KARADENİZ TECHNICAL UNIVERSITY
Faculty of Engineering
Department of Electrical and Electronics Engineering

EEE 2006 CIRCUITS II LABORATORY

TWO-GATE CIRCUITS AND THE DUALITY PROPERTY

Preparation Work

1. What is the T and π circuit? What is the most appropriate circuit parameterization method for these circuits?
2. **a)** What are the optimal circuit parameterization methods for two circuits whose input and output terminals (input-output) are connected S-S, P-P, S-P and P-S?
   b) If the circuit parameters of two circuits are known separately, how to calculate the parameters of the larger circuit using these values?
3. What is duality (reciprocity) and how is it determined?

NOTE: Come to the experiments by preparing the preparatory work as a report (with the report cover). Those who do not have a report will not be admitted to the experiments.

Purpose of the Experiment

- To learn the types of circuit parameters that can be used in two-port circuits.
- Calculation and measurement of y and z parameters in two-port circuits
- To learn the optimal circuit parameters for multiple circuits with input and output terminals connected in series-serial, parallel-parallel, series-parallel and parallel-serial
- To learn the duality (reciprocity) property of a circuit.

GENERAL INFORMATION

Two-port (4-ended) circuits can be defined as circuits in which the currents entering at one end of the input or output gates and leaving at the other end of the same gates are equal to each other. For example, in the two-gate circuit in Figure 1, $I_1=I_1'$ for the input gate and $I_2=I_2'$ for the output gate.

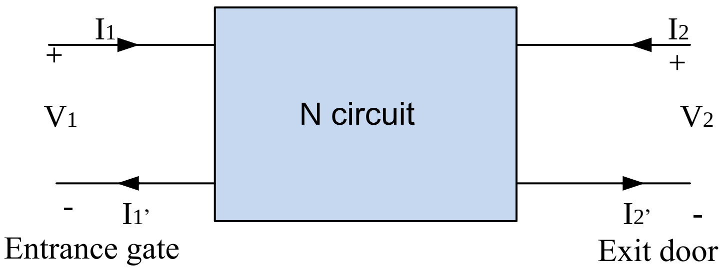

Figure 1. Two-gate circuit representation

Here, we consider circuits with linear and time-invariant elements. For the case where there are no independent sources inside the 2-port N circuit and the initial conditions are zero, the circuit parameters can be calculated and formulated in the s or jw domain. Furthermore, if the two-port circuit is part of a larger circuit, there should be no coupling or dependent terms between the current-voltage variables of the elements of this two-port circuit and the current and voltage of the elements of another part.

The variables that define a two-port are V_1, V_2, I_1 and I_2. Two of them will be defined as dependent and the other two as independent variables. We can choose our 2 independent variables in 6 different ways as (V_1,V_2), (I_1,I_2), (V_1,I_2), (I_1,V_2), (V_1,I_1) and (V_2,I_2). The parameter types obtained according to this selection will be defined as given in Table 1.

Table 1: Parameter Models in Two-Gate Circuits

Circuit Parameters	Independent Variables (Inputs)	Dependent Variables (Outputs)
Z Impedance	I_1, I_2	V_1, V_2
Y Admitance	V_1, V_2	I_1, I_2
Mixed g	V_1, I_2	I_1, V_2
Mixed h	I_1, V_2	V_1, I_2
Transmission	V_2, I_2	V_1, I_1
Reverse Transmission	V_1, I_1	V_2, I_2

Table 2: Parameter Definitions in Two-Gate Circuits

Parameter Type	Definitions
Z impedance parameters	$\begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix}$
Y admittance parameters	$\begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} y_{11} & y_{12} \\ y_{21} & y_{22} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix}$
Mixed h-parameters	$\begin{bmatrix} V_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ V_2 \end{bmatrix}$
Mixed g-parameters	$\begin{bmatrix} I_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} g_{11} & g_{12} \\ g_{21} & g_{22} \end{bmatrix} \begin{bmatrix} V_1 \\ I_2 \end{bmatrix}$
Chain parameters	$\begin{bmatrix} V_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_2 \\ -I_2 \end{bmatrix}$
Reverse chain parameters	$\begin{bmatrix} V_2 \\ I_2 \end{bmatrix} = \begin{bmatrix} a & b \\ c & d \end{bmatrix} \begin{bmatrix} V_1 \\ -I_1 \end{bmatrix}$

Z Finding Open Circuit Impedance Parameters

Voltage definitions of two gates

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

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

is given as. Z_{11}, Z_{12}, Z_{21}, Z_{22} the following procedures will be applied when calculating the parameters.

