**4. Laboratory work. Electrical Circuit Analysis Methods.**

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name, surname student ID test board number

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Table 1. Values of parameters | | | | | | | | |
| Test board numbers | | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Parameters | Ri1, kΩ | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Ri2, Ω | 100 | 120 | 100 | 120 | 100 | 120 | 100 |
| R1, kΩ | 1.5 | 1.3 | 1.8 | 1.2 | 1.5 | 1.3 | 1.8 |
| R2, kΩ | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| R3, kΩ | 2.4 | 2.7 | 2.4 | 2.7 | 2.4 | 2.7 | 2.4 |
| R4, kΩ | 3.3 | 3.6 | 3.3 | 3.6 | 3.3 | 3.6 | 3.3 |
| R5, kΩ | 1.5 | 1.8 | 1.3 | 1.2 | 1.5 | 1.2 | 1.3 |
| R6, kΩ | 1.0 | 1.1 | 1.0 | 1.1 | 1.0 | 1.1 | 1.0 |
| us1, V | 20 | 22 | 24 | 20 | 22 | 24 | 20 |
| us2, V | 5 | 6 | 6 | 8 | 6 | 8 | 6 |
| Rx | R1 | R2 | R3 | R4 | R5 | R6 | R1 |
| 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

**I5**

**I3**

**I1**

Ri 1

**us1**

**R2**

**R4**

**Ri 2**

**R5**

**R3**

R1

**R6**

**us2**

**4**

**2**

**1**

**3**

**+**

**-**

-

**+**

**I4**

**I2**

**Im2**

**Im1**

**Im3**

**I6**

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

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Table 1. Measured branch currents | | | | | | |
| Quantity | IR1 | IR2 | IR3 | IR4 | IR5 | IR6 |
| 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 – Im1

Loop 2 – Im2

Loop 3 – Im3

**Branch Currents and Mesh Currents equivalence**

|  |  |  |  |
| --- | --- | --- | --- |
| Table 2. Measured node voltages | | | |
| **Quantity** | **U 1 a** | **U 2 a** | **U 4 a** |
| 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**

Node V1

Node V2

Node V4

**LTspice Simulation for Question 1**

A diagram of electrical wiring

Description automatically generated

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

2.1. replace Rx with an open-circuit and measure the voltage across the terminals of the network external to the resistor Rx (see Table 1) *u*oc = V

2.2. replace Rx 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: = \_\_\_\_\_\_\_\_\_\_

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** | **IR1** | **IR2** | **IR3** | **IR4** | **IR5** | **IR6** |
| 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**

Loop 1 – Im1

Loop 2 – Im2

Loop 3 – Im3

**Branch Currents and Mesh Currents equivalence**

**LTspice Simulation for Question 3.1)**

**A diagram of electrical wiring

Description automatically generated**

3.2. the voltage *u*R3 = V, when only the first voltage source is active *u*s1;

**Calculations Used :**

**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** | **IR1** | **IR2** | **IR3** | **IR4** | **IR5** | **IR6** |
| 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**

Loop 1 – Im1

Loop 2 – Im2

Loop 3 – Im3

**Branch Currents and Mesh Currents equivalence**

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** | **IR1** | **IR2** | **IR3** | **IR4** | **IR5** | **IR6** |
| 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**

Loop 1 – Im1

Loop 2 – Im2

Loop 3 – Im3

**Branch Currents and Mesh Currents equivalence**

**A diagram of electrical wiring

Description automatically generatedLTspice 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 | IR1 | IR2 | IR3 | IR4 | IR5 | IR6 |
| Value, mA |  |  |  |  |  |  |

|  |  |  |  |
| --- | --- | --- | --- |
| Table 7. Node voltages obtained by LTSpice | | | |
| Quantity | U a | U a | U a |
| 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**

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

Node V1

Node V2

Node V4

**LTspice Simulation for Open-circuit voltage at R2**

A diagram of a circuit

Description automatically generated

Short-Circuit Voltage Calculations

**Mesh Analysis for calculating the loop currents**

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

Loop 1 – Im1

Loop 2 – Im2

Loop 3 – Im3

**LTspice Simulation for Short-Circuit current at R2**

A diagram of a voltage

Description automatically generated

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