CMPE 263 ELECTRONIC CIRCUITS PROJECT

PROJECT REPORT

Project No:1

z-Parameters of Two-Port Networks

Group 2

Submitted by:

Oussama Tanfouri(CE)

Léa Hijazi(CE)

Muhammad Izaan Ul Haque(CE)

Instructor

Feza Kerestecioğlu

Mentors

Selçuk Öğrenci

Taner Arsan

Teaching Assistants

Umut İlhan Beyaztaş

Sedanur Özdamar

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1 INTRODUCTION

This Project deals with the concept of Two-Port Network where there are two pairs of terminals in an electrical circuit introducing a concept of Z-Parameters.

This Parameter describes how voltage and current at one pair corresponds to ones at the other port.

Furthermore, there are 4 Z-Parameters z11, z12, z21 and z22 which establishes a mechanism to gain insights into the input and output impedance.

This makes Z-Parameters a valuable tool which focuses on resistive characteristics of the circuit to analyze circuit design .

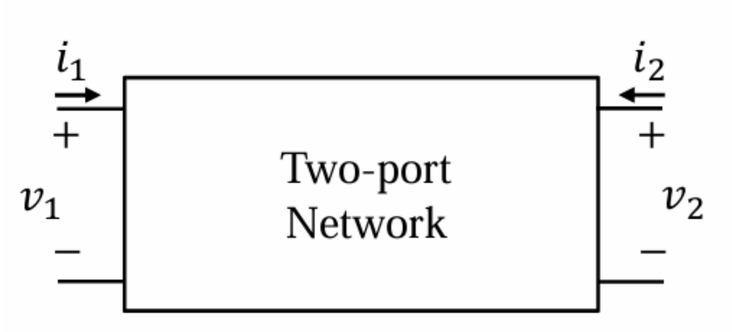

Figure 1.1 Two-port Network Circuit

1.1 Objectives

The main objective of this project is to derive Z-Parameters in terms of the four resistors in this circuit with different resistance values. Voltage (<= 5) will be induced from a power supply to measure the current and calculate the four Z-Parameter values.

Furthermore, the report will compare experimental and theoretical values to assess the accuracy and effectiveness of the circuit and discuss discrepancies that may have been found.

1.2 Outline

The main focus of this project is to derive and analyze the Z-Parameter values in a Bridged-T circuit in terms of the four resistors: R1, R2, R3, and R4.

Z-Parameters will be calculated using nominal and measured values of the resistances, experimental results and theoretical results will be compared and discussed to identify any variations and gauge the accuracy of the circuit built.

1.3 Materials used

The following materials were used during the execution of our project:

- Bread board
- 4 resistors (R1, R2, R3, R4)
- Multimeter
- Power supply
- 1 crocodile wire
- 3 jumper wires
- 2 banana-to-alligator wires
- 2 banana jack universal cables

2 CIRCUIT ANALYSIS

Two-port network circuits, as depicted in Figure 2.21, are circuit systems characterized by two pairs of terminals.

The focus of this project will be studying the two-port network circuit based on its z-parameters or impedance parameters.

The four z-parameters Z_{11}, Z_{12}, Z_{21} and Z_{22} regulate the interaction between input and output currents and voltages.

- The input impedance is represented by Z_{11} (if our output is open-circuited).
- The output impedance is represented by Z_{22}.
- The forward transfer impedance is represented by Z_{21}, this parameter dictates the effect of the input on the output.
- The forward transfer impedance is represented by Z_{12}, this parameter dictates the effect of the input on the output.

2.1 Z-Parameters

By creating a voltage across the circuit and measuring the current flowing through it, four Z-parameters are computed to represent linear resistance values in a two-port network.

The following formulas represent the voltages at each port:

$$V_1 = Z_{11} \times I_1 + Z_{12} \times I_2$$

$$V_2 = Z_{21} \times I_1 + Z_{22} \times I_2$$

When the output port is open and the current is zero, the first parameter, Z_{11}, indicates the input impedance; hence, it can be presumed that the circuit is closed.

Likewise, when the input port is open circuited with a current of zero, Z_{22} denotes the output impedance.

The input-output relationship is described by parameters Z_{12} and Z_{21}. When the input is open, Z_{12} represents the reverse transfer impedance, which illustrates how output current influences input voltage, and Z_{21} represents the forward transfer impedance, which illustrates how input current influences output voltage.

These parameters offer a thorough method of describing the circuit's reaction to modifications at either port.

2.2 Circuit Characteristics

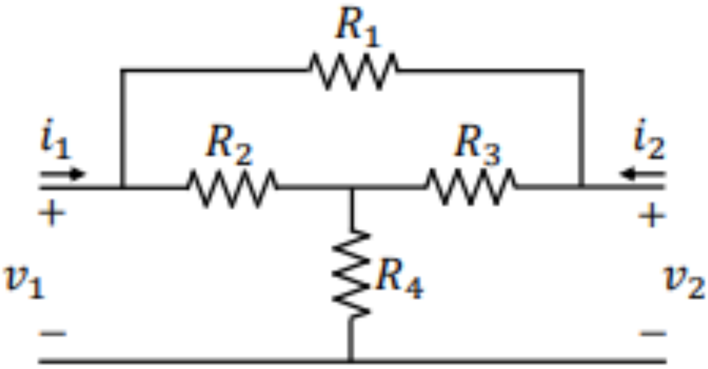

Figure 2.2.1 Two-Network Circuit with four resistors including a bridge resistor

The figure above is a circuit including the design of a bridge resistor between the input and the output. The circuit has four resistors: R_1, R_2, R_3 , and R_4.

