4. Laboratory work. Electrical Circuit Analysis Methods.

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Table 1. Values of parameters

Test board numbers		1	2	3	4	5	6	7
Parameters	R_{i1}, kΩ	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	R_{i2}, Ω	100	120	100	120	100	120	100
	R_1, kΩ	1.5	1.3	1.8	1.2	1.5	1.3	1.8
	R_2, kΩ	2.0	2.0	2.0	2.0	2.0	2.0	2.0
	R_3, kΩ	2.4	2.7	2.4	2.7	2.4	2.7	2.4
	R_4, kΩ	3.3	3.6	3.3	3.6	3.3	3.6	3.3
	R_5, kΩ	1.5	1.8	1.3	1.2	1.5	1.2	1.3
	R_6, kΩ	1.0	1.1	1.0	1.1	1.0	1.1	1.0
	u_{s1}, V	20	22	24	20	22	24	20
	u_{s2}, V	5	6	6	8	6	8	6
	R_x	R_1	R_2	R_3	R_4	R_5	R_6	R_1
	Reference node	1	3	2	4	1	3	4

1. Make connections between test board elements as specified in Figure 1. Set the output voltages of the power supply to u_{s1} un u_{s2}, respectively. (see Table 1). In order to verify experimentally the results obtained by using both Mesh Analysis and Nodal analysis
   - 1.1. measure the current through each branch
   - 1.2. designate the reference node according to Table 1 and measure each node voltage

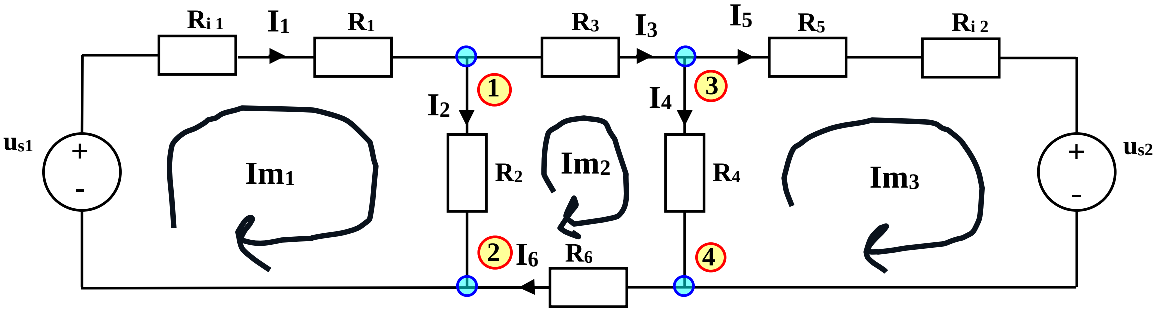


Fig 1. The circuit for the measurement of currents and voltages

Table 1. Measured branch currents

Quantity	I_{R1}	I_{R2}	I_{R3}	I_{R4}	I_{R5}	I_{R6}
Value, mA Calculated	5.596	4.564	1.032	1.446	-0.414	1.032
Value, mA LTspice	5.596	4.564	1.032	1.446	-0.414	1.032
Value, mA Measured						

Mesh Analysis for calculating the loop currents

Loop 1 – Im_1

$$-V_{s1} + Im_1(R_{i1} + R_1) + R_2(Im_1 - Im_2) = 0$$
$$Im_1(R_{i1} + R_1 + R_2) - Im_2(R_2) = V_{s1}$$

Loop 2 – Im_2

$$Im_2(R_3) + R_4(Im_2 - Im_3) + Im_2(R6) - R_2(Im_1 - Im_2) = 0$$
$$-Im_1(R_2) + Im_2(R_3 + R_4 + R_6 + R_2) - Im_3(R_4) = 0$$

Loop 3 – Im_3

$$Im_3(R_5 + R_{i2}) + V_{s2} - R_4(Im_2 - Im_3) = 0$$
$$-Im_2(R_4) + Im_3(R_5 + R_{i2} + R_4) = -V_{s2}$$

$$\begin{pmatrix} (R\_i1 + R1 + R2) & -R2 & 0 \\ (-R2) & (R2 + R3 + R4 + R6) & -R4 \\ 0 & -R4 & (R4 + R5 + R\_i2) \end{pmatrix} \begin{pmatrix} Im_1 \\ Im_2 \\ Im_3 \end{pmatrix} = \begin{pmatrix} V_{s1} \\ 0 \\ -V_{s2} \end{pmatrix}$$

$$\boldsymbol{Im_1 = 5.5964\ mA}$$
$$\boldsymbol{Im_2 = 1.0323\ mA}$$
$$\boldsymbol{Im_3 = -0.4137\ mA}$$

Branch Currents and Mesh Currents equivalence

$$I_1 = Im_1 = 5.5964\ mA$$
$$I_2 = Im_1 - Im_2 = 4.5641\ mA$$
$$I_3 = Im_2 = 1.0323\ mA$$
$$I_4 = Im_2 - Im_3 = 1.4460\ mA$$
$$I_5 = Im_3 = -0.4137\ mA$$
$$I_6 = Im_2 = 1.0323\ mA$$

Table 2. Measured node voltages

Quantity	U_1	U_2	U_4
Value, V Calculated	2.787	-6.341	-5.206
Value, V LTspice	2.787	-6.341	-5.206
Value, V Measured			

Nodal Analysis for calculating Nodal voltages

$$V3 = 0V \text{ as it is ground}$$
$$G = \frac{1}{R} \rightarrow \text{this is conductance}$$
$$G_{i11} = \frac{1}{Ri1 + R1} \quad \text{and } G_{i25} = \frac{1}{Ri2 + R5}$$

<u>Node V1</u>

$$(V1 - V_{s1} - V2) * G_{i11} - (0 - V1) * G_3 - (V2 - V1) * G_2 = 0$$
$$V1(G_{i11} + G_3 + G_2) - V2(G_{i11} + G_2) = V_{s1} * G_{i11}$$

