SIMULATION OF A PARALLEL RESONANT CIRCUIT

ECE562: Power Electronics I
COLORADO STATE UNIVERSITY

Modified in Fall 2011
PURPOSE: The purpose of this lab is to simulate the parallel resonant circuit using MATLAB® and NL5 to better familiarize the student with some of its operating characteristics. This lab will explore some of the following aspects of the parallel resonant circuit:

- Input impedance
- Magnitude and phase margin
- Zero frequency
- Output power
- Output current
- Plot the natural response for the output voltage
- Zero poles
- Phase of transfer function
- Input impedance for varying resistance (R)

NOTE: The simulations that follow are intended to be completed with NL5. It is assumed that the student has a fundamental understanding of the operation of NL5.

Build the schematic shown in Figure A.

- $I_1$ is an AC current source. Set the type to ‘Sin,’ and the magnitude to 1 mA.
- $L_1$ is an ideal inductor. Set to 0.1 H.
- $R_1$ is an ideal resistor. Set to 20 kΩ.
- $C_1$ is an ideal capacitor. Set to 100 nF.

Figure A – Initial schematic.
Under the ‘AC Settings’ tab, specify I1 as the source, a frequency range of 100 Hz to 10 MHz, 1000 points, and a logarithmic scale.

Add a trace for the input impedance by selecting AC / Data / Traces from the menu. Click on ‘Function’ in the ‘Add new trace’ section. Add the function V(I1)/I(I1).
Run the simulation by selecting ‘AC’ and then ‘Start’ from the drop down menus.

Referring to Figure B, what is the input impedance value of the circuit?

![Figure B – Magnitude and phase of the input impedance.](image)

Next, we want to measure the output voltage of the parallel circuit. For this example, take the output voltage as the voltage across the capacitor. Right click on the capacitor and select Add trace / Voltage. Run the simulation and adjust the data display to show this voltage.
Next, we want to simulate the input impedance of the parallel resonant circuit with a varying resistor. Use the same circuit as above, but change the resistor values to 5k, 10k, 20k, 40k, 200k, 400k, and 800k $\Omega$. This type of parametric sweep is accomplished in NL5 with a script. Go to Tools / Script and click on the Sweep tab. Select List instead of Loop. Enter R1 as the Name, enter the parametric values in the box, and select AC sweep. Click on the blue arrow to start the script.
What is the input impedance value of the circuit with varying resistances?

*Figure D – Input impedance as a function of resistance.*
We would also like to measure the output voltage as a function of resistance.

![Figure E – Output voltage as a function of resistance.](image)

What is the value of the output voltage? Describe the phase characteristics of the output voltage.

**For Homework:**

You need to re-solve the parallel resonant circuit with inductor ESR and see its effects on the magnitude and phase plots in some detail. For example choose the ratio of the L ESR to the load resistance to be in the ratio range from 0.01 to 1.
Parallel Resonant circuit using MATLAB

NOTE: The simulations that follow are intended to be completed with MATLAB®. It is assumed that the student has a fundamental understanding of the operation of MATLAB®. MATLAB® provides tutorials for users that are not experienced with its functions.

In this lab you will learn how to write a function to varying, calculating and plotting the input impedance, current and output voltage of the series RLC resonant tank circuit. Also plot the natural response of the parallel RLC tank circuit. You can define your own function in MATLAB. A function must start with a line.

    Function return-value = function-name (arguments)

So that MATLAB will recognize it as a function. Each function must have its own file and the file must have the same as the function.

PROCEDURE:

Part 1: Write a function to calculate the total input impedance of parallel RLC resonant circuit as shown in Figure 1.

\( I_m \) is a variable current. Set to 0.001 amps

\( L \) is a variable inductor. Set to 0.1H.

\( R \) is a variable ideal resistor. Set to 20000\( \Omega \).

