İZMİR UNIVERSITY OF ECONOMICS

Instructor: Dr A. K. Topallı

TA: B. Akbuğday

EEE 331 / 333 ANALOG ELECTRONICS PROJECT

ONAT FİLİK 20200607020

Type: Individual Assignment

Due: 05.01.2024, 23.59 – Friday

Design a 12 µA current source using bipolar junction transistors and necessary circuit components.

Limitations:

- You can use max 10 KΩ resistors.
- You can use min 5 V voltage source as V^+.

Report:

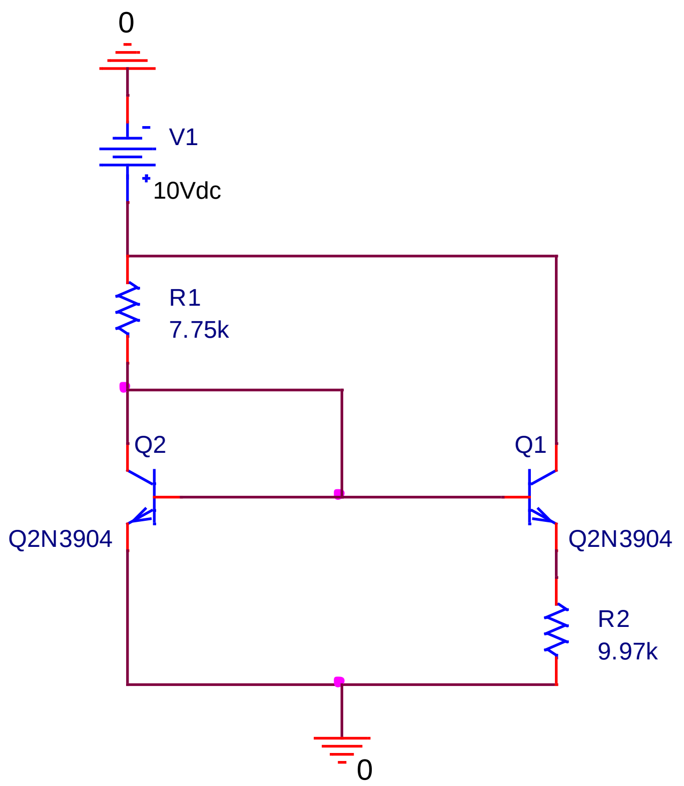
- In your report, show your circuit design, OrCAD schematic and simulation results, and give all necessary calculations. Calculations must be done by hand.
- Explain what kind of current source you have selected and why.
- Use potentiometers and explain the effect of different resistance values (up to 10 KΩ) to the output current you measure. Draw R vs I graphs. Justify your measurements with the theory.
- Is it important to use matched transistors in your design? Discuss the effect of using matched or mis-matched transistors.
- Include a photo of your actual circuit and component names in your report.
- Upload your report to the Blackboard as a .PDF file.
- Also upload your OrCAD project files as a .ZIP file in the same submission.

Circuit:

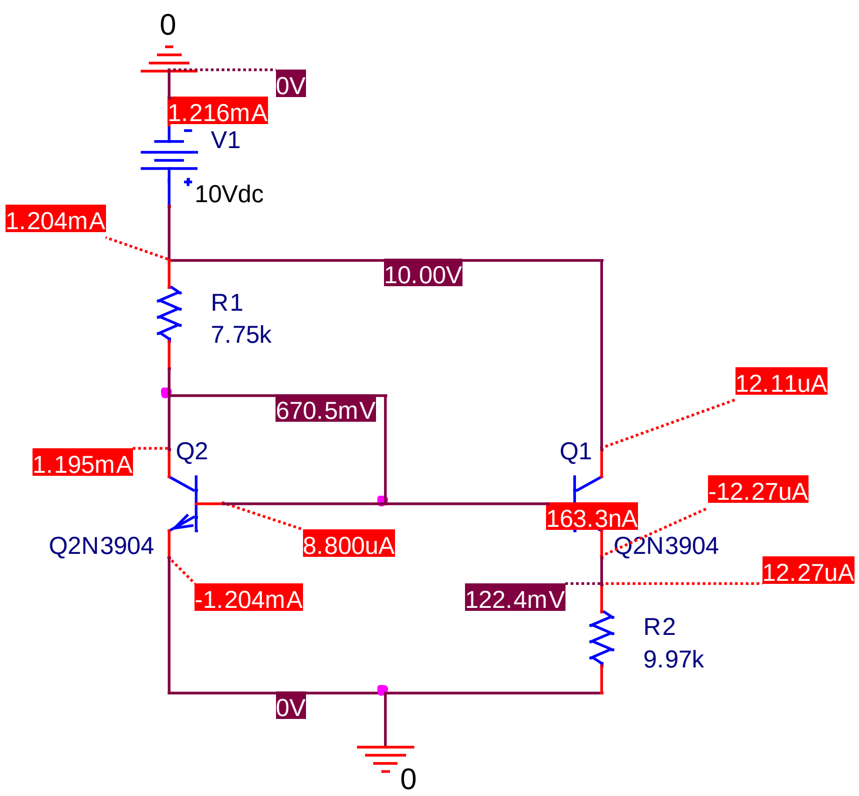
- Provide your circuit, make a demo to your TA.
- You will be asked several questions regarding the project while you are showing your demo to your TA, please be prepared.

In your report, show your circuit design, OrCAD schematic and simulation results, and give all necessary calculations. Calculations must be done by hand. (I determined my Iref as 1.2mA.)

1- OrCAD Schematic

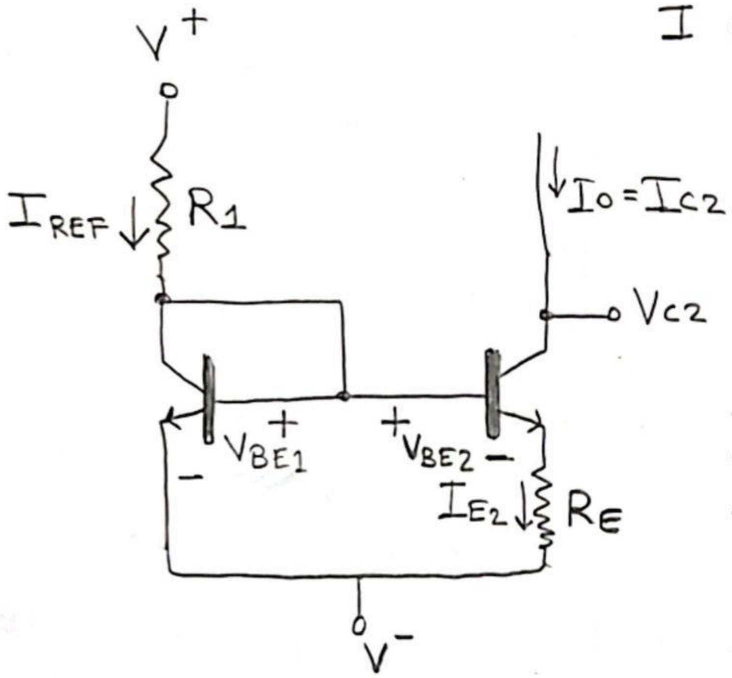


2-OrCAD Simulation



Widlar Current Source

I choose $I_{REF} = 1.2mA$



$I_{REF} = 1.2mA$

$I_O = 12\mu A$

$$R_1 = \frac{V^+ - V_{BE1} - V^-}{I_{REF}} = \frac{5 - 0.7 - (-5)}{1.2mA}$$

$$R_1 = 7.75k\,\Omega$$

$$R_E = \frac{V_T}{I_O} \ln\left(\frac{I_{REF}}{I_O}\right) = \frac{26mV}{12\mu A} \ln\left(\frac{1.2mA}{12\mu A}\right)$$

$$R_E = 9.97k\,\Omega$$

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- Explain what kind of current source you have selected and why.