<u>Node V2</u>

$$-(V1 - V_{s1} - V2) * G_{i11} + (V2 - V4) * G_6 + (V2 - V1) * G_2 = 0$$
$$-V1(G_{i11} + G_2) + V2(G_{i11} + G_6 + G_2) - V4(G_6) = -V_{s1} * G_{i11}$$

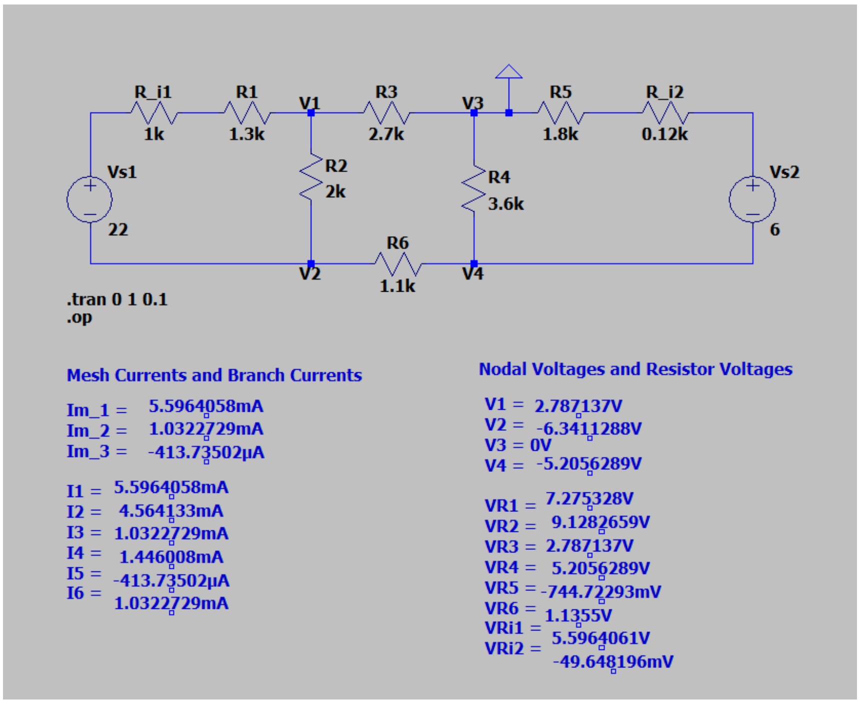
<u>Node V4</u>

$$-(V2 - V4) * G_6 + (V4 + V_{s2} - 0) * G_{i25} + (V4 - 0) * G_4 = 0$$
$$-V2(G_6) + V4(G_6 + G_{i25} + G_4) = -V_{s2} * G_{i25}$$

$$\begin{pmatrix} (G_{i11} + G_3 + G_2) & -(G_{i11} + G_6 + G_2) & 0 \\ -(G_{i11} + G_2) & (R2 + R3 + R4 + R6) & -G_6 \\ 0 & -G_6 & (G_6 + G_{i25} + G_4) \end{pmatrix} \begin{pmatrix} V1 \\ V2 \\ V4 \end{pmatrix} = \begin{pmatrix} V_{s1} * G_{i11} \\ -V_{s1} * G_{i11} \\ -V_{s2} * G_{i25} \end{pmatrix}$$

$$\boldsymbol{V1 = 2.7871\ V}$$
$$\boldsymbol{V2 = -6.3411\ V}$$
$$\boldsymbol{V4 = -5.2056\ V}$$

LTspice Simulation for Question 1



2. To verify experimentally that Thevenin's and Nortons theorems hold

2.1. replace R_x with an open-circuit and measure the voltage across the terminals of the network external to the resistor R_x (see Table 1) u_{oc} = _______ V

2.2. replace R_x with a short-circuit and measure the current through it i_{sc} = mA

2.3. use ohmmeter to measure the Thevenin equivalent resistance R_{th} = kΩ

2.4. Using the following formula, check the correctness of the measured values of short-circuit current, open-circuit voltage and Thevenin equivalent resistance:

$R_{\text{th}} = \frac{u_{oc}}{i_{sc}}$ = __________

3. To verify experimentally the validity of the superposition and compensation principles, measure

3.1. the current through each branch, with u_{s1} acting alone

u_{s1};

Table 3. Measured branch currents, when u_{s2} is switched off

Quantity	**I_{R1}**	**I_{R2}**	**I_{R3}**	**I_{R4}**	**I_{R5}**	**I_{R6}**
Value, mA Calculated	5.894	4.222	1.671	0.581	1.090	1.671
Values, mA LTspice	5.894	4.222	1.671	0.581	1.090	1.671
Values, mA Measured						

Mesh Analysis for calculating the loop currents

$$\boldsymbol{V_{s2} = 0V; since\ only\ V_{s1}\ is\ working\ alone}$$

<u>Loop 1 – Im_1</u>

$$-V_{s1} + Im_1(R_{i1} + R_1) + R_2(Im_1 - Im_2) = 0$$
$$Im_1(R_{i1} + R_1 + R_2) - Im_2(R_2) = V_{s1}$$

<u>Loop 2 – Im_2</u>

$$Im_2(R_3) + R_4(Im_2 - Im_3) + Im_2(R6) - R_2(Im_1 - Im_2) = 0$$
$$-Im_1(R_2) + Im_2(R_3 + R_4 + R_6 + R_2) - Im_3(R_4) = 0$$

<u>Loop 3 – Im_3</u>

$$Im_3(R_5 + R_{i2}) + V_{s2} - R_4(Im_2 - Im_3) = 0$$
$$-Im_2(R_4) + Im_3(R_5 + R_{i2} + R_4) = -V_{s2}$$

