Lab Experiment #2

Wheatstone Bridge

Barış DEMİRCİ agu@338.rocks

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Contents

Chapter 1

Overview

This lab experiment aims to introduce the Wheatstone Bridge and its applications. The Wheatstone Bridge is a circuit that is used to measure an unknown resistance by balancing two legs of a bridge circuit. The Wheatstone Bridge is a fundamental circuit in electrical engineering and is used in many applications such as strain gauges, thermistors, and potentiometers. This lab will also introduce the concept of a potentiometer and its applications.

Chapter 2

Pre-Lab Work

The purpose of this pre-lab work is to prepare for this experiment (Laboratory Experiment #2) in the ESD Capsule. This lab aims to teach students about the Wheatstone Bridge and its applications in measuring resistance values.

The pre-lab work is divided into two parts: theoretical analysis and LTspice simulations.

Outcomes of these pre-lab works will not be shown here explicitly, but will be used in the next pages of this paper with the experimental part results.

2.1 Theoretical Analysis

We analyzed the Wheatstone Bridge circuit theoretically and calculated the expected values based on the provided circuit configurations and component values.

2.2 LTspice Simulations

Using LTspice, we implemented the Wheatstone Bridge circuit and conducted simulations to verify the expected outcomes. The simulation results were appropriately labeled and aligned with the theoretical analysis.

Chapter 3

Exercises

3.1 Exercise 1: Wheatstone Bridge

3.1.1 Objective

The objective of this exercise is to build and analyze the Wheatstone Bridge circuit and measure the resistance values using a multimeter.

3.1.2 Equipment

- Digital multimeter
- Breadboard
- Resistors (2×1kΩ, 2×2.2kΩ, 1×10kΩ)
- Potentiometer (5kΩ)
- Pover supply (5V)
- Wires and connectors

3.1.3 Procedure

1. We analysed the Wheatstone Bridge circuit theoretically and calculated the expected values based on the provided circuit configurations and component values.

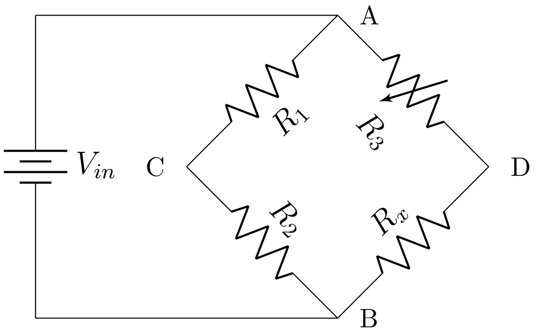

Figure 3.1: Wheatstone Bridge circuit

Let's try to derive Wheatstone balance equation to find R_x:

$$
\begin{aligned}
V_{out} = V_C - V_D &= V_{R_2} - V_{R_x} = 0 \\
R_C = \frac{R_2}{R_1 + R_2} \quad &\text{and} \quad R_D = \frac{R_x}{R_3 + R_x} \\
\text{At balance,} \quad R_C &= R_D \\
\frac{R_2}{R_1 + R_2} &= \frac{R_x}{R_3 + R_x} \\
R_2(R_3 + R_x) &= R_x(R_1 + R_2) \\
R_2R_3 + R_2R_x &= R_xR_1 + R_xR_2 \\
R_2R_3 &= R_xR_1 \\
R_x &= \boxed{\frac{R_2R_3}{R_1}}
\end{aligned}
$$

2. Then, we have simulated the Wheatstone Bridge circuit in LTspice. The circuit is shown in Figure 3.2. The simulation results are shown in Table 3.1. The simulation results show that the output voltage is zero when the bridge is balanced. The output voltage increases as the bridge becomes unbalanced.