Answer: I chose Widlar current source in my project to design a 12 µA current source. The biggest reason why I prefer Widlar current source is that the current output can be easily adjusted. It is one of the most common current source circuits used to provide a constant current at the output node.

I thought it was the most ideal circuit to design a 12 µA current source using 10 V. I determined my Iref current as 1.2mA. Since the base-emitter voltages of Q1 and Q2 are similar, the base currents of transistors Q1 and Q2 will be almost equal. Thus, the collector currents of Q1 and Q2 are proportional to each other. Thanks to this proportion, Widlar Current Source provides a constant current. The resistor values used in the circuit must be chosen carefully because these values determine the Iref and Io current. I carefully adjusted R1 and Re values to ensure the desired output current.

- Use potentiometers and explain the effect of different resistance values (up to 10 KΩ) to the output current you measure. Draw R vs I graphs. Justify your measurements with the theory.

Breadboard Measurements

for $R_1 = 7.75k\Omega$

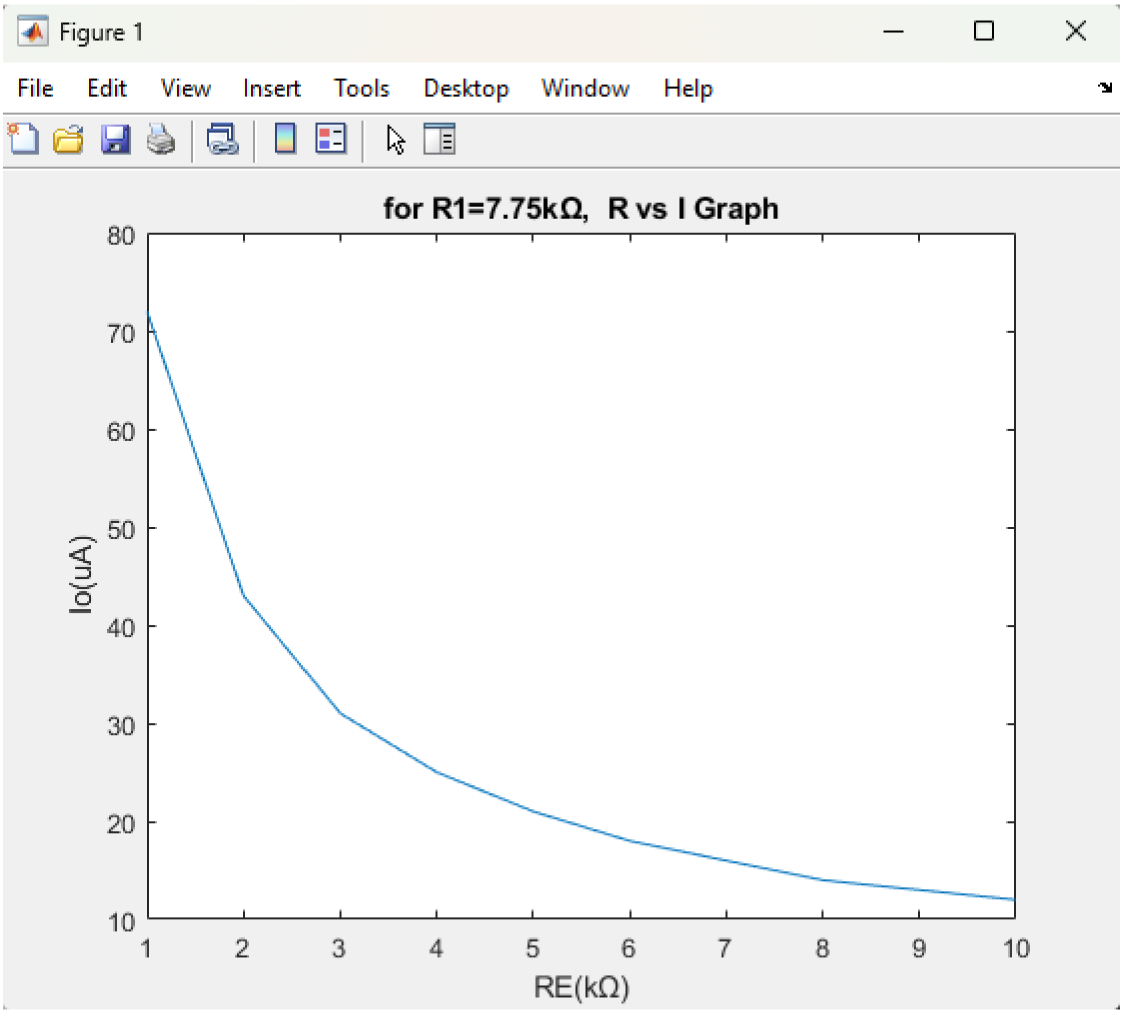
$R_E (\Omega)$	I_o
1k	72μA
2k	43μA
3k	31μA
4k	25μA
5k	21μA
6k	18μA
7k	16μA
8k	14μA
9k	13μA
9.75k	12μA

