

BOĞAZIÇI UNIVERSITY
ELECTRICAL&ELECTRONIC ENGINEERING DEPARTMENT

EE327-ELECTRICAL NETWORK LABORATORY REPORT

Number of The Experiment : 6.....
Name of The Experiment : Two Port Parameters and Equivalent Circuits.....

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Grading

General		/20
Data		/30
Discussion		/20
Answers		/30
Total		/100
Delay		
SCORE		/100

1. THE EQUIPMENT USED IN THE LAB

- 1.1 AC Voltmeter
- 1.2 3x100Ω Resistors
- 1.3 2x10K Resistors
- 1.4 100 nF Capacitor
- 1.5 Oscilloscope
- 1.6 Breadboard

2. THEORY AND METHOD

In this experiment we calculated the z and y parameters of a circuit and then calculated the T and Π impedances from these parameters. These parameters form a relation between the input and the output of the circuit. In the following figure general form of two-port networks is shown.

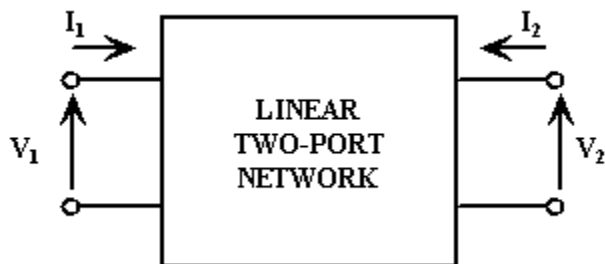


Figure: General form of two-port networks

Given that there are no independent sources or stored energy in the circuit and also dependent sources are dependent on the circuit if there are any, then V_1 , I_1 , V_2 , I_2 can be interrelated by some parameters. We have various parameters like z, y, h, t and g. Formulas for z and y which we have used in this experiment are given below.

$$\begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} z_{11} & z_{12} \\ z_{21} & z_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} \quad (Z \text{ parameters})$$

$$\begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} y_{11} & y_{12} \\ y_{21} & y_{22} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix} \quad (Y \text{ parameters})$$

By these equations, we can obtain the following ways to find the z and y parameters of a circuit.

$$z_{11} = \frac{V_1}{I_1} \Big|_{I_2 = 0} \quad z_{12} = \frac{V_1}{I_2} \Big|_{I_1 = 0} \quad z_{21} = \frac{V_2}{I_1} \Big|_{I_2 = 0} \quad z_{22} = \frac{V_2}{I_2} \Big|_{I_1 = 0}$$

$$y_{11} = \frac{I_1}{V_1} \Big|_{V_2 = 0} \quad y_{12} = \frac{I_1}{V_2} \Big|_{V_1 = 0} \quad y_{21} = \frac{I_2}{V_1} \Big|_{V_2 = 0} \quad y_{22} = \frac{I_2}{V_2} \Big|_{V_1 = 0}$$

For cases where the circuit contains reactive elements there may be phase difference between voltages and currents. In such cases we expect these parameters to be complex numbers. Experimentally, this angle of a parameter is found by Lissajou Ellipse. In the rest of the report use of this ellipse is seen in more detail.

In this experiment we worked with the following network which is a symmetric circuit. Therefore according to the formulas represented above we expect that $Z_{11}=Z_{22}$, $Z_{12}=Z_{21}$, $y_{11}=y_{22}$, $y_{12}=y_{21}$. Below that connection of the network with the AC source and the oscilloscope is shown.