1. $I_2=0$ is taken, i.e. when both ends of the output gate are open-circuited, Z_{11} and Z_{21} parameters will be found.

$$V_1 = Z_{11} I_1 \rightarrow Z_{11} = \frac{V_1}{I_1}\Big|_{I_2=0}$$: Open circuit input impedance function

$$V_2 = Z_{21} I_1 \rightarrow Z_{21} = \frac{V_2}{I_1}\Big|_{I_2=0}$$: Open circuit forward transient impedance function

2. I_1=0 in case of receipt Z_{12} , and Z_{22} parameters are found.

$$V_1 = Z_{12} I_2 \rightarrow Z_{12} = \frac{V_1}{I_2}\bigg|_{I_1=0}$$: Open circuit reverse impedance switching function

$$V_2 = Z_{22} I_2 \rightarrow Z_{22} = \frac{V_2}{I_2}\bigg|_{I_1=0}$$: Open circuit output impedance function

Note 1: In 2-port circuits, if there is no dependent source and the circuit is composed of passive RLCM elements, Z_{12}=Z_{21}, i.e. this circuit exhibits duality.

Note 2: The total impedance of the new circuit formed by the circuits connected in series at the inputs and outputs is the sum of the individual impedances of these connected circuits.

Y Finding Short Circuit Admittance Parameters Bulunması

Definition of a two-door

$$I_1 = y_{11} V_1 + y_{12} V_2$$

$$I_2 = y_{21} V_1 + y_{22} V_2$$

When calculating the parameters y_{11} , y_{12} , y_{21} , y_{22} , the following procedures will be applied.

1. When V_2=0, i.e. both ends of the output gate are short-circuited, the parameters y_{11}, and y_{21} will be found.

$$I_1 = y_{11} V_1\big|_{V_2=0} \rightarrow y_{11} = \frac{I_1}{V_1}\bigg|_{V_2=0}$$: Short circuit input admittance function

$$I_2 = y_{21} V_1\big|_{V_2=0} \rightarrow y_{21} = \frac{I_2}{V_1}\bigg|_{V_2=0}$$: Short circuit forward pass admintance function

2. In case V_1=0, the parameters y_{12} , and y_{22} are found.

$$I_1 = y_{12} V_2\big|_{V_1=0} \rightarrow y_{12} = \frac{I_1}{V_2}\bigg|_{V_1=0}$$: Short circuit reversing transition admintance function

$$I_2 = y_{22} V_2\big|_{V_1=0} \rightarrow y_{22} = \frac{I_2}{V_2}\bigg|_{V_1=0}$$: Short circuit output admintance function

Note 1: In the absence of a dependent source in 2-port circuits, y_{12}=y_{21} if the circuit consists of passive RLCM parameters.

Note 2: The total admittance of the new circuit formed by the circuits connected in parallel at the inputs and outputs is the sum of the individual admittances of these connected circuits.

PREPARATION

1. For the circuit in Figure 2, find the Z impedance parameters of the circuit as Z_1=680 ohm, Z_2=10k and Z_3=4.7k before the experiment and write them in Table 1.
2. Find the admittance matrix Y by taking the inverse of this parameter matrix Z and write it in the necessary places in Table 2.
3. For the circuit in Figure 3, find the Y admittance parameters of the circuit as Z_A=4.7k , Z_B=10k and Z_C=680 ohm before the experiment and write them in Table 3.

4. Find the impedance matrix Z by taking the inverse of this parameter matrix Y and write it in the necessary places in Table 4.
5. Using the parameters you found above, calculate the value of the impedance from the relation $Z_T=Z_1+Z_2$ by considering the circuits you prepared in Experiments 2 and 3 connected in series at their inputs and outputs.
6. Considering the inputs and outputs connected in parallel, calculate the value of the admittance from the relation $Y_T=Y_1+Y_2$.

CONDUCTING THE EXPERIMENT

Components to be used in the experiment

- Circuit module, signal generator, two meters capable of measuring in the range of 20 mA AC and 20 V AC instrument, Oscilloscope, Fasteners.
- 4 pcs 4.7 kΩ resistance
- 3 pcs 680 Ω resistance
- 3 pcs 10 kΩ resistance

EXPERİMENT 1.

