İhsan Doğramacı Bilkent University

ELECTRICAL and ELECTRONICS ENGINEERING

Bilkent University
Department of Electrical and Electronics Engineering

EE-313 ELECTRONIC CIRCUIT DESIGN

LAB-2 FINAL REPORT

Low-Dropout Voltage Regulator

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1 Introduction

In this lab, two questions are asked. First, we need to propose a method to measure β_F and β_R. Then, we need to design a low-dropout voltage regulator. Voltage regulators supply the same voltage whatever the V_{in} is. Low-dropout means low loss in V_{out}.

In experimental work, first we were asked to test our method. Second, we designed our low dropout voltage regulator and test 6 conditions if they were satisfed or not.

2 A Method to measure β_F and β_R

PRELIMINARY WORK

1. Forward Active Mode (β_F Measurement)

Step 1: Biasing:

- We can apply a forward bias voltage between the emitter and base (for example, with the emitter being more positive and the base approximately 0.6–0.7 V more negative).
- Then, applying a reverse bias voltage between the collector and base.

Step 2: Measurements:

- Measuring the base current, I_B.
- Measuring the collector current, I_C.

Step 3: Formula:

$$\beta_F = \frac{I_C}{I_B}$$

2. Reverse Active Mode (β_R Measurement)

Step 1: Biasing:

- We need reverse active mode. In this mode, the original collector-emitter roles are swapped, meaning the "collector" now functions as the emitter.
- Ensure proper biasing to make the transistor operate in the reverse mode.

Step 2: Measurements:

- Again, measuring the base current, I_B.
- Measuring the current at the terminal now acting as the emitter (denoted as I_E) in the reverse configuration.

Step 3: Formula:

$$\beta_R = \frac{I_E}{I_B}$$

EXPERIMENTAL WORK

We designed a circuit that we can measure I_{C} and I_{B}.

I added a 1K resistor to each leg of the BD136. Then, I made a voltage divider to supply a different voltage to each leg. Finally, I measured a voltage drop between legs and find current for emitter, base, and collector.

Forward Active Bias

Figure 1: V_{C}

Figure 2: V_{B}

$$\beta_F = \frac{I_C}{I_B}$$

$$\beta_F = 90$$

Reverse Active Bias

Figure 3: V_{C}

Figure 4: V_{B}

I_{B}= 0.004A
I_{B}= 0.001A

$$\beta_R = \frac{I_C new}{I_B}$$

$$\beta_F = 0.25$$

3 Low-Dropout Voltage Regulator

IMPORTANT NOTE: In this part, since there was not suitable Zener diode in the lab equipments, I changed my LTSpice simulation part.

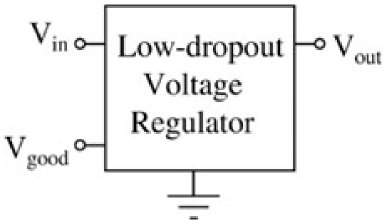


Figure 5: Low-Dropout Voltage Regulator Design

In this part, we are asked to design a low-dropout voltage regulator. We need these kinds of circuits when we want the same voltage whatever the input voltage is.

$$V_{\text{out}} = 6.5 + \frac{\text{mod(YourIDNumber}, 10)}{2} \tag{1}$$

YourIDNumber = 22102104:

$$\begin{aligned} V_{\text{out}} &= 6.5 + \frac{\text{mod}(22102104, 10)}{2} \\ &= 6.5 + \frac{4}{2} \\ &= 6.5 + 2 \\ &= 8.5 \text{ V} \end{aligned} \tag{2}$$

PRELIMINARY WORK

Using the given hint, I designed a circuit in LTspice simulation software. According to our output voltage, V_{out}=8.5, I choose the values of the resistor and capacitor. Then, I found the appropriate **Zener diode which is both in Lab and LTSpice simulation.** Finally, I made some adjustments to achieve stable output voltage by doing some regulations, line regulation, and load regulation.

After changing the Zener diode, V_{out} will be around 8.44V in LTS.