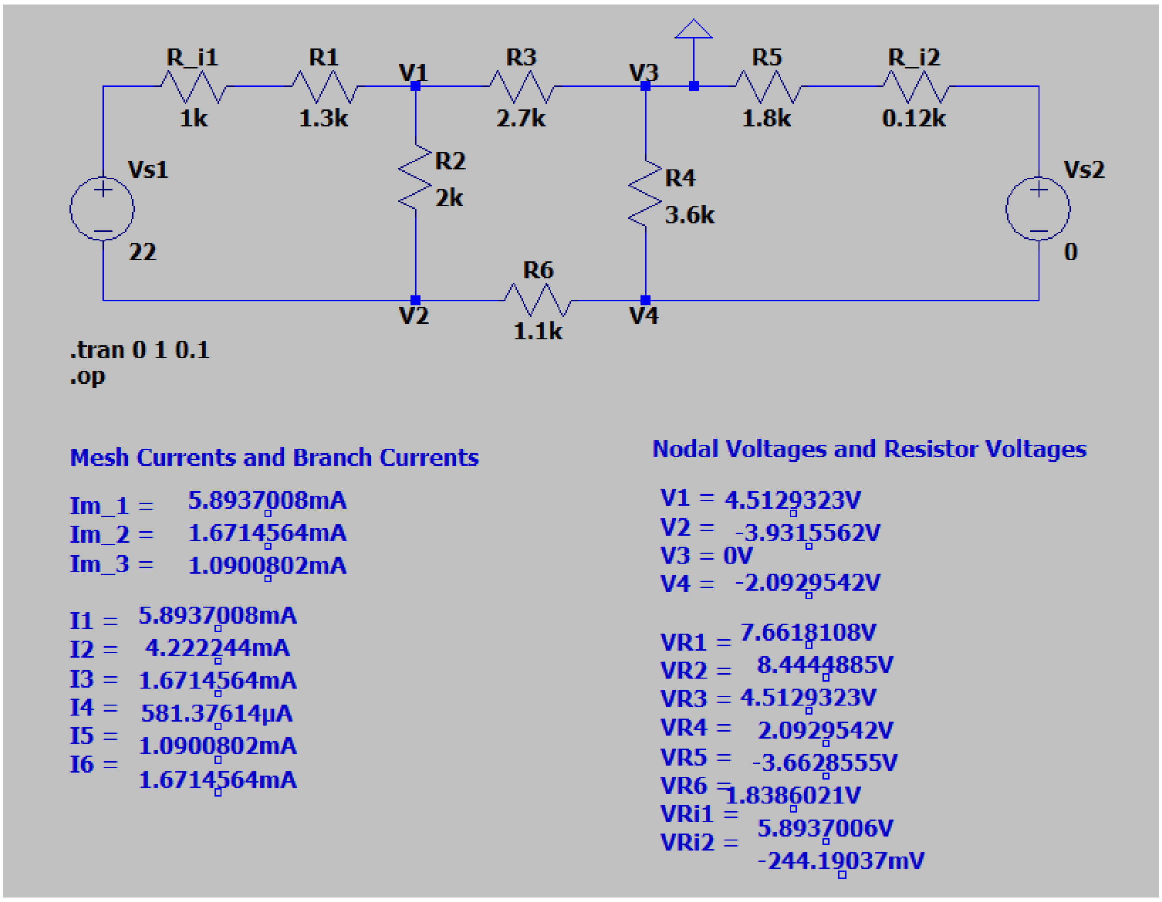
$$\begin{pmatrix} (R\_i1 + R1 + R2) & -R2 & 0 \\ (-R2) & (R2 + R3 + R4 + R6) & -R4 \\ 0 & -R4 & (R4 + R5 + R\_i2) \end{pmatrix} \begin{pmatrix} Im_1 \\ Im_2 \\ Im_3 \end{pmatrix} = \begin{pmatrix} V_{s1} \\ 0 \\ -V_{s2} \end{pmatrix}$$

$$\boldsymbol{Im_1 = 5.8937mA}$$
$$\boldsymbol{Im_2 = 1.6715\ mA}$$
$$\boldsymbol{Im_3 = 1.0901\ mA}$$

Branch Currents and Mesh Currents equivalence

$$I_1 = Im_1 = 5.8937\ mA$$
$$I_2 = Im_1 - Im_2 = 4.2222\ mA$$
$$I_3 = Im_2 = 1.6714\ mA$$
$$I_4 = Im_2 - Im_3 = 0.5814mA$$
$$I_5 = Im_3 = 1.0901\ mA$$
$$I_6 = Im_2 = 1.6715\ mA$$

LTspice Simulation for Question 3.1)



3.2. the voltage u_{R3} = ________ V, when only the first voltage source is active u_{s1};

Calculations Used :

$$\boldsymbol{U_{R3}} = I_3 * R_3 = 1.6715\ mA * 2.7k = \boldsymbol{4.513\ V}$$

This U_R3 values can also be seen in the above LTspice Simulation of Question 3.1.

3.3. the current through each branch, with u_{s2} acting alone

Table 4. Measured branch currents, when u_{s1} is switched off

Quantity	**I_{R1}**	**I_{R2}**	**I_{R3}**	**I_{R4}**	**I_{R5}**	**I_{R6}**
Value, mA Calculated	-0.297	0.342	-0.639	0.864	-1.504	-0.639
Value, mA LTspice	-0.297	0.342	-0.639	0.864	-1.504	-0.639
Value, mA Measured						

Mesh Analysis for calculating the loop currents

$$\boldsymbol{V_{s1} = 0V; since\ only\ V_{s2}\ is\ working\ alone}$$

Loop 1 – Im_1

$$-V_{s1} + Im_1(R_{i1} + R_1) + R_2(Im_1 - Im_2) = 0$$
$$Im_1(R_{i1} + R_1 + R_2) - Im_2(R_2) = V_{s1}$$

Loop 2 – Im_2

$$Im_2(R_3) + R_4(Im_2 - Im_3) + Im_2(R6) - R_2(Im_1 - Im_2) = 0$$
$$-Im_1(R_2) + Im_2(R_3 + R_4 + R_6 + R_2) - Im_3(R_4) = 0$$