1. Set up the circuit in Figure 2 with Z_1= 680 ohm, Z_2=10k and Z_3=4.7k and find the Z impedance parameters of the circuit using the steps below and write the information in Table 1.
Step 1. To find the values of Z_{11} and Z_{21}, make the output terminals of both terminals open circuit and connect a voltage source of V_1=1Volt to the input terminals.
Step 2. Measure I_1 and V_2 values. Calculate $Z_{11}=V_1/I_1$ and $Z_{21}=V_2/I_1$.
Step 3. To calculate Z_{22} and Z_{12}, make the input terminals open circuit and connect a voltage source with V_2 = 1Volt to the output terminals.
Step 4. Measure I2 and V1 and calculate $Z_{22}=V_2/I_2$ and $Z_{12}=V_1/I_2$.

2. Does this circuit exhibit duality? Why?

3. Using these Z impedance matrix values, calculate the Y admittance matrix of the same circuit and write them in Table 2.

4. Find the difference between the Y values in the first two rows of Table 2, write it in the last row and explain why

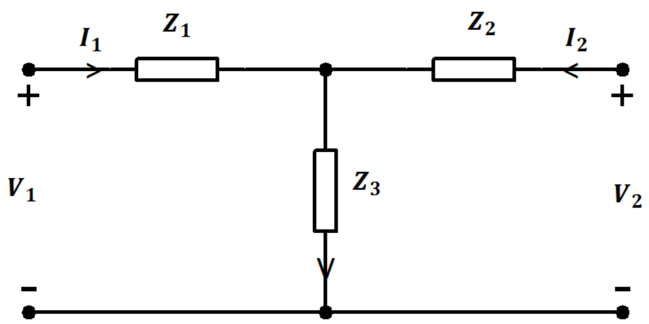

Figure 2. T circuit

EXPERİMENT 2.

1. Set up the circuit in Figure 3 with Z_A=4.7k, Z_B=10k and Z_C=680 ohm and find the Y admittance parameters of the circuit using the following steps and present the information in Table 3 write to the necessary places.

Step 1. To find the values of y_{11} and y_{21}, short-circuit the output terminals of both terminals and connect a voltage source of V_1=1Volt to the input terminals.

Step 2. Measure I_1 and I_2 values. Calculate $y_{11}=I_1/V_1$ and $y_{21}=I_2/V_1$.

Step 3. To calculate y_{22} and y_{12}, short-circuit the input terminals and connect a voltage source of V_2 = 1Volt to the output terminals.

Step 4. Calculate $y_{22}=I_2/V_2$ and $y_{12}=I_1/V_2$ by measuring I_2 and I_1.

2. Does this circuit show duality? Why?
3. Using these Y admittance matrix values, calculate the Z impedance matrix of the same circuit and write them in Table 4.
4. Find the difference between the Z values in the first two rows of Table 4, write it in the last row and explain why

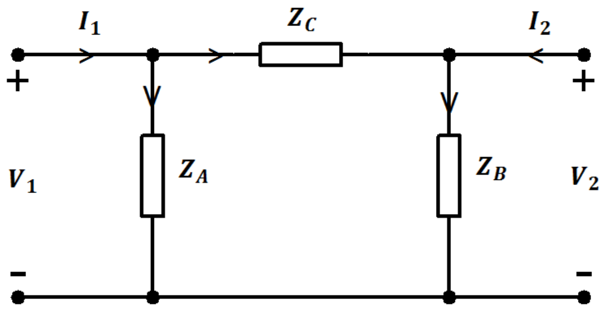

Figure 3. π circuit

EXPERİMENT 3.

1. Connect the circuits prepared in Experiments 2 and 3 in series at their inputs and outputs. Obtain the Z impedance parameters of the resulting two gates using the steps in Experiment 1 and place the results in Table 5.
2. Connect the circuits prepared in Experiments 2 and 3 in parallel at their inputs and outputs. Obtain the Y admittance parameters of the resulting two gates using the steps in Experiment 2 and place the results in Table 6.
3. Are these Z impedance (Table 5) and Y admittance (Table 6) values equal to the sum of the values you found in Experiments 1 and 2 (add these values and place them in Tables 5 and 6). Explain.

IMPORTANT NOTE

In order to perform the experiments properly, preparatory questions should be done and the theoretical part of the methods should be well known.