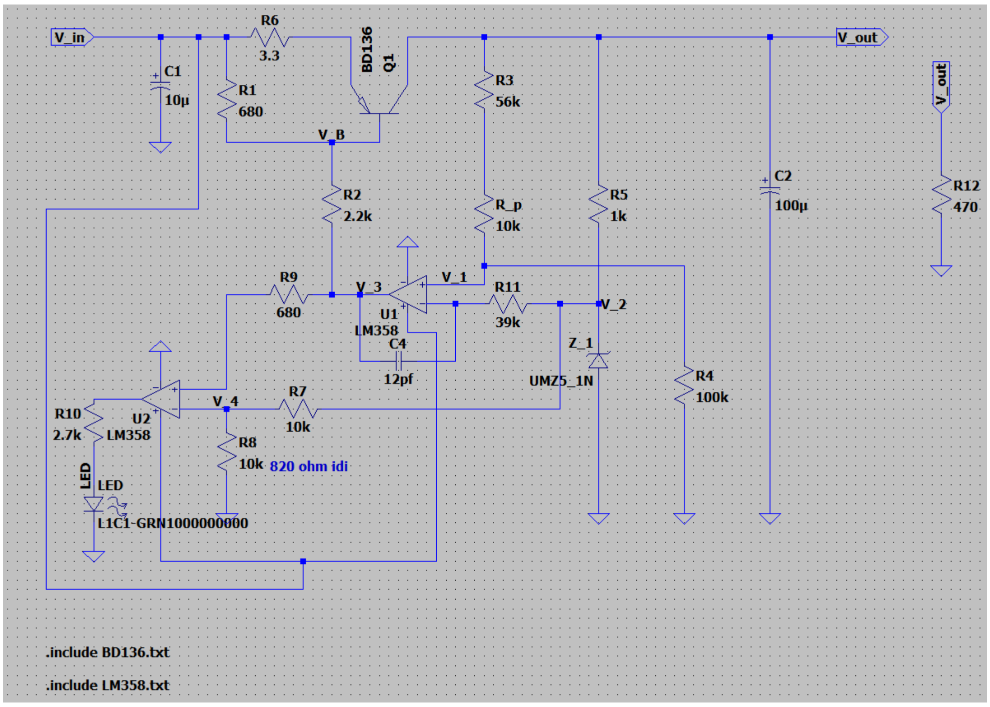


Figure 6: Low-Dropout Voltage Regulator Design

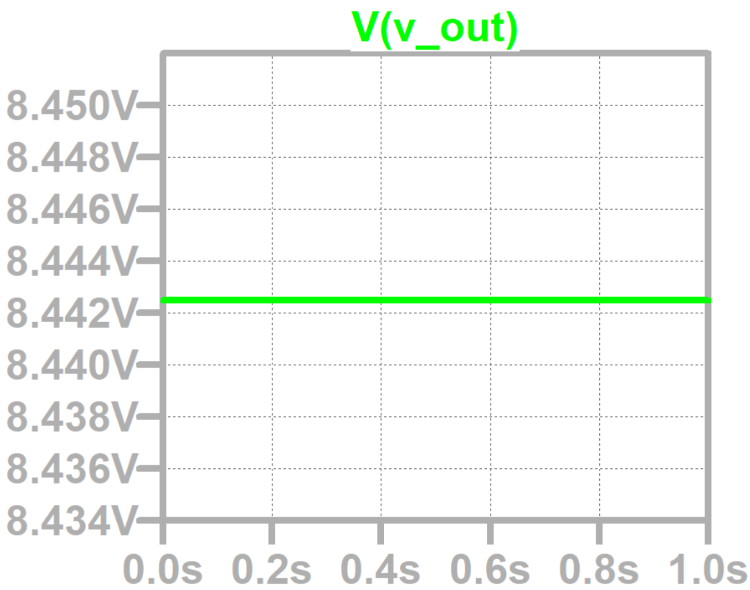


Figure 7: Low-Dropout Voltage Regulator V_{out}

EXPERIMENTAL WORK

In experimental part, V_{out}=8.75. However, assistant said that this is not a problem since V_{out} is stable. Also, for R_L's I used the next-standard resistor value.

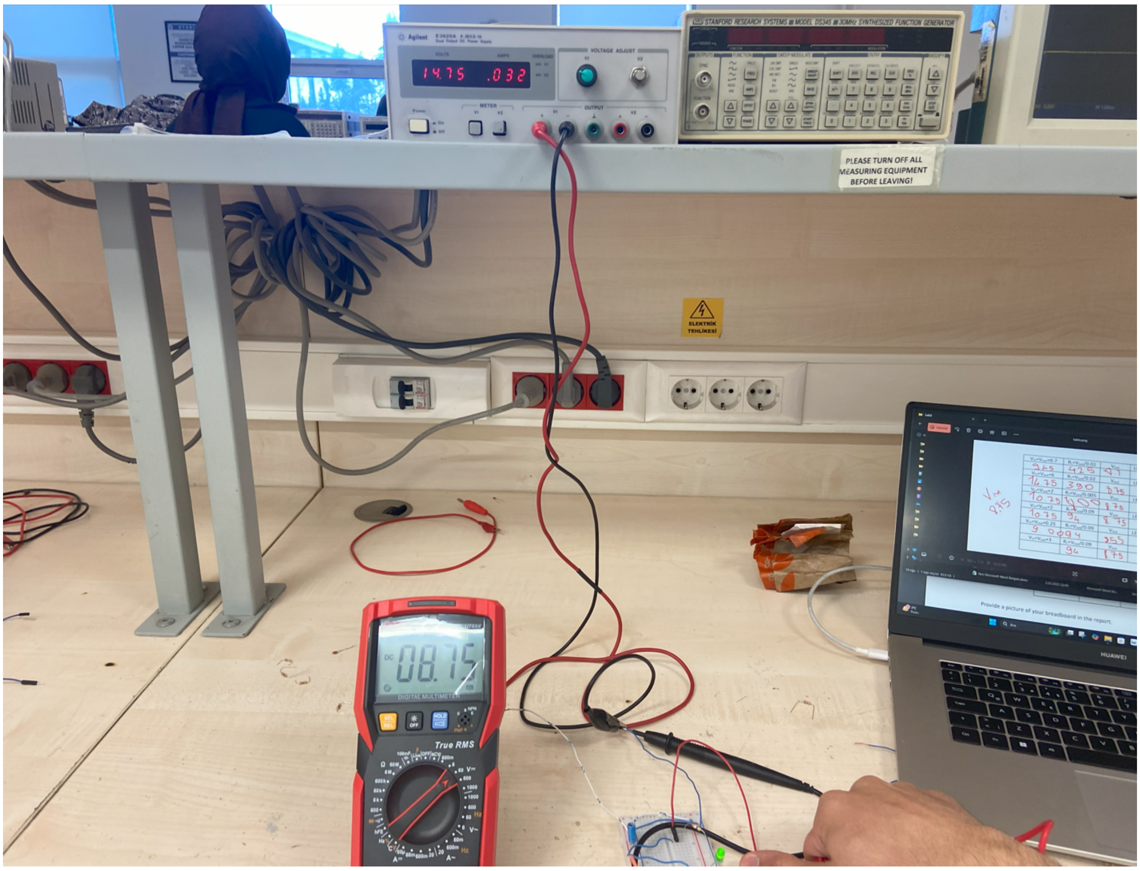


Figure 8: Experimental V_{out}=8.75V

3.1 Specifications for Low-Dropout Voltage Regulator

PRELIMINARY WORK

1. **Line Regulation:**
   As shown in the figures, we have a change of no more than 10 mV. In addition, the current through R_L is almost 20 mA. For this test, we used 18000 Hz sinusoidal signal.