for $R_E = 9.75k$

$R_1 (\Omega)$	I_o
1k	18μA
2k	17μA
3k	16μA
4k	14μA
5k	13μA
6k	13μA
7k	12μA
8k	12μA
9k	11μA
10k	11μA

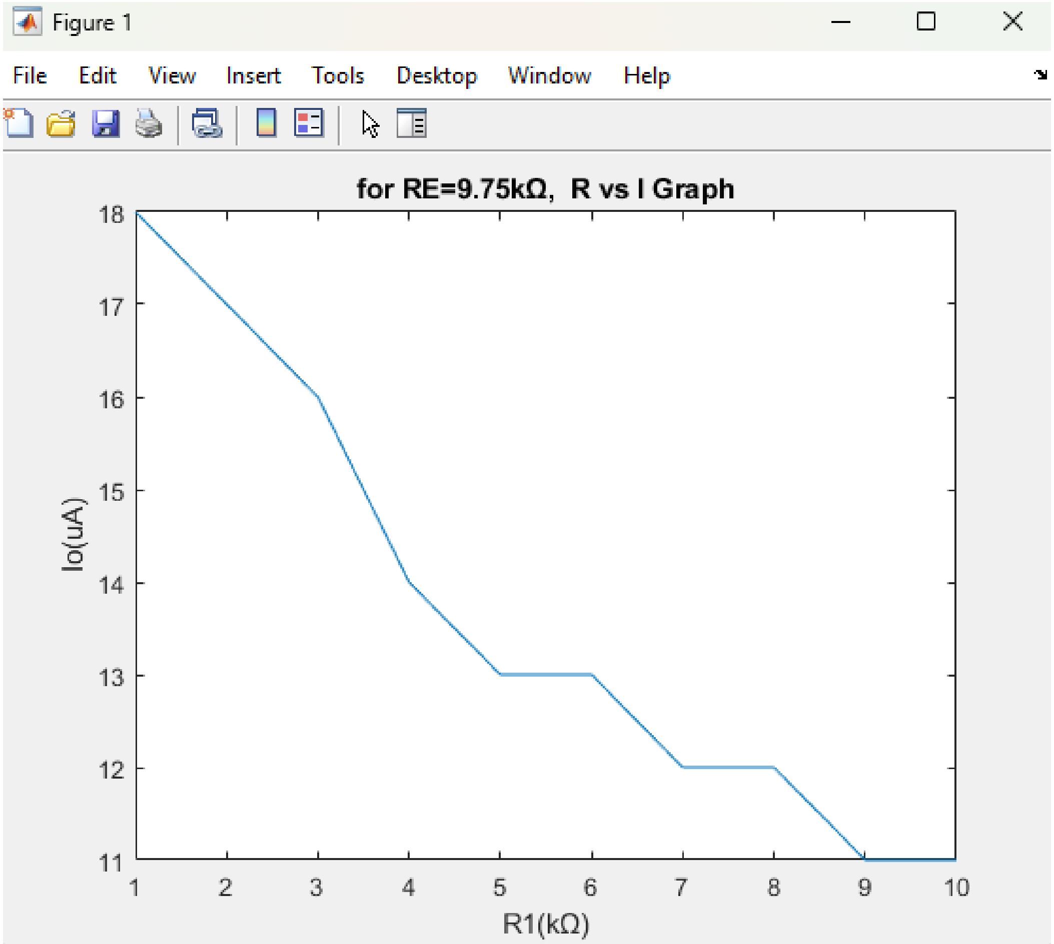
```
Re=[1 2 3 4 5 6 7 8 9 10];
Io=[72 43 31 25 21 18 16 14 13 12]

plot(Re,Io)
xlabel('RE(kΩ)')
ylabel('Io(uA)')
title('for R1=7.75kΩ,  R vs I Graph')
```




```
R1=[1 2 3 4 5 6 7 8 9 10];
Io=[18 17 16 14 13 13 12 12 11 11]

plot(R1,Io)
xlabel('R1(kΩ)')
ylabel('Io(uA)')
title('for RE=9.75kΩ,  R vs I Graph')
```



