INSTITUTE OF ENGINEERING
CENTRAL CAMPUS,PULCHOWK

FILTER DESIGN

LAB #1

ANALYSIS OF FILTER NETWORKS

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1 Title

ANALYSIS OF FILTER NETWORKS

2 Objective

- To analyze the given Filter Networks.

3 Requirement

3.1 MATLAB

MATLAB stands for MATrix LABoratory. It is used to analyze and design systems and products. Its built-in visuals make data visualization and analysis a breeze. Toolboxes are a type of application-specific solution available in MATLAB. Toolboxes are essential for most MATLAB users since they allow you to understand and use specific technologies.

3.2 Proteus Design Suite

Proteus is a simulation and design software tool developed by Labcenter Electronics for Electrical and Electronic circuit design.It is used to create schematic of a circuit and Visualization of its operation.

4 Procedure

With the help of MATLAB we plotted derived transfer function and using Proteus Design suite we simulate and plot the frequency response of the given circuit. Then we compared the two observation and also observed the effects of varying network components.

5 Exercises:

5.1 Question -1

Derive the transfer function of each of the network and determine the nature of filter network; (i.e. whether it is lowpass, highpass, bandpass or bandstop) .

5.1.1 TF Derivation of Figure a

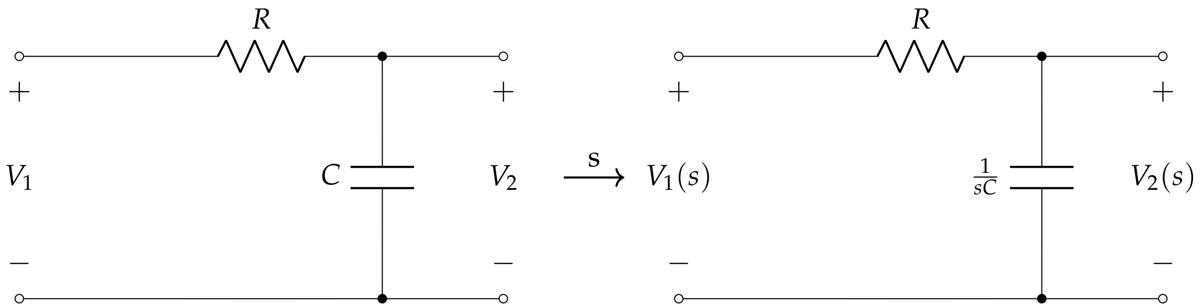


Figure 1: TF Derivation of Figure a

Using voltage divider rule,

$$V_2(s) = \frac{V_1(s).\frac{1}{sC}}{R + \frac{1}{sC}}$$
$$\frac{V_2(s)}{V_1(s)} = \frac{\frac{1}{sC}}{R + \frac{1}{sC}}$$
$$H(s) = \frac{1}{sRC + 1}$$

The given circuit is **Low pass filter** as for lower frequency capacitor restricts currents flow through it because of high reactance, so voltage at V_1 is replicated V_2, but for higher frequency currents flows through capacitor due to low reactance, hence restricting the high frequency signal from V_1 to reach V_2.

5.1.2 TF Derivation of Figure b

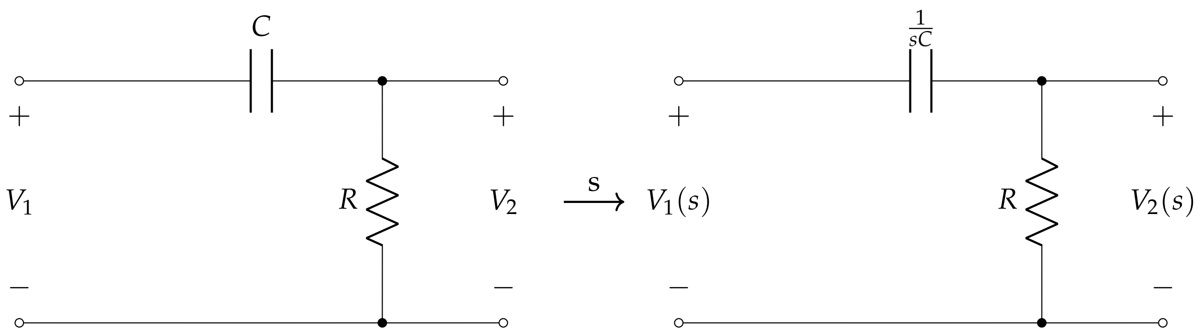


Figure 2: TF Derivation of Figure b

Using voltage divider rule,

$$V_2(s) = \frac{V_1(s).R}{R + \frac{1}{sC}}$$
$$\frac{V_2(s)}{V_1(s)} = \frac{sRC}{sRC + 1}$$
$$H(s) = \frac{sRC}{sRC + 1}$$

The given circuit is **High pass filter** as Capacitor allows higher frequency signal to pass through it, as it reduces the reactance, but blocks the low frequency signal because of high reactance.