\( C \) is a variable ideal capacitor. Set to 100nF.
function [Zinput]=Zinput_parallelRLC1() \ is the function declaration. Note:

% The word “function” must be the first (non-comment) word of the program.
% “Zinput” is the value that this function returns, or calculates, a.k.a. the output.
% “radius” is the name of the variable taken as input.
% “Zinput_parallelRLC1” should be both the name of the function and the name
% that you use to save the file.

disp('Starting the function of Zinput_seriesRLC1');
% define all the component values and units for Tank
    %unit
    Im=0.001; \ %Amps
    F=20000; \ %ohms
    C=100e-9; \ %Farads
    L=0.1; \ %henrys

% define the input impedance
Zinductor=tf([L 0], [0 1]);
Zcapacitor=tf([0 1], [C 0]);
Zinput=1/(1/R+1/Zcapacitor+1/Zinductor)
figure(1)
hold(Zinput)
title('input impedance of parallel RLC tank circuit')

% calculating important parameters of the tank
[z,p,k]=zpkdata(Zinput, 'v');
wo=sqrt(1/(1/C))
Beta=1/R/C
Q=wo/Beta

disp('finished the function of Zinput_seriesRLC1');

Figure 1: The input impedance of parallel RLC tank circuit.

Once the above function file is captured, the simulations can be run. First, go to your directory. Find your function file and then run your file. If there is a red
message on your MATLAB window, then you need to correct your error. Otherwise, you will see the solution as show in figure 2.

Starting the function of Zinput_seriesRLC1

Transfer function:
\[ \frac{0.1}{s} \]
---------------------------
\[1 \times 10^{-6} s^2 + 5 \times 10^{-6} s + 1\]

\(\omega_0 = 10\times10^3\)

\(\beta = 500.0000\)

\(Q = 20.0000\)

finished the function of Zinput_seriesRLC1

Transfer function:
\[ \frac{0.1}{s} \]
---------------------------
\[1 \times 10^{-6} s^2 + 5 \times 10^{-6} s + 1\]

>>
Figure 2: The output of input impedance of parallel RLC tank circuit.

Next, plot the output voltage of the parallel resonant RLC tank circuit. Write another function to calculate the output voltage and plot of parallel RLC tank circuit as shown in Figure 3. All the initial variables and values are remain the same.

*\( \textbf{Im} \) is a variable current. Set to 0.001 amps

*\( \textbf{L} \) is a variable inductor. Set to 0.1H.

*\( \textbf{R} \) is a variable ideal resistor. Set to 20000Ω.

*\( \textbf{C} \) is a variable ideal capacitor. Set to 100nF.
function []=Zinput_parallelRLC2(Zin)
%"Zin" is the name of the variable taken as input.
%define all the component values and units for Tank
disp('Starting the function of Zinput_seriesRLC2');
    %unit
    I_m=0.001;  %Amps
    R=20000;   %ohms
    C=100e-9;  %Farads
    L=0.01;    %henrys

    Zin=Zinput_parallelRLC1;
    Vout=I_m*Zin
    figure(2)
    bode(Vout)
    title('Output voltage in parallel RLC tank circuit')

Figure 3: the function to calculate the total input current of series RLC tank circuit

Once the above function file is captured, the simulations can be run. First, go to your directory. Find your function file and then run your file. If there is a red message on your MATLAB window, then you need to correct your error. Otherwise, you will see the solution as show in figure 4.
Starting the function of Zinput_seriesRLC2
Starting the function of Zinput_seriesRLC1

Transfer function:
0.1 s
---------------------
1e-008 s^2 + 5e-006 s + 1

wo =

10000

Beta =

500.0000

Q =

20.0000

finished the function of Zinput_seriesRLC1

Transfer function:
0.0001 s
---------------------
1e-008 s^2 + 5e-006 s + 1
Figure 4: the output and plot of the output voltage of parallel RLC tank circuit

Now write a function to varying R of the output voltage in parallel RLC resonant circuit by adding an array of Resistors (R) value. Again all the initial variables and values are remain the same.