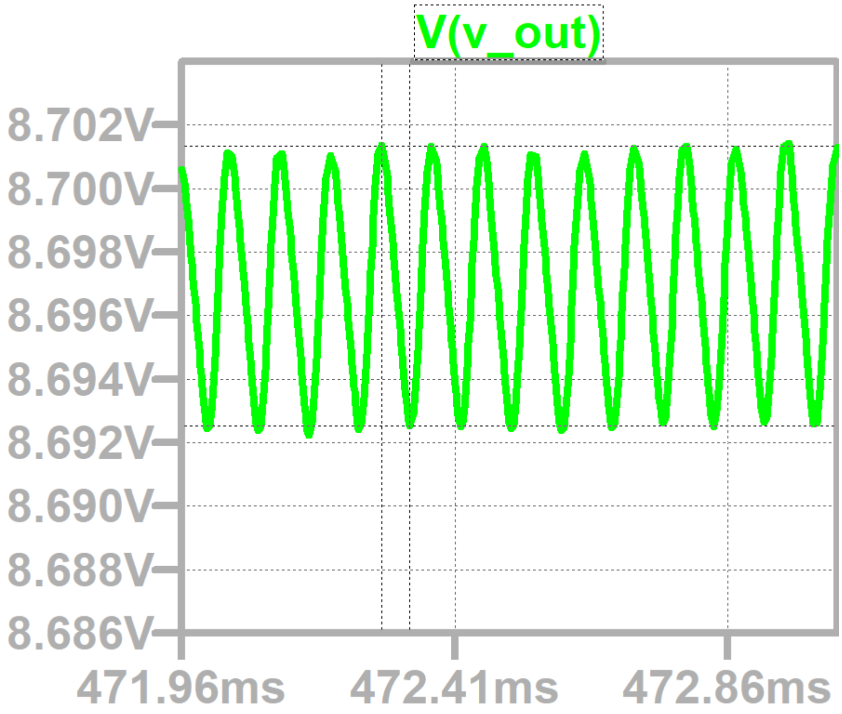
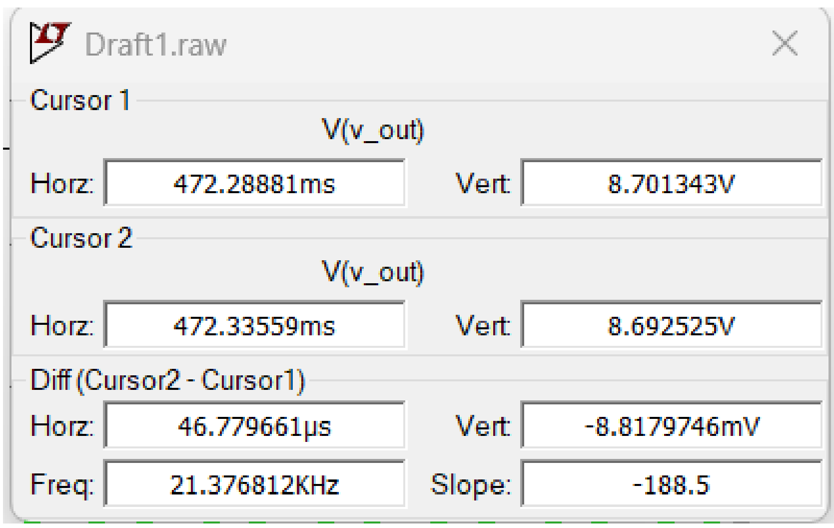


Figure 9: Line Regulation: V_{out} Graph



Draft1.raw			
Cursor 1			
	V(v_out)		
Horz:	472.28881ms	Vert:	8.701343V
Cursor 2			
	V(v_out)		
Horz:	472.33559ms	Vert:	8.692525V
Diff (Cursor2 - Cursor1)			
Horz:	46.779661µs	Vert:	-8.8179746mV
Freq:	21.376812KHz	Slope:	-188.5

Figure 10: Line Regulation: Voltage Difference

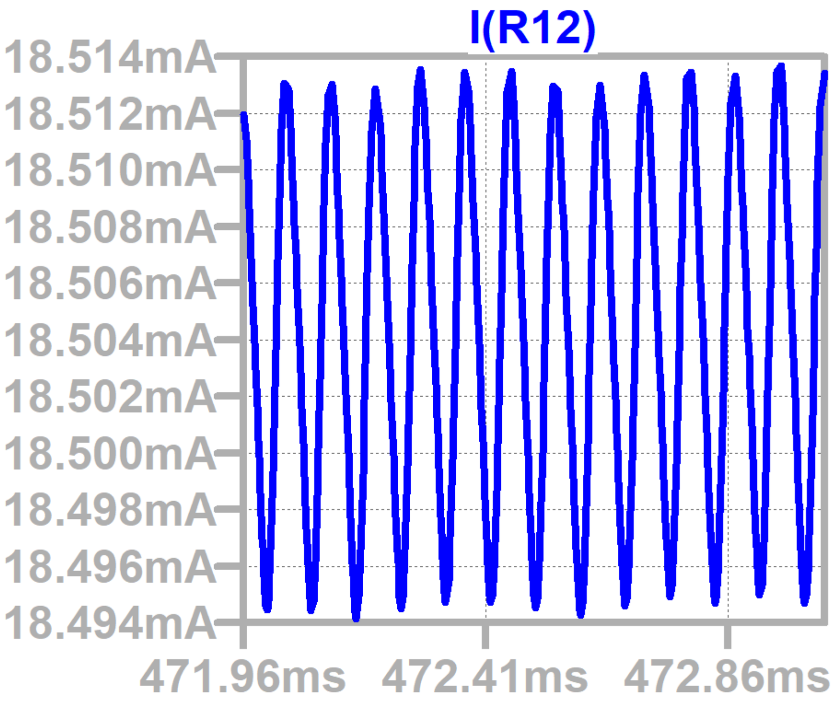


Figure 11: Line Regulation: Current through R_L

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2. **Load Regulation:**

   As shown in the figures, voltage difference between two cases is significantly less than 50 mV. Therefore, our design satisfies the specification.

