Bilkent University

Electrical and Electronics Department

EE313-02 Lab 1 Final Report:

“Diode Characterization and Differential Temperature Sensor”

05/10/2024

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Introduction:

This experiment consisted of two parts: A and B. In part A, we were asked to design a method to measure Is of a p-n diode, 1N4148. In part B, we were asked to design a differential temperature sensor using the temperature dependence of a diode forward voltage under constant current with certain specifications.

Hardware Implementation & Analysis:

Part A:

The following circuit was implemented on a breadboard using a 1N4148 diode, 14V DC power supply, and a 120kΩ resistor **(Figure 1)**.

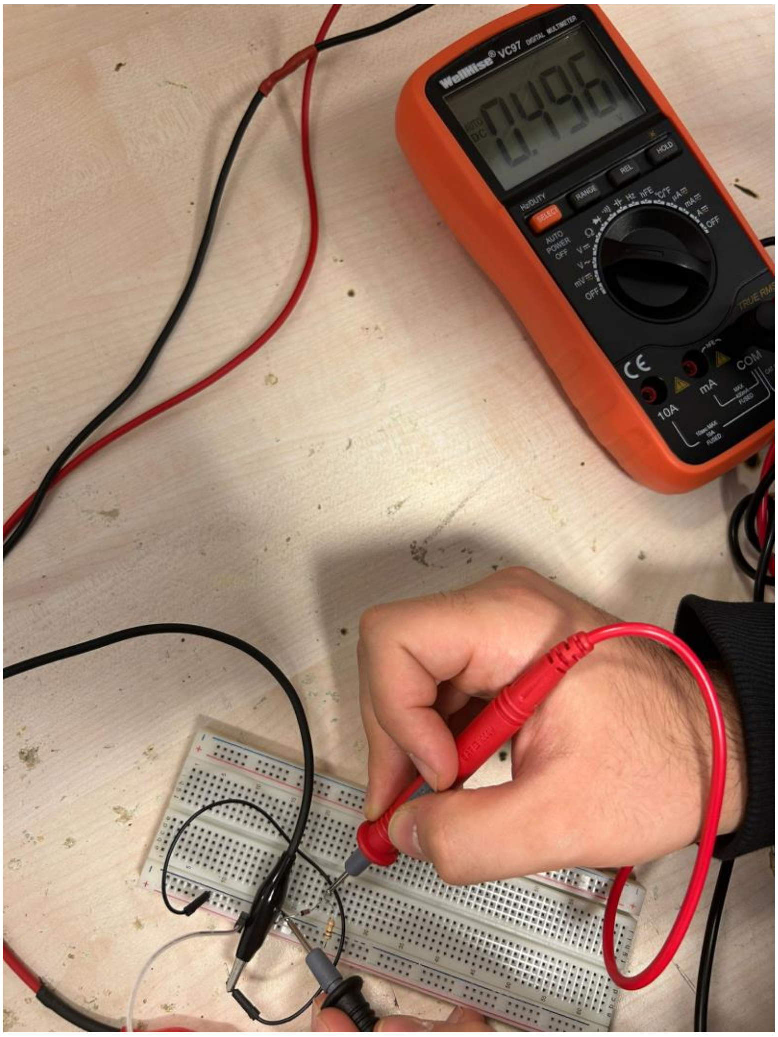

Figure 1: Voltage accross the 1N4148 diode

The relationship between I_d and I_s is given in **(1)** & **(2)**. Where T = 296K (Lab Environment Temperature), k = 1.38 * 10^{-23} , n = 1.752 and q = 1.6 * 10^{-19}.

$$I_d = I_s \cdot \left(e^{\left(\frac{V_d}{n \cdot V_T}\right)} - 1\right) \qquad \textbf{(1)}$$

$$V_T = \frac{k \cdot T}{q} \qquad \textbf{(2)}$$

The V_d value we measured was 0.496 Volts. **(3)** shows the calculations to find I_d.

$$I_d = \frac{14V - 0.496V}{120k\Omega} = 112.53\mu A \qquad \textbf{(3)}$$

The final value for I_s can be found in **(4)**.

$$I_s = \frac{112.53 \cdot 10^{-6}}{\left(e^{\left(\frac{1.6 \cdot 10^{-19} \cdot 0.496}{1.38 \cdot 10^{-23} \cdot 1.752 \cdot 296}\right)} - 1\right)} = 2.38nA \qquad \textbf{(4)}$$

Table I shows the difference between simulation and hardware values of I_s. The error is 5.56%.