Loop 3 – Im_3

$$Im_3(R_5 + R_{i2}) + V_{s2} - R_4(Im_2 - Im_3) = 0$$
$$-Im_2(R_4) + Im_3(R_5 + R_{i2} + R_4) = -V_{s2}$$

$$\begin{pmatrix} (R\_i1 + R1 + R2) & -R2 & 0 \\ (-R2) & (R2 + R3 + R4 + R6) & -R4 \\ 0 & -R4 & (R4 + R5 + R\_i2) \end{pmatrix} \begin{pmatrix} Im_1 \\ Im_2 \\ Im_3 \end{pmatrix} = \begin{pmatrix} V_{s1} \\ 0 \\ -V_{s2} \end{pmatrix}$$

$$\boldsymbol{Im_1 = -0.2973mA}$$
$$\boldsymbol{Im_2 = -0.6392\ mA}$$
$$\boldsymbol{Im_3 = \ -1.5038\ mA}$$

Branch Currents and Mesh Currents equivalence

$$I_1 = Im_1 = -0.2973\ mA$$
$$I_2 = Im_1 - Im_2 = \ 0.3419\ mA$$
$$I_3 = Im_2 = -0.6392\ mA$$
$$I_4 = Im_2 - Im_3 = 0.8646mA$$
$$I_5 = Im_3 = -1.5038\ mA$$
$$I_6 = Im_2 = -0.6392\ mA$$

3.4. the current through each branch, when u_{s1} is acting alone and the other voltage source is set to u_{R3} and connected in place of the resistor R_3 (polarities of both elements mush agree).

Table 5. Measured branch currents, when u_{s2} = u_{R3} is connected in place of R3

Quantity	I_{R1}	I_{R2}	I_{R3}	I_{R4}	I_{R5}	I_{R6}
Value, mA Calculated	5.894	4.222	1.671	0.581	1.090	1.671
Value, mA LTspice	5.894	4.222	1.671	0.581	1.090	1.671
Value, mA Measured						

Mesh Analysis for calculating the loop currents

$$\boldsymbol{V_{s2} = 0V; since\ only\ V_{s1}\ is\ working\ alone}$$
$$\boldsymbol{R_3\ is\ replaced\ with\ a\ Voltage\ Source\ of\ V_{R3} = 4.513\ V}$$

<u>Loop 1 – Im1</u>

$$-V_{s1} + Im_1(R_{i1} + R_1) + R_2(Im_1 - Im_2) = 0$$
$$Im_1(R_{i1} + R_1 + R_2) - Im_2(R_2) = V_{s1}$$

<u>Loop 2 – Im2</u>

$$V\_R3 + R_4(Im_2 - Im_3) + Im_2(R6) - R_2(Im_1 - Im_2) = 0$$
$$-Im_1(R_2) + Im_2(R_4 + R_6 + R_2) - Im_3(R_4) = -V\_R3$$

<u>Loop 3 – Im3</u>

$$Im_3(R_5 + R_{i2}) + V_{s2} - R_4(Im_2 - Im_3) = 0$$
$$-Im_2(R_4) + Im_3(R_5 + R_{i2} + R_4) = -V_{s2}$$

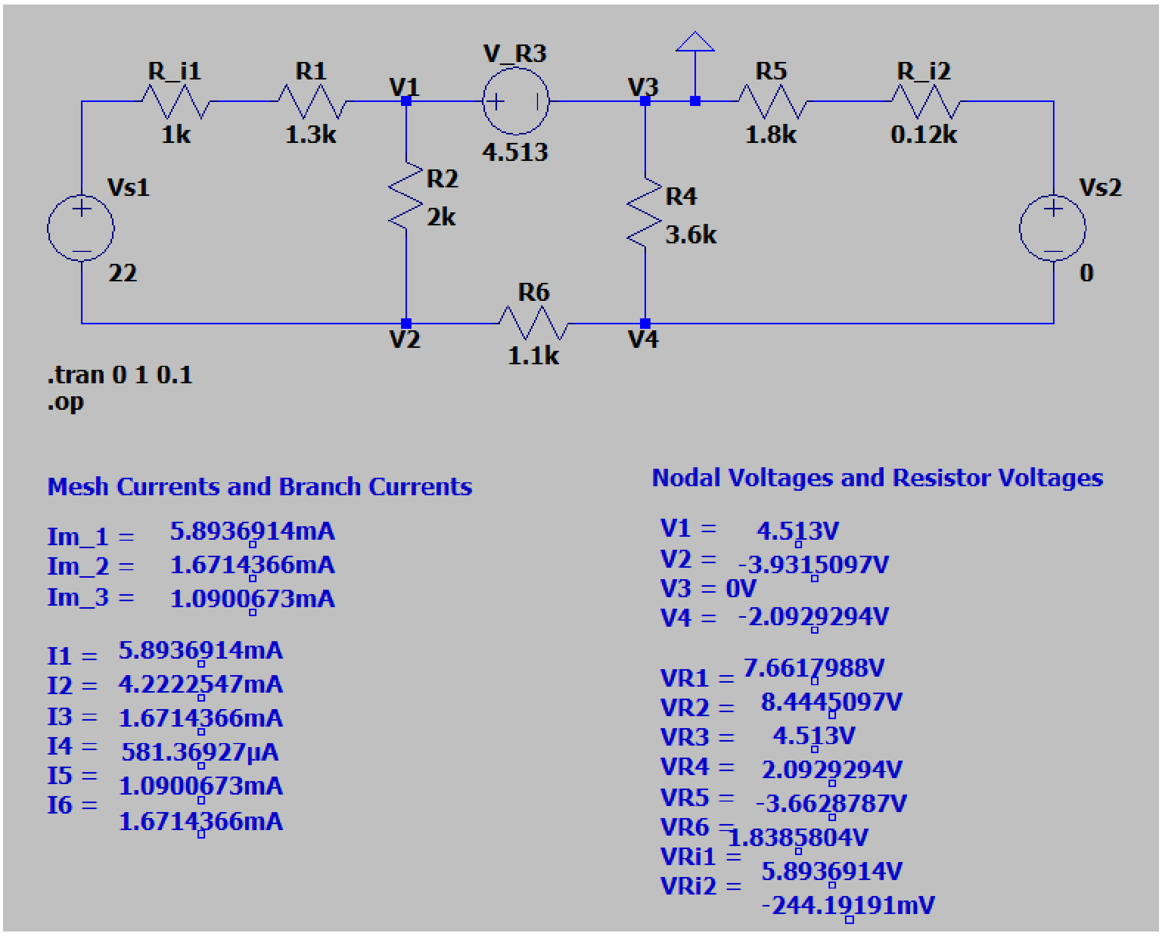
$$\begin{pmatrix} (R\_i1 + R1 + R2) & -R2 & 0 \\ (-R2) & (R2 + R4 + R6) & -R4 \\ 0 & -R4 & (R4 + R5 + R\_i2) \end{pmatrix} \begin{pmatrix} Im_1 \\ Im_2 \\ Im_3 \end{pmatrix} = \begin{pmatrix} V_{s1} \\ -V\_R3 \\ -V_{s2} \end{pmatrix}$$

