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**Report for Experiment #11**

**Two-Port Networks**

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**Abstract:-**

**Aim of experiment :**

The experiment was done to examine how to calculate the two ports parameter for given two ports network .

**Method used :**

- 1- DMM .
- 2- Oscilloscope.
- 3- Function Wave Generator.
- 4- DC power supply .
- 5- Circuit board and circuit elements.

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## Theory:

In general, it is easy to analyze any electrical network, if it is represented with an equivalent model, which gives the relation between input and output variables. For this, we can use two port network representations. As the name suggests, two port networks contain two ports. Among which, one port is used as an input port and the other port is used as an output port. The first and second ports are called as port1 and port2 respectively.....(1)

One port network is a two terminal electrical network in which, current enters through one terminal and leaves through another terminal. Resistors, inductors and capacitors are the examples of one port network because each one has two terminals. One port network representation is shown in the Figure 1

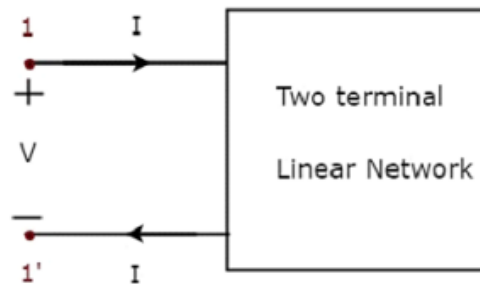


Figure 1

Here, the pair of terminals, 1 & 1' represents a port. In this case, we are having only one port since it is a one port network.....(1)

Similarly, two port network is a pair of two terminal electrical network in which, current enters through one terminal and leaves through another terminal of each port. Two port network representation is shown in the Figure 2

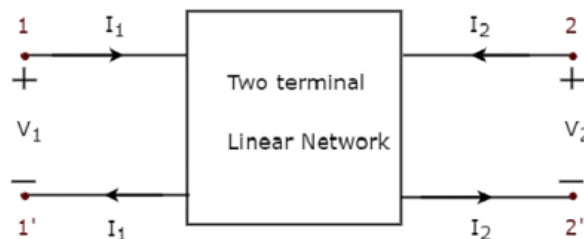


Figure 2

Here, one pair of terminals, 1 & 1' represents one port, which is called as port1 and the other pair of terminals, 2 & 2' represents another port, which is called as port2.....(1)

There are four variables  $V_1$ ,  $V_2$ ,  $I_1$  and  $I_2$  in a two port network as shown in the figure. Out of which, we can choose two variables as independent and another two variables as dependent. So, we will get six possible pairs of equations. These equations represent the dependent variables in terms of independent variables. The coefficients of independent variables are called as parameters. So, each pair of equations will give a set of four parameters.

### Two Port Network Parameters

The parameters of a two port network are called as two port network parameters or simply, two port parameters. Following are the types of two port network parameters..... (1)

- Z parameters
- Y parameters
- a parameters
- b parameters
- h-parameters
- g-parameters

### Z parameters

We will get the following set of two equations by considering the variables  $V_1$  &  $V_2$  as dependent and  $I_1$  &  $I_2$  as independent. The coefficients of independent variables,  $I_1$  and  $I_2$  are called as

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

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

The Z parameters are

$$Z_{11} = \frac{V_1}{I_1}, \text{ when } I_2 = 0$$

$$Z_{12} = \frac{V_1}{I_2}, \text{ when } I_1 = 0$$

$$Z_{21} = \frac{V_2}{I_1}, \text{ when } I_2 = 0$$

$$Z_{22} = \frac{V_2}{I_2}, \text{ when } I_1 = 0$$

Z parameters are called as impedance parameters because these are simply the ratios of voltages and currents. Units of Z parameters are Ohm ( $\Omega$ ).

We can calculate two Z parameters,  $Z_{11}$  and  $Z_{21}$ , by doing open circuit of port2. Similarly, we can calculate the other two Z parameters,  $Z_{12}$  and  $Z_{22}$  by doing open circuit of port1. Hence, the Z parameters are also called as open-circuit impedance parameters.... (1)

### For another two port parameters

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

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

$$V_1 = a_{11}V_2 - a_{12}I_2,$$

$$I_1 = a_{21}V_2 - a_{22}I_2;$$

$$V_2 = b_{11}V_1 - b_{12}I_1,$$

$$I_2 = b_{21}V_1 - b_{22}I_1;$$

$$V_1 = h_{11}I_1 + h_{12}V_2,$$

$$I_2 = h_{21}I_1 + h_{22}V_2;$$

$$I_1 = g_{11}V_1 + g_{12}I_2,$$

$$V_2 = g_{21}V_1 + g_{22}I_2.$$

Each parameter is the ratio of a voltage to a current and therefore is an impedance with the dimension of ohms. We use the same process to determine the remaining port parameters, which are either calculated or measured. A port parameter is obtained by either opening or shorting a port. Moreover, a port parameter is an impedance, an admittance, or a dimensionless ratio. The dimensionless ratio is the ratio of either two

voltages or two currents. The following equations summarize these observations..... (2)