LTSpice Simulation Value	Hardware Experimental Value	Error
2.52nA	2.38nA	5.56%

Table I

Part B:

The hardware implementation of the heat sensor circuit can be seen in the following figure **(Figure 2.1)**:

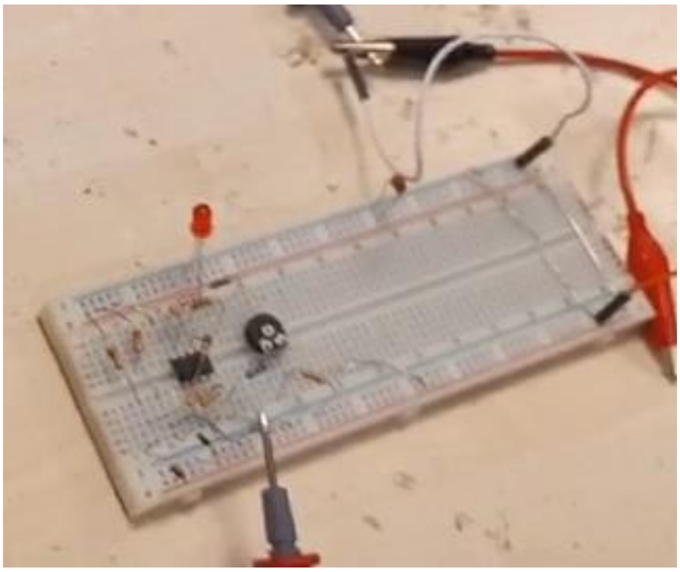

Figure 2.1: The circuit for part B

There are 4 requirements that the circuit should met. These were given in the lab manual **(Figure 2.2)**:

1. When both diodes are at room temperature (v_{D1}=v_{D2}), the output voltage, v_{out}, should be at (V_{cc}−2)/4
2. The output voltage should show the temperature difference between the room temperature and the temperature of the sensor diode in degrees with a 10% tolerance. For example, if the sensor diode is +1-degree warmer, v_{out} should change by +1V.
3. A red LED should turn on when the sensor's temperature exceeds +5±0.5°C the room temperature.
4. The LED should never flicker around the thresholds: It should have a 0.1°C (0.1V) hysteresis.

Figure 2.2: The 4 Requirements the Circuit should Meet

Now let’s dive deep in each criterion.

Criterion 1-) When both diodes are at room temperature, the output voltage, vout, should be 3 Volts:

When both diodes are at room temperature, Vout is measured as 2.873 Volts. Table II compares the simulation & experimental data. **(Figure 2.3)**

Figure 2.3: Vout being 2.873 Volts when both diodes are at the same temperature.

LTSpice Simulation Value	Hardware Experimental Value	Error
3 Volts	2.873 Volts	4.23%

Table II

Criterion 2-) When the temperature difference is 1°C, Vout should also change by 1 Volts.

Criterion 3-) A red LED should turn on when the sensor's temperature exceeds +5±0.5°C the room temperature.

Since there was not a precise device present for measuring temperature in the lab, I will try to show these both criterions at once by showing that a red LED does turn on when there is a 5V difference between the LED turn-on voltage and the room temperature voltage (3V).

Here you can see the turn-on voltage for the red LED **(Figure 2.4)** which is 8.27 Volts. Table III compares the simulation & experimental data.

