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Course Code: EEE313

Section: 02

Experiment Number: 02

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Lab 2 Experimental Report

Introduction:

First part of the experiment is about calculation β value of the BD136 pnp transistor. For the second part, an LDO (0.7V) voltage regulator is built on a breadboard. Design specifications for second part is listed below:

1. Line regulation: When Vin is between V_{out}+0.7 to V_{out}+6, the output voltage, Vout, changes by no more than 10mV when the output current is 20mA (R_L=Vout/0.02).

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 (R_L is varied between V_{out}/0.005 to V_{out}/0.1)

3. An output short circuit current of smaller than 250mA when V_{in}=V_{out}+0.7.

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

Methodology:

For the first part, I created the circuit on the breadboard (Figure 1). From this circuit, I measured the voltage across the resistors and divided the voltage values to the corresponding resistor values. By doing that, I found the currents across the resistor.

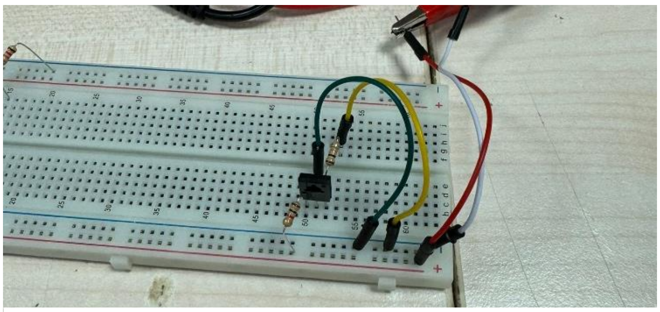

Figure 1: Circuit for β calculation

For the second part of the experiment, again I built the circuit on the breadboard (Figure 2). I used 560Ω at load because 500Ω resistor is not available in the lab. Also, I used 82nF capacitor in the first OPAMP because there is not any 91nF valued capacitor either in the lab. The circuit basically adjusts the base current according to the output voltages, therefore we can get constant voltage at the output.

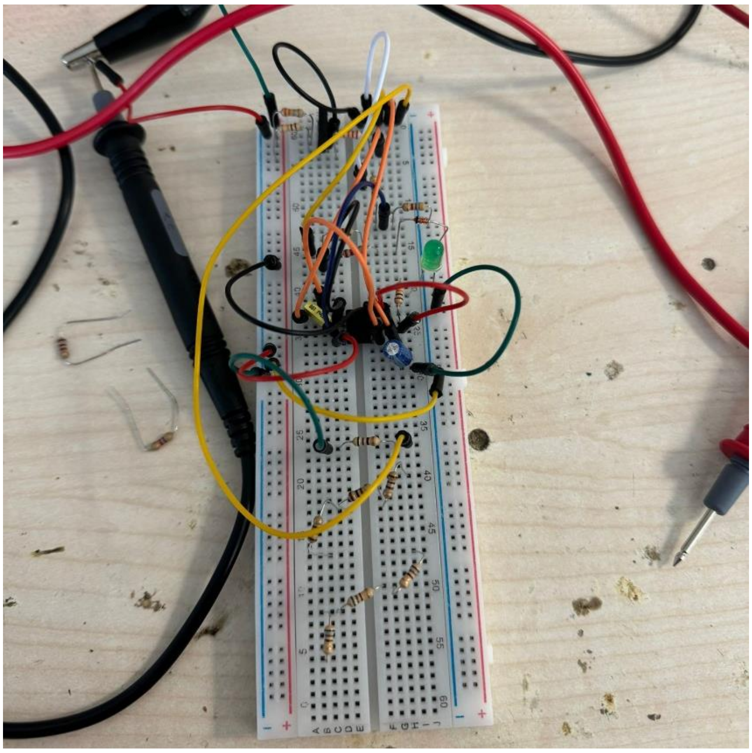

Figure 2: Circuit for LDO voltage regulator

Analysis:

Part A

Below given the equation for β (Eqn. 1).

$$I_E = I_B * (\beta + 1)$$

$$\beta = \frac{I_E}{I_B} - 1 \qquad \text{(Eqn. 1)}$$

Figure 3 shows the voltage across the 10KΩ resistor (base branch), and Figure 4 shows the voltage across 1KΩ resistor (emitter branch).