   I_L= 5 mA , R_L= 1700 Ω $\Rightarrow$ V_{out}=8.5033455 v

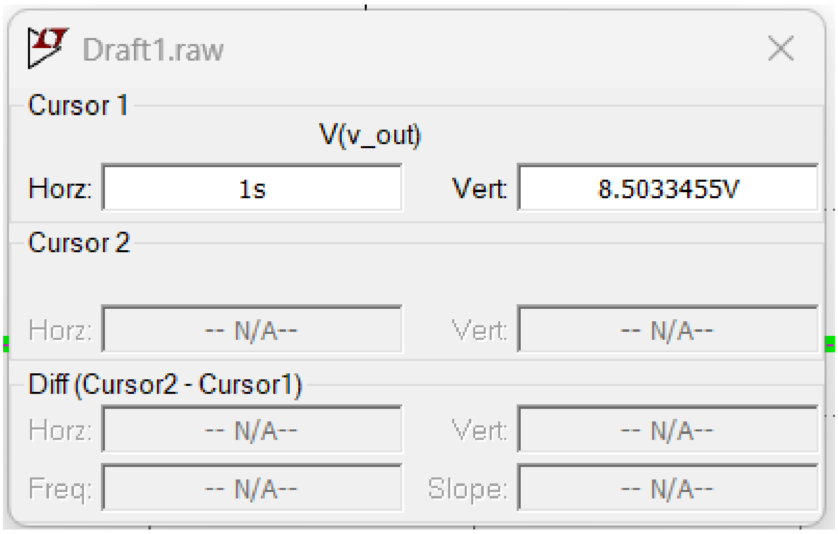

Figure 12: Load Regulation: V_{out}=8.5033455

I_L= 90 mA , R_L= 94.4 Ω ⇒ V_{out}=8.5032854

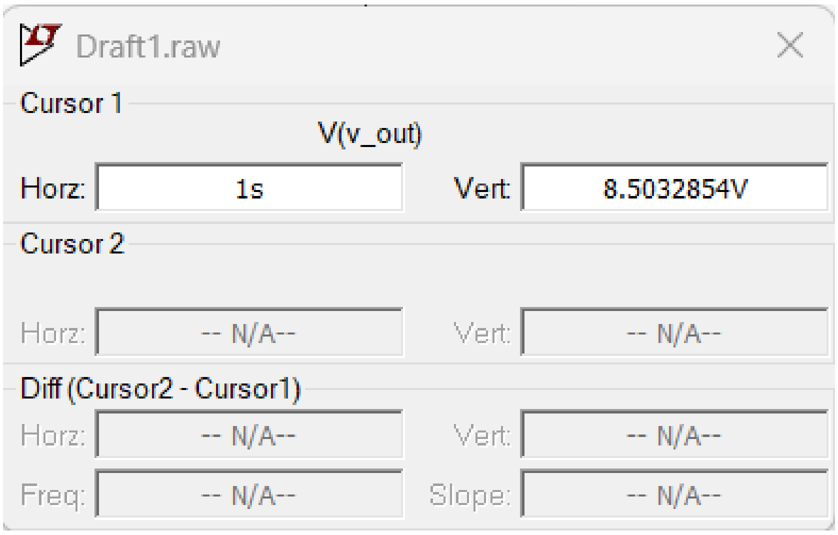

Figure 13: Load Regulation: V_{out}=8.5032854

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3. **LED Operation:** As shown in the figure, LED works. Therefore, our regulator works well.

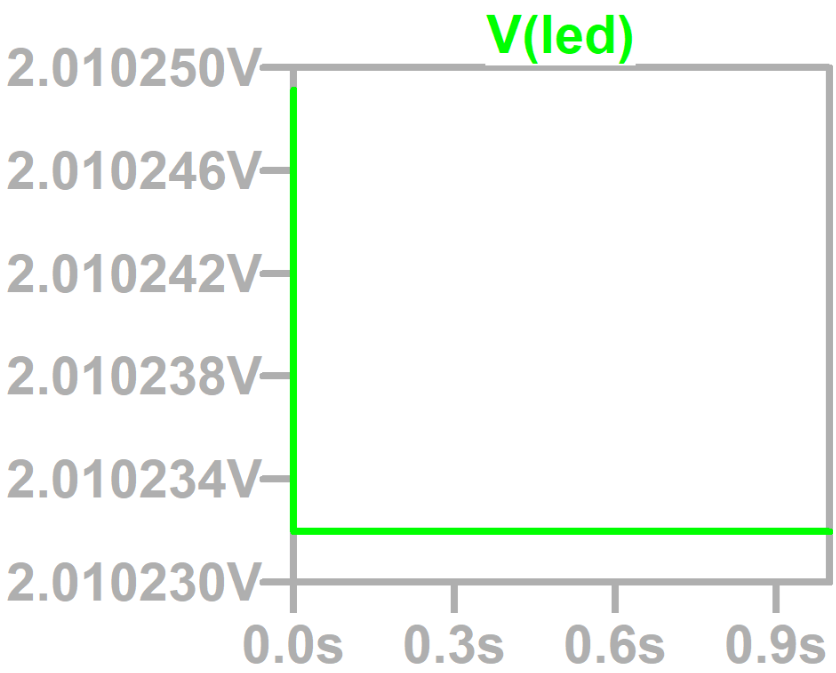

Figure 14: V_{LED}

EXPERIMENTAL WORK

In experimental work; according to our design, voltage regulator works. Regulator supplies 8.75V fix whatever the V_{in} is.

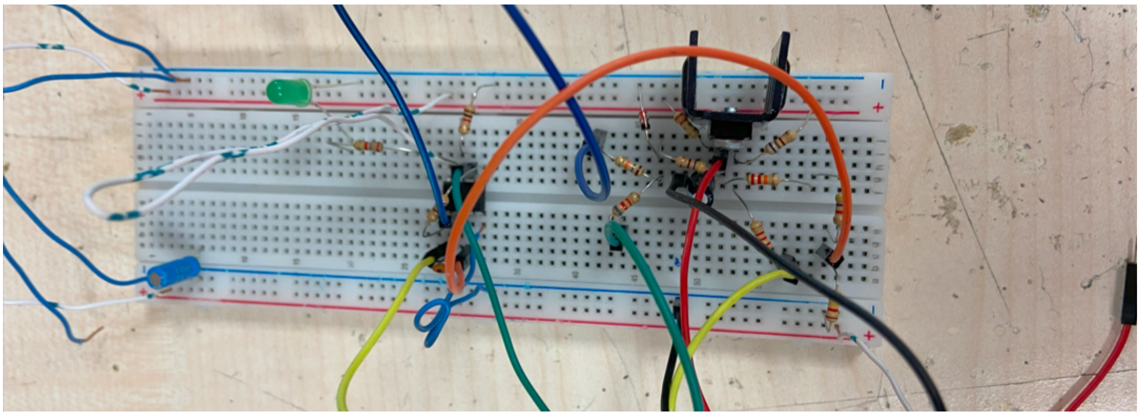

Figure 15: Breadboard Design

1.	$V_{in} = V_{out} + 0.7$	$R_L = V_{out}/0.02$	V_{out}	LED On/Off
	9.45 V	390	8.75V	ON
2.	$V_{in} = V_{out} + 6$	$R_L = V_{out}/0.02$	V_{out}	LED On/Off
	14.75 V	390	8.75V	ON
3.	$V_{in} = V_{out} + 2$	$R_L = V_{out}/0.005$	V_{out}	LED On/Off
	10.75 V	1800	8.75V	ON
4.	$V_{in} = V_{out} + 2$	$R_L = V_{out}/0.09$	V_{out}	LED On/Off
	10.75 V	100	8.75V	ON
5.	$V_{in} = V_{out} + 0.25$	$R_L = V_{out}/0.09$	V_{out}	LED On/Off
	9 V	100	8.53V	OFF
6.	$V_{in} = V_{out} + 3$	$R_L = V_{out}/0.09$	V_{out}	$T_C(C)$
	11.75 V	100	8.75V	29

Table 1: LED ON/OFF

1st Criteria

For the first criteria, when we give 9.45 V as an input voltage, we have to measure our V_{out} voltage, which is 8.75 V