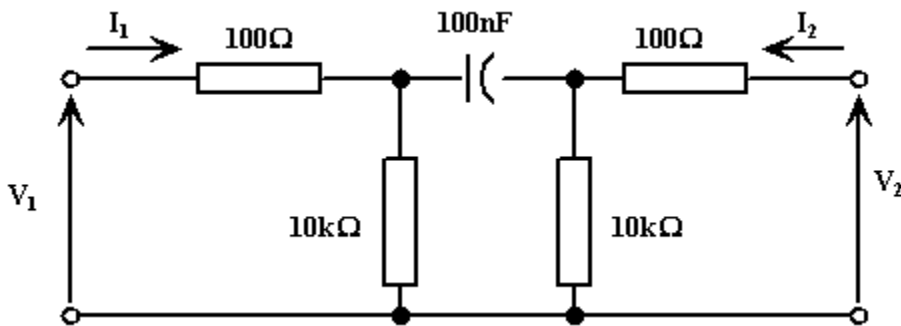


Figure: Implemented two-port network

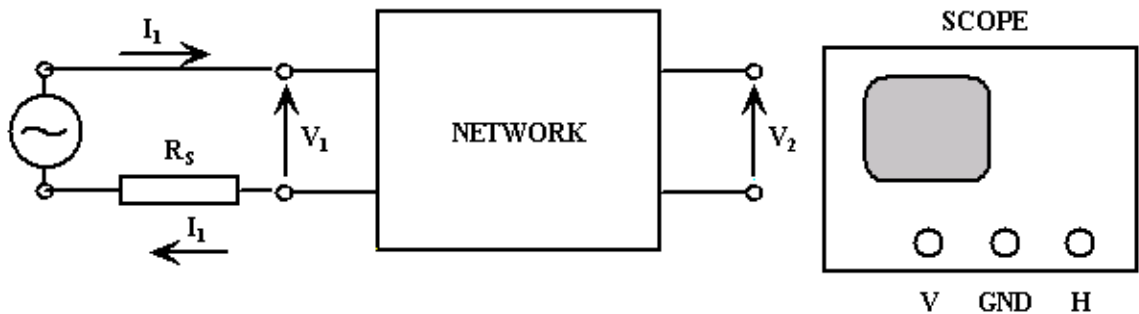


Figure: Experimental Setup

3. DATA

Below, the circuits which were implemented to fill the first two columns of the table at the end of this chapter is shown. Other two columns have the same circuits and Lissajou curves as the presented figures because of the symmetry of the circuit. Following every circuit figure, there is the corresponding Lissajou Ellipse which is obtained by simulating the circuit in Multisim. The calculations to find the angle of every parameter is given below the Lissajou Ellipse figure. This simulation part is done to represent the way we followed in order to find the angle of the parameters.