$$\boldsymbol{Im_1 = 5.8937mA}$$
$$\boldsymbol{Im_2 = 1.6714\ mA}$$
$$\boldsymbol{Im_3 = 1.0901\ mA}$$

Branch Currents and Mesh Currents equivalence

$$I_1 = Im_1 = 5.8937\ mA$$
$$I_2 = Im_1 - Im_2 = 4.2222\ mA$$
$$I_3 = Im_2 = 1.6714\ mA$$
$$I_4 = Im_2 - Im_3 = 0.5814mA$$
$$I_5 = Im_3 = 1.0901\ mA$$
$$I_6 = Im_2 = 1.6714\ mA$$

LTspice Simulation for question 3.4



4. So as to verify the reciprocity principle experimentally, measure:

4.1. the current i_{R5}= ________ mA, with u_{s1} acting alone

4.2. the current i_{R1}= ________ mA, with u_{s1} acting alone and connected in place of the second one (swap the ammeter and voltage source)

5. Using LTSpice electrical circuit simulation software

5.1 build the model of the circuit of Figure 1 and determine the current though each branch, as well as each node voltage (the reference node must be the same as in 1.2). Record the results of the simulation in Tables 6 and 7

Table 6. Branch currents obtained by LTSpice

Quantity	I_{R1}	I_{R2}	I_{R3}	I_{R4}	I_{R5}	I_{R6}
Value, mA						

Table 7. Node voltages obtained by LTSpice

Quantity	U_	U_	U_
Value, V			

5.2. for the same circuit find the open-circuit voltage u_{oc} = _________ V and short-circuit current i_{sc} =_________ mA

Open-Circuit Voltage Calculations

Nodal Analysis for calculating Nodal voltages

$$V3 = 0V \ as\ it\ is\ ground$$
$$G = \frac{1}{R} \rightarrow this\ is\ conductance$$
$$G_{i11} = \frac{1}{Ri1 + R1} \quad and\ G_{i25} = \frac{1}{Ri2 + R5}$$

$\boldsymbol{R_X = R_2}$,

And it is open-circuited at the place of the R2 with reference to the Figure 1 in Question 1

$\boldsymbol{So: \ G_2 = 0}$,

Node V1

$$(V1 - V_{s1} - V2) * G_{i11} - (0 - V1) * G_3 - (V2 - V1) * G_2 = 0$$
$$V1(G_{i11} + G_3 + G_2) - V2(G_{i11} + G_2) = V_{s1} * G_{i11}$$

Node V2

$$-(V1 - V_{s1} - V2) * G_{i11} + (V2 - V4) * G_6 + (V2 - V1) * G_2 = 0$$
$$-V1(G_{i11} + G_2) + V2(G_{i11} + G_6 + G_2) - V4(G_6) = -V_{s1} * G_{i11}$$

Node V4

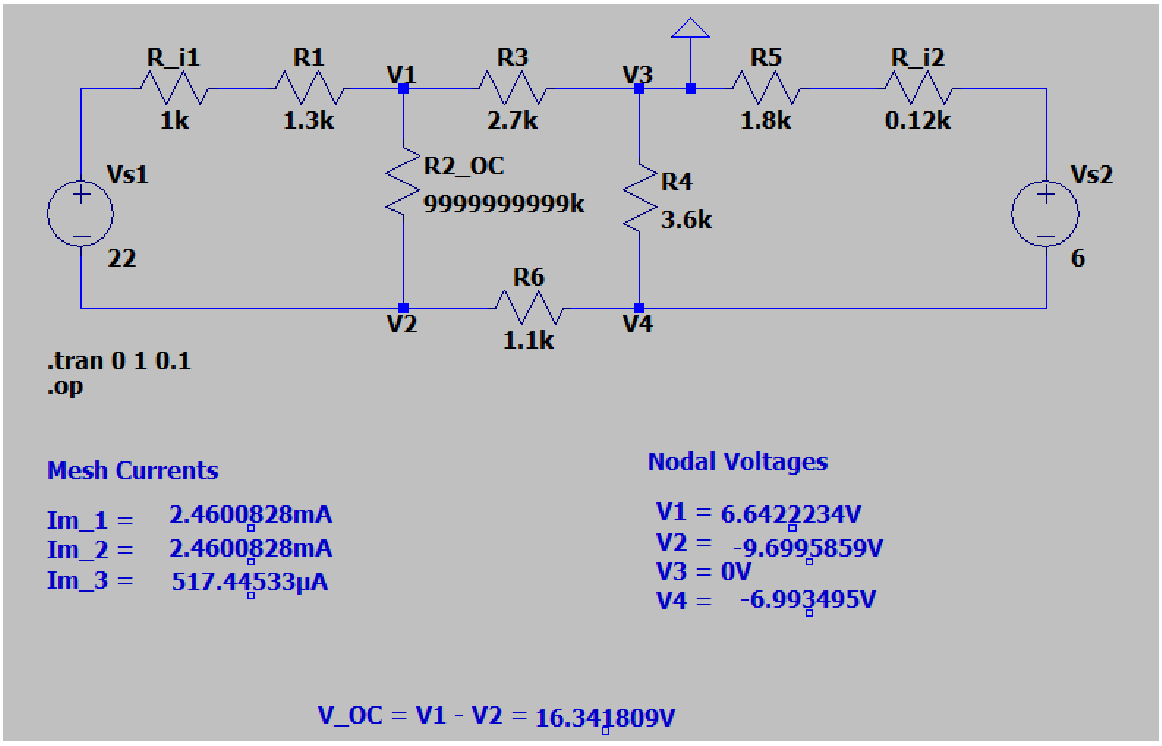
$$-(V2 - V4) * G_6 + (V4 + V_{s2} - 0) * G_{i25} + (V4 - 0) * G_4 = 0$$
$$-V2(G_6) + V4(G_6 + G_{i25} + G_4) = -V_{s2} * G_{i25}$$