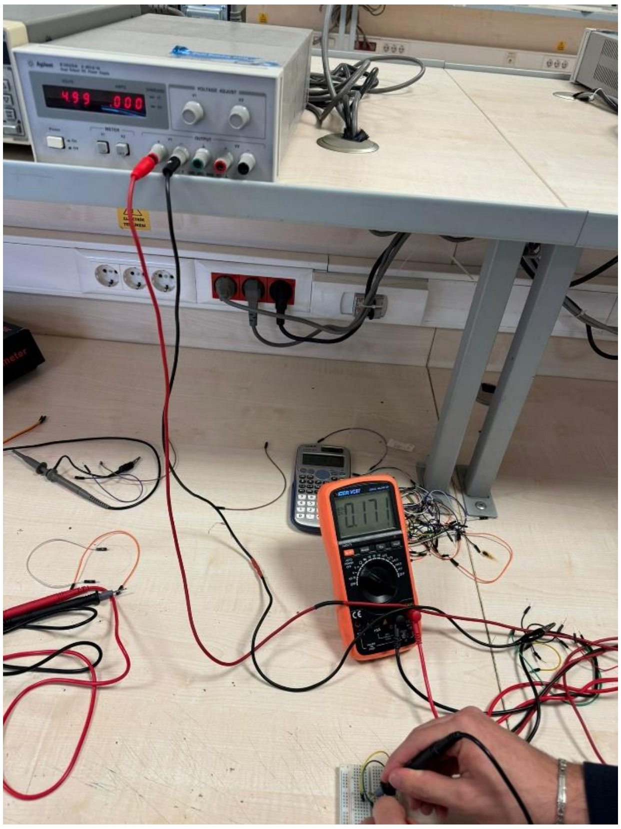

Figure 3: Voltage across 10KΩ resistor (Base)

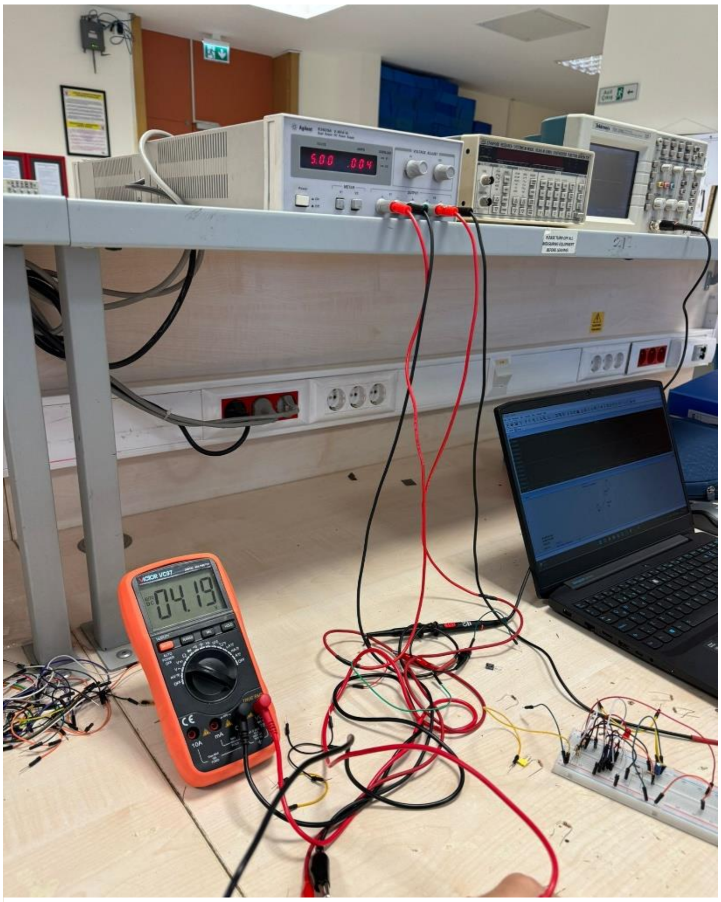

Figure 4: Voltage across 1KΩ resistor (Emitter)

Using the values in Figure 3 and Figure 4, I_B and I_E values are found.

$$I_B = \frac{0.171}{10^4} = 17.1\mu A$$

$$I_E = \frac{4.19}{10^3} = 4.19mA$$

Inserting these values into (Eqn.1), β value is calculated.

$$\beta = \frac{4.19mA}{17.1\mu A} - 1 = 244$$

In preliminary part, β value is measured as 223.2. Below table (Table 1) shows the error percentage between the values measured in preliminary and experimental part.