$y_{11} = \frac{I_1}{V_1} \Big _{V_2=0} \text{ S,}$	$y_{12} = \frac{I_1}{V_2} \Big _{V_1=0} \text{ S,}$	$h_{11} = \frac{V_1}{I_1} \Big _{V_2=0} \Omega,$	$h_{12} = \frac{V_1}{V_2} \Big _{I_1=0}$
$y_{21} = \frac{I_2}{V_1} \Big _{V_2=0} \text{ S,}$	$y_{22} = \frac{I_2}{V_2} \Big _{V_1=0} \text{ S.}$	$h_{21} = \frac{I_2}{I_1} \Big _{V_2=0}$	$h_{22} = \frac{I_2}{V_2} \Big _{I_1=0} \text{ S.}$
$a_{11} = \frac{V_1}{V_2} \Big _{I_2=0}$	$a_{12} = -\frac{V_1}{I_2} \Big _{V_2=0} \Omega,$	$g_{11} = \frac{I_1}{V_1} \Big _{I_2=0} \text{ S,}$	$g_{12} = \frac{I_1}{I_2} \Big _{V_1=0}$
$a_{21} = \frac{I_1}{V_2} \Big _{I_2=0} \text{ S,}$	$a_{22} = -\frac{I_1}{I_2} \Big _{V_2=0}$	$g_{21} = \frac{V_2}{V_1} \Big _{I_2=0}$	$g_{22} = \frac{V_2}{I_2} \Big _{V_1=0} \Omega.$
$b_{11} = \frac{V_2}{V_1} \Big _{I_1=0}$	$b_{12} = -\frac{V_2}{I_1} \Big _{V_1=0} \Omega,$		
$b_{21} = \frac{I_2}{V_1} \Big _{I_1=0} \text{ S,}$	$b_{22} = -\frac{I_2}{I_1} \Big _{V_1=0}$		

Procedure:-

Part A: Z-parameters and series interconnected two port networks:-

The circuit in the Figure 3 was connected using Dc voltage with value 10V.

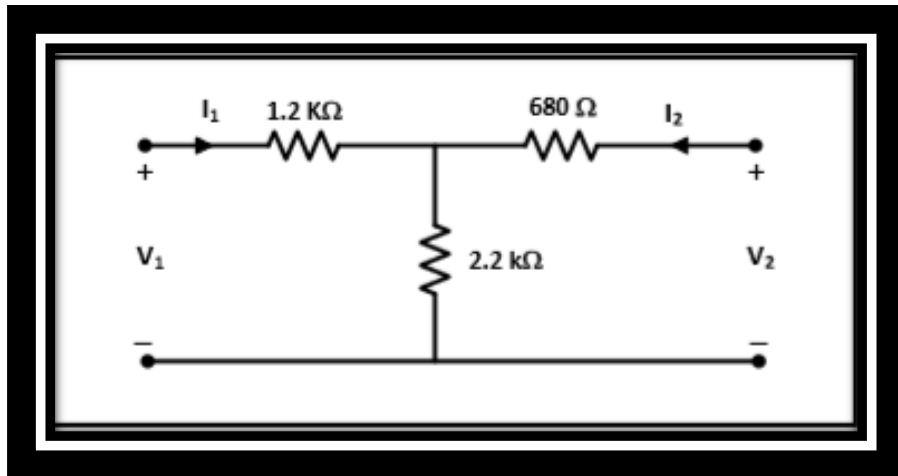


Figure 3

Initially, the value of  $V_1$  was set 10V and  $V_2$  was left open circuit ,then the value of  $I_1, I_2, V_2$  was measured using DMM and recorded in Table 1, After that,  $V_1$  was set open circuit , and  $V_2$  was set 10V, then the value of  $I_1, I_2, V_1$  was measured using DMM and recorded in Table 1.

The circuit in the Figure 4 was connected using Dc voltage with value 5V.