V_{in}= 9.45 V , R_{L}= 390 Ω ⇒ V_{out}=8.75 V, LED: ON

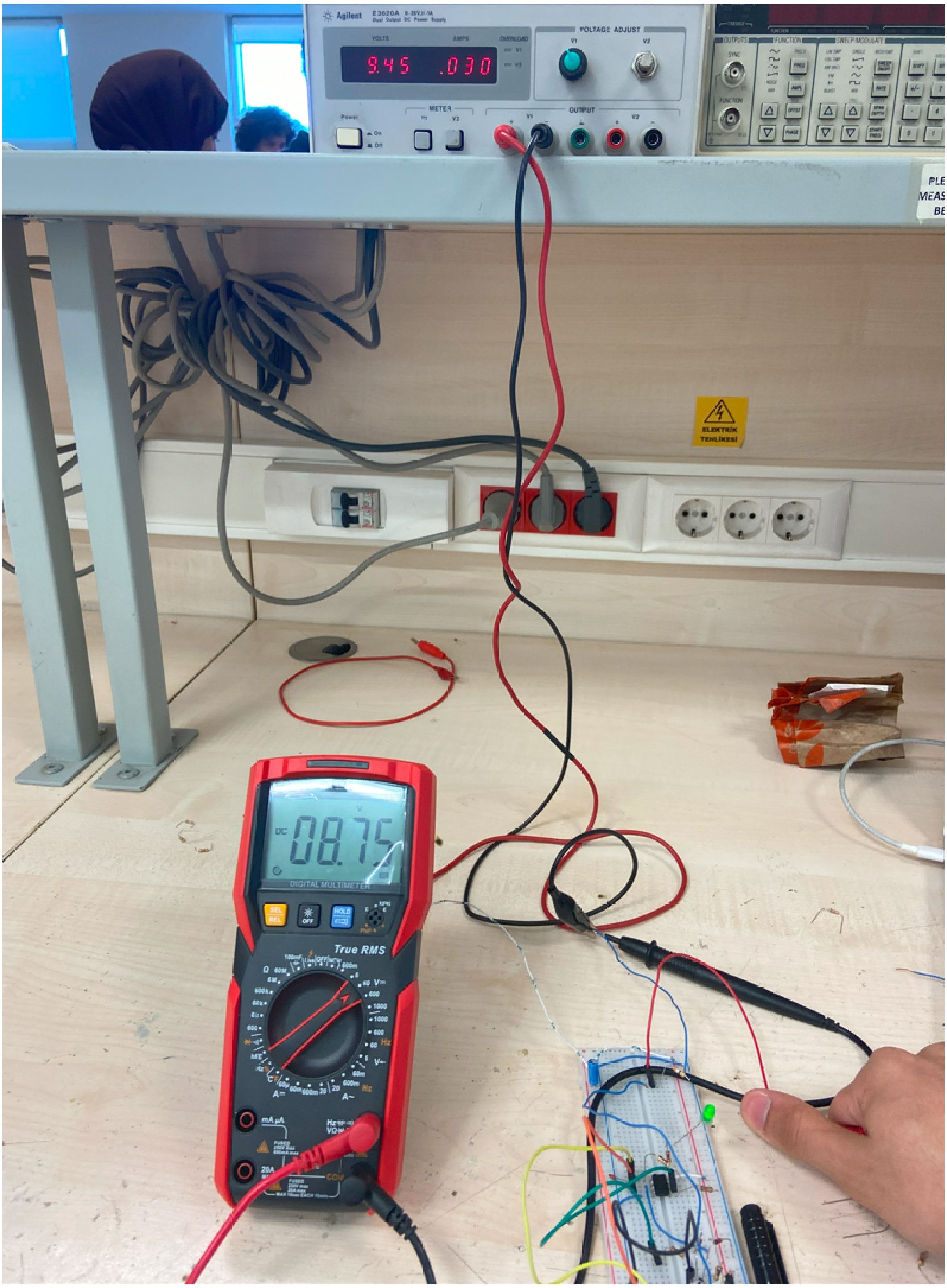

Figure 16: 1st Criteria

2nd Criteria

For the second criteria, when we give 14.75 V as an input voltage, we have to measure our V_{out} voltage, which is 8.75 V

