**Laboratory work 1. DC circuit analysis.**

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name, surname student ID testboard number

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Table 1: Values of voltage sources and resistors | | | | | | | | | | | | |
| Parameter | | Ri1, kΩ | Ri2, Ω | R1, kΩ | R2, kΩ | R3, kΩ | R4, kΩ | R5, kΩ | R6, kΩ | Vs1, V | Vs2, V |
| Testboard number | 1 | 1,0 | 100 | 1,5 | 2,0 | 2,4 | 3,3 | 1,5 | 1,0 | 20 | 5 |
| 2 | 1,0 | 120 | 1,3 | 2,0 | 2,7 | 3,6 | 1,8 | 1,1 | 22 | 6 |
| 3 | 1,0 | 100 | 1,8 | 2,0 | 2,4 | 3,3 | 1,3 | 1,0 | 24 | 6 |
| 4 | 1,0 | 120 | 1,2 | 2,0 | 2,7 | 3,6 | 1,2 | 1,1 | 20 | 8 |
| 5 | 1,0 | 100 | 1,5 | 2,0 | 2,4 | 3,3 | 1,5 | 1,0 | 22 | 6 |
| 6 | 1,0 | 120 | 1,3 | 2,0 | 2,7 | 3,6 | 1,2 | 1,1 | 24 | 8 |
| 7 | 1,0 | 100 | 1,8 | 2,0 | 2,4 | 3,3 | 1,3 | 1,0 | 20 | 6 |

1. Build a voltage divider circuit as shown in Figure 1, using part A of the testboard only. Measure the voltage across the load resistor for different values of its resistance given in Table 2. During the measurement, the input voltage must be kept at the fixed level Vs1. Record the measured values in Table 2.

Ri

**Vs1**

**V1**

**V2**

**RL**

**VL**

**+**

**-**

Figure 1. Voltage divider

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Table 2: Measured values of load voltage | | | | | | |
| **RL** | **100** **Ω** | **200 Ω** | **500 Ω** | **800 Ω** | **900 Ω** | **1 kΩ** |
| UL, V  Calculated | 2 | 3.67 | 7.33 | 9.78 | 10.42 | 11 |
| UL, V  LTspice | 2 | 3.67 | 7.33 | 9.78 | 10.42 | 11 |
| UL, V  Measured |  |  |  |  |  |  |
| **RL** | **1.1 kΩ** | **1.2 kΩ** | **1.5 kΩ** | **2 kΩ** | **5 kΩ** | **10 kΩ** |
| UL, V  Calculated | 11.52 | 12 | 13.2 | 14.67 | 18.33 | 20 |
| UL, V  LTspice | 11.52 | 12 | 13.2 | 14.67 | 18.33 | 20 |
| UL, V  Measured |  |  |  |  |  |  |

Ltspice Simulation

**Figure 1: LTspice simulation for the Voltage Divider circuit when RL = 100 Ω**

A diagram of a circuit

Description automatically generated

The equation used for Calculation

2. Build a circuit as specified in Fig. 2. Set the voltages Vs1 and Vs2 according to Table 1. and measure the current through and voltage across each resistor. Write the measured values of currents and voltages in Tables 3 and 4, respectively.

**I5**

**I3**

**I1**

Ri 1

**Vs1**

**R2**

**R4**

**Ri 2**

**R5**

**R3**

R1

**R6**

**Vs2**

**4**

**2**

**1**

**3**

**+**

**-**

-

**+**

**I4**

**I2**

**Im2**

**Im3**

**Im1**

**I6**

Figure 2. Circuit for measurement of currents and voltages

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Table 3: Measured values of branch currents | | | | | | |
| Quantity | I1 | I2 | I3 | I4 | I5 | I6 |
| Value, mA  Calculated | 5.60 | 4.56 | 1.03 | 1.45 | -0.414 | 1.03 |
| Value, mA  LTspice | 5.60 | 4.56 | 1.03 | 1.45 | -0.414 | 1.03 |
| 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 4: Measured values of voltages | | | | | | | | |
| Quantity | VR1 | VR2 | VR3 | VR4 | VR5 | VR6 | VRi1 | VRi2 |
| Value, V  Calculated | 7.2753 | 9.1283 | 2.7871 | 5.2056 | -0.7447 | 1.1355 | 5.5964 | -0.0496 |
| Value, V  LTspice | 7.2753 | 9.1283 | 2.7871 | 5.2056 | -0.7447 | 1.1355 | 5.5964 | -0.0496 |
| Value, V  Measured |  |  |  |  |  |  |  |  |