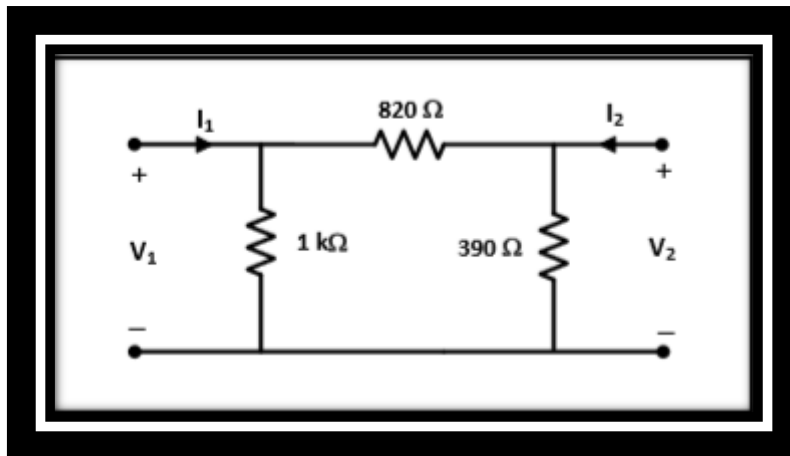


Figure 4

By repeating the steps in the previous part, The values of  $I_1, I_2$  was measured and recorded in Table 2 .

The two circuits in Figure 3,4 was connected as series interconnected and shown in the Figure 5



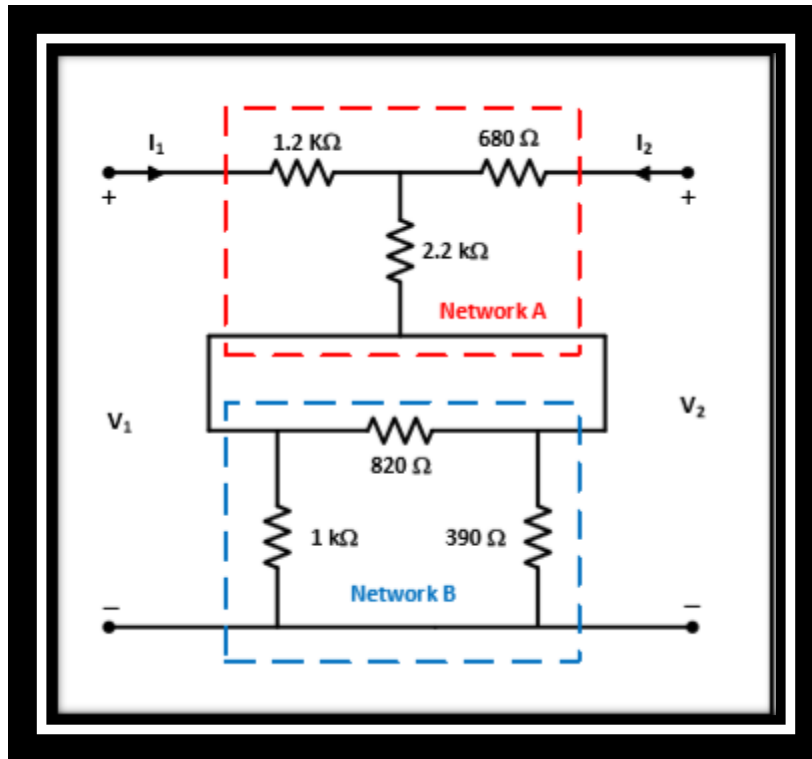


Figure 5

Initially, the value of  $V_1$  was set 10V and  $V_2$  was left open circuit ,then the value of  $I_1, I_2, V_2$  was measured using DMM and recorded in Table 1, After that,  $V_1$  was set open circuit , and  $V_2$  was set 10V, then the value of  $I_1, I_2, V_1$  was measured using DMM and recorded in Table 3.

### Part B: A-parameters and cascade interconnected two port networks

The circuit in the Figure 6 was connected as shown:

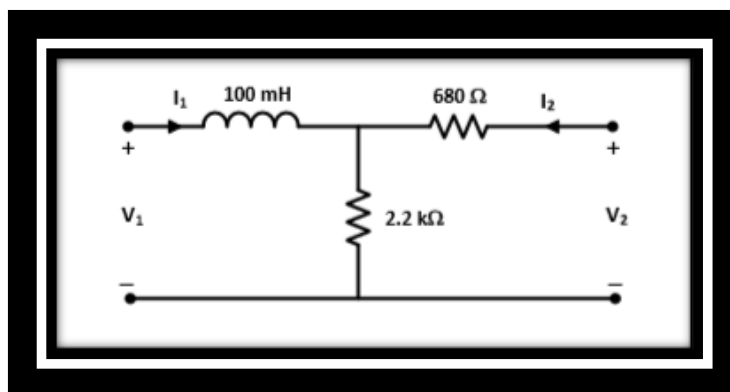


Figure 6

Initially,  $V_1$  was set to be sinusoidal with RMS value 4V and frequency 1 KHz, and  $V_2$  was left open circuit, then the value of  $I_1, I_2, V_2$  was measured using DMM and recorded in table 4, After that,  $V_1$  was set short circuit and  $V_2$  was set to be sinusoidal with RMS value 4V and frequency 1KHz, then the value of  $I_1, I_2$  was measured and recorded in table 4.