V_{in}= 14.75 V , R_L= 390 Ω ⇒ V_{out}=8.75 V, LED: ON

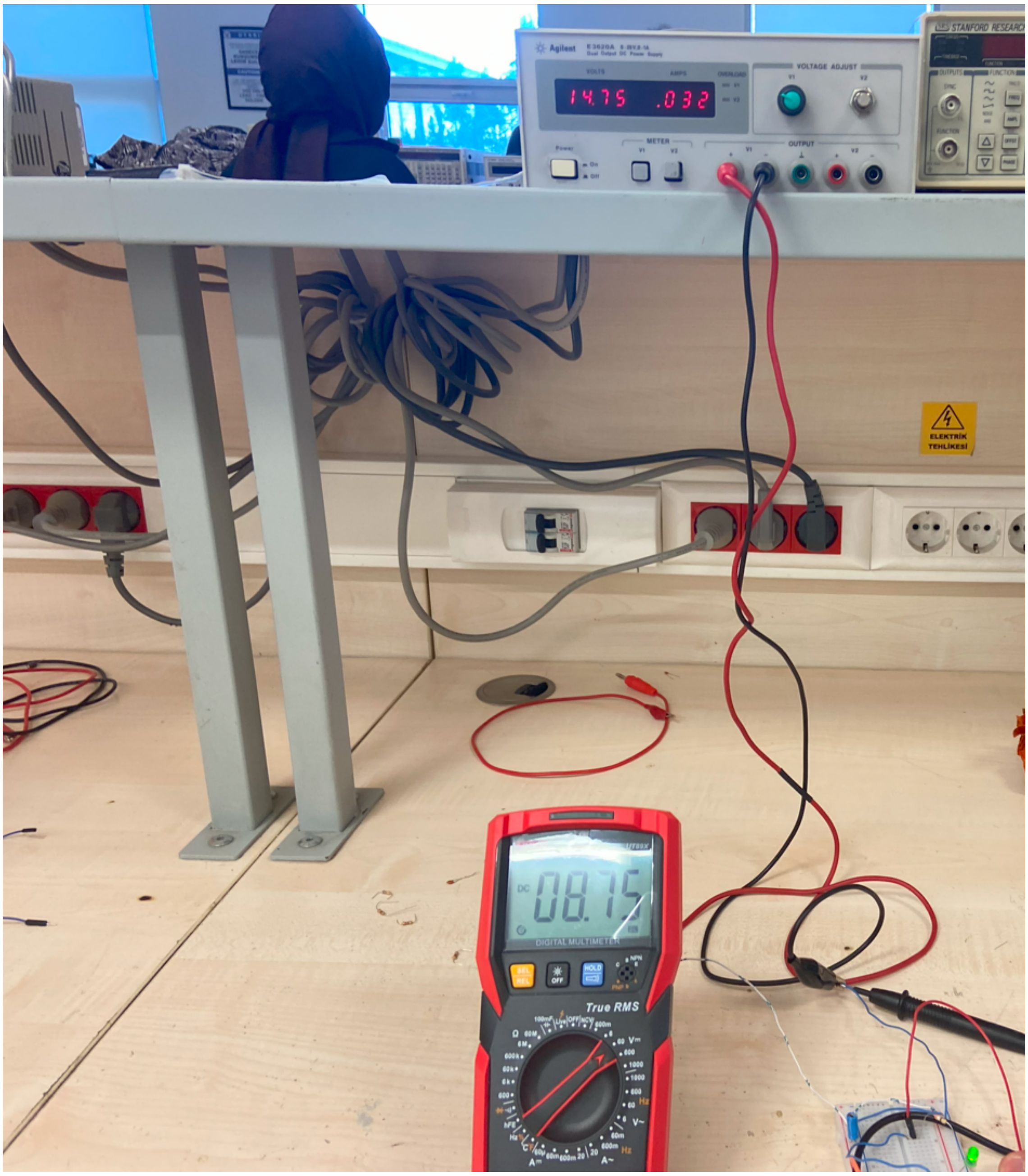

Figure 17: 2nd Criteria

3rd Criteria

For the third criteria, when we give 14.75 V as an input voltage, we have to measure our V_{out} voltage, which is 8.75 V

V_{in}= 10.75 V , R_{L}= 1800 Ω ⇒ V_{out}=8.75 V, LED: ON

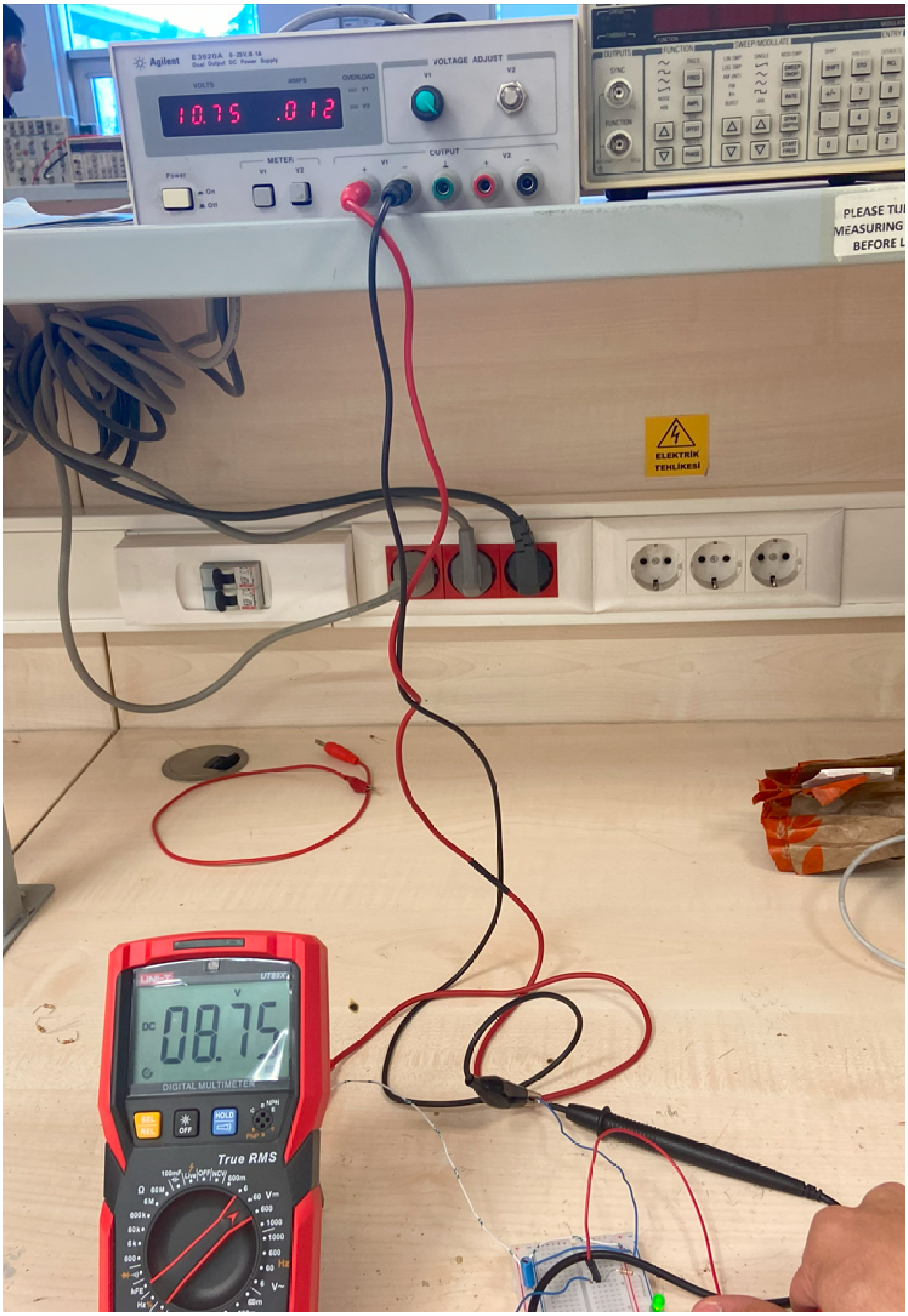

Figure 18: 3rd Criteria

4th Criteria

For the fourth criteria, when we give 10.75 V as an input voltage, we have to measure our V_{out} voltage, which is 8.75 V

