New York City College of Technology

**Department of Computer Engineering Technology**

Electrical Networks Laboratory

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# LAB Experiment # 10

## Method of analysis: mesh analysis

## Matlab: Complex numbers; determinant

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## OBJECTIVE

This laboratory experiment main objective is to demonstrate that a three independent loop circuit can be analyze in matlab using mesh analysis by writing a static code in matlab where the components and voltage source can be entered by the user. In this laboratory experiment, complex number will be involve in order to solve for the current and voltages across the three resistors in the circuit. The voltages and current across each resistors will be display in time domain. The program will also display a waveform of the voltage and current across each resistors.

## INTRODUCTION

Mesh analysis is a method of analysis use to solve for the current and voltages across elements in a close loop circuit. Mesh analysis is very important technique to solve circuits with many loops. The current flow in each loop can be found by writing mesh equations for each loop and then solving for the current. Mesh equation can be easily solve by using crammers rule. Crammers rule allows to find solution for a system of linear equations with as many equations. For example:

(a1)(i1)+ (b1)(i2)+(c1)(i3)=d1

(a2)(i1)+ (b2)(i2)+(c2)(i3)=d2

(a3)(i1)+ (b3)(i2)+(c3)(i3)=d3

To solve for i1, find the determinant for di1 and the determinant d which are given by:

$$\text{Di1}=\begin{matrix} d1 & b1 & c1 \\ d2 & b2 & c2 \\ d3 & b3 & c3 \end{matrix} \qquad \text{D}=\begin{matrix} a1 & b1 & c1 \\ a2 & b2 & c2 \\ a3 & b3 & c3 \end{matrix}$$

Then i1 will be given by

$(i1)=\frac{Di1}{D}$

To solve for i2, find the determinant for di2 and the determinant d which are given by:

$$Di2=\begin{matrix} a1 & d1 & c1 \\ a2 & d2 & c2 \\ a3 & d3 & c3 \end{matrix} \qquad D=\begin{matrix} a1 & b1 & c1 \\ a2 & b2 & c2 \\ a3 & b3 & c3 \end{matrix}$$

Then i2 will be given by

$(i2)=\frac{Di2}{D}$

To solve for i3, find the determinant for di3 and the determinant d which are given by:

$$Di3=\begin{matrix} a1 & b1 & d1 \\ a2 & b2 & d2 \\ a3 & b3 & d3 \end{matrix} \qquad D=\begin{matrix} a1 & b1 & c1 \\ a2 & b2 & c2 \\ a3 & b3 & c3 \end{matrix}$$

Then i3 will be given by

$(i3)=\frac{Di3}{D}$

The user will be asked to enter the phase angle of each ac voltage source, for programming purpose the entered angle in degree needs to be converted to radians since matlab makes calculations using radians. Conversion between radians and degree can be easily calculate as follow:

Degrees to radians=(degrees)(PI/180°)

Radians to degree=(radians)(180°/PI)

Since the circuit that will be analyze is an AC-RC circuit, complex numbers are involved when programming to solve the circuit. Matlab allows to find imaginary and real part of complex numbers. The command use to find the imaginary part of a complex number is *imag()*. The command use to obtain the real part of a complex number is *real()*.

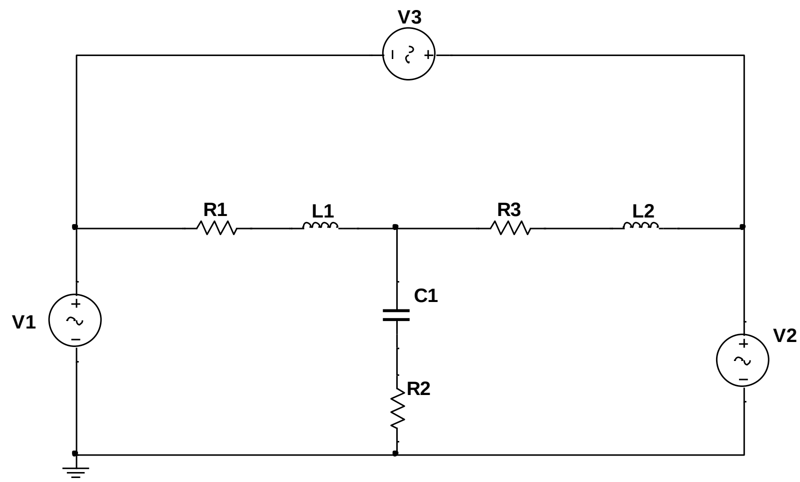
## EXPERIMENTAL

For the purpose of this laboratory experiment, circuit A1 will be analyze.