i) V_1-I_1 for $I_2=0$

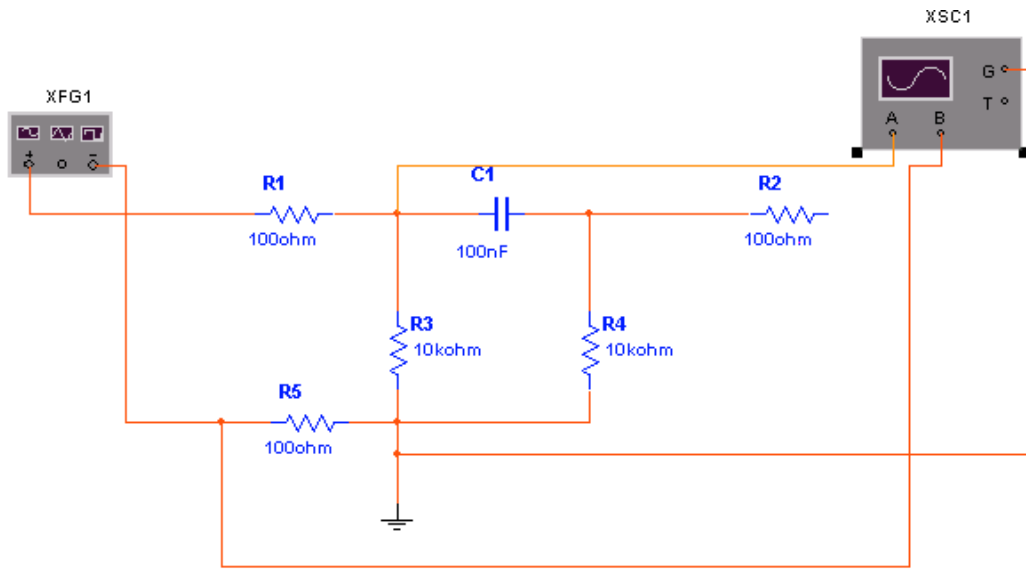


Figure: Circuit to calculate Z_{11}

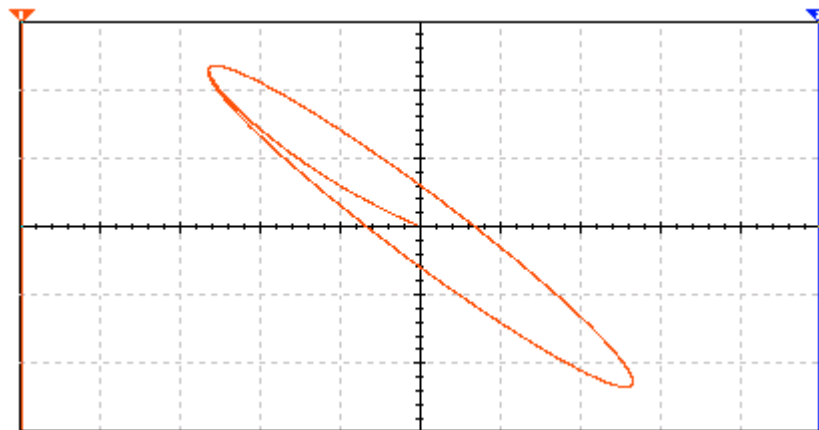


Figure: Lissajou curve for Z_{11} (V_1/I_1)

From the figure, we have, $\sin^{-1}(4/12)=14.5^\circ$. Direction of motion is CW. Since the ellipse lies in the 2nd and 4th quadrant, $90^\circ < \theta < 180^\circ$. Then $\theta=180-14.5=165.5^\circ$. Also since I_1 is reversed, we subtract 180° and obtain $\theta=165.5-180=-14.5^\circ$.