Table 1: β value comparison

	Β Value	Error percentage
LTspice Simulation	223.2	8.52%
Hardware Implementation	244	

Part B

For this part, I implemented the circuit on the breadboard. Youtube link below shows the output voltage when the input voltage is in the range ($V_{in} = V_{out} + 0.7V$ to $V_{out} + 6V$).

https://youtube.com/shorts/TBVbraqWkFg?feature=share

As seen from the video, voltage across the load resistance (R_L) is 10.08V constant even the input voltage V_{in} changes. Therefore the first condition is satisfied.

For the line regulation part, I used three 33Ω resistors in series to get 100Ω resistor and three 680Ω resistor in series to get 2KΩ resistor. Because common axial resistors can only dissipate 250mW, I connected three of them in series to handle the power dissipation. Figure 5 and Figure 6 shows relatively the load resistor values for 100Ω and 2KΩ.

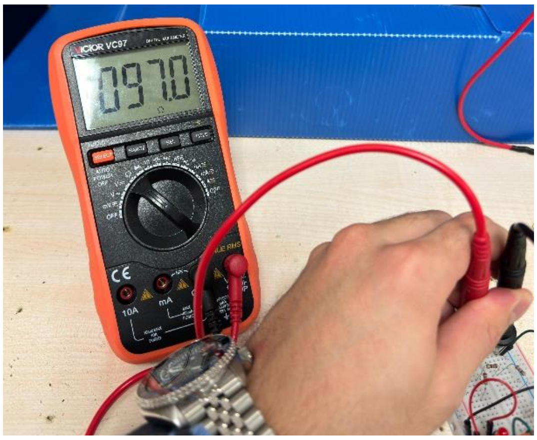

Figure 5: 100Ω resistor as load resistance

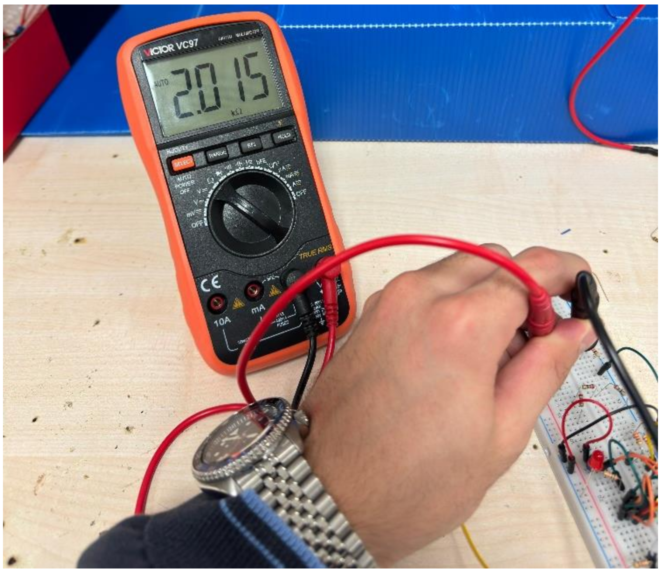

Figure 6: 2KΩ resistor as load resistance

Now, I adjusted the input voltage to be $V_{in} = V_{out} + 2V = 12V$. Then I measured the voltages across the load resistors. Figure 7 shows the result for 100Ω is connected as load resistance (R_L).