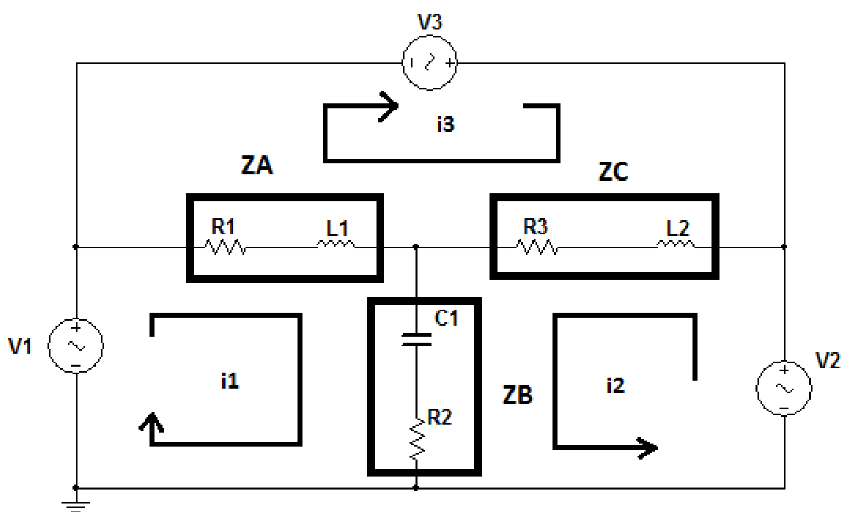
- First, combine the components to obtain a simpler circuit for coding purposes. As shown in circuit A2.
- Select the loop flow and identify each loop in the circuit.
- Write the linear equation for each loop.
- Write a code in matlab where the user enters the value for each component and voltage source and then the current flow and the voltage drop across each resistor in the circuit is display as well a waveform graph of the current and voltages across each resistor.