**Nodal Analysis for calculating Nodal voltages**

Node V1

Node V2

Node V4

**Sample Calculation for VR1** :

**Tellegens Theorem**

**LTspice Simulation for question 2**

A diagram of electrical wiring

Description automatically generated

3. Build a circuit as shown in Fig. 3 and measure the following voltages:

**U12**

**U34**

**R5**

**R3**

R1

**R6**

Ri 1

**Vs1**

**Ri 2**

**3**

**1**

**2**

**4**

**+**

**-**

Figure 3. Voltage divider circuit without resistors R2 and R4

|  |  |  |
| --- | --- | --- |
| **Voltage,V** | **V12** | **V34** |
| Calculated values,V | 15.6908 | 5.2668 |
| LTspice values,V | 15.6908 | 5.2668 |
| Measured values,V |  |  |

**Calculation of V12 and V34 :**

**LTspice Simulation circuit for question 3**

A screenshot of a computer

Description automatically generated

4. Build a circuit as specified in Fig. 4 and measure the following voltages :

Ri 1

**V12**

**V34**

**R2**

**R4**

**R5**

**R3**

R1

**R6**

**Vs1**

**Ri 2**

**3**

**4**

**1**

**2**

**+**

**-**

Figure 4. Voltage divider circuit with resistors R2 and R4

|  |  |  |
| --- | --- | --- |
| **Voltage,V** | **V12** | **V34** |
| Calculated values,V | 8.4444 | 2.0930 |
| LTspice values,V | 8.4444 | 2.0930 |
| Measured values,V |  |  |

**Calculations for V12 and V34**

**Mesh Analysis for calculating the loop currents**

Loop 1 – Im1

Loop 2 – Im2

Loop 3 – Im3

**LTspice Simulations for question 4**

**A diagram of a circuit

Description automatically generated with medium confidence**

5. Circuit simulation by means of LTSpice

5.1. use LTSpice to create a model for the circuit specified in Fig. 4 (use values from Table 1) and determine the voltages: **V12** = **15.6908** un **V34** =**5.2668**

5.2 remove from the circuit resistors R2 un R4 and determine the following voltages **V12** = **8.4444** un **V34** = **2.0930**.

6. Use MATLAB code to create a Word file containing graphical results (in MATLAB code replace the values of elements of array Vsle with the measured values of the output voltage from Table 2, as well as set the value of variable V1 to the corresponding value from Table 1).

**MATLAB program for calculations and Word file creation**

% Calculations

% assign a value from Table 1 to variable U1

U1=20;

Rsl=0:50:1e4;

Ri = 1e3;

Isl=U1./(Rsl+Ri);

Psl=(Isl.^2).\*Rsl;

Pkop=(Isl.^2).\*(Rsl+Ri); % the total power

L\_K=100\*Psl./Pkop; % efficiency

% Experimental data

Rsle = [100 200 500 800 900 1e3 1.1e3 1.2e3 1.5e3 2e3 5e3 10e3];

Usle = [2 8.8 9.5 10 10.47 13.3 15 16 16.5 17 17.5 17.7];

Psle=(Usle.^2)./Rsle;

fg(1)=figure(1)

plot(Rsl,Psl,Rsle,Psle,'o','LineWidth',2),

grid on,title('Power'),xlabel('Rsl'),ylabel('Psl')

fg(2)=figure(2)

plot(Rsl,Isl.\*Rsl,Rsle,Usle,'o','LineWidth',2),

grid on,title('Usl,Usle'),xlabel('Rsl'),ylabel('Usl')

% Creating a Word file

word = actxserver('Word.Application'); % run Word application

word.Visible = 1; % make it visible

document = word.Documents.Add; % create a new document

selection = word.Selection;

selection.ParagraphFormat.Alignment = 1; % text alignment

selection.Font.Size=12; % change font size

selection.TypeText('Laboratory work 3.'); % input some text

selection.TypeParagraph; % new line

selection.TypeText('Graphical results.');

grname = {'The output power against the load resistance', ...