Justify Phase

- Use potentiometers and explain the effect of different resistance values (up to 10 KΩ) to the output current you measure. Draw R vs I graphs. Justify your measurements with the theory.

$$R_E = \frac{V_T}{I_o} \cdot \ln\left(\frac{I_{REF}}{I_o}\right)$$

For Re = 1k ohm measured 72x10^-6 A

$$\frac{26 \times 10^{-3}}{72 \times 10^{-6}} \times \ln\left(\frac{1.2 \times 10^{-3}}{72 \times 10^{-6}}\right) = 1016\ \Omega$$

For Re = 2k ohm measured 43x10^-6 A

$$\frac{26 \times 10^{-3}}{43 \times 10^{-6}} \times \ln\left(\frac{1.2 \times 10^{-3}}{43 \times 10^{-6}}\right) = 2013\ \Omega$$

For Re = 3k ohm measured 31x10^-6 A

$$\frac{26 \times 10^{-3}}{31 \times 10^{-6}} \times \ln\left(\frac{1.2 \times 10^{-3}}{31 \times 10^{-6}}\right) = 3066\ \Omega$$

For Re = 4k ohm measured 25x10^-6 A

$$\frac{26 \times 10^{-3}}{25 \times 10^{-6}} \times \ln\left(\frac{1.2 \times 10^{-3}}{25 \times 10^{-6}}\right) = 4026\,\Omega$$

For Re = 5k ohm measured 21x10^-6 A

$$\frac{26 \times 10^{-3}}{21 \times 10^{-6}} \times \ln\left(\frac{1.2 \times 10^{-3}}{21 \times 10^{-6}}\right) = 5009\,\Omega$$

For Re = 6k ohm measured 18x10^-6 A

$$\frac{26 \times 10^{-3}}{18 \times 10^{-6}} \times \ln\left(\frac{1.2 \times 10^{-3}}{18 \times 10^{-6}}\right) = 6066\,\Omega$$

For Re = 7k ohm measured 16x10^-6 A

$$\frac{26 \times 10^{-3}}{16 \times 10^{-6}} \times \ln\left(\frac{1.2 \times 10^{-3}}{16 \times 10^{-6}}\right) = 7016\,\Omega$$

For Re = 8k ohm measured 14x10^-6 A

$$\frac{26 \times 10^{-3}}{14 \times 10^{-6}} \times \ln\left(\frac{1.2 \times 10^{-3}}{14 \times 10^{-6}}\right) = 8266\,\Omega$$

For Re = 9k ohm measured 13x10^-6 A

$$\frac{26 \times 10^{-3}}{13 \times 10^{-6}} \times \ln\left(\frac{1.2 \times 10^{-3}}{13 \times 10^{-6}}\right) = 9050\,\Omega$$

For Re = 10k ohm measured 12x10^-6 A

$$\frac{26 \times 10^{-3}}{12 \times 10^{-6}} \times \ln\left(\frac{1.2 \times 10^{-3}}{12 \times 10^{-6}}\right) = 9978\,\Omega$$