ii) V_2-I_1 for $I_2=0$

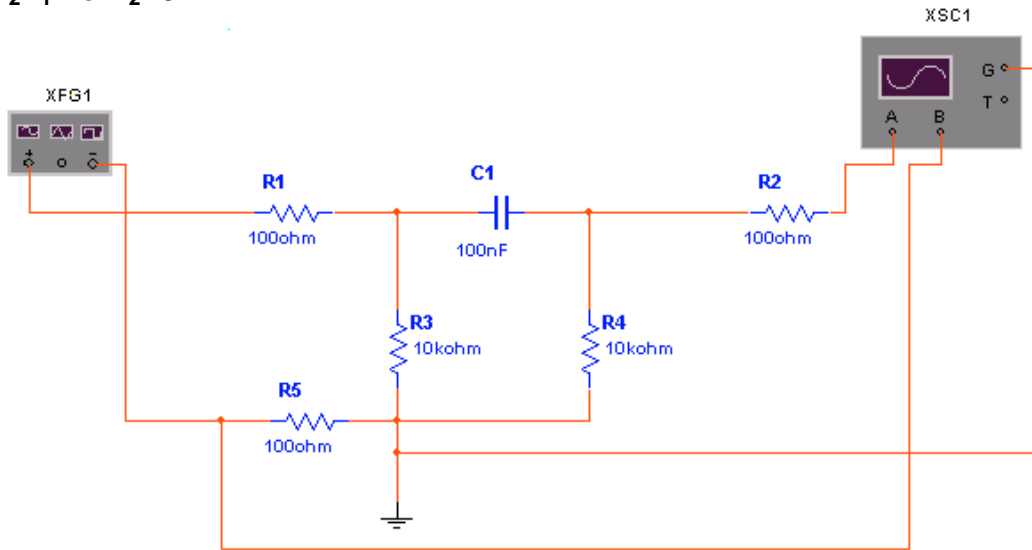


Figure: Circuit to calculate Z_{21}

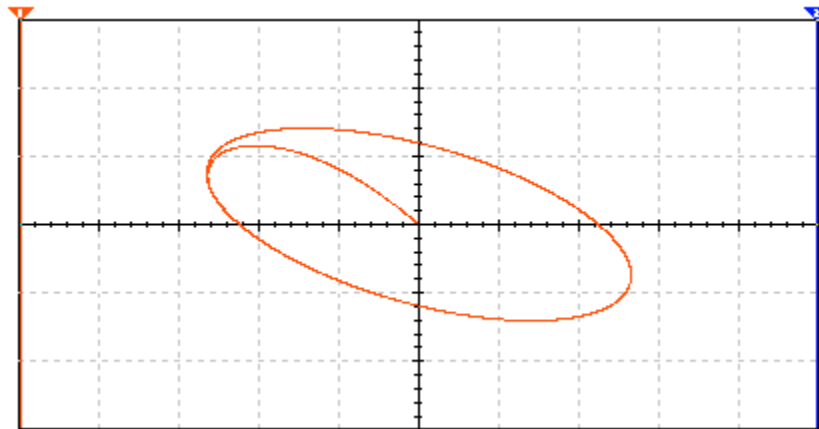


Figure: Lissajou curve for Z_{21} (V_2/I_1)

From the figure, we have, $\sin^{-1}(6/7) = 58.9^\circ$. Direction of motion is CCW. So $\theta = -58.9^\circ$. Since the ellipse lies in the 2nd and 4th quadrant, $90^\circ < |\theta| < 180^\circ$. Then $\theta = -180^\circ - (-58.9^\circ) = -121.1^\circ$. Also since I_1 is reversed, we subtract 180° and obtain $\theta = -121.1^\circ - 180^\circ = -301.1^\circ = 58.9^\circ$.