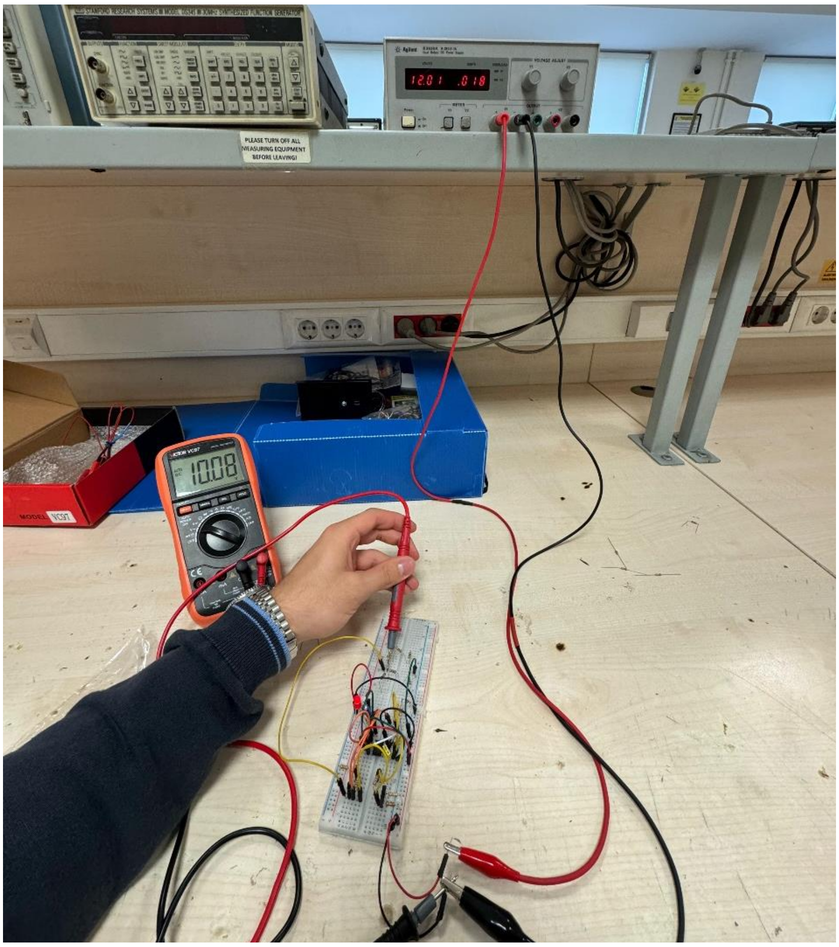

Figure 7: Voltage across 100Ω resistor as load resistance

Figure 8 again shows the output voltage across the 2K resistor connected ad load resistance (R_L).

