Jacobs University Bremen

Natural Science Laboratory
Signals and Systems Lab

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Lab Theory 2 – RLC Circuits – Frequency Response

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Prelab: RLC Circuits – Frequency Response

Problem: RLC Resonator

1) Show the Bode magnitude plot across the resistor, the capacitor, the inductor, and across both the capacitor and the inductor. Use a 5 V amplitude and vary the frequency starting at 100 Hz up to 100 KHz. Develop a MATLAB script to show all four characteristics in one plot.

   - The voltage calculation across the respective electrical devices was done using the voltage divider principle for the series RLC circuit.

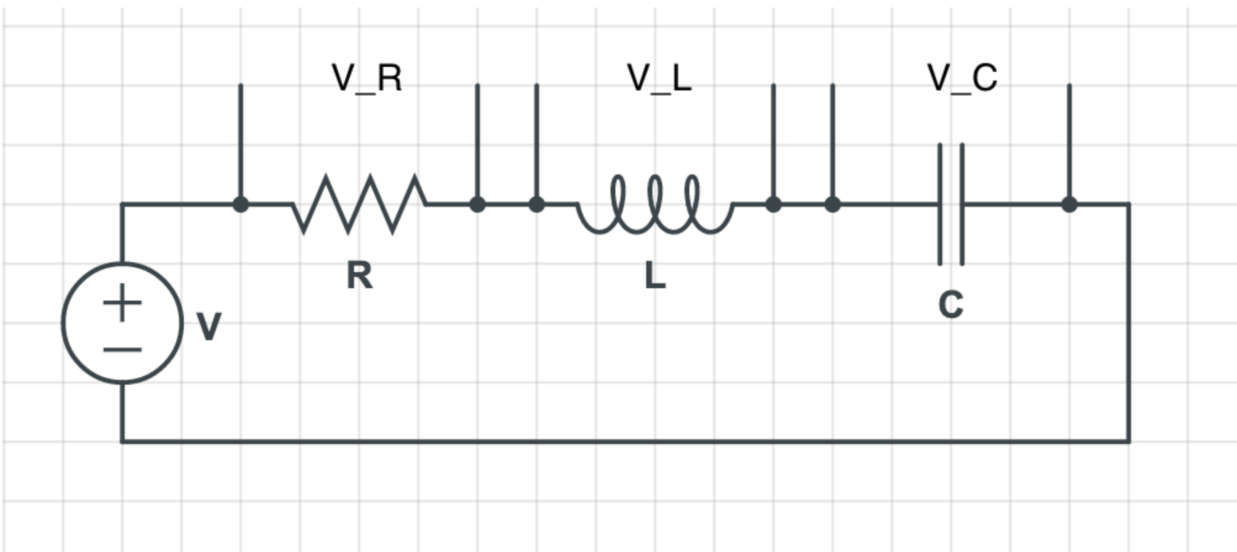

Figure 1: A series RLC circuit

Then the transfer function for each component, H($j\omega$) is calculated by the following equation:

$$H(j\omega) = 20 \cdot log\left(\left|\frac{Z}{Z_{Total}}\right|\right)$$

where,

Z is Impedance of the particular component

Z_{Total} is Total Impedance of the circuit

The values used were: $R = 390\Omega, C = 270\,nF\ and\ L = 10\,mH.$

The plot:

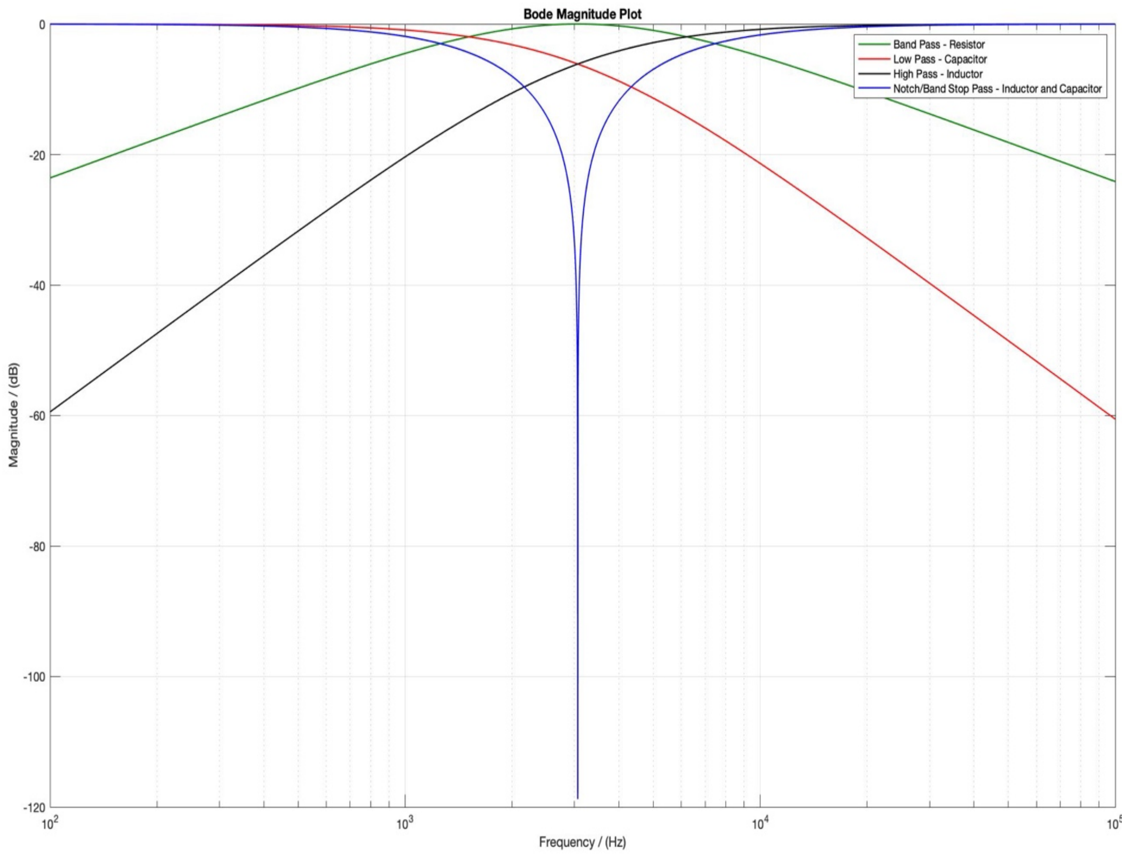

Figure 2: Bode Magnitude Plot for all elements

The MATLAB code used is:

```
%specifying value of the components
R=390;
C=270*10^(-9);
L=10^(-2);
f = logspace(2,5,2000000); %100Hz to 100kHz
omega=2*pi.*f;

Z_R=R;  %Impedance across resistor
Z_L=1i*L.*omega; %Impedance across inductor
Z_C=1./(1i*C.*omega); %Impedance across capacitor

Z_T = Z_R+Z_L+Z_C; %Total Impedance

H_R=Z_R./Z_T; % Transfer Function for Resistor
semilogx(f,(20*log10(abs(H_R))),'color', [0 0.5 0], 'linewidth', 1.1); %
Bode Plot for Resistor
```

```
grid on;
hold on;

H_C = Z_C./Z_T; % Transfer Function for Capacitor
semilogx(f,(20*log10(abs(H_C))),'r', 'linewidth', 1.1); % Bode Plot for
Capacitor

grid on;
hold on;

H_L= Z_L./Z_T;    % Transfer Function for Inductor
semilogx(f, 20*log10(abs(H_L)),'k', 'linewidth', 1.1); % Bode Plot for
Inductor
grid on;
hold on;


H_L_C = (Z_L+Z_C)./Z_T;  % Transfer Function for Inductor and Capacitor
semilogx(f, 20*log10(abs(H_L_C)),'b', 'linewidth', 1.1); % Bode Plot for
Inductor and Capacitor

title('Bode Magnitude Plot')
xlabel('Frequency / (Hz)')
ylabel('Magnitude / (dB)')
legend('Band Pass - Resistor','Low Pass - Capacitor', 'High Pass -
Inductor','Notch/Band Stop Pass - Inductor and Capacitor')
```

2) Taking the magnitude across the resistance represents a band-pass filter. Extract the bandwidth from the MATLAB plot and calculate the Q-factor.

- The bode plot for the bandpass filter is plotted. From the plot the cutoff frequency (f_0) and $-3\ dB$ frequencies ($f_1\ and\ f_2$) are found:

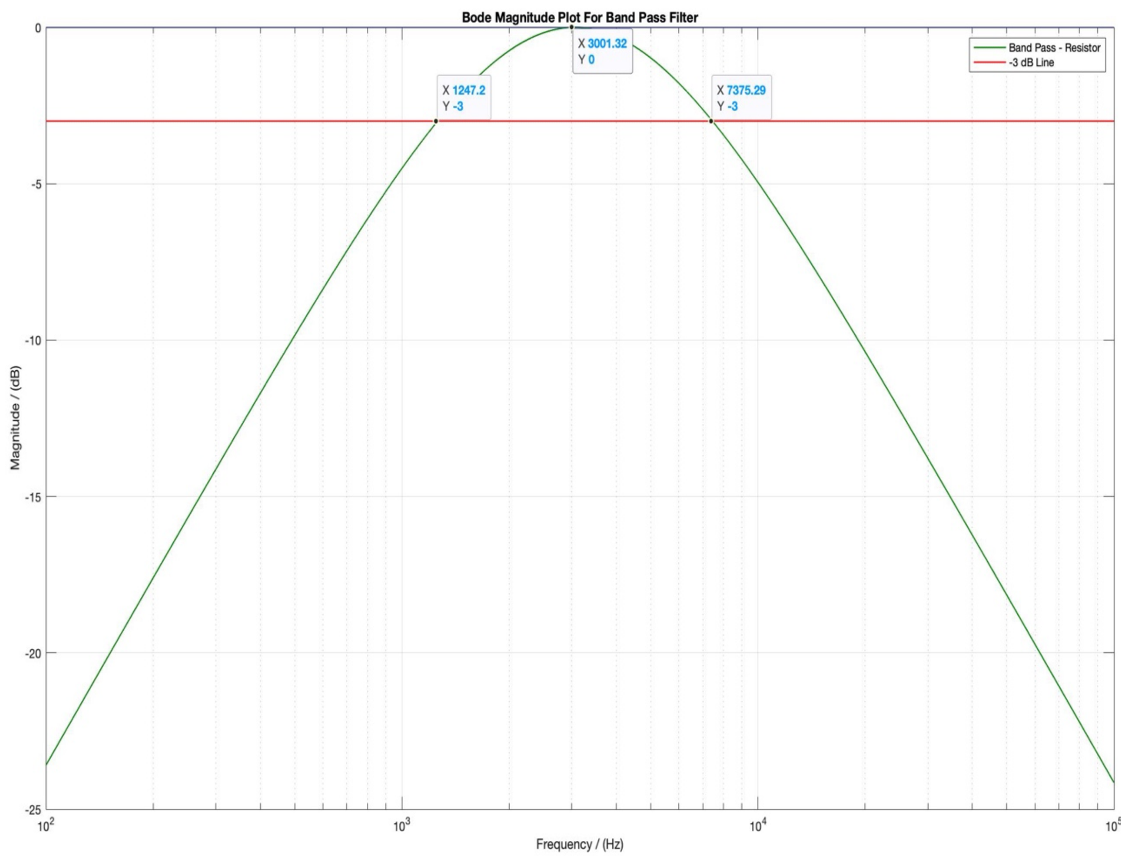

Figure 3: Bode plot of Bandpass Filter

The MATLAB code used is:

```
R=390;
C=270*10^(-9);
L=10^(-2);
f = logspace(2,5,200000);
omega=2*pi.*f;

Z_R=R;  %Impedance across resistor
Z_L=1i*L.*omega; %Impedance across inductor
Z_C=1./(1i*C.*omega); %Impedance across capacitor
Z_T = Z_R+Z_L+Z_C; %Total Impedance

H_R=Z_R./Z_T; % Transfer Function for Resistor
semilogx(f,(20*log10(abs(H_R))),'color', [0 0.5 0], 'linewidth', 1.1); %
Bode Plot for Resistor
```

```
grid on;
hold on;
Con = -3 * (f./f); %-3dB line
[x,y] = intersect(Con, H_R);

semilogx(f,Con,'r', 'linewidth', 1.1);
grid on;
hold on;
Cut = 0*(f./f) ;
[a,b] = intersect(Cut,f);
semilogx(f,Cut,'b');


title('Bode Magnitude Plot For Band Pass Filter');
xlabel('Frequency / (Hz)');
ylabel('Magnitude / (dB)');
legend('Band Pass - Resistor', '-3 dB Line');
```

From the plot:
$Cutoff\ frequemcy\ (f_0) = 3001.32\ Hz$

$-3dB\ frequencies$:
$f_1 = 1247.20\ Hz$
$f_2 = 7375.29\ Hz$

Now,

$$Bandwidth\ (B) = f_2 - f_1 = 6128.09\ Hz$$

$$Quality\ factor\ (Q) = \frac{f_0}{B} = 0.490$$

3) Name the remaining filter characteristic measured over the different components, component combinations.

- The filter properties of all the components are:

Electrical Component(s)	Type of Filter
Resistor	Band-Pass
Capacitor	Low Pass
Inductor	High Pass
Capacitor and Inductor	Band-Stop