The input and output terminals are connected via a network formed by these resistors. The bridge resistors between the input and output terminals in this arrangement are R1 and R3. In the meantime, R2 and R4 provide current pathways inside each terminal set by directly connecting each port.

The applied voltage on the input side is represented by the input terminals with the labels V1 and V2, respectively, and the output voltage is represented by V2.

This circuit configuration is appropriate for Z-parameter computation since it enables us to assess how well a two-port network functions.

2.3 Derivation of Z-Parameters

To derive the Z-parameters of the two-port network, the following formula was employed.

$$V_1 = \frac{R_2 \times I_x + R_3 \times I_2}{I_2}$$

$$V_2 = \frac{R_3 \times I_x + R_4 \times I_1}{I_1}$$

3 EXPERIMENTAL DATA AND RESULTS

3.1 Experimental Setup and Procedure

To determine the Z-parameters, we constructed the circuit using the following resistor values: R1 = 2.1kΩ, R2 = 1.5kΩ, R3 = 2.2kΩ and R4 = 2.5kΩ.

Values for the resistors were within the range [0.5kΩ, 3kΩ] thus ensuring varied resistance is varied.

DC power supply and a multimeter were employed, and the input, output, voltages and currents were measured.

Specifically, we conducted measurements with open-circuited input and output conditions to check each parameter. Then we took notes of each measurement for correct calculations.

Z-Parameter	R_1 kΩ	R_2 kΩ	R_3 kΩ	R_4 c	V_1 (V)	V_2 (V)	I_1 (mA)	I_2 (mA)	Calculated values
Z_{11}	2	1.5	2.1	2.5	5	-	1.6	-	0.914
Z_{12}	2	1.5	2.1	2.5	5.03	-	-	1.48	0.914
Z_{21}	2	1.5	2.1	2.5	-	4.05	1.6	-	0.914
Z_{22}	2	1.5	2.1	2.5	-	5	-	1.4	0.914

Figure 3.1 Table of measurements and calculations comparing theoretical and experimental results

Based on our calculations: as R1 and R3 are on series, and R2 and R4 are on series, and both ae parallel, the two series form a parallel. Using KVL:

$Z_{11}=Z_{12}=Z_{21}=Z_{22}=$ R2.R4/R1+R3= 0.914 Ω.

3.2 Experimental Result Analysis

In the experimental analysis, we measured various voltage and current values across resistors to calculate the Z-parameters.

By setting specific conditions in the circuit, we obtained the values of V_1 and V_2 and recorded the corresponding current values i_1 and i_2. These values allowed us to compute the experimental Z-parameters, including Z_{11} and Z_{21}.

We found that under the given conditions, the Z-parameters aligned reasonably with theoretical expectations but showed slight deviations due to real-world factors.

These results were recorded and analyzed for insights into the behavior of the circuit under the given resistor values.

3.2.1 Key Points in the Experiment Tables

The table above mentions the values of the voltage, current and the derived Z-Parameters. Some of the key takeaways were that the measured Value for V1 was similar to our expectation and nearing 5V, while V2 saw a decline in its reading, going to 3.954V.

However, both of the readings for I1 and I2 were accurate, which resulted in a near perfect calculation of the Z-Parameter.

Overall, the outcome of this experiment was close to our theoretical predictions.

3.3 Theoretical Result Analysis

We derived expressions for the Z-parameters of the circuit. After using known values of resistances and applying circuit analysis principles, we calculated the expected values of voltages V1 and V2 under the best possible conditions.

Theoretical calculations resulted in the same Z-parameters, so we used these values as a guide for our experimental data.

We expected V1 to be 5 V and V2 to be about 4.05 V based on the resistances and circuit setup.

3.3.1 Key Points in the Theoretical Values

Key takeaways from theoretical analysis include that the theoretical value of V1 was similar to our experimental value, however, V2 was expected to be around 4.05v which is slightly different from the measured value of 3.954v.

Furthermore, theoretical Z-Parameters provided key information to conclude the accuracy of our experimental results.

3.4 Comparison of the Experimental and Theoretical Voltage Output:

Both the values of our experimental and theoretical values are largely similar although some variance can be seen. If the workings are correct experimental measurements are naturally close to each other as supported by the table above.

4 ERROR HANDLING

4.1 Error Analysis

To understand differences between theoretical and experimental values, error analysis is immensely important.

In this specific circuit, differences between theoretical and measured Z-Parameters and voltage arise from various reasons.

4.1.1 Sources of Error

One of the common sources of error is resistance tolerance, most resistors have a tolerance of ±1% or ±5% which can lead to slight deviations.