V_{in}= 10.75 V , R_{L}= 100 Ω   ⇒ V_{out}=8.75 V, LED: ON

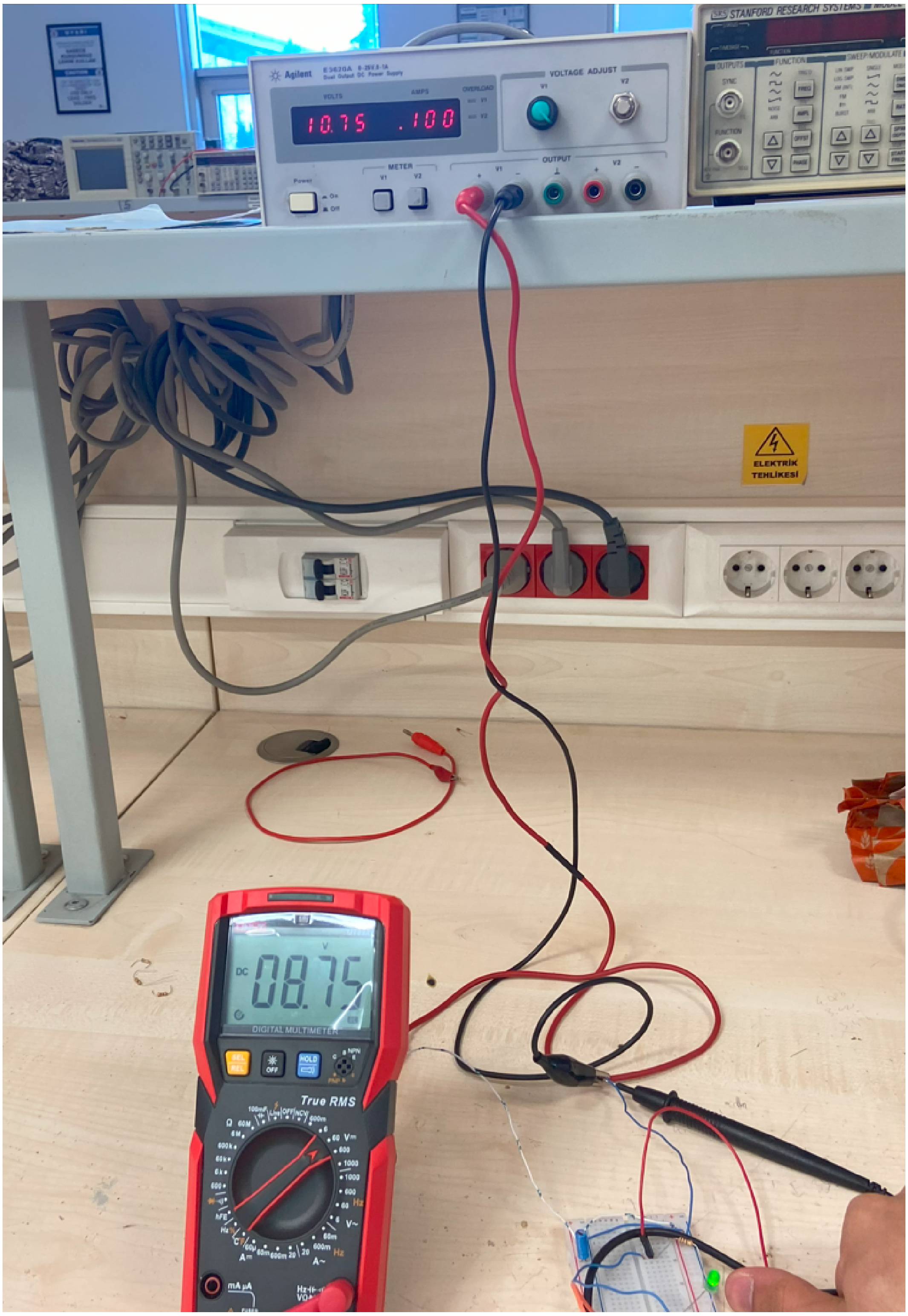

Figure 19: 4th Criteria

5th Criteria

For the fifth criteria, when we give 9 V as an input voltage, we shouldn't see our stable V_{out}, and LED shouldn't work.

V_{in}= 9 V , R_L= 100 Ω ⇒ V_{out}=8.53 V, LED: ON

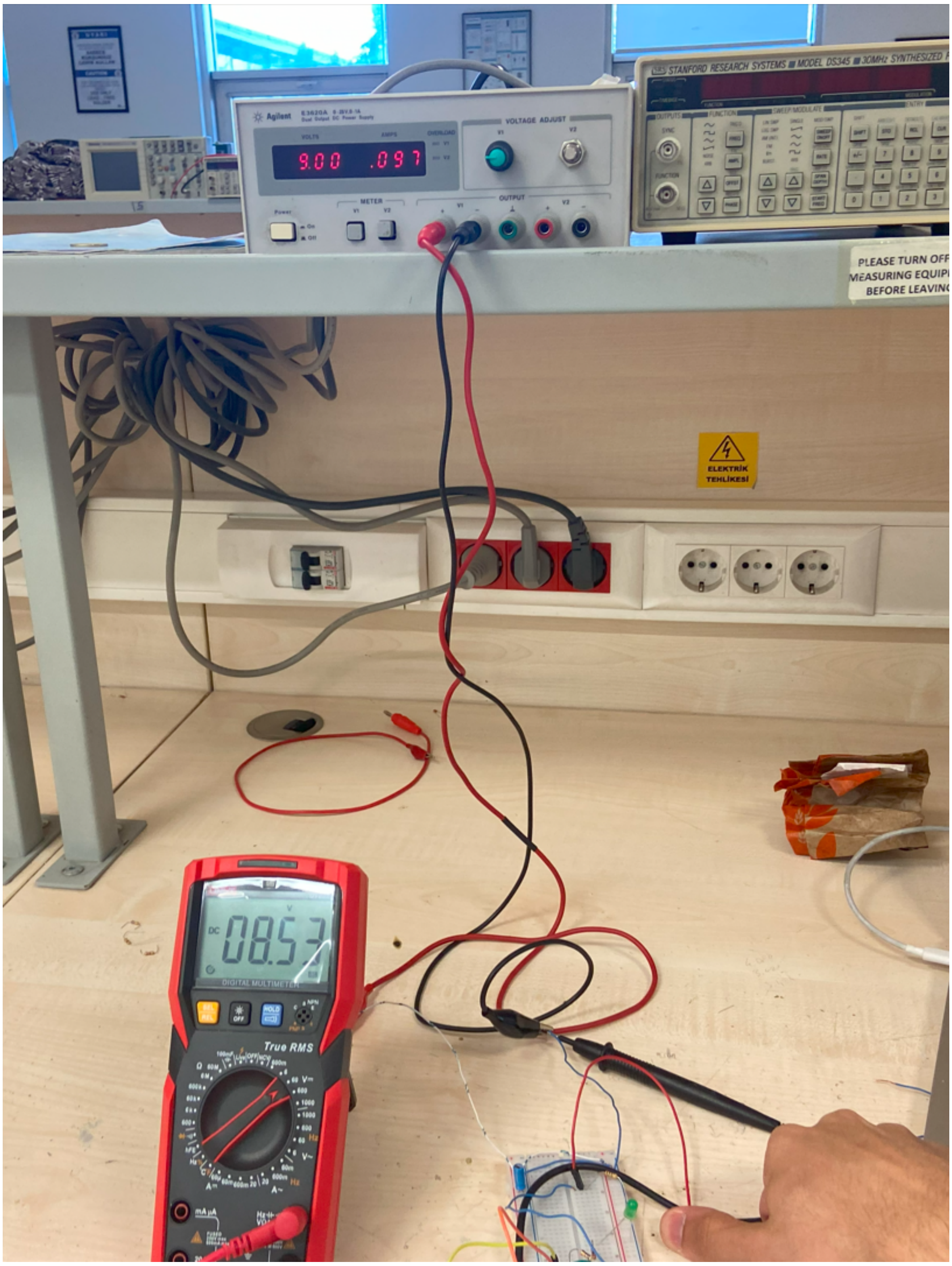

Figure 20: 5th Criteria

6th Criteria

For the sixth criteria, we need to measure the degree of the BD136.