**Im** is a variable current. Set to 0.001 amps

**L** is a variable inductor. Set to 0.1H.

**R** is a variable ideal resistor. Set to 20000Ω.

**C** is a variable ideal capacitor. Set to 100nF.
Write a loop function to do the varying resistors value, calculate and plot the output voltage of parallel RLC resonant circuit. When the function to varying $R$ of the output voltage of parallel RLC resonant circuit function file is captured, the simulations can be run. If there is any error message on your MATLAB windows, then correct your error and then rerun the simulation. Otherwise, you will see the result as show below

```matlab
% parallel RLC Resonant circuit
% Minh Anh Thi Nguyen
% Colorado State University
% Electrical and Computer Engineering student
%
function [Zinput]=Zinput_parallelRLC3()

disp('Starting the function of Zinput_seriesRLC3');
% define all the component values and units for Tank
% unit
Im=0.001;  % amps
R=20000;  % ohms
C=100e-9;  % Farads
L=0.1;  % henrys

% define the varying loads value
R=[R/4 R/2 R*2 R*10 R*20 R*40]

% define the input impedance for varying Rs
for i=1:7
    Zinductor=tf([L 0], [0,1]);
    Zcapacitor=tf([0 1], [C 0]);
    Zinput=1/(1/R(i)+1/Zcapacitor+1/Zinductor);
    Vm=Im*Zinput;
    figure(3)
    bode(Vm)
    if i==1,
        hold,
    end
end
title('Output voltage parallel RLC tank circuit for varying R')
disp('finished the function of Zinput_seriesRLC3');
```
Figure 5: A function to calculate and plot of the output voltage in parallel RLC resonant circuit with varying Resistor

Starting the function of Zinput_seriesRLC3

R =

| 5000 | 10000 | 20000 | 40000 | 200000 | 400000 | 800000 |

Current plot held
finished the function of Zinput_seriesRLC3

Transfer function:

0.1 s

-------------------------
1e-008 s^2 + 1.25e-007 s + 1
For Homework:

You need to re-solve the parallel resonant circuit with inductor ESR and see its effects on the magnitude and phase plots in some detail. For example choose the ratio of the L ESR to the load resistance to be in the ratio range from 0.01 to 1.
Next write m file to varying R of the natural response of current in parallel RLC resonant circuit by adding an array of Resistors (R) value. Again all the initial variables are remain the same but change their values.  

**Im** is a variable current. Set to 1 volts  
**L** is a variable inductor. Set to 39.487 H.  
**R** is a variable ideal resistor. Set to 2000Ω.  
**C** is a variable ideal capacitor. Set to 1µF  
**Io** is a variable ideal of inductor current. Set to 0 amps.  
**Vo** is a variable ideal of capacitor voltage. Set to 0 volts.  

Write a loop function to do the varying resistors value, calculate and plot the natural response of current for parallel RLC resonant circuit. When the m file to varying R of the natural response of current in parallel RLC resonant circuit file is captured, the simulations can be run. If there is any error message on your MATLAB windows, then correct your error and then rerun the simulation. Otherwise, you will see the result as show below
% Parallel RLC Resonant circuit
% Minh Anh Thi Nguyen
% Colorado State University
% Electrical and Computer Engineering student
% **************************************************************

% clear all the windows
clear;
disp('Starting the natural response of current')

% define all the component values and units for Tank
    % unit
    I_m=1;     %Amps
    R=2000;    %ohms
    C=1e-6;    %Farads
    L=39.487;  %henrys
    I_o=0;     %amps (initial Ic on inductor)
    V_o=0;     %Volts ( initial Vc on capacitor)

% defining impedances of the RLC circuit

% the inductor impedance
    Z_inductor=tf([L 0], [0 1]);
% the capacitor impedance
    Z_capacitor=tf([0 1],[C 0]);

% define the varying loads
    R=[R/4 R/2 R*R/10]
% stepp to the inductor current for varying R
    hold off