iii) I_1-V_1 for $V_2=0$

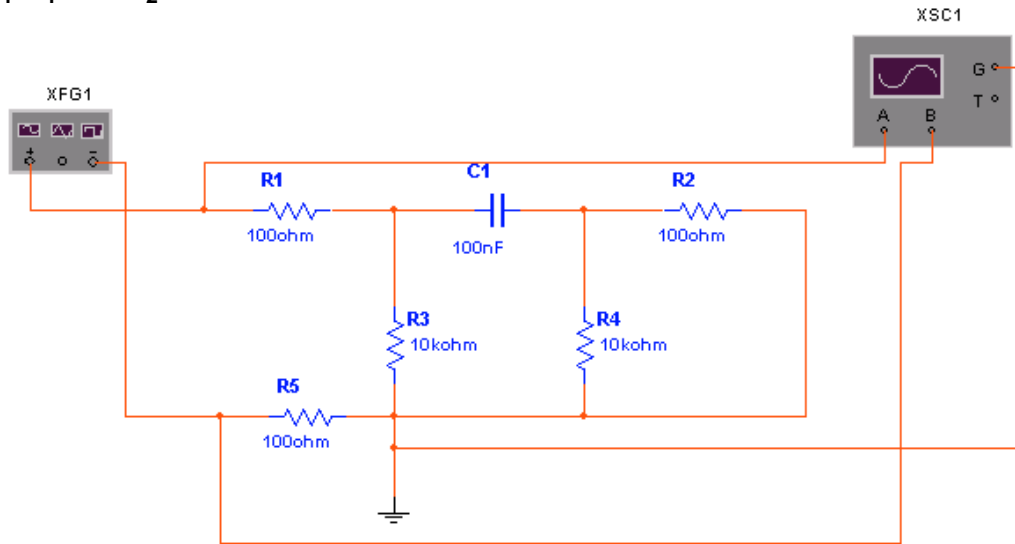


Figure: Circuit to calculate y_{11}

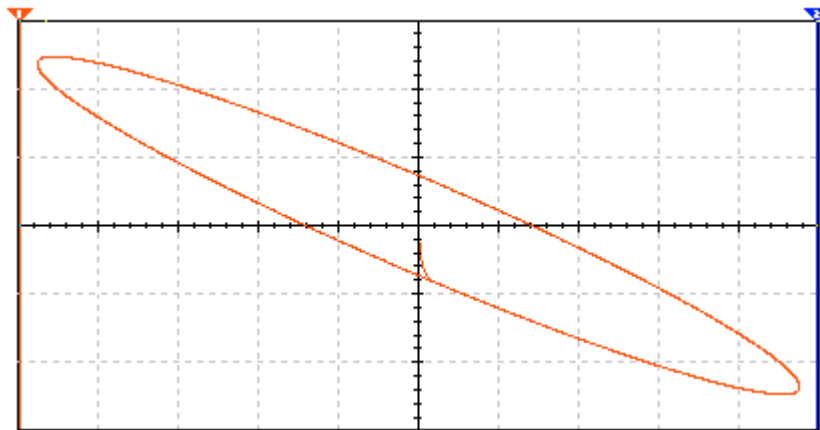


Figure: Lissajou curve for y_{11} (I_1/V_1)

From the figure, we have, $\sin^{-1}(3.5/12) = 17.0^\circ$. Direction of motion is CCW. So $\theta = -17.0$. Since the ellipse lies in the 2nd and 4th quadrant, $90 < |\theta| < 180$. Then $\theta = -180 - (-17.0) = -163^\circ$. Also since I_1 is reversed, we subtract 180° and obtain $\theta = -163 - 180 = -343^\circ = 17.0^\circ$.