5.1.3 TF Derivation of Figure c

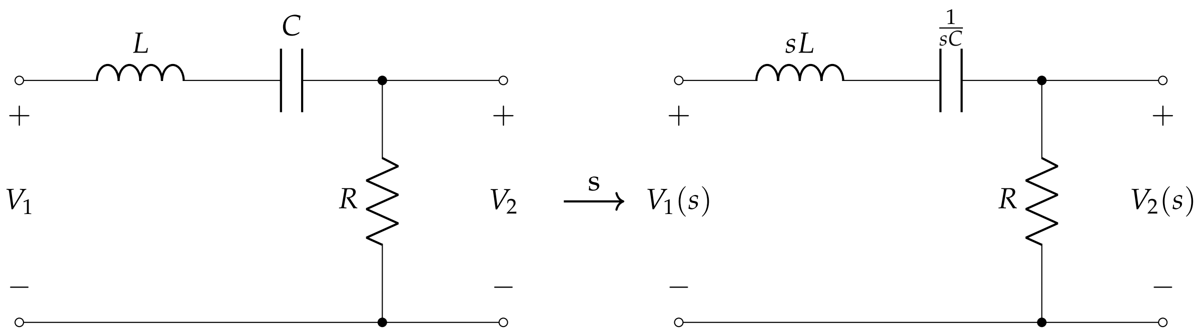


Figure 3: TF Derivation of Figure c

Using voltage divider rule,

$$V_2(s) = \frac{V_1(s).R}{R + \frac{1}{sC} + sL}$$
$$\frac{V_2(s)}{V_1(s)} = \frac{sRC}{s^2LC + sRC + 1}$$
$$H(s) = \frac{sRC}{s^2LC + sRC + 1}$$

The given circuit is **Band pass filter** as only limited range of frequency (Resonant frequency) is allowed. For other frequencies , due to high reactance of Inductor at high frequency and Capacitor at low frequency, is blocked.

5.1.4 TF Derivation of Figure d

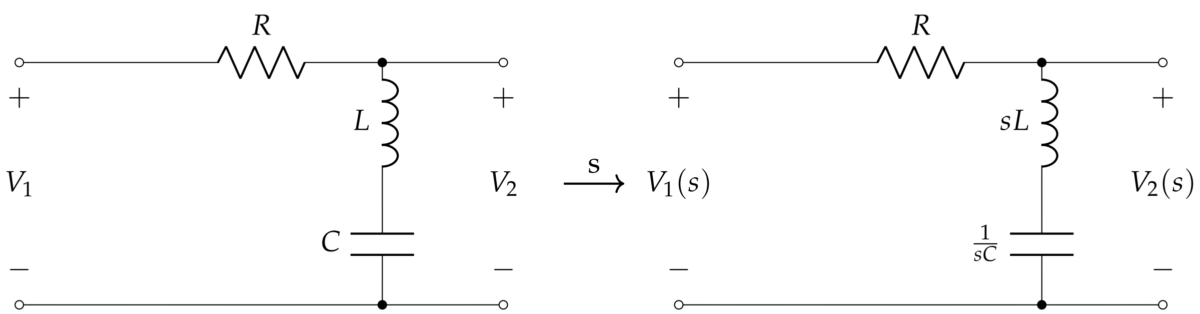


Figure 4: TF Derivation of Figure d

Using voltage divider rule,

$$V_2(s) = \frac{V_1(s)\left(sL + \frac{1}{sC}\right)}{R + \frac{1}{sC} + sL}$$

$$\frac{V_2(s)}{V_1(s)} = \frac{s^2LC + 1}{sC\left(R + \frac{1}{sC} + sL\right)}$$

$$H(s) = \frac{s^2LC + 1}{s^2LC + sRC + 1}$$

The given circuit is **Band stop filter** as it passes all other frequencies except the frequency in the resonant frequency range.

5.1.5 TF Derivation of Figure e

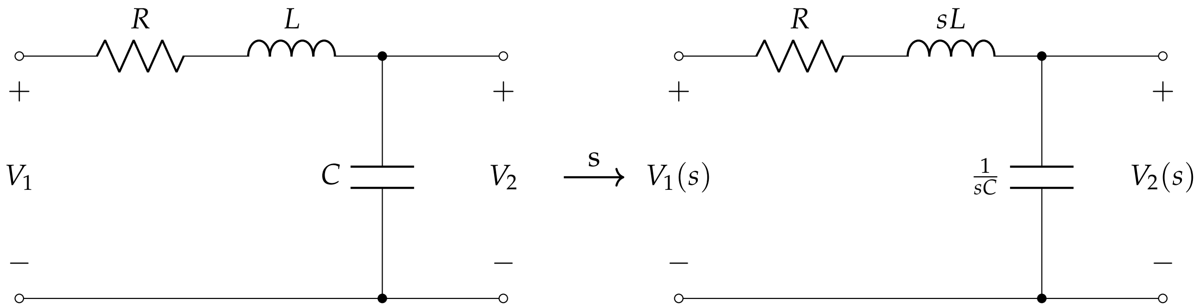


Figure 5: TF Derivation of Figure e

Using voltage divider rule,

$$V_2(s) = \frac{V_1(s)\left(\frac{1}{sC}\right)}{R + \frac{1}{sC} + sL}$$

$$\frac{V_2(s)}{V_1(s)} = \frac{1}{sC\left(R + \frac{1}{sC} + sL\right)}$$

$$H(s) = \frac{1}{s^2LC + sRC + 1}$$

The given circuit is **Low pass filter** as for lower frequency inductor allows flow of current and capacitor restricts currents flow through it because of high reactance so voltage at V_1 is replicated at V_2, but for higher frequency currents flows through capacitor due to low reactance, restricting the high frequency signal from V_1 to reach V_2.