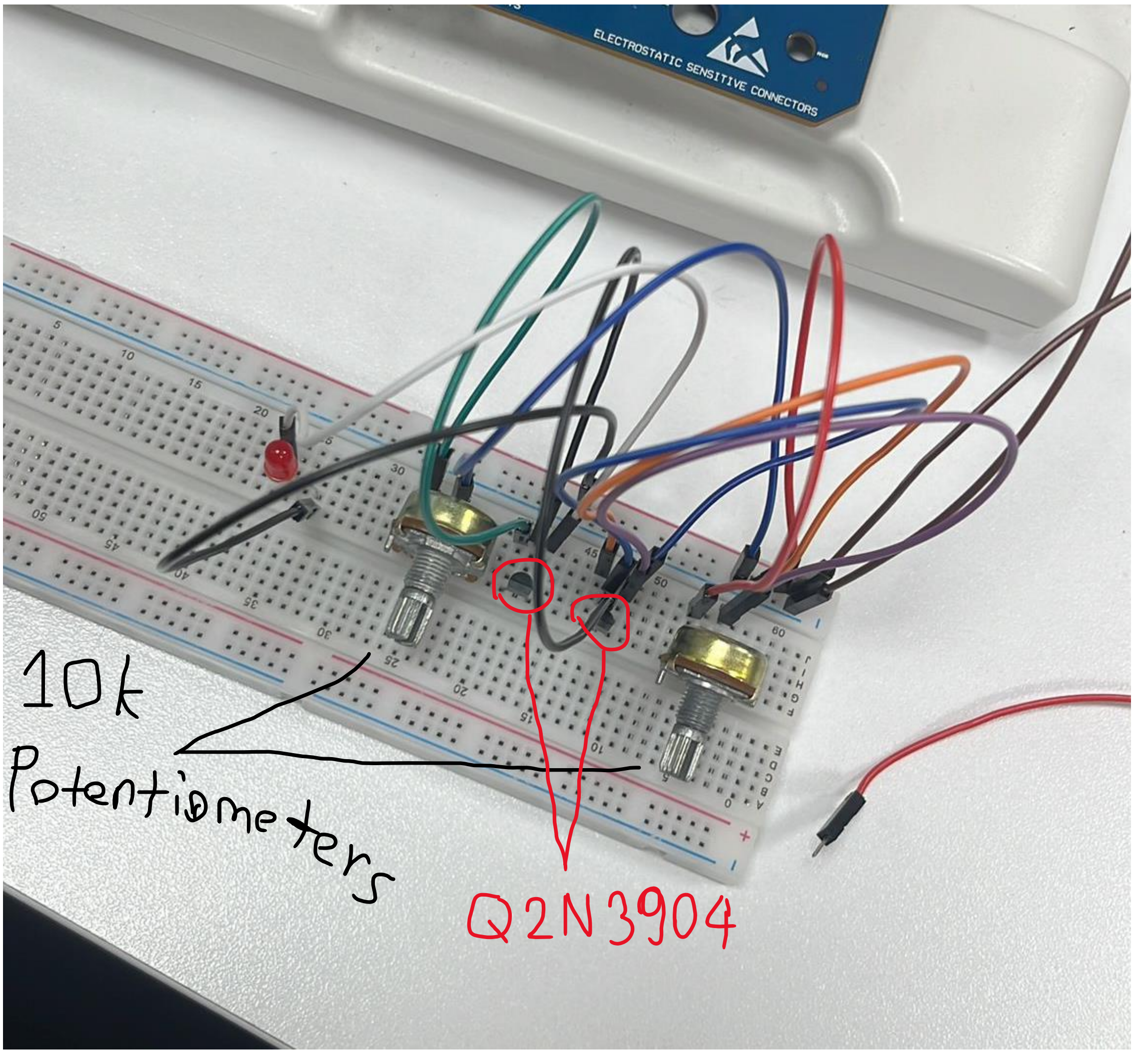
- Is it important to use matched transistors in your design? Discuss the effect of using matched or mis-matched transistors.