### Circuit schematics

**Circuit A1**




**Circuit A2**



## CALCULATIONS

$ZA=ZR1+ZL1$

$ZB=ZR2+ZC1$

$ZC=ZR3+ZL2$

**Equations**

$(i1)(ZA+ZB)+(i2)(ZB)-(i3)(ZA)=V1 \quad (I)$

$(i1)(ZB)+(i2)(ZB+ZC)+(i3)(ZC)=V2 \quad (II)$

$-(i1)(ZA)+(i2)(ZC)+(i3)(ZA+ZC)=V3 \quad (III)$

$VR1=ZR1(i1-i3) \quad IR1=(i1-i3)$

$VR2+ZR2(I2+i1) \quad IR2=(I2+i1)$

$VR3=ZR3(i2+i3) \quad IR3=(i2+i3)$

## Matlab Code:

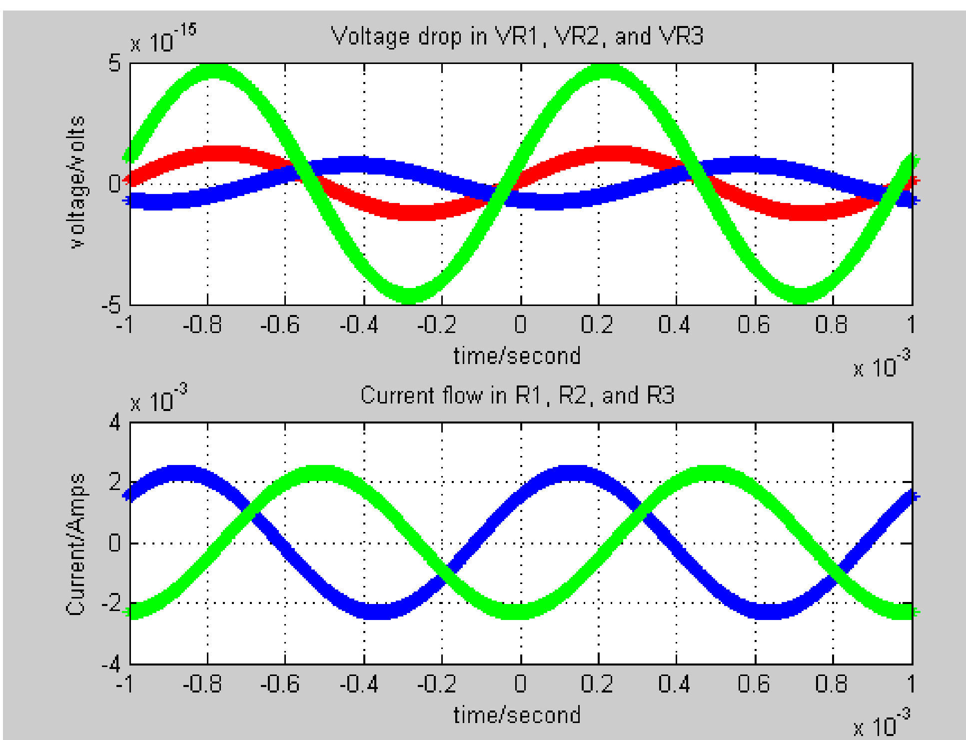
```
%Karen Gordillo and Yeradina Estrella
%Lab 09- Mesh Analysis
%Enter values for the circuit(done)
clear
clc
R1=input('Enter value for R1(ohms): ');
R2=input('Enter value for R2(ohms): ');
R3=input('Enter value for R3(ohms): ');
L1=input('Enter value for L1(H): ');
L2=input('Enter value for L2(H): ');
C1=input('Enter value for C(F): ');
V1_P=input('Enter value for V1 peak(V): ');
V1_S=input('Enter value of shifting of V1(degree): ');
V2_P=input('Enter value for V2 peak(V): ');
V2_S=input('Enter value of shifting of V2(degree): ');
V3_P=input('Enter value for V3 peak(V): ');
V3_S=input('Enter value of shifting of V3(degree): ');
F=input('Enter value for frequency(Hz): ');
%Find the work using the frequency (done)
W=(2*pi*F);

%Find the rectangular form for the components
%Find the Vrms for each voltage(done)
V1RMS=(V1_P*0.707);
V2RMS=(V2_P*0.707);
V3RMS=(V3_P*0.707);

%Find the Angles for the voltages(done)
V1_ANGLE=V1_S*(pi/180);
V2_ANGLE=V2_S*(pi/180);
V3_ANGLE=V3_S*(pi/180);

%Find real and imaginary (done)
V1_REAL=V1RMS*cos(V1_ANGLE);
V1_IMG=V1RMS*sin(V1_ANGLE);
V2_REAL=V2RMS*cos(V2_ANGLE);
V2_IMG=V2RMS*sin(V2_ANGLE);
V3_REAL=V3RMS*cos(V3_ANGLE);
V3_IMG=V3RMS*sin(V3_ANGLE);
%Find the reatangular form(done)
V1=V1_REAL+V1_IMG;
V2=V2_REAL+V2_IMG;
V3=V3_REAL+V3_IMG;

%Find the Impedance in the resistor(done)
ZR1=R1;
ZR2=R2;
ZR3=R3;
%Find the reactance in Inductor and Capacitor (done)
XL1=(W*L1);
XL2=(W*L2);
%Find the reactangular for Inductor (done)
ZL1=XL1*1j;
ZL2=XL2*1j;
```

```
%Obtain the impendance and reactance rectangular form of the
%capacitor(done)
XC1=1/(W*C1);
ZC1=XC1*-1j;

%Boxes done in circuit (done)
ZA=ZR1+ZL1;
ZB=ZR2+ZC1;
ZC=ZR3+ZL2;

%Matrix for i1, i2, i3 (done)
Ai1=[V1,ZB,-ZA;V2,(ZB+ZC),ZC;V3,ZC,(ZC+ZA)];
A_I1 = det(Ai1);
Ai2=[(ZA+ZB),V1,-ZA;ZB,V2,ZC;-ZA,V3,(ZC+ZA)];
A_I2 = det(Ai2);
Ai3=[(ZA+ZB),ZB,V1;ZB,(ZC+ZB),V2;-ZA,ZC,V3];
A_I3 = det(Ai3);
A_I=[(ZA+ZB),ZB,-ZA;ZB,(ZC+ZB),ZC;ZA,ZC,(ZC+ZA)];
A = det(A_I);

I1=A_I1/A;
I2=A_I2/A;
I3=A_I3/A;

%Display in Time Domain for i1, i2, i3;
Amp_I1=abs(I1) *sqrt(2);
Angle_I1=angle(I1)*(180/pi);
Amp_I2 = abs(I2) *sqrt(2);
Angle_I2=angle(I2)*(180/pi);
Amp_I3 = abs(I3) *sqrt(2);
Angle_I3=angle(I3)*(180/pi);

%For the voltage in time domain
VR1=ZR1*(I1-I3);
VR2=ZR2*(I2+I1);
VR3=ZR3*(I3+I2);

Amp_VR1=abs(VR1)*sqrt(2);
Angle_VR1=angle(VR1)*(180/pi);
Amp_VR2=abs(VR2)*sqrt(2);
Angle_VR2=angle(VR2)*(180/pi);
Amp_VR3=abs(VR3)*sqrt(2);
Angle_VR3=angle(VR3)*(180/pi);

%displaying in time domain
fprintf('I1(t) = %4.1e sin(%4.1ft+(%4.1f)) A )\n',Amp_I1,W,Angle_I1);

fprintf('I2(t) = %4.1e sin(%4.1ft+(%4.1f)) A )\n',Amp_I2,W,Angle_I2);

fprintf('I3(t) = %4.1e sin(%4.1ft+(%4.1f)) A )\n',Amp_I3,W,Angle_I3);

fprintf('VR1(t) = %4.1e sin(%4.1ft+(%4.1f)) V )\n',Amp_VR1,W,Angle_VR1);
```

```matlab
fprintf('VR2(t) = %4.1e sin(%4.1ft+(%4.1f)) V )\n',Amp_VR2,W,Angle_VR2);

fprintf('VR3(t) = %4.1e sin(%4.1ft+(%4.1f)) V )\n',Amp_VR3,W,Angle_VR3);


%time domain
t=1/F;
x=-t:0.001*t:t;
VR1_t=Amp_VR1*sin(W*x+Angle_VR1);

VR2_t=Amp_VR2*sin(W*x+Angle_VR2);
VR3_t=Amp_VR3*sin(W*x+Angle_VR3);
I1_t=Amp_I1*sin(W*x+Angle_I1);
I2_t=Amp_I2*sin(W*x+Angle_I2);
I3_t=Amp_I3*sin(W*x+Angle_I3);

%Plot the current and voltage
subplot(2,1,1)
plot(x,VR1_t,'r*');
hold all
plot(x,VR2_t,'b*');
hold all
plot(x,VR3_t,'g*');
hold all
title('Voltage drop in VR1, VR2, and VR3');
xlabel('time/second');
ylabel('voltage/volts');
grid on

subplot(2,1,2)
plot(x,I1_t,'r*');
hold all
plot(x,I2_t,'b*');
hold all
plot(x,I3_t,'g*');
hold all
title('Current flow in R1, R2, and R3');
xlabel('time/second');
ylabel('Current/Amps');
grid on
```