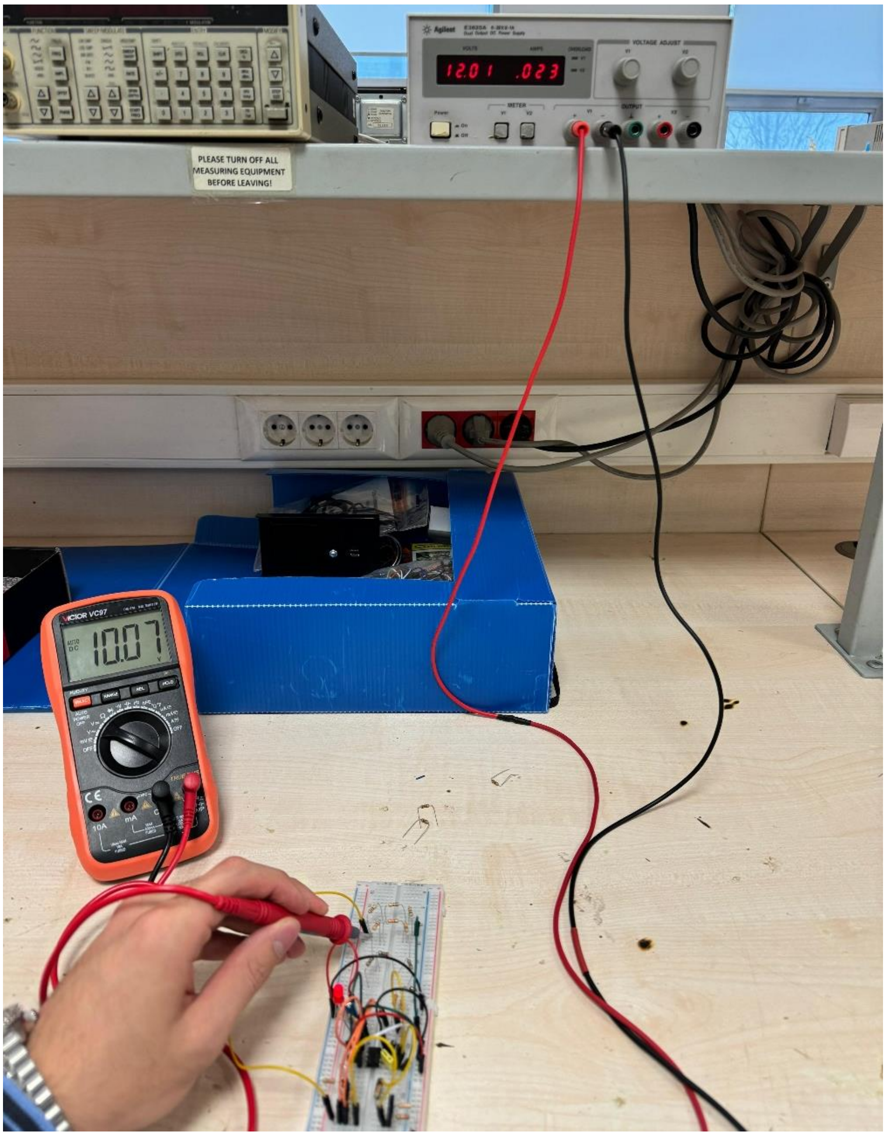

Figure 8: Voltage across 2KΩ resistor as load resistance

As seen from the results, the output voltage only changes from 10.08V to 10.07V. This difference is 10mV. The second condition which is load regulation is provided also.

In the LTspice simulation, for both 100Ω case and 2KΩ case, output voltage value is 9.99V. In hardware implementation, for 100Ω case, V_{out} = 10.08V and 2KΩ case, V_{out} = 10.07V. The results are similar as expected with a slight difference included.

For the third condition, I measured the output short circuit current. In order to calculate it, I connected a 1Ω resistor as load resistance. Therefore, the measured voltage value will be equal to short circuit current. Figure below shows the output short circuit current measurement value when $V_{in} = V_{out} + 0.7V = 10.7V$.