The circuit in the Figure 7 was connected and shown below

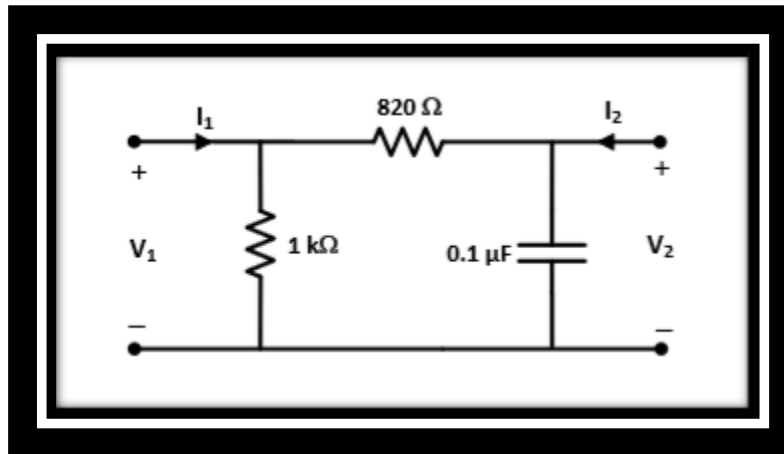


Figure 7

By repeating the steps in the previous part, the measured values were recorded in Table 5.

The two circuits in Figures 6,7 were connected as series interconnected and shown in the Figure 8

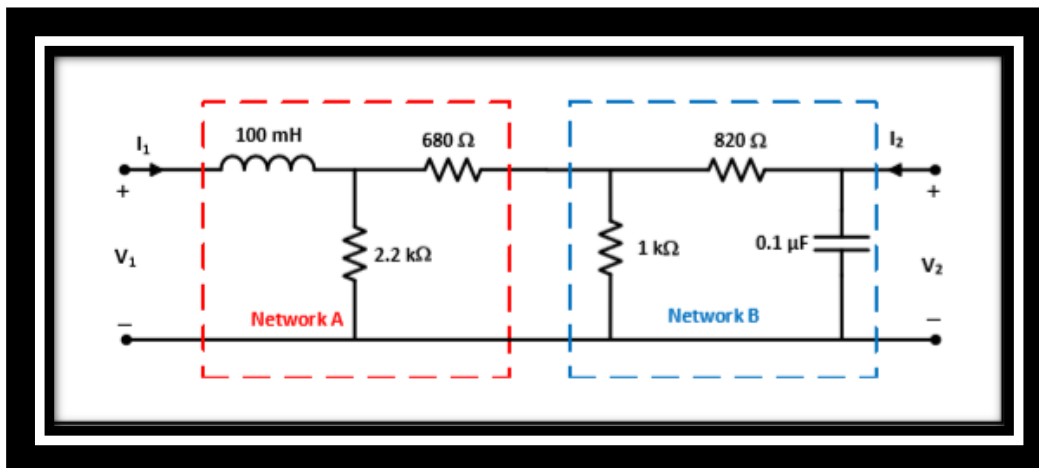


Figure 8

By repeating the steps in the previous part ,the measured values was recorded in Table 6.

### Data and calculation:-

#### Part A: Z-parameters and series interconnected two port networks:-

$$Z_{11} = 10/2.99 = 3.3 \Omega \quad Z_{21} = 6.5/2.99 = 2.1$$

$$Z_{12} = 10/3.5 = 2.85 \Omega \quad Z_{22} = 10/3.5 = 2.85$$

Input conditions		Measure		Calculate	
$V_1 = 10V$	$I_2 = 0$	$I_1 = 2.99$	$V_2 = 6.5$	$Z_{11} = 3.3$	$Z_{21} = 2.1$
$I_1 = 0$	$V_2 = 10 V$	$V_1 = 10$	$I_2 = 3.5$	$Z_{12} = 2.85$	$Z_{22} = 2.85$