iv) I_2-V_1 for $V_2=0$

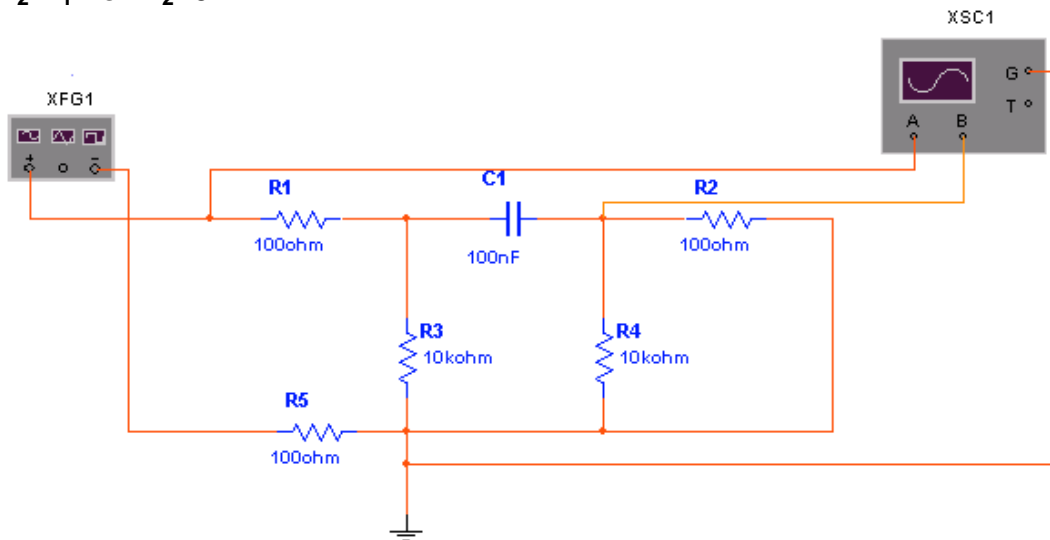


Figure: Circuit to calculate y_{21}

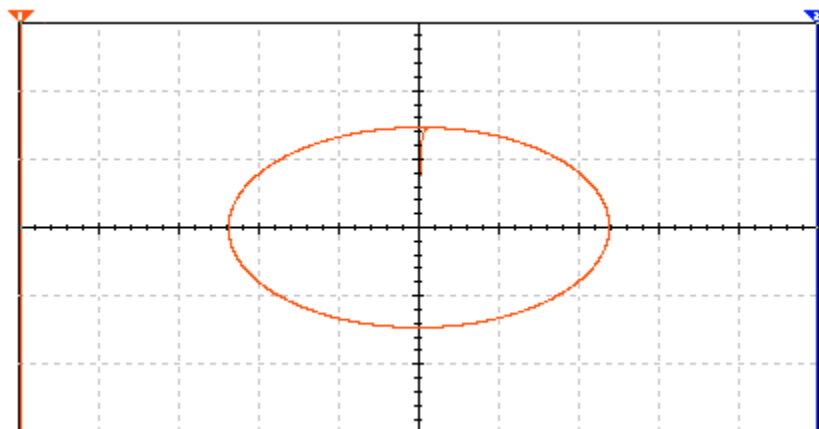


Figure: Lissajou curve for y_{21} (I_2/V_1)

It seems from the figure that the $\theta = \sin^{-1}(1/1) = 90^\circ$. Here we have I_2 reversed, therefore we subtract 180° and obtain $\theta = -90^\circ$.

Real values of the z and y parameters of the circuit was found beforehand by exploiting the capabilities of MATLAB according to the formulas given in part 2.

	Z_{11}	Z_{12}	Z_{21}	Z_{22}
Calculated	$8.97 \cdot 10^3 \angle -14.5^\circ$	$2.69 \cdot 10^3 \angle 57.9^\circ$	$2.69 \cdot 10^3 \angle 57.9^\circ$	$8.97 \cdot 10^3 \angle -14.5^\circ$
Measured	$8.61 \cdot 10^3 \angle -15.3^\circ$	$2.52 \cdot 10^3 \angle 58.5^\circ$	$2.54 \cdot 10^3 \angle 58.2^\circ$	$8.56 \cdot 10^3 \angle -15.0^\circ$

Table: Calculated and measured values of Z parameters

	y_{11}	y_{12}	y_{21}	y_{22}
Calculated	$1.04 \cdot 10^{-4} \angle 17.2^\circ$	$3.08 \cdot 10^{-5} \angle -90.5^\circ$	$3.08 \cdot 10^{-5} \angle -90.5^\circ$	$1.04 \cdot 10^{-4} \angle 17.2^\circ$
Measured	$1.11 \cdot 10^{-4} \angle 15.8^\circ$	$3.15 \cdot 10^{-5} \angle -90^\circ$	$2.90 \cdot 10^{-5} \angle -90^\circ$	$1.09 \cdot 10^{-4} \angle 16.1^\circ$

Table: Calculated and measured values of y parameters

$I_2=0$		$V_2=0$		$I_1=0$		$V_1=0$	
V_1	V_2	V_1	V_1	V_2	V_1	V_2	V_2
12.05	3.55	12.05	12.05	12.05	3.55	12.05	12.05
I_1	I_1	I_1	I_2	I_2	I_2	I_2	I_1
1.40	1.40	1.34	0.35	1.41	1.41	1.32	0.38
q	q	q	q	q	q	q	q
-15.3	58.2	15.8	-90	-15.0	58.5	16.1	-90
$ Z_{11} $	$ Z_{21} $	$ y_{11} $	$ y_{21} $	$ Z_{22} $	$ Z_{12} $	$ y_{22} $	$ y_{12} $
$8.61 \cdot 10^3$	$2.54 \cdot 10^3$	$1.11 \cdot 10^{-4}$	$2.90 \cdot 10^{-5}$	$8.56 \cdot 10^3$	$2.52 \cdot 10^3$	$1.09 \cdot 10^{-4}$	$3.15 \cdot 10^{-5}$

Table: Measured voltage values in V, current values in mA, Z's in Ω , Y's in S.