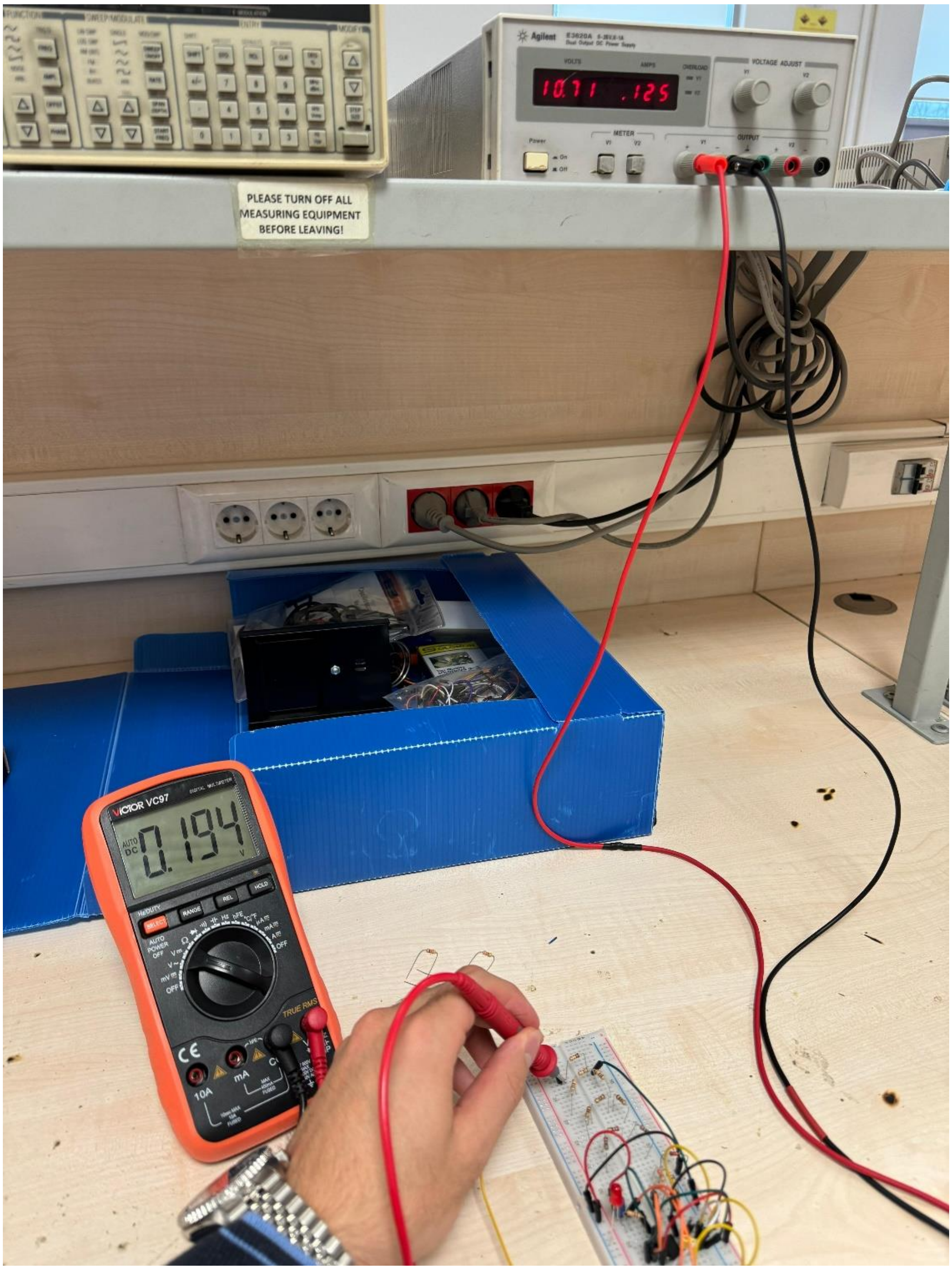

Figure 9: Output short circuit current value

Output short circuit current is measured as 194mA. In the LTspice simulation, the value is found as 248mA. Both results are below 250mA, which the third condition's requirement. Therefore, third condition is also satisfied.

For the last condition, which is turning the LED on when the circuit regulates the voltage correctly, Youtube video provided above shows the LED condition. To give a counter example, Figure 10 shows the LED when V_{out} = 9.96V.

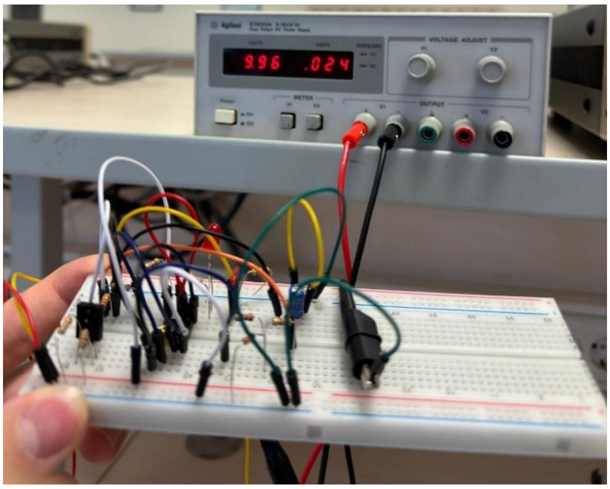

Figure 10: LED off when V_{in} = 9.96V

As expected, when input voltage is low, LED turns off. Therefore all 4 conditions are satisfied.

For “Thermal Analysis” condition, in the preliminary report, I found R_L = 90Ω. The nearest resistor value available in the lab is 82Ω therefore I used it as load resistance. The current across the 82Ω resistor is found to be 90mA, which is similar to lab requirement with a slight error included, 90mA. Also I changed the input voltage $V_{in} = V_{out} + 3V = 13V$.