5.1.6 TF Derivation of Figure f

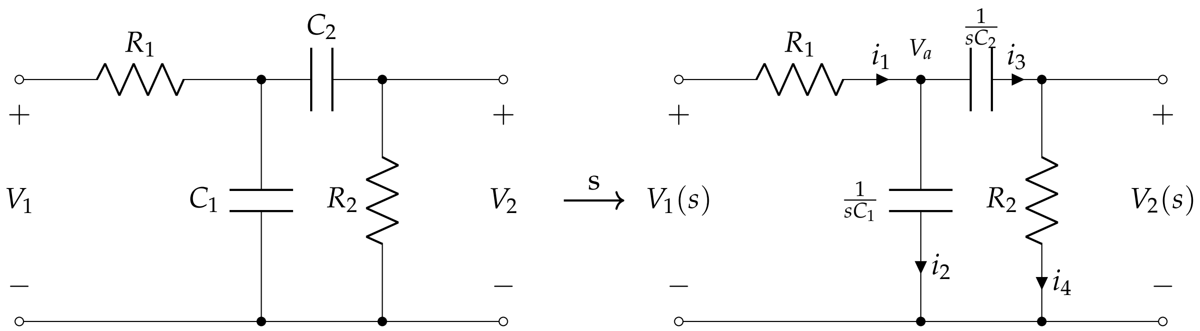


Figure 6: TF Derivation of Figure f

Using voltage divider rule,

$$i_3 = i_4$$
$$\frac{V_a(s) - V_2(s)}{\frac{1}{sC_2}} = \frac{V_2(s)}{R_2}$$
$$sR_2C_2V_a(s) = V_2(s)(sR_2C_2 + 1)$$
$$V_a(s) = V_2(s)\frac{sR_2C_2 + 1}{sR_2C_2}$$

$$i_1 = i_2 + i_3 \Rightarrow \frac{V_1(s) - V_a(s)}{R_1} = \frac{V_a(s)}{\frac{1}{sC_1}} + \frac{V_a(s) - V_2(s)}{\frac{1}{sC_2}}$$
$$V_1(s) - V_a(s) = sR_1C_1V_a(s) + sR_1C_2V_a(s) - sR_1C_2V_2(s)$$
$$V_1(s) = V_a(s)(sR_1C_1 + sR_1C_2 + 1) - sR_1C_2V_2(s)$$

Substituting value of $V_a(s)$,we get,

$$V_1(s) = V_2(s)\frac{sR_2C_2 + 1}{sR_2C_2}(sR_1C_1 + sR_1C_2 + 1) - sR_1C_2V_2(s)$$
$$sR_2C_2V_1(s) = V_2(s)(s^2R_1R_2C_1C_2 + s^2R_1R_2{C_2}^2 + sR_2C_2 + sR_1C_1 + sR_1C_2 + 1) - s^2R_1R_2{C_2}^2V_2(s)$$
$$\frac{V_2(s)}{V_1(s)} = \frac{sR_2C_2}{s^2R_1R_2C_1C_2 + sR_1C_1 + sR_1C_2 + sR_2C_2 + 1}$$
$$H(s) = \frac{sR_2C_2}{s^2R_1R_2C_1C_2 + s(R_1C_1 + R_1C_2 + R_2C_2) + 1}$$

The given circuit is **Band pass filter** as the circuit of Low pass and High Pass is combined as one. The low frequency signals from V_1 is allowed by Low pass circuit but is blocked by High pass. For high frequency signal Low pass circuit will block it.Thus only limited frequency colud pass through it.

5.2 Question -2

Plot the magnitude and phase response of each network from the derived transfer function (using MATLAB or any tool) and note down the followings:

- **Gain in passband**
- **Half power frequency/frequencies**
- **Bandwidth**

Choose the element values as followings: R = 1kΩ , L = 1 mH , C = 0.1μF , R1 = 1 kΩ , C1 = 0.01μF , R2 = 10kΩ , C2 = 0.1μF.

5.2.1 MATLAB Codes

```
function Amrit_prasad_LAB1_bode_func(n,d)
H=tf(n,d);
options = bodeoptions;
options.FreqUnits = 'Hz';  % or 'rad/second', 'rpm', etc.
bode(H,options,'.-');
grid on;
end
```

Code 1: MATLAB Function for Bode Plot

```
%Initializing componenets
R = 1e3;      L = 1e-3;    C = 0.1e-6;      R1 = 1e3;
C1 = 0.01e-6;     R2 = 10e3;      C2 = 0.1e-6;

%Calling Bode polt Function
Amrit_prasad_LAB1_bode_func(1,[R*C 1]);

%Title
title('Bode Diagram Amrit Prasad LAB1A');
```

Code 2: MATLAB code to Bode Plot for Figure a

```
%Initializing componenets
R = 1e3;      L = 1e-3;    C = 0.1e-6;      R1 = 1e3;
C1 = 0.01e-6;     R2 = 10e3;      C2 = 0.1e-6;

%Calling Bode polt Function
Amrit_prasad_LAB1_bode_func([R*C,0],[R*C 1]);

%Title
title('Bode Diagram Amrit Prasad LAB1B');
```

Code 3: MATLAB code to Bode Plot for Figure b

```
%Initializing componenets
R = 1e3;      L = 1e-3;    C = 0.1e-6;      R1 = 1e3;
C1 = 0.01e-6;     R2 = 10e3;      C2 = 0.1e-6;

%Calling Bode polt Function
Amrit_prasad_LAB1_bode_func([R*C, 0],[L*C , R*C , 1]);

%Title
title('Bode Diagram Amrit Prasad LAB1C');
```

