Vin, Vout and the current on the resistor **(Figure 2.11)**. In the figure, we can conclude a few things. Firstly, the output voltage gets regulated when the input voltage is high enough. Secondly, the current on the LED goes up when Vout gets regulated. This means that our circuit successfully satisfies this criterion.

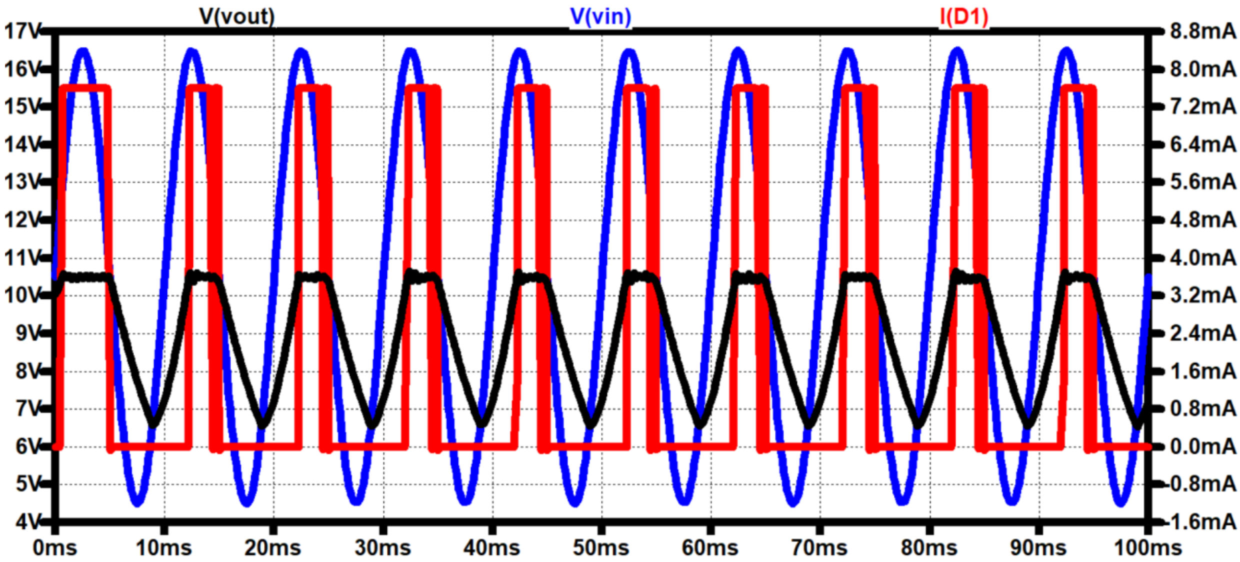
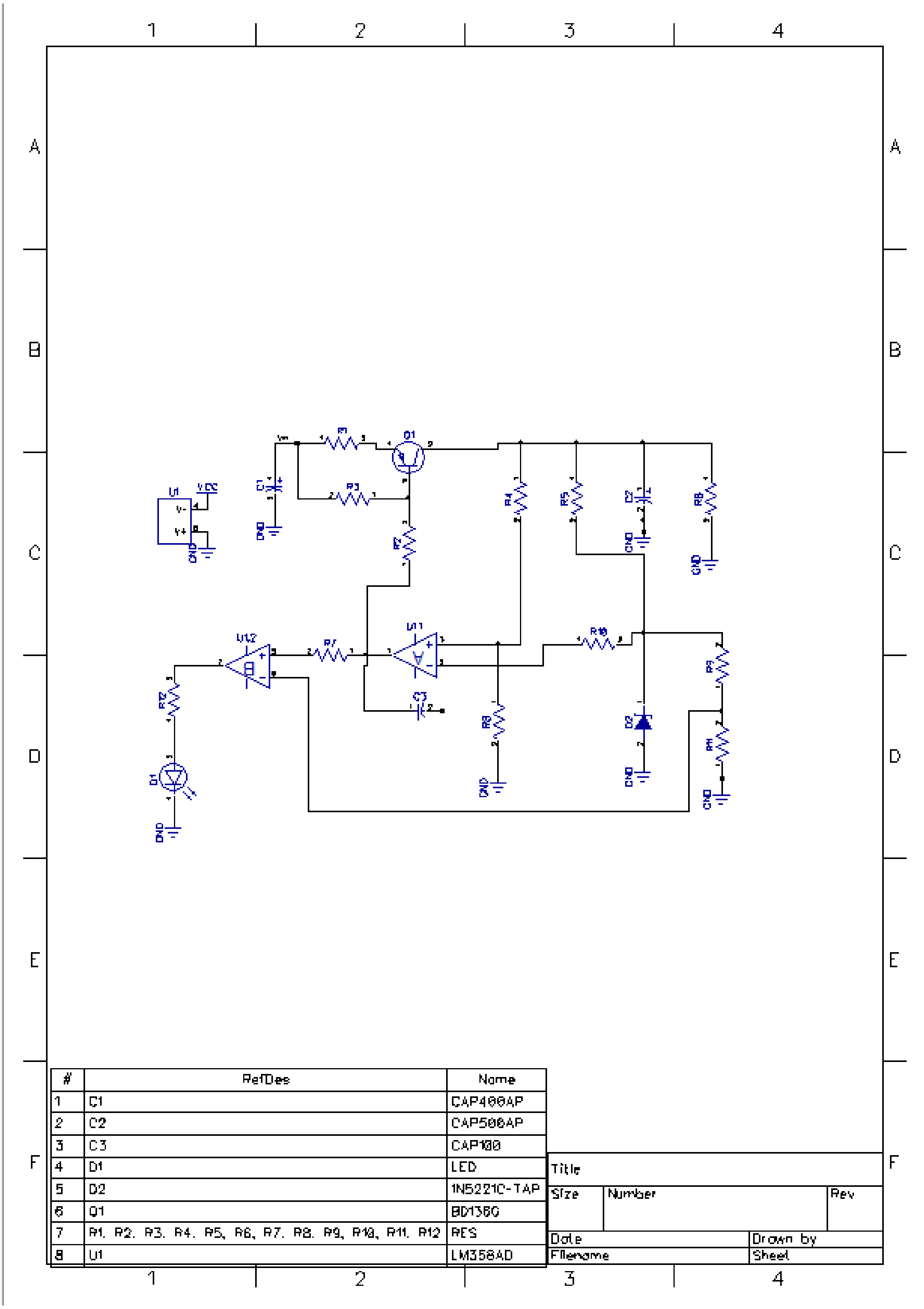