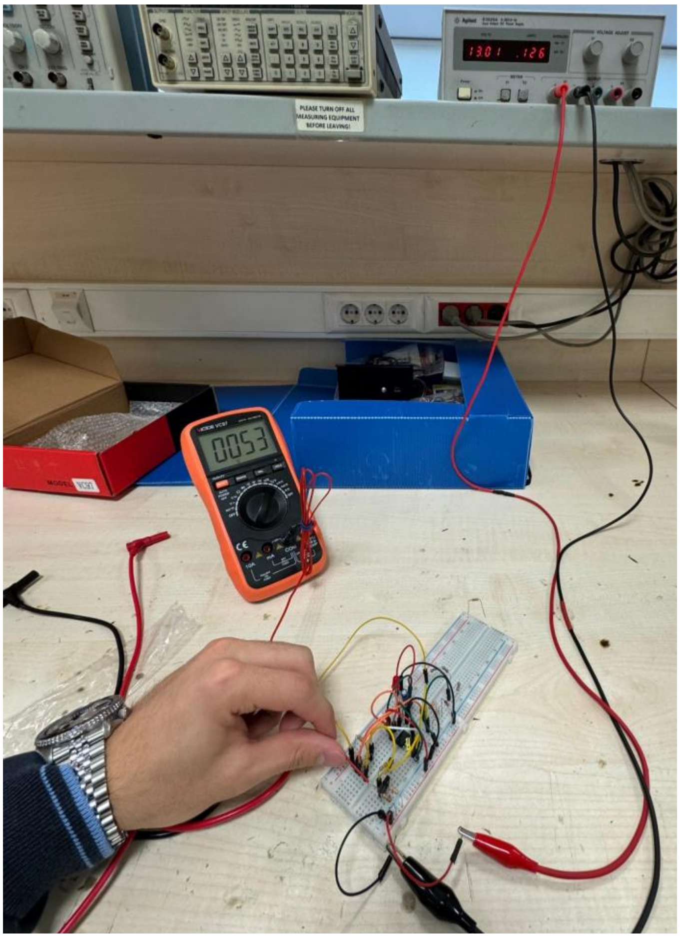

Figure 11: Case temperature of the transistor

Figure 11 shows the case temperature of the BD136 pnp transistor when R_L = 82Ω, and V_{in} = 13V. The case temperature is T_C = 53°C.

The ambient temperature of the lab is measured as 21°C. (Figure 12)

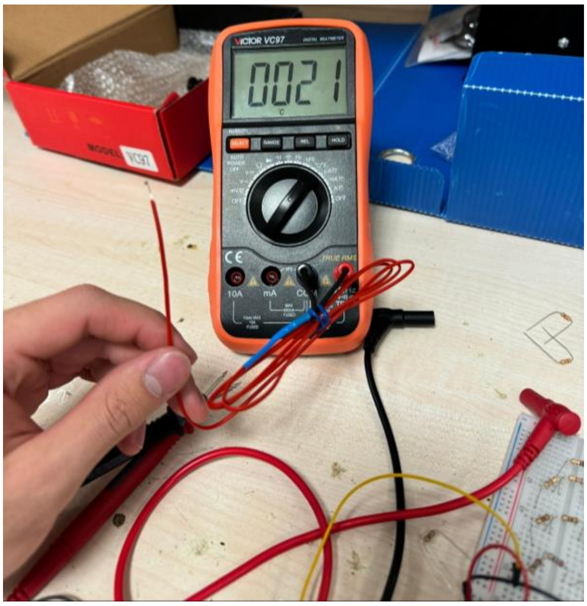

Figure 12: Ambient Temperature

Then I connected heat sink to the transistor and repeated the process. Figure 13 shows the heat sink temperature of the transistor after it reached steady state.