T-Network Impedances	II-Network Admittances
$Z_a = (Z_{21} + Z_{12})/2 = 2.53 \cdot 10^3 \angle 58.3^\circ$	$Y_A = y_{11} + y_{12} = 1.068 \angle -0.69^\circ$
$Z_b = Z_{11} - Z_{12} = 6.97 \cdot 10^3 \angle -0.93^\circ$	$Y_B = -(y_{12} + y_{21})/2 = -3.02 \cdot 10^{-5} \angle -90^\circ$
$Z_c = Z_{22} - Z_{21} = 9.60 \cdot 10^3 \angle -0.3^\circ$	$Y_C = y_{22} + y_{21} = 1.05 \angle 0.66^\circ$

Table: Calculated values of network impedances and admittances

4. ANALYSIS AND DISCUSSION

-In this experiment, surprisingly, we had our measured values very close to the theoretical values. This is surprising because the oscilloscope seemed to be drawing distorted Lissajou ellipses. However the calculations carried out according to these distorted ellipses turned out to be close to the theoretical values.

-Beside this distortion of the Lissajou Ellipse, the oscilloscope was not successful in giving us any idea about the direction of motion, whether it is clockwise or counter-clockwise.

Therefore, we did not calculate the angles of the parameters in the manner they should be calculated. We looked at our theoretical values of the angles and then determined the sign of our measured values accordingly. However, in the 3rd part of this report, simulation results presented which are obtained by a perfect Multisim oscilloscope. The way of finding the angle of a parameter is given with this simulations.

-One important thing I've learned in this experiment was that grounds of both probes of the oscilloscope were the same. Without knowing this, at the beginning of the experiment we tried to see the both signals from V_1 and I_1 (voltage over the resistor) without connecting the extra R_S resistor. But we failed to do so, then we've realised that both probes have the same ground.

-During the experiment we didn't find $Z_{11}=Z_{22}$, $Z_{12}=Z_{21}$, $y_{11}=y_{22}$, $y_{12}=y_{21}$. There were little differences between these values due to the resistance tolerances.

-There seems to be an error in the name of the second column of the last table in the lab book. The word "Impedance" should be replaced with "Admittance".

5. ANSWERS TO THE QUESTIONS

1.

$$Z = Y^{-1} \Rightarrow Z = \begin{bmatrix} y_{11} & y_{12} \\ y_{21} & y_{22} \end{bmatrix}^{-1} = \frac{1}{y_{11}y_{22} - y_{12}y_{21}} \begin{bmatrix} y_{22} & -y_{12} \\ -y_{21} & y_{11} \end{bmatrix}$$

$$Y = Z^{-1} \Rightarrow Y = \begin{bmatrix} z_{11} & z_{12} \\ z_{21} & z_{22} \end{bmatrix}^{-1} = \frac{1}{z_{11}z_{22} - z_{12}z_{21}} \begin{bmatrix} z_{22} & -z_{12} \\ -z_{21} & z_{11} \end{bmatrix}$$

2.

$$\frac{Z(\text{at port 1; port 2 oc})}{Z(\text{at port 1; port 2 sc})} \stackrel{?}{=} \frac{Z(\text{at port 2; port 1 oc})}{Z(\text{at port 2; port 1 sc})}$$

$$\frac{\left. \frac{V_1}{I_1} \right|_{I_2=0}}{1} \stackrel{?}{=} \frac{\left. \frac{V_2}{I_2} \right|_{I_1=0}}{1} \Rightarrow \frac{z_{11}}{1} \stackrel{?}{=} \frac{z_{22}}{1}$$

$$\frac{\left. \frac{I_1}{V_1} \right|_{V_2=0}}{1} \stackrel{?}{=} \frac{\left. \frac{I_2}{V_2} \right|_{V_1=0}}{1} \Rightarrow \frac{y_{11}}{1} \stackrel{?}{=} \frac{y_{22}}{1}$$

$$\Rightarrow \frac{y_{11}}{y_{22}} \stackrel{?}{=} \frac{z_{22}}{z_{11}}$$

From the first question replace y's in terms of z's.

$$\Rightarrow \frac{z_{22}/\Delta Z}{z_{11}/\Delta Z} = \frac{z_{22}}{z_{11}}$$

$$\Rightarrow \frac{z_{22}}{z_{11}} = \frac{z_{22}}{z_{11}}$$