V_{in}= 11.75 V , R_{L}= 100 Ω $\quad\Rightarrow\quad$ V_{out}=8.75 V, T=30 C

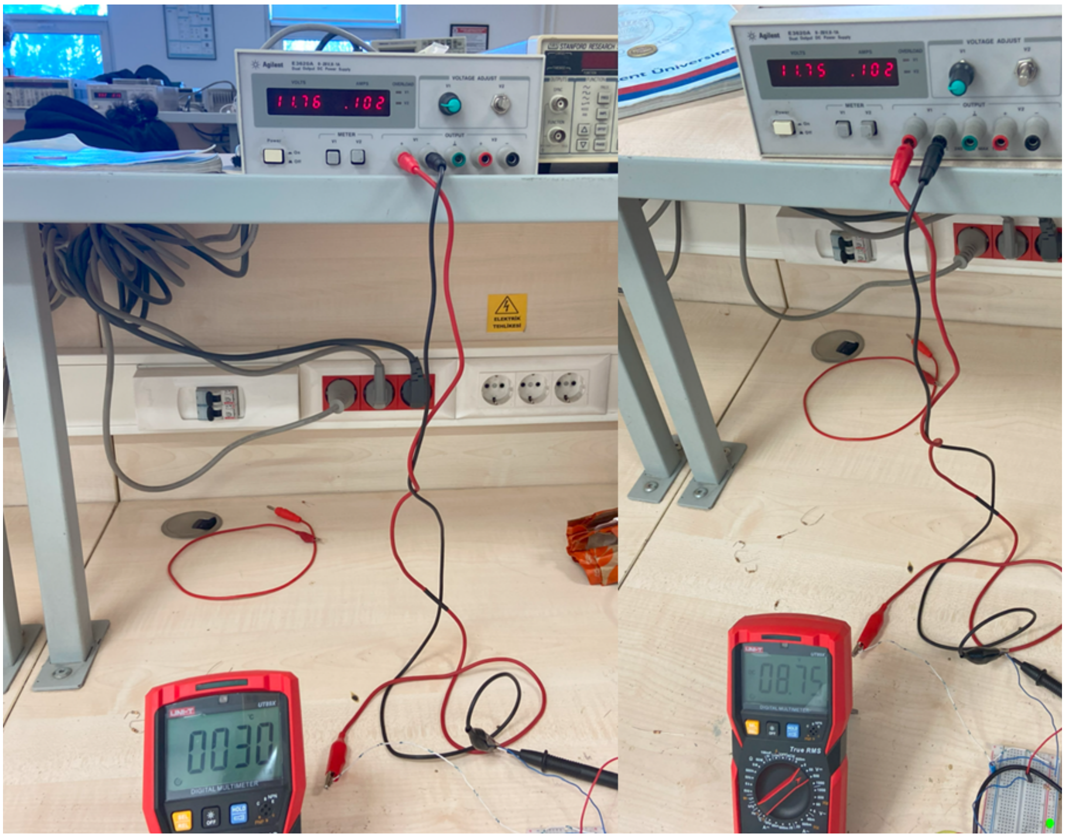

Figure 21: 6th Criteria

4 Thermal Analysis of BD136 (from Preliminary)

SYMBOL	PARAMETER	VALUE	UNIT
$R_{\text{th j-a}}$	Thermal resistance from junction to ambient	100	K/W
$R_{\text{th j-mb}}$	Thermal resistance from junction to mounting base	10	K/W

Table 2: Thermal Characteristics

Rating	Symbol	Max	Unit
Collector Dissipation	P_C	12.5	W
Collector Dissipation ($T_A = 25$°C)	P_C	1.25	W
Junction Temperature	T_J	150	°C
Storage Temperature Range	T_{STG}	$-55 \sim 150$	°C

Table 3: Transistor Maximum Ratings

From the **BD136** datasheet, the following thermal resistance values and maximum junction temperature are obtained:

- **Junction to Ambient Thermal Resistance** ($R_{\theta JA}$): 100 K/W
- **Junction to Case Thermal Resistance** ($R_{\theta JC}$): 10 K/W
- **Maximum Junction Temperature** (T_{Jmax}): 150°C

To estimate the junction temperature (T_J) and case temperature (T_C) when $V_{in} = V_{out} + 3V$ and a $90mA$ load current is drawn:

4.1 1. Calculate the Power Dissipation (P_D)

The power dissipation in the transistor is given by:

$$P_D = (V_{in} - V_{out}) \times I_{load} \tag{3}$$

Substituting the given values:

$$P_D = (V_{out} + 3 - V_{out}) \times 90mA = 3V \times 0.09A = 0.27W \tag{4}$$

4.2 2. Estimate the Junction Temperature (T_J)

Using the junction-to-ambient thermal resistance:

$$T_J = T_A + (R_{\theta JA} \times P_D) \tag{5}$$

$$T_J = 25 + (100 \times 0.27) = 25 + 27 = 52°C \tag{6}$$

4.3 3. Estimate the Case Temperature (T_C)

Using the junction-to-case thermal resistance:

$$T_C = T_J - (R_{\theta JC} \times P_D) \tag{7}$$

$$T_C = 52 - (10 \times 0.27) = 52 - 2.7 = 49.3°C \tag{8}$$

Thus, under these conditions:

- The estimated **junction temperature** (T_J) is **52°C**.
- The estimated **case temperature** (T_C) is **49.3°C**.

These values indicate that the transistor operates within safe limits, but a heatsink may be considered if additional power dissipation occurs.

5 Conclusion

In this lab, we suggested a method to find β_F and β_R. β_F is an important value to determine the gain of the transistor. Then we focused on low-dropout voltage regulator. First, we made some calculations to find appropriate resistors and capacitors. After that, we adjusted our design with load regulation and line regulation. Finally, our circuit worked and green LED lighted up.

In experimetnal part, first we designed a method to measure current on each leg of the BD136. This part was a bit tough since it was really hard to measure such a small voltage difference. Second we tested our low dropout voltage regulator and tested 6 conditions. Our voltage regulator worked very well.