Code 4: MATLAB code to Bode Plot for Figure c

```matlab
%Initializing componenets
R = 1e3;     L = 1e-3;    C = 0.1e-6;     R1 = 1e3;
C1 = 0.01e-6;     R2 = 10e3;     C2 = 0.1e-6;

%Calling Bode polt Function
Amrit_prasad_LAB1_bode_func([L*C 0 1],[L*C R*C 1]);

%Title
title('Bode Diagram Amrit Prasad LAB1D');
```

Code 5: MATLAB code to Bode Plot for Figure d

```matlab
%Initializing componenets
R = 1e3;     L = 1e-3;    C = 0.1e-6;     R1 = 1e3;
C1 = 0.01e-6;     R2 = 10e3;     C2 = 0.1e-6;

%Calling Bode polt Function
Amrit_prasad_LAB1_bode_func([1],[L*C R*C 1]);

%Title
title('Bode Diagram Amrit Prasad LAB1E');
```

Code 6: MATLAB code to Bode Plot for Figure e

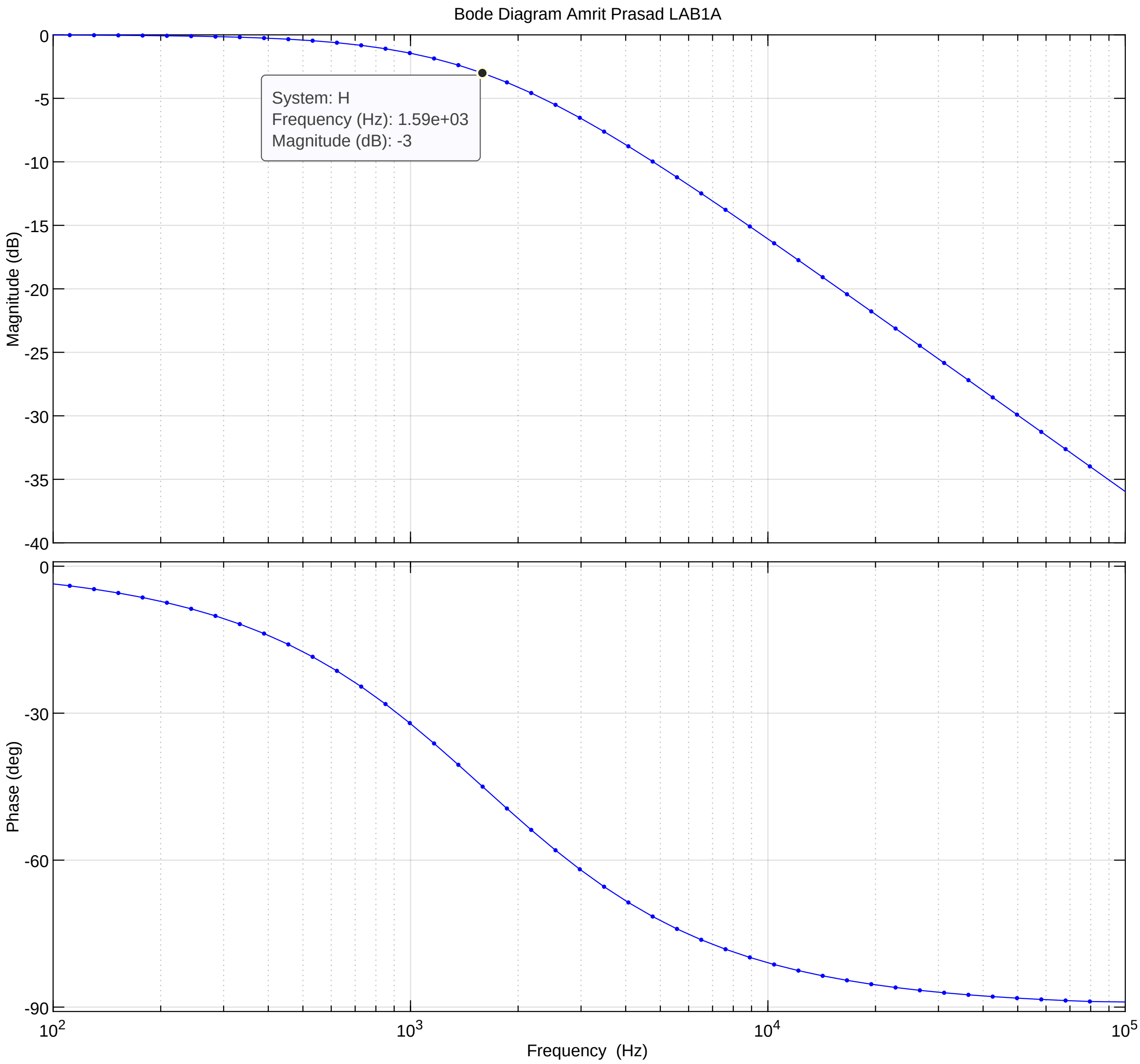
```matlab
%Initializing componenets
R = 1e3;     L = 1e-3;    C = 0.1e-6;     R1 = 1e3;
C1 = 0.01e-6;     R2 = 10e3;     C2 = 0.1e-6;

%Calling Bode polt Function
Amrit_prasad_LAB1_bode_func([R2*C2 0],[R1*R2*C1*C2 R1*C1+R1*C2+R2*C2 1]);

%Title
title('Bode Diagram Amrit Prasad LAB1F');
```

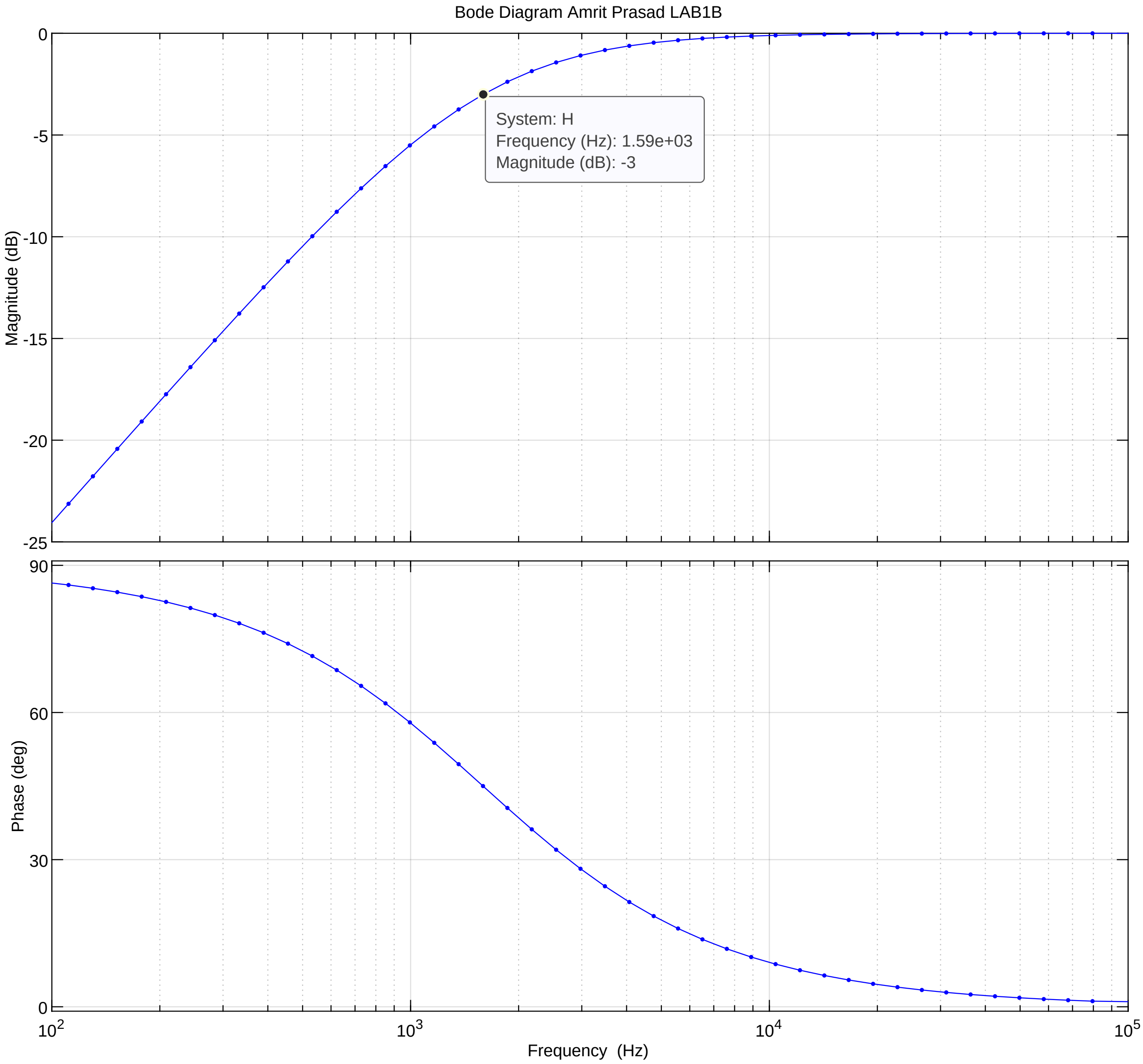
Code 7: MATLAB code to Bode Plot for Figure f

5.2.2 MATLAB Observations



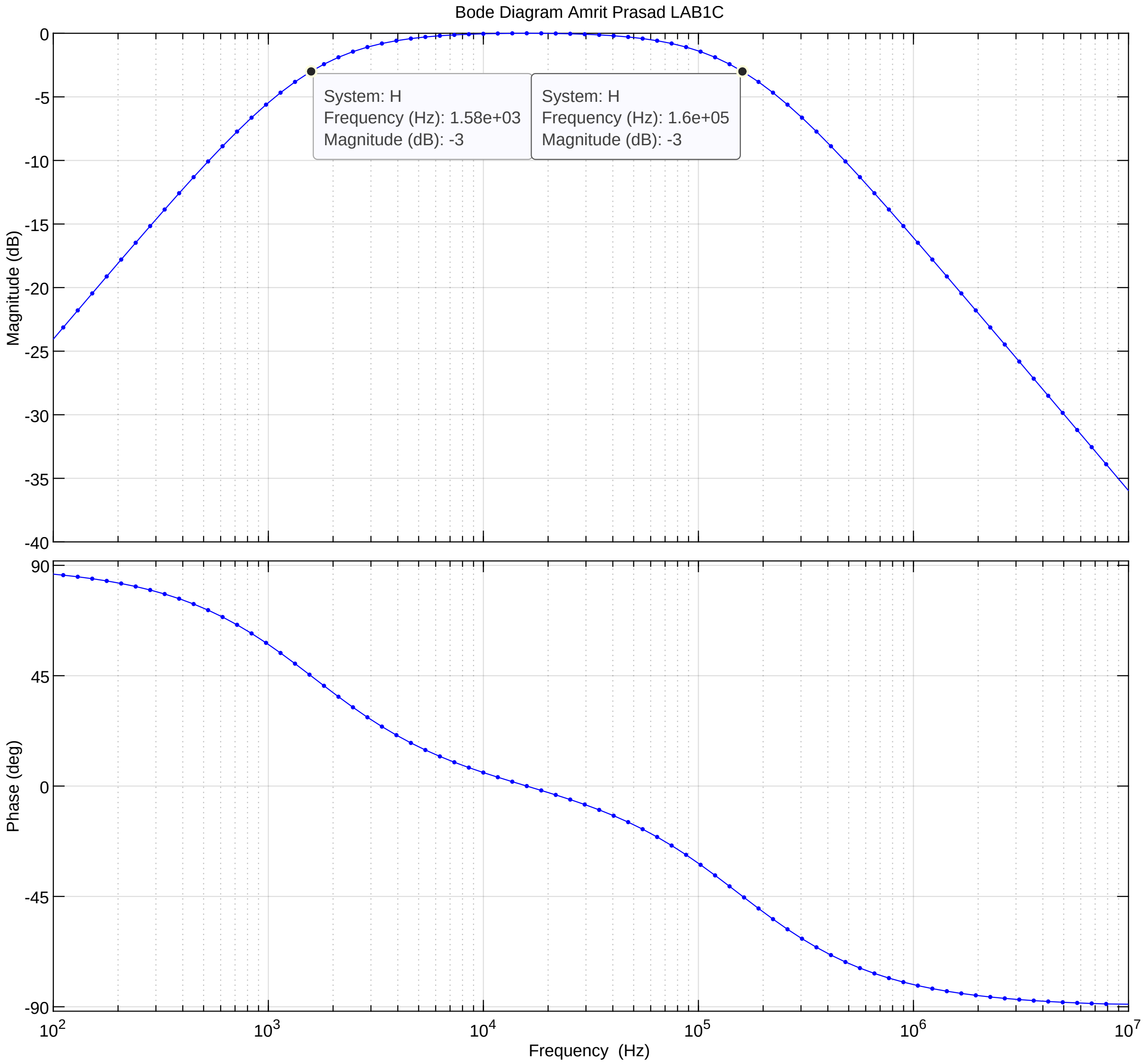
Gain in passband	Half power frequency / frequencies	Bandwidth
0 dB	(1.59) KHz	1.59 KHz

Figure 7: MATLAB Observation Figure a



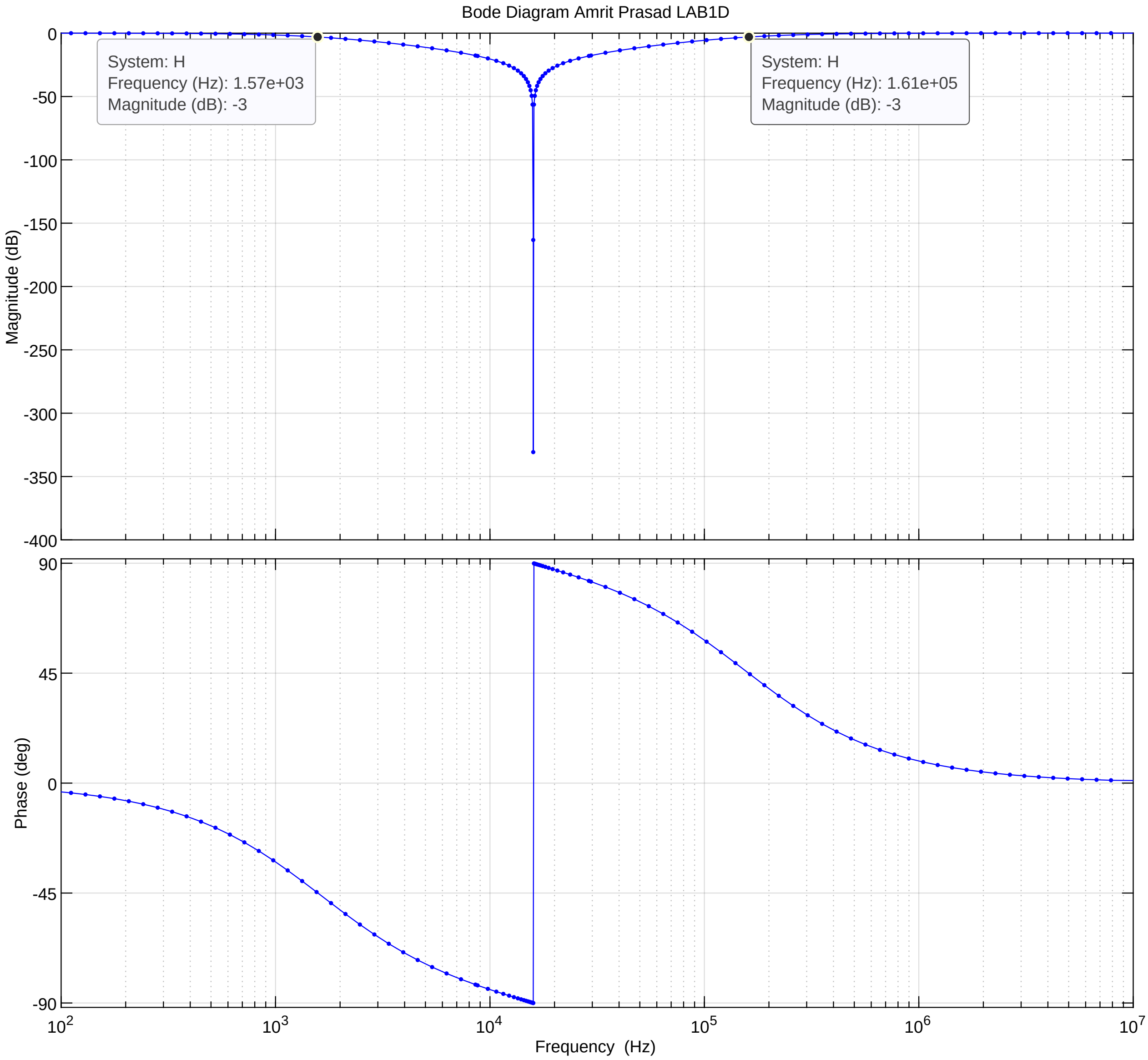
Gain in passband	Half power frequency / frequencies	Bandwidth
0 dB	(1.59) KHz	1.59 KHz

Figure 8: MATLAB Observation Figure b



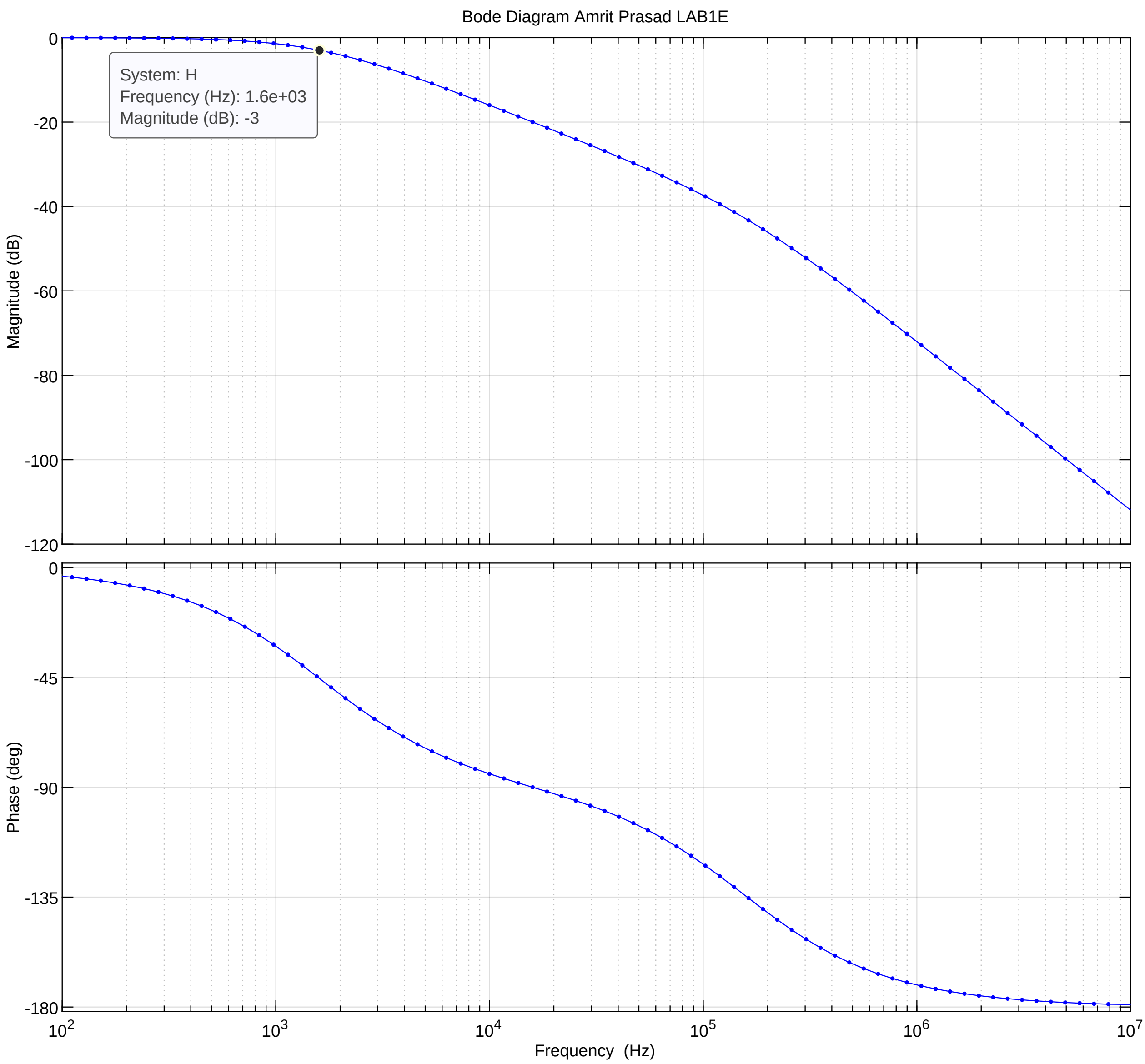
Gain in passband	Half power frequency / frequencies	Bandwidth
0 dB	(1.58 & 160) KHz	158.42 KHz

Figure 9: MATLAB Observation Figure c



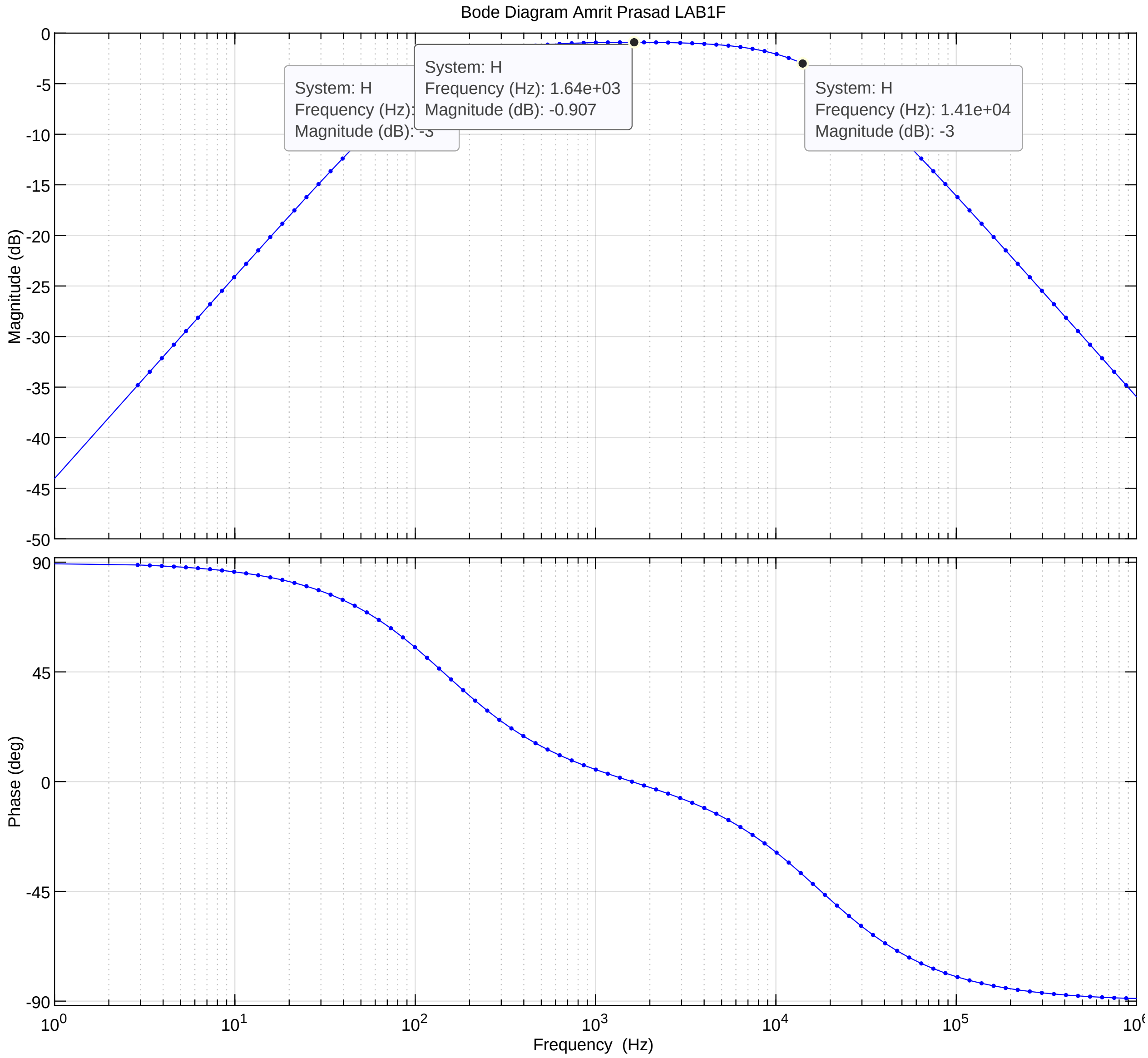
Gain in passband	Half power frequency / frequencies	Bandwidth
0 dB	(1.57 & 161) KHz	159.43 KHz

Figure 10: MATLAB Observation Figure d



Gain in passband	Half power frequency / frequencies	Bandwidth
0 dB	(1.6) KHz	1.6 KHz

Figure 11: MATLAB Observation Figure e



Gain in passband	Half power frequency / frequencies	Bandwidth
-0.907 dB	(0.18 & 14.1) KHz	13.92 KHz

Figure 12: MATLAB Observation Figure f

5.3 Question -3

Observe the magnitude response of given filter networks by realizing the circuit using circuit simulation tools and note down the followings:

- **Gain in passband**
- **Half power frequency/frequencies**
- **Bandwidth**

Compare the result obtained in activity 2.

Choose the element values as followings: R = 1kΩ , L = 1 mH , C = 0.1μF , R1 = 1 kΩ , C1 = 0.01μF , R2 = 10kΩ , C2 = 0.1μF.

5.3.1 Proteus Observations

The result obtained in both MATLAB and Proteus observations are almost similar.