% defining the input impedance for varying Rs.
    jmax=5;

    for i=1:jmax
        Z_input=1/(1/Z_capacitor+1/Z_inductor+i/R(i));
        Output_voltage=I_m*Z_input;
        Inductor=Output_voltage/Z_inductor;
        figure(4)
        Step(Inductor)
        title('the natural response of inductor current in a parallel RLC circuit')
        if i==1,
            hold,
        end;
    end;
end

disp('finished the function natural response of current');
Figure 11: The m file to calculate and plot the natural response of current in parallel RLC resonant circuit with varying Resistor

Starting the natural response of current

R =

500 1600 2000 4000 20000

Current plot held
finished the function natural response of current

>>
Figure 12: This figure is shown the output of the natural responses of current in parallel RLC resonant circuit with varying Resistor

Now write m file to varying R of the natural response of output voltage in a parallel RLC resonant circuit by adding an array of Resistors (R) value. Again all the initial variables are remain the same but change their values.

\textbf{Im} is a variable current. Set to 1 volts

\textbf{L} is a variable inductor. Set to 39.487 H.

\textbf{R} is a variable ideal resistor. Set to 2000\,\Omega.

\textbf{C} is a variable ideal capacitor. Set to 1\,\mu F.

\textbf{Io} is a variable ideal of inductor current. Set to 0 amps.

\textbf{Vo} is a variable ideal of capacitor voltage. Set to 0 volts.

Write a loop function to do the varying resistors value, calculate and plot the natural response of output voltage in a parallel RLC resonant circuit. When the m file to varying R of the natural response of parallel RLC resonant circuit file is captured, the simulations can be run. If there is any error message on your MATLAB windows, then correct your error and then rerun the simulation. Otherwise, you will see the result as show below.
% Parallel RLC Resonant circuit
% Minh Anh Thi nguyen
% Colorado State University
% Electrical and Computer Engineering student
% ************************************************************************************
% clear all window
clc;
disp('Starting the natural response of capacitor voltage')
%define all the component values and units for Tank
    %unit
I_m=1;    %amps
R=2000;    %ohms
C=1e-6;    %Farads
L=39.487;  %henrys
I_o=0;    %amps (initial I on inductor)
V_o=0;    %Volts ( initial Vc on capacitor)

% transfer function of tank current with initial conditions

% Defining impedances of the RLC circuit

% the inductor impedance
Z_inductor=tf([L 0], [0 1]);
% the capacitor impedance
Z_capacitor=tf([0 1],[C 0]);

% define the varying loads
R=[R/4 R/2 R*R^2]
% stepp to the inductor current for varying R
hold off
% defining the input impedance for varying Rs.
hold off
% defining the input impedance for varying Rs.
for i=1:4
    Z_input=1/(1/Z_capacitor+1/Z_inductor+1/R(i))
    V_output=I_m*Z_input;
    I_inductor=V_output/Z_inductor;
    figure(5)
    step(V_output)
    if i==1,
        hold,
    end;
end
title('natural response of capacitor voltage')
disp('finished the function natural response of capacitor voltage');
Figure 13: the m file to calculate and plot the natural response of current in a parallel RLC resonant circuit with varying Resistor

Starting the natural response of capacitor voltage

\[ R = \]
\[
\begin{array}{cccc}
500 & 1000 & 2000 & 4000
\end{array}
\]

Transfer function:
\[ 39.49 \frac{s}{3.940e-005 s^2 + 0.07897 s + 1} \]

Current plot held

Transfer function:
\[ 39.49 \frac{s}{3.940e-005 s^2 + 0.03949 s + 1} \]

Transfer function:
\[ 39.49 \frac{s}{3.940e-005 s^2 + 0.01974 s + 1} \]

Transfer function:
\[ 39.49 \frac{s}{3.940e-005 s^2 + 0.009872 s + 1} \]

finished the function natural response of capacitor voltage

>>&
Figure 14: the output of the natural response of capacitor voltage in a parallel RLC resonant circuit with varying Resistor