'The output voltage against the load resistance'}

for n=1:2,

print(fg(n),'-dmeta'); % copy graph into clipboard

invoke(word.Selection,'Paste'); % paste graph to the document

selection.ParagraphFormat.Alignment = 1;

selection.Font.Size=11;

selection.TypeText([num2str(n),'.att. ', grname{n}]);

end

**Appendix**

MATLAB Code used for calculations in Lab 1 – Part 1

clc,format compact, clear

%% Lab 1 - Part 1

%% Question 1

R\_L = [100,200,500,800,900,1e3,1.1e3,1.2e3,1.5e3,2e3,5e3,10e3]; % in ohms

R\_i = 1e3; % in ohms

V\_s1 = 22; % in V

R\_tot = R\_i + R\_L; % total resistance in ohms

I=V\_s1 ./ R\_tot % current in certain resistances of R\_L in A

V\_L = I.\*R\_L % Load voltage in specific R\_L values in V

%% -------Question 2------------

%% Mesh currents

R\_i1=1e3; % in ohms

R\_i2=120; % in ohms

R1=1.3e3; % in ohms

R2=2e3; % in ohms

R3=2.7e3; % in ohms

R4=3.6e3; % in ohms

R5=1.8e3; % in ohms

R6=1.1e3; % in ohms

V\_s1=22; % in V

V\_s2=6; % in V

% Conductance Values in Siemens

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;

% Matrix Calculation

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 % in mA for mesh 1

Im\_2 = solutions(2)\*1e3 % in mA for mesh 2

Im\_3 = solutions(3)\*1e3 % in mA for mesh 3

% Branch Currents

I1 = Im\_1 % in mA

I2 = Im\_1-Im\_2 % in mA

I3 = Im\_2 % in mA

I4 = Im\_2-Im\_3 % in mA

I5 = Im\_3 % in mA

I6 = Im\_2 % in mA

% Voltages of the Resistors

V\_R1=I1\*R1\*1e-3 % in V

V\_R2=I2\*R2\*1e-3 % in V

V\_R3=I3\*R3\*1e-3 % in V

V\_R4=I4\*R4\*1e-3 % in V

V\_R5=I5\*R5\*1e-3 % in V

V\_R6=I6\*R6\*1e-3 % in V

V\_Ri1=I1\*R\_i1\*1e-3 % in V

V\_Ri2=I5\*R\_i2\*1e-3 % in V

%% Telegens theorem

% Power in Watts

TELLEGENS\_Power=-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

G\_i11=1/(R\_i1+R1); % Conductance for R\_i1 and R1 in series, in Siemens

G\_i25=1/(R\_i2+R5); % Conductance for R\_i2 and R5 in series, in Siemens

% Matrix Calculation

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) % in V

V2 = n\_solutions(2) % in V

V4 = n\_solutions(3) % in V

V3 = 0 % It is Zero, as it is the Ground, in V

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

R\_total\_p3 =R\_i1+R1+R3+R5+R\_i2+R6;% in ohms

V12 =V\_s1\*((R3+R5+R\_i2+R6)/(R\_total\_p3)) % in V

V34 =V\_s1\*((R5+R\_i2)/(R\_total\_p3)) % in V

%% ------Question 4-----

% Mesh Current Analysis

% Matrix Calculation

coefs = [(R\_i1+R1+R2) -R2 0

-R2 (R2+R3+R4+R6) -R4

0 -R4 (R4+R5+R\_i2)];

results = [V\_s1; 0; 0];

solutions = coefs\results;

Im\_1 = solutions(1)\*1e3; % in mA

Im\_2 = solutions(2)\*1e3; % in mA

Im\_3 = solutions(3)\*1e3; % in mA

I2 = (Im\_1-Im\_2)\*1e-3; % Branch current in R2, in mA

I4 = (Im\_2-Im\_3)\*1e-3; % Branch current in R4, in mA

V\_R2 = I2\*R2; % Voltage across R2, in V

V\_R4 = I4\*R4; % Voltage across R4, in V

V12\_w24 = V\_R2 % in V

V34\_w24 = V\_R4 % in V