Table1

$$Z_{11} = 5/0.6 = 8.3 \Omega \quad Z_{21} = 2.5/0.6 = 4.1 \Omega$$

$$Z_{12} = 4/0.33 = 13.15 \Omega \quad Z_{22} = 5/0.33 = 15.15 \Omega$$

Input conditions		Measure		Calculate	
$V_1 = 5V$	$I_2 = 0$	$I_1 = 0.6$	$V_2 = 2.5$	$Z_{11} = 8.3$	$Z_{21} = 4.1$
$I_1 = 0$	$V_2 = 5 V$	$V_1 = 4.34$	$I_2 = 0.33$	$Z_{12} = 13.15$	$Z_{22} = 15.15$

Table2

$$Z_{11} = 10/2.78 = 3.6$$

$$Z_{21} = 6.79/2.78 = 2.4$$

$$Z_{12} = 7.86/3.21 = 2.4$$

$$Z_{22} = 10/3.21 = 3.1$$

Input conditions		Measure		Calculate	
$V_1 = 10V$	$I_2 = 0$	$I_1 = 2.78$	$V_2 = 6.79$	$Z_{11} = 3.6$	$Z_{21} = 2.4$
$I_1 = 0$	$V_2 = 10 V$	$V_1 = 7.86$	$I_2 = 3.21$	$Z_{12} = 2.4$	$Z_{22} = 3.1$

Table 3

The Z-parameters in this case didn't equal the sum of the Z-parameter in the previous tables (table 1 ,table 2) because of errors was happened when the measurements talked .

### Part B: A-parameters and cascade interconnected two port networks

$$a_{11} = 4/3.68 = 1.08$$

$$a_{21} = 1.86/3.68 = 0.5$$

$$a_{12} = 4/3.57 = -1.12$$

$$a_{22} = 5.2/3.57 = -1.45$$

Input conditions		Measure		Calculate	
$V_1 = 4V_{RMS}$	$I_2 = 0$	$I_1 = 1.86$	$V_2 = 3.68$	$a_{11} = 1.08$	$a_{21} = 0.5$
$V_1 = 4 V_{RMS}$	$V_2 = 0$	$I_1 = 5.2$	$I_2 = 3.57$	$a_{12} = -1.12$	$a_{22} = -1.45$

Table 4

$$a_{11} = 4/3.2 = 1.25$$

$$a_{21} = 2.19/3.2 = 0.68$$

$$a_{12} = 4/4.27 = -0.93$$

$$a_{22} = 5.2/3.57 = -1.8$$

Input conditions		Measure		Calculate	
$V_1 = 4V_{RMS}$	$I_2 = 0$	$I_1 = 2.19$	$V_2 = 3.2$	$a_{11} = 1.25$	$a_{21} = 0.68$
$V_1 = 4 V_{RMS}$	$V_2 = 0$	$I_1 = 7.71$	$I_2 = 4.27$	$a_{12} = -0.93$	$a_{22} = -1.8$

Table 5

$$a_{11} = 4/1.403 = 2.8$$

$$a_{21} = 3.67/1.403 = 2.62$$

$$a_{12} = 4/1.34 = -2.98$$

$$a_{22} = 3.37/1.34 = -2.5$$

Input conditions		Measure		Calculate	
$V_1 = 4V_{RMS}$	$I_2 = 0$	$I_1 = 3.67$	$V_2 = 1.403$	$a_{11} = 2.8$	$a_{21} = 2.62$
$V_1 = 4 V_{RMS}$	$V_2 = 0$	$I_1 = 3.37$	$I_2 = 1.34$	$a_{12} = -2.98$	$a_{22} = 2.5$

Table 6

The A-parameters was calculated using measured value of current and voltage that recorded in table 6

To verify the results , The a-parameters in table 6 must equal to the matrix multiplication of A-parameters of the circuits in Table 4 and 5.

$$a_{11} = a_{11}' \cdot a_{11}'' + a_{12}' \cdot a_{21}'' = 2.5 \quad a_{21} = a_{21}' \cdot a_{11}'' + a_{22}' \cdot a_{21}'' = 2.1$$

$$a_{12} = a_{11}' \cdot a_{12}'' + a_{12}' \cdot a_{22}'' = -3 \quad a_{22} = a_{21}' \cdot a_{12}'' + a_{22}' \cdot a_{22}'' = -1.9$$

The previous results same with the results in table 6 with some errors because of wire connection or uncelebrated equipment.

### Conclusion :-

Two ports parameters was calculated using measured value of (V & I) ,the calculated results same with theoretical results (done in prelab) with some errors that may be refer to wire connection or uncelebrated equipment or incorrect values of resistors .

## References :-

[1] [www.tutorialspoint.com](http://www.tutorialspoint.com) 1/12/2018 12:30 Pm

[2] lab circuit manual