# Output results

```
Command Window
Enter value for R1(ohms): 1000
Enter value for R2(ohms): 2500
Enter value for R3(ohms): 3000
Enter value for L1(H): 1
Enter value for L2(H): 20
Enter value for C(F): 47
Enter value for V1 peak(V): 10
Enter value of shifting of V1(degree): 45
Enter value for V2 peak(V): 60
Enter value of shifting of V2(degree): 55
Enter value for V3 peak(V): 30
Enter value of shifting of V3(degree): 25
Enter value for frequency(Hz): 1000
I1(t) = 2.3e-03 sin(6283.2t+(99.0)) A )
I2(t) = 2.3e-03 sin(6283.2t+(-81.0)) A )
I3(t) = 2.3e-03 sin(6283.2t+(99.0)) A )
VR1(t) = 1.2e-15 sin(6283.2t+(100.6)) V )
VR2(t) = 7.7e-16 sin(6283.2t+(-90.0)) V )
VR3(t) = 4.7e-15 sin(6283.2t+(-81.5)) V )
fx >>
```



# DISCUSSION OF RESULTS

AC circuits can be analyze using matlab and properly writing a code to solve for currents and voltages. An ac circuit that contain three independent loops can be analyses by applying mesh analysis and properly writing a code to obtain the desire computations. In this laboratory experiment, circuit A1 was analyze using matlab. The user is able to change the values of each component and voltage source but cannot change the arrangement of the component and the voltage sources. This mean that the program written to solve this circuit is static.

Matlab allows to make calculations of complex numbers and determinants. In the program written, crammers rule was use to solve for the current flow in each loop. Matlab made the calculations for each loop by writing the linear equation and using the command *det()* to find the current in each loop. Since the circuit involve complex number, the program was written using rectangular form complex number to identify the voltage source and obtain the voltage across each resistor with the corresponding phase angle. The user enter the phase angle of each voltage source in degrees and since the matlab perform operation with degree radians, the entered phase angle was converted to radians for programming purposes and then converted back to degrees to print the voltages across each resistor in time domain. The angular velocity was calculate using the frequency value entered by the user. Matlab allows to make calculation involving complex numbers allowing to solve ac circuits. The program written clearly demonstrate that matlab can be used to solve a three independent loop ac circuit using mesh analysis and properly writing the code for the static circuit.

# CONCLUSION

In conclusion, mesh analysis is a method of analysis that allows to easily solve a complex ac circuit involving capacitor, resistor and inductors. In this laboratory experiment, mesh analysis in conjunction with matlab was use to solve for the voltages and current across each resistors in circuit A1. The mesh equations for each independent loop was written accordingly to the passive element in each loop. The mesh equations allowed to use crammer rule to obtain the value of the current in each loop. Matlab made the calculations for the current in each loop and then calculated the current and voltage across each resistor. This laboratory experiment demonstrated that matlab is very useful to solve ac circuits with passive elements and obtained waveforms and time domain equation of the voltages and current across the desire elements.