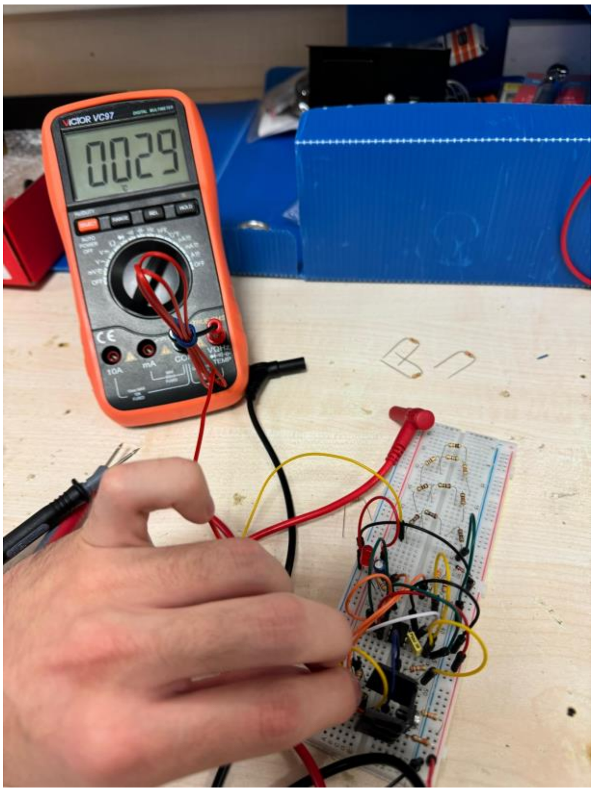

Figure 13: Heat sink temperature

Heat sink temperature is found as 29°C.

Below given the equation for R_{HS} (Thermal resistance) for transistor (Eqn. 2).

$$R_{HS} = \frac{T_C - T_A}{P_D} \qquad \text{(Eqn. 2)}$$

T_C: Case temperature

T_A: Ambient temperature

P_D: Power dissipation

The P_D for a BJT transistor is given as:

$$P_D = I_C V_{CE} + I_B V_{BE} \approx I_C V_{CE} \qquad \text{(Eqn. 3)}$$

As mentioned above, $I_C \approx 90mA$, and measure $V_{CE} = 4.024V$ (Figure 14).

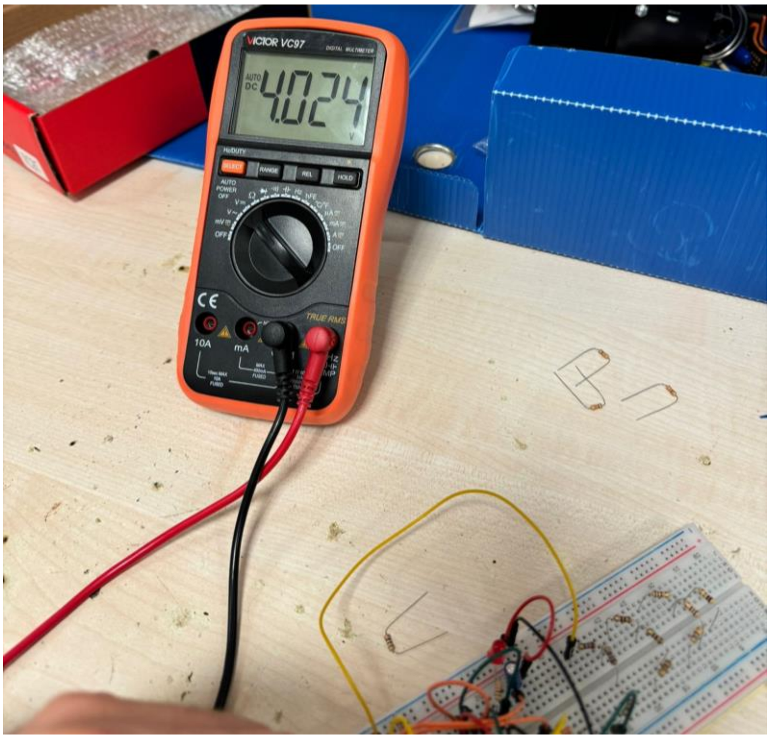

Figure 14: V_{CE} = 4.024V

Inserting these values in (Eqn. 3), P_D value is found as 363 mW.

Now, using (Eqn. 2), R_{HS} (Thermal resistance) value can be found.

$$R_{HS} = \frac{53 - 21}{0.363} = 88.2$$

In the preliminary part, under same conditions, V_{CE} of the BJT is measured as 5.12V, and I_C current is measured as 88mA. The power dissipated by BJT is calculated as P_D = 451 mW. The P_D value is found less in the hardware implementation compared to the LTspice simulation. Also, in LTspice simulation, from calculations, T_C value is calculated as 44.84°C for T_A = 25°C. In hardware implementation of the circuit, T_C value is measured as 53°C for T_A = 21°C. The results are similar to each other with a slight error included maybe because of the voltage generator and insensistiveness of the experimenter.