$$\begin{pmatrix} (G_{i11} + G_3 + G_2) & -(G_{i11} + G_6 + G_2) & 0 \\ -(G_{i11} + G_2) & (G_2 + G_3 + G_4 + G_6) & -G_6 \\ 0 & -G_6 & (G_6 + G_{i25} + G_4) \end{pmatrix} \begin{pmatrix} V1 \\ V2 \\ V4 \end{pmatrix} = \begin{pmatrix} V_{s1} * G_{i11} \\ -V_{s1} * G_{i11} \\ -V_{s2} * G_{i25} \end{pmatrix}$$

$$\boldsymbol{V1 = 6.6422V}$$
$$\boldsymbol{V2 = -9.6996\ V}$$
$$\boldsymbol{V4 = -6.9935\ V}$$

$$\boldsymbol{V_{OC} = V1 - V2 = 16.3418\ V}$$

LTspice Simulation for Open-circuit voltage at R2



<u>Short-Circuit Voltage Calculations</u>

Mesh Analysis for calculating the loop currents

$\boldsymbol{R_X = R_2}$,

And it is Short-circuited at the place of the R2 with reference to the Figure 1 in Question 1

$\boldsymbol{So: \; R_2 = 0 \; ohms}$,

<u>Loop 1 – Im_1</u>

$$-V_{s1} + Im_1(R_{i1} + R_1) + R_2(Im_1 - Im_2) = 0$$
$$Im_1(R_{i1} + R_1 + R_2) - Im_2(R_2) = V_{s1}$$

<u>Loop 2 – Im_2</u>

$$Im_2(R_3) + R_4(Im_2 - Im_3) + Im_2(R6) - R_2(Im_1 - Im_2) = 0$$
$$-Im_1(R_2) + Im_2(R_3 + R_4 + R_6 + R_2) - Im_3(R_4) = 0$$

<u>Loop 3 – Im_3</u>

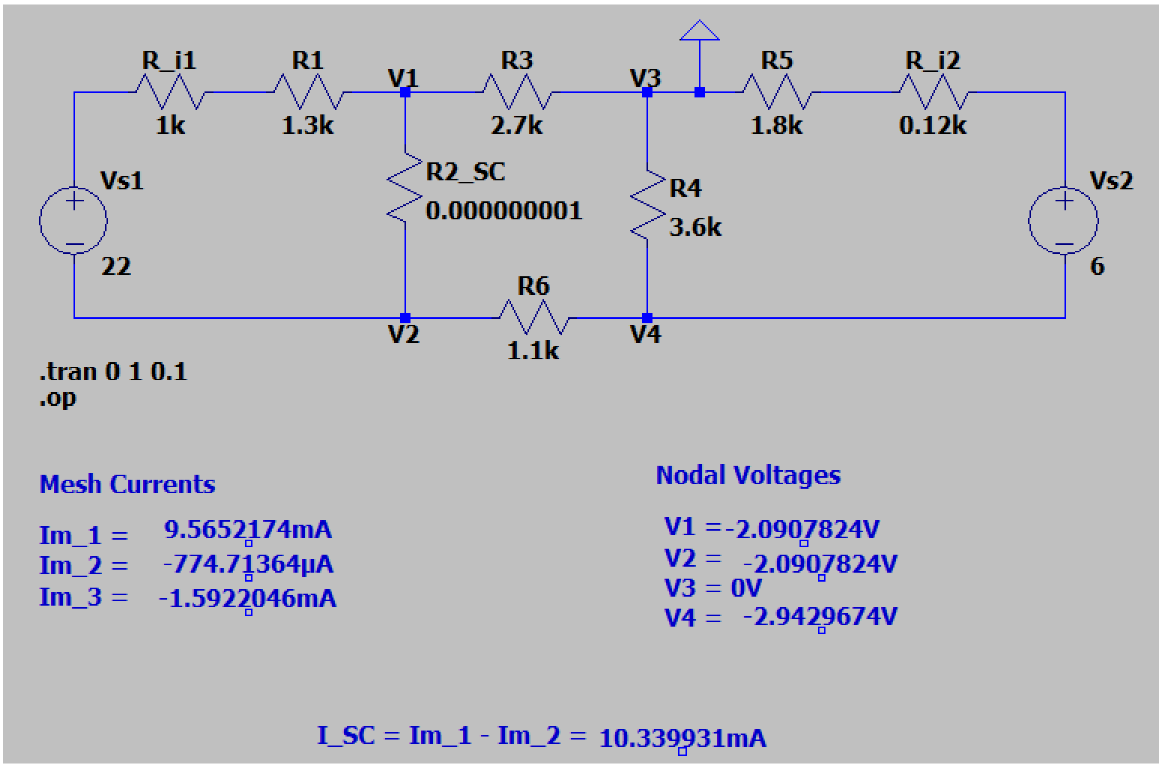
$$Im_3(R_5 + R_{i2}) + V_{s2} - R_4(Im_2 - Im_3) = 0$$
$$-Im_2(R_4) + Im_3(R_5 + R_{i2} + R_4) = -V_{s2}$$

$$\begin{pmatrix} (R\_i1 + R1 + R2) & -R2 & 0 \\ (-R2) & (R2 + R3 + R4 + R6) & -R4 \\ 0 & -R4 & (R4 + R5 + R\_i2) \end{pmatrix} \begin{pmatrix} Im_1 \\ Im_2 \\ Im_3 \end{pmatrix} = \begin{pmatrix} V_{s1} \\ 0 \\ -V_{s2} \end{pmatrix}$$