Another important reason is the inaccuracies within the multimeter itself, which is used to measure voltage and current.

Environmental factors such as temperature and humidity can increase resistance within the circuit especially if the components are sensitive.

Lastly, there is contact resistance which happens when the components are not connected properly leading to oxidation at certain points leading to an unaccounted increase in resistance

.4.2 Outcome in Tackling Error

Various Errors can be found in the circuit, and to reduce such errors it is crucial to take multiple readings of the resistors, current, and voltage and then to average them out to ensure precise measurement. This is especially important to ensure that the values in calculations are accurate.

Additionally, it is important to calibrate all the instruments used and provide a steady supply to the circuit to minimize errors while measuring. All in All, such undertakings increase the accuracy and reliability of the measurements.

5 DISCUSSIONS

Our analysis of the two-port network's Z-parameters yielded some significant conclusions on the behavior of the network and the precision of theoretical vs experimental values, This precision was achieved by carefully selecting resistor values (R1, R2, R3, and R4) that fit within an acceptable tolerance range. The experimental setups we carried out were generally reliable and strayed little from theoretical values.

However, some little differences were noted, especially in Z21 and Z12 values, due to minor environmental influences such contact resistance and resistor tolerance levels. Every Z-parameter Z_{11}, Z_{12}, Z_{21}, and Z_{22} had a unique function in determining the properties of the circuit, Particularly Z_{11} and Z_{22} were essential in figuring out the input and output impedance respectively.

The degree of mutual interaction between the ports was shown by Z_{12} and Z_{21}, which showed how modifications at one port impacted the other. Because of the bridge arrangement in our circuit, these values were more sensitive.

Differences between Theoretical and Measured Values Even though the practical values were quite near to the theoretical Z-parameters, there were differences when there was a lot of current flowing through the terminals and the voltage fluctuated. Component tolerance, minute changes in resistor values, and environmental elements like temperature that affect resistance values could all be to blame for this.

There are a few strategies that could help mitigate Errors and ensure that future experiments are more accurate such as the improvement of circuit connections as this could decrease contact resistance mistakes.

Environmental Control is also crucial as Temperature-induced resistance variations may be lessened by doing measurements in a controlled setting.

It is also crucial to comprehend and precisely calculate Z-parameters, the knowledge gained from this project serves as a basis for the design of circuits that need controlled inter-port coupling and accurate impedance matching, both of which are critical in electronics and communications applications.

6 CONCLUSIONS

The objective of this project was to identify the Z-parameters for a two-port network and use both theoretical and experimental methods to examine how they affect circuit performance. By means of meticulous circuit building and accurate measurements.

The Z-parameters for the two port-network were effectively obtained, giving a clear grasp of the impacts of mutual coupling and input/output impedance.

Theoretical predictions and experimental results have a close correlation, However Due to outside influences, there were a few minor variations, but they were within reasonable range.

To conclude the knowledge acquired here can be used to a number of domains where signal integrity and impedance matching are crucial, these include telecommunications, and analog circuit design, The objective of the project were attained by following a distinct outline.

Through this project we showcased how useful Z-parameter analysis is for two-port networks, especially when dealing with intricate connections between circuit elements.

7 APPENDIX A

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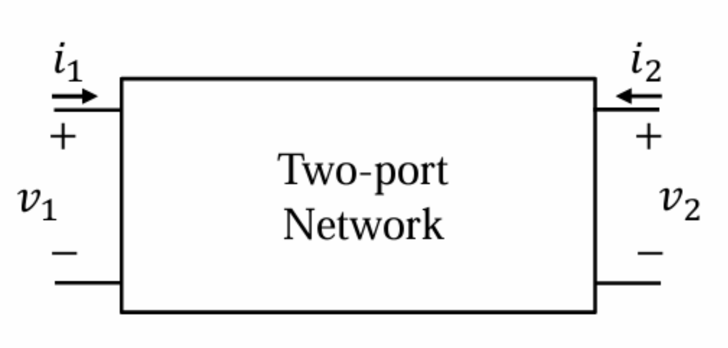

Figure 1.1 Two-port Network Circuit

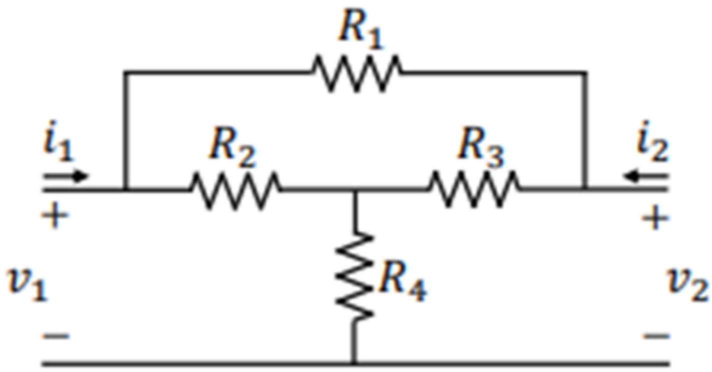

Figure 2.2.1 Two-Network Circuit with four resistors including a bridge resistor

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