Figure 2.11: Vin (Blue), Vout(Black) and I(LED)(Red)

Here you can see the Diptrace Schematic of my design as well as the component list **(Figure 2.12)**:



#	RefDes	Name
1	C1	CAP400AP
2	C2	CAP500AP
3	C3	CAP100
4	D1	LED
5	D2	1N5221C-TAP
6	Q1	BD136G
7	R1, R2, R3, R4, R5, R6, R7, R8, R9, R10, R11, R12	RES
8	U1	LM358AD

Figure 2.12: Diptrace Schematic of the circuit with the component list

Now let's take a look at the temperature analysis of BD136. Here are some constants from the datasheet of BD136 **(Appendix 1)**. Also, (2), (3) and (4) are the equations I used which were given in the lab manual:

Junction to Ambient Thermal Resistance (RθJA) -> 100 °C/W

Junction to Case Thermal Resistance (RθJC) -> 10 °C/W

Maximum Junction Temperature (TJ) -> 150 °C

$$P_D = (V_{in} - V_{out}) \cdot I_{out} = 0.3W \quad \textbf{(2)}$$

$$T_J = T_A + R_{\theta JA} \cdot P_D \textbf{(3)}$$

$$T_C = T_J - R_{\theta JC} \cdot P_D \qquad \textbf{(4)}$$

If we solve (3) and (4), we get (5) and (6):

$$T_J = 25°C + \left(100° \frac{C}{W} \cdot 0.3\,W\right) = 55°C \qquad \textbf{(5)}$$

$$T_C = 55°C - \left(10° \frac{C}{W} \cdot 0.3\,W\right) = 52°C \qquad \textbf{(6)}$$

Conclusion & Thoughts on HW Part:

The preliminary work was successfully finished. The requirements were met both in part A and part B. The LTSpice & Diptrace softwares were used. Properties of diodes, opamps and BJT's were learned and used practically. I believe this lab will help us a lot in our courses because we learned so much about diodes, opamps and BJT's. We also used diptrace which will help us in our course project.

I believe the hardware implementation of this lab will be detrimental to us. This is beacuse the 20mV difference that is asked cannot be seen in an oscilloscope. I wonder whether we will have any error limits for hardware part. This measurement preciseness will definitely be a hard challenge for us. I believe the TA's will be more tolerant on this issue.

Appendices:

1- https://www.onsemi.com/pdf/datasheet/bd136-d.pdf