$$\boldsymbol{Im_1 = 9.5652\ mA}$$
$$\boldsymbol{Im_2 = -0.7745\ mA}$$
$$\boldsymbol{Im_3 = -1.5921\ mA}$$

$$\boldsymbol{I_{SC} = Im_1 - Im_2 = 10.3397\ mA}$$

LTspice Simulation for Short-Circuit current at R2



6. Employing the MATLAB program create a Word file with tables containing calculation results.

APENDIX

MATLAB program for calculation of currents and voltages, as well as for Word report generation (first part)

```
N = 3; % test board number
I = []; U = [];

% parameter value table
PAR = [ 1.0e3, 100, 1.5e3, 2.0e3, 2.4e3, 3.3e3, 1.5e3, 1.0e3, 20, 5, 1;
        1.0e3, 120, 1.3e3, 2.0e3, 2.7e3, 3.6e3, 1.8e3, 1.1e3, 22, 6, 3;
        1.0e3, 100, 1.8e3, 2.0e3, 2.4e3, 3.3e3, 1.3e3, 1.0e3, 24, 6, 2;
        1.0e3, 120, 1.2e3, 2.0e3, 2.7e3, 3.6e3, 1.2e3, 1.1e3, 20, 8, 4;
        1.0e3, 100, 1.5e3, 2.0e3, 2.4e3, 3.3e3, 1.5e3, 1.0e3, 22, 6, 1;
        1.0e3, 120, 1.3e3, 2.0e3, 2.7e3, 3.6e3, 1.2e3, 1.1e3, 24, 8, 3;
        1.0e3, 100, 1.8e3, 2.0e3, 2.4e3, 3.3e3, 1.3e3, 1.0e3, 20, 6, 4];

Ri1 = PAR(N,1); Ri2 = PAR(N,2);
R1 = PAR(N,3); R2 = PAR(N,4); R3 = PAR(N,5);
R4 = PAR(N,6); R5 = PAR(N,7); R6 = PAR(N,8);
U1 = PAR(N,9); U2 = PAR(N,10);

A = [ Ri1 + R1 + R2, -R2, 0;
     -R2, R2 + R3 + R6 + R4, -R4;
      0, -R4, R4 + R5 + Ri2];

b = [U1; 0; -U2];

Ik = A\b;

I(1) = Ik(1); I(2) = Ik(1)-Ik(2); I(3) = Ik(2);
I(4) = Ik(2)-Ik(3); I(5) = Ik(3); I(6) = Ik(2);

U12 = I(2)*R2; U24 = I(6)*R6;
U13 = I(3)*R3; U34 = I(4)*R4;

Unode = [-U12, -U13, -(U13+U34);
          U12, U12-U13,  U24;
          U13, U13-U12, -U34;
         -U24+U12, -U24, U34];

U = Unode(PAR(N,11),:);

word = actxserver('Word.Application');   % run Word application
word.Visible = 1;                        % make it visible
document = word.Documents.Add;           % crate a new document
selection = word.Selection;
selection.ParagraphFormat.Alignment = 1; % text alignment
selection.Font.Size=14;                  % font change
selection.Font.Bold = 1;
selection.TypeText('4. Laboratory work. Electrical circuit analysis
methods.'); % text input
selection.Font.Size=12; selection.TypeParagraph; selection.TypeParagraph;
```

MATLAB program (second part)

```
selection.TypeText(['6. Results of calculations for test board Nr.',
num2str(N),'.']);
selection.TypeParagraph;
selection.TypeParagraph;
selection.Font.Bold = 0;
selection.ParagraphFormat.Alignment = 1;

%table = selection.Tables.Add(selection.Range, 3, 7);
table = selection.Tables.Add(selection.Range, 3, 7);
table.Borders.Enable=1;
table.Title='Aprēķinatās zaru strāvu vērtības';
cel=table.Cell(1,1);
cel.Merge(table.Cell(1,7));
cel.Range.InsertAfter('Calculated values of branch currents');

cel1=table.Cell(2,1);
cel2=table.Cell(3,1);
cel1.Range.InsertAfter('Quantity');
cel2.Range.InsertAfter('Value, mA');

for n=1:6,
  cel1=table.Cell(2,n+1);
  cel2=table.Cell(3,n+1);
  %cel1.Range.InsertAfter(['I']);
  cel1.Select;
  selection.TypeText('I');
  selection.Font.Subscript = 1;
  selection.TypeText(['R', num2str(n)]);
  cel2.Range.InsertAfter(num2str(I(n)*1e3,4));
end

while(selection.MoveDown ~=0),
end
selection.TypeParagraph;                 % new line
table2 = selection.Tables.Add(selection.Range, 3, 4);
table2.Borders.Enable=1;
cel=table2.Cell(1,1);
cel.Merge(table2.Cell(1,4));
cel.Range.InsertAfter('Calculated values of node voltages');

cel1=table2.Cell(2,1);
cel2=table2.Cell(3,1);
cel1.Range.InsertAfter('Quantity');
cel2.Range.InsertAfter('Value, V');
ind = setdiff(1:4,PAR(N,11));
for n=1:3,
  cel1=table2.Cell(2,n+1);
  cel2=table2.Cell(3,n+1);
  cel1.Select;
  selection.TypeText('U');
  selection.Font.Subscript = 1;
  selection.TypeText(num2str(ind(n)));
  cel2.Range.InsertAfter(num2str(U(n),4));
end
```