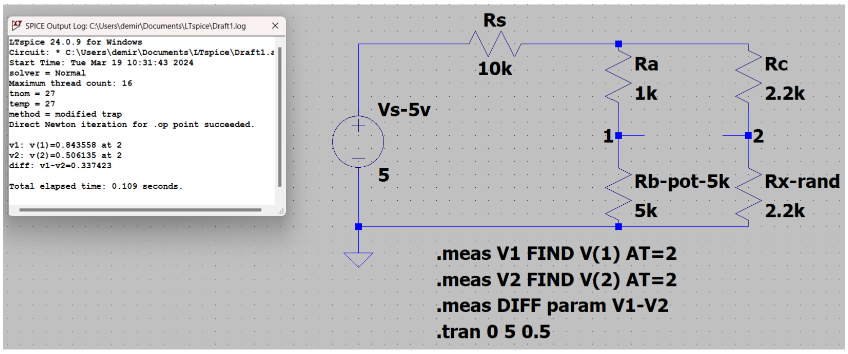

Figure 3.2: LTspice simulation of the Wheatstone Bridge

For $R_x = 2.2$k		For $R_x = 1$k	
R_b	V_{12}	R_b	V_{12}
1k	0	1k	0.10274
2.2k	0.146536	2.2k	0.258621
3k	0.216535	3k	0.330189
4k	0.284483	4k	0.397959
5k	0.337423	5k	0.44964

Table 3.1: LTspice simulation results of the Wheatstone Bridge circuit

3. We have theoretically calculated the expected resistance values for the Wheatstone Bridge circuit and check if the values verify the theoretical analysis.

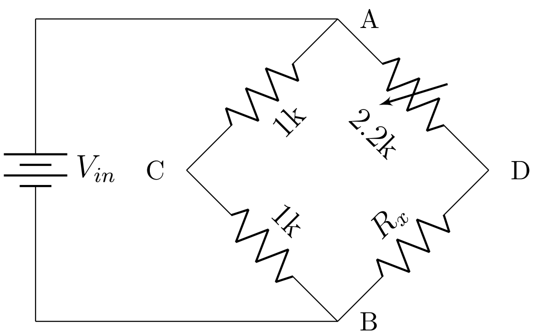

Figure 3.3: Wheatstone Bridge circuit

If we apply the balance equation (Where $V_{CD} = 0$) we can find the value of R_x which should be $2.2k$ according to LTspice result:

$$R_x = \frac{R_2 R_3}{R_1}$$
$$R_x = \frac{1k \times 2.2k}{1k}$$
$$R_x = 2.2k$$

The LTspice results are consistent with the theoretical results.

4. We have built the Wheatstone Bridge circuit on the breadboard according to the Figure 3.4 where $R_x = 2.2k\Omega$. We have connected the power supply to the circuit and measured the potential difference between C and D (V_{CD}) using a multimeter. We have adjusted the potentiometer to balance the bridge and measured the resistance value using a multimeter.