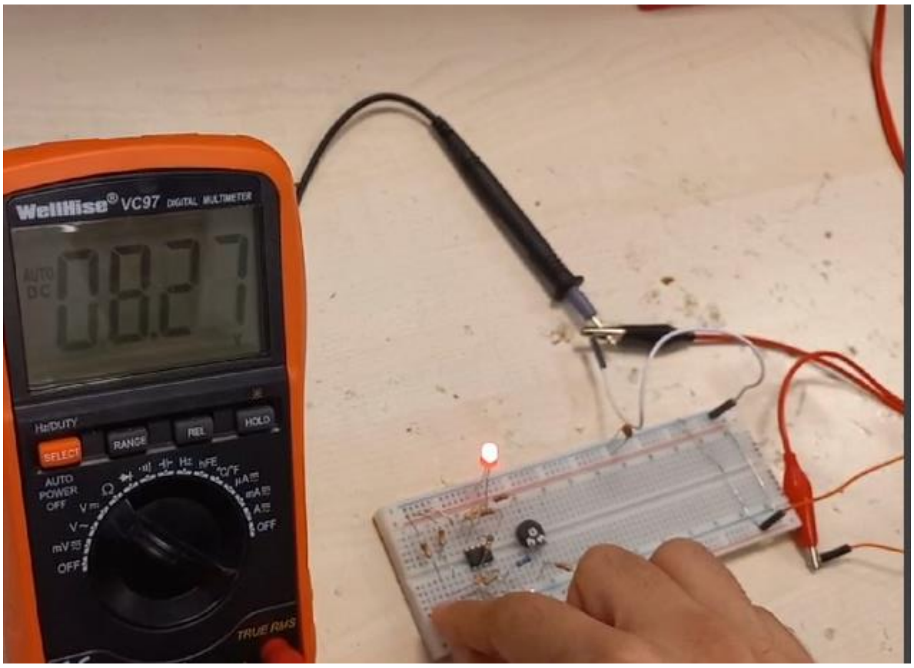

Figure 2.4: LED turn-on voltage is 8.27 Volts.

LTSpice Simulation Value	Hardware Experimental Value	Error
8 Volts	8.27 Volts	3.375%

Table III

Criterion 4-) The LED should have a 0.1°C (0.1V) hysteresis.

Here you can see the turn-off voltage for the LED **(Figure 2.5)**. Table IV compares the simulation & experimental data.

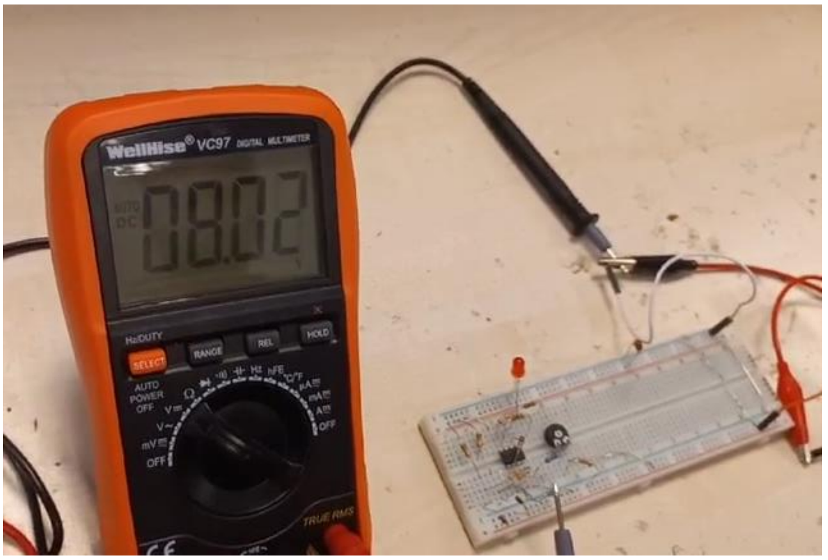

Figure 2.5: LED turn-off voltage is 8.02 Volts.

LTSpice Simulation Value	Hardware Experimental Value	Error
7.9 Volts	8.02 Volts	1.51%

Conclusion & Comments:

This experiment consisted of two parts: A and B. In part A, we were asked to design a method to measure Is of a p-n diode, 1N4148. In part B, we were asked to design a differential temperature sensor using the temperature dependence of a diode forward voltage under constant current with certain specifications.

In part A, we successfully measured I_s with 5.56% error. In part B, all the error percentages we obtained were under 5%. The error rates can be caused by the change in the values of the resistors in the lab, the sensitivity of the OPAMPs or even the inductance of the breadboard.

To conclude, the lab was a success. Errors were under the limits. Heat sensor was successfully implemented. All 4 conditions were met.