MATLAB Code for Lab 1 – Part 2

```
%% Lab 1 - PART 2

%% ------Question 1-------

%% Mesh currents

% All Resistor values in Ohms
% ALL Voltage values in V
% All Current values in mA

R_i1=1e3;
R_i2=120;
R1=1.3e3;
R2=2e3;
R3=2.7e3;
R4=3.6e3;
R5=1.8e3;
R6=1.1e3;
V_s1=22;
V_s2=6;

G_i1 = 1/R_i1;
G_i2 = 1/R_i2;
G1 = 1/R1;
G2 = 1/R2;
G3 = 1/R3;
G4 = 1/R4;
G5 = 1/R5;
G6 = 1/R6;

coefs = [(R_i1+R1+R2)     -R2                 0
          -R2         (R2+R3+R4+R6)          -R4
           0               -R4          (R4+R5+R_i2)];
results = [V_s1; 0; -V_s2];
solutions = coefs\results

Im_1 = solutions(1)*1e3
Im_2 = solutions(2)*1e3
Im_3 = solutions(3)*1e3

%Branch Currents

I1 = Im_1
I2 = Im_1-Im_2
I3 = Im_2
I4 = Im_2-Im_3
I5 = Im_3
I6 = Im_2


%Voltages of the Resistors

V_R1=I1*R1*1e-3
V_R2=I2*R2*1e-3
V_R3=I3*R3*1e-3
V_R4=I4*R4*1e-3
V_R5=I5*R5*1e-3
```

```
V_R6=I6*R6*1e-3
V_Ri1=I1*R_i1*1e-3
V_Ri2=I5*R_i2*1e-3

%% Telegens theorem

TELLEGENS=-
I1*V_s1+V_Ri1*I1+V_R1*I1+V_R2*I2+V_R3*I3+V_R4*I4+V_R5*I5+V_Ri2*I5+V_s2*I5+V_R6
*I6

%% Nodal voltages

% All Resistor values in Ohms
% ALL Voltage values in V
% All Current values in mA

G_i11=1/(R_i1+R1);
G_i25=1/(R_i2+R5);
n_coefs = [G_i11+G2+G3       -(G_i11+G2)           0
          -(G_i11+G2)         G_i11+G6+G2         -G6
                0                 -G6         G6+G_i25+G4    ];
n_results = [V_s1*(G_i11); -V_s1*(G_i11); -V_s2*(G_i25)];

n_solutions = n_coefs\n_results;

V1 = n_solutions(1)
V2 = n_solutions(2)
V4 = n_solutions(3)
V3 = 0

%% ----Question 3----

%% 3.1) current through each branch, with us1 acting alone; Us2=0V

% All Resistor values in Ohms
% ALL Voltage values in V
% All Current values in mA

V_s1=22;
V_s2=0; % since Us1 is working alone

% Mesh Currents

coefs = [(R_i1+R1+R2)     -R2                  0
          -R2         (R2+R3+R4+R6)           -R4
            0             -R4          (R4+R5+R_i2)];
results = [V_s1; 0; -V_s2];
solutions = coefs\results

Im_1 = solutions(1)*1e3
Im_2 = solutions(2)*1e3
Im_3 = solutions(3)*1e3

%Branch Currents

I1 = Im_1
I2 = Im_1-Im_2
I3 = Im_2
I4 = Im_2-Im_3
```

```
I5 = Im_3
I6 = Im_2

%% 3.2) The Voltage across when only Us1 is only working

V_R3=I3*R3*1e-3 % I3 taken from 3.1 question

%% 3.3) the current through each branch, with us2 acting alone, Us1=0V;

% All Resistor values in Ohms
% ALL Voltage values in V
% All Current values in mA

V_s1=0; % since Us2 is working alone
V_s2=6;

% Mesh Currents

coefs = [(R_i1+R1+R2)     -R2                  0
           -R2         (R2+R3+R4+R6)          -R4
            0               -R4           (R4+R5+R_i2)];
results = [V_s1; 0; -V_s2];
solutions = coefs\results

Im_1 = solutions(1)*1e3
Im_2 = solutions(2)*1e3
Im_3 = solutions(3)*1e3

%Branch Currents

I1 = Im_1
I2 = Im_1-Im_2
I3 = Im_2
I4 = Im_2-Im_3
I5 = Im_3
I6 = Im_2

%% 3.4) R3 replaced with a Voltage Source, which is V_R3 = 4.513 V and ONLY
Us1 is working.

% All Resistor values in Ohms
% ALL Voltage values in V
% All Current values in mA

V_R3=4.513; % Voltage source in place of R3, and value calclated in question
3.2
V_s1=22;
V_s2=0; % since Us1 is working alone

% Mesh Currents

coefs = [(R_i1+R1+R2)     -R2                  0
           -R2          (R2+R4+R6)           -R4
            0               -R4           (R4+R5+R_i2)];
results = [V_s1; -V_R3; -V_s2];
solutions = coefs\results

Im_1 = solutions(1)*1e3
Im_2 = solutions(2)*1e3
```

```
Im_3 = solutions(3)*1e3

%Branch Currents

I1 = Im_1
I2 = Im_1-Im_2
I3 = Im_2
I4 = Im_2-Im_3
I5 = Im_3
I6 = Im_2


%% 5.2) Open Circuit at R2 voltage:

% All Resistor values in Ohms
% ALL Voltage values in V
% All Current values in mA

V_s1=22;
V_s2=6;

%Nodal Voltage analysis

G2 = 0; % since R2 is open-circuited, R2 = infinite ohms

n_coefs = [G_i11+G2+G3       -(G_i11+G2)           0
                   -(G_i11+G2)         G_i11+G6+G2         -G6
                        0                 -G6         G6+G_i25+G4    ];
n_results = [V_s1*(G_i11); -V_s1*(G_i11); -V_s2*(G_i25)];

n_solutions = n_coefs\n_results;

V1_n = n_solutions(1);
V2_n = n_solutions(2);
V4_n = n_solutions(3);
V3_n = 0 ;

V_OC = V1_n- V2_n

%% 5.2) Short Circuit at R2 voltage, Nortons Calculations

% All Resistor values in Ohms
% ALL Voltage values in V
% All Current values in mA

% Mesh Current Analysis

R2=0; % R2 is short circuited

coefs = [(R_i1+R1+R2)     -R2                    0
          -R2         (R2+R3+R4+R6)           -R4
            0             -R4           (R4+R5+R_i2)];
results = [V_s1; 0; -V_s2];
solutions = coefs\results;

Im_1 = solutions(1)*1e3
Im_2 = solutions(2)*1e3
Im_3 = solutions(3)*1e3
```

```
I_SC = Im_1-Im_2
```