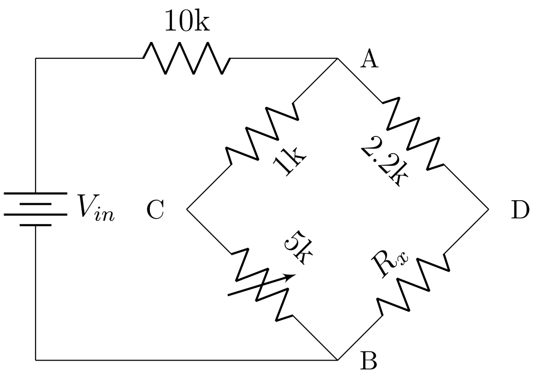

Figure 3.4: Wheatstone Bridge circuit

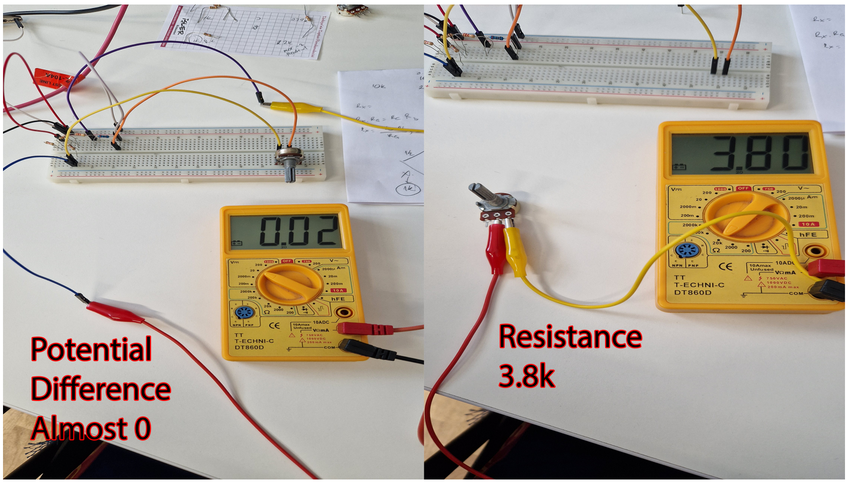

Figure 3.5: Balanced Wheatstone Bridge

We have measured the voltage and resistance values of the circuit and compared the results with the theoretical values. The results are close to the theoretical values. The differences between the theoretical and experimental values are due to the tolerance of the resistors, non-ideal cables and the measurement errors.

5. We have changed the value of R_x to 1kΩ and repeated the measurements.

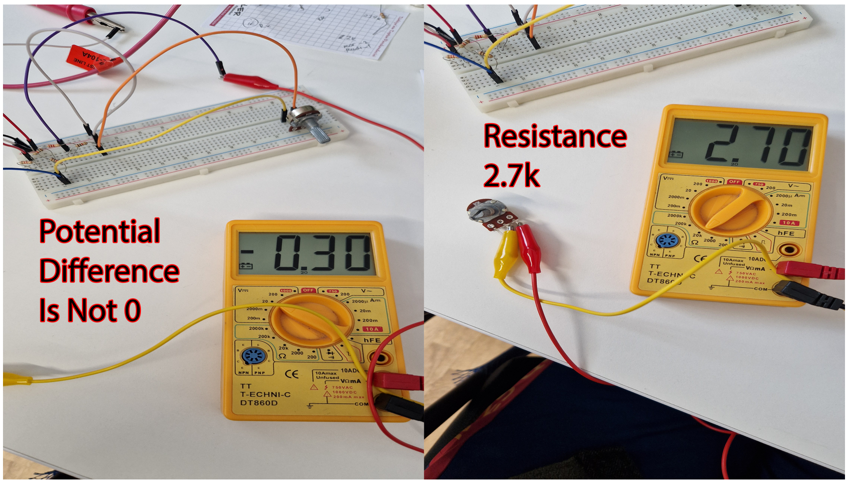

Figure 3.6: Unbalanced Wheatstone Bridge

When the circuit is not balanced, we can not apply the balance equation but if we apply the balance equation (Where $V_{CD} = 0$) we can find the theoretical value of R_x:

$$R_x = \frac{R_2 R_3}{R_1}$$
$$R_x = \frac{2.7k \times 2.2k}{1k}$$
$$R_x = 5.94k$$

According to this setup and the theoretical calculations, the expected value of R_x should be 5.94kΩ instead of 1kΩ.

3.1.4 Results

We have built the Wheatstone Bridge and measured the resistance values using a multimeter. Compared the results with the theoretical values and observed that the results are close to the theoretical values. The differences between the theoretical and experimental values are due to the tolerance of the resistors, non-ideal cables and the measurement errors.

Chapter 4

Conclusion

In this laboratory session, we have learned how to analyze and build the Wheatstone Bridge circuit. We learned the use cases of Wheatstone Bridge and how to calculate the resistance values using the balance equation. We have successfully built the Wheatstone Bridge circuit and measured the resistance values of the resistors using a digital multimeter. We have also verified the balance equation by comparing the calculated and measured resistance values. We have also learned how to use a potentiometer to adjust the resistance value and observe the changes in the output voltage. Overall, this laboratory session was very informative and helped us understand the practical applications of Wheatstone Bridge in real-world scenarios.