Answer: In the Widlar current source, this circuit usually contains PNP or NPN transistors and is usually created using dual transistors. It is important that the transistors used have similar characteristics, especially in terms of thermal and beta values.

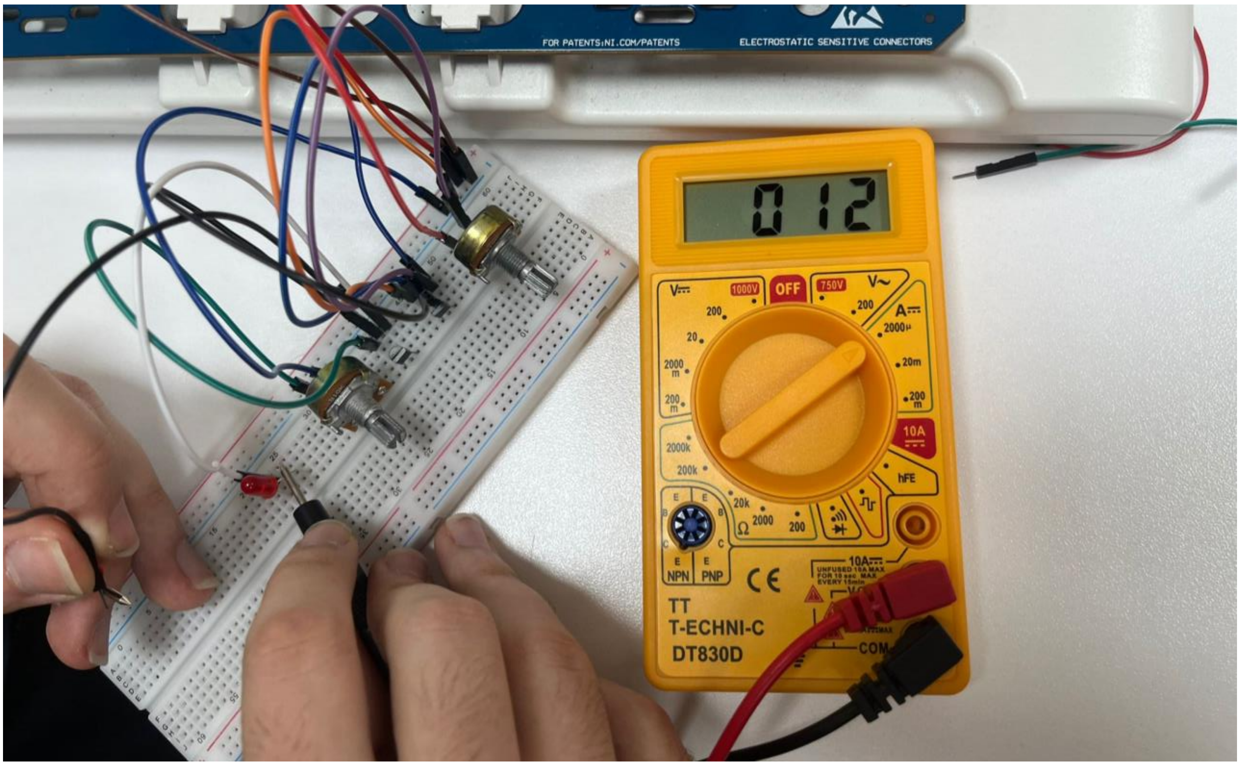
It is not necessary to use the same transistors, but it is important that they have similar characteristics. It is generally preferred to use the same transistors, as this ensures that the design is more stable and the output current is clearer. If different transistors are used, there may be undesirable fluctuations in the output current. If so, additional measures should be taken to stabilize the design.

I chose to use two 2N3904 NPN transistors in my Widlar current source circuit. Since I used two identical transistors, I obtained clear data without fluctuation when I measured the output current.

- Include a photo of your actual circuit and component names in your report.



Io (Output Current)



IREF (I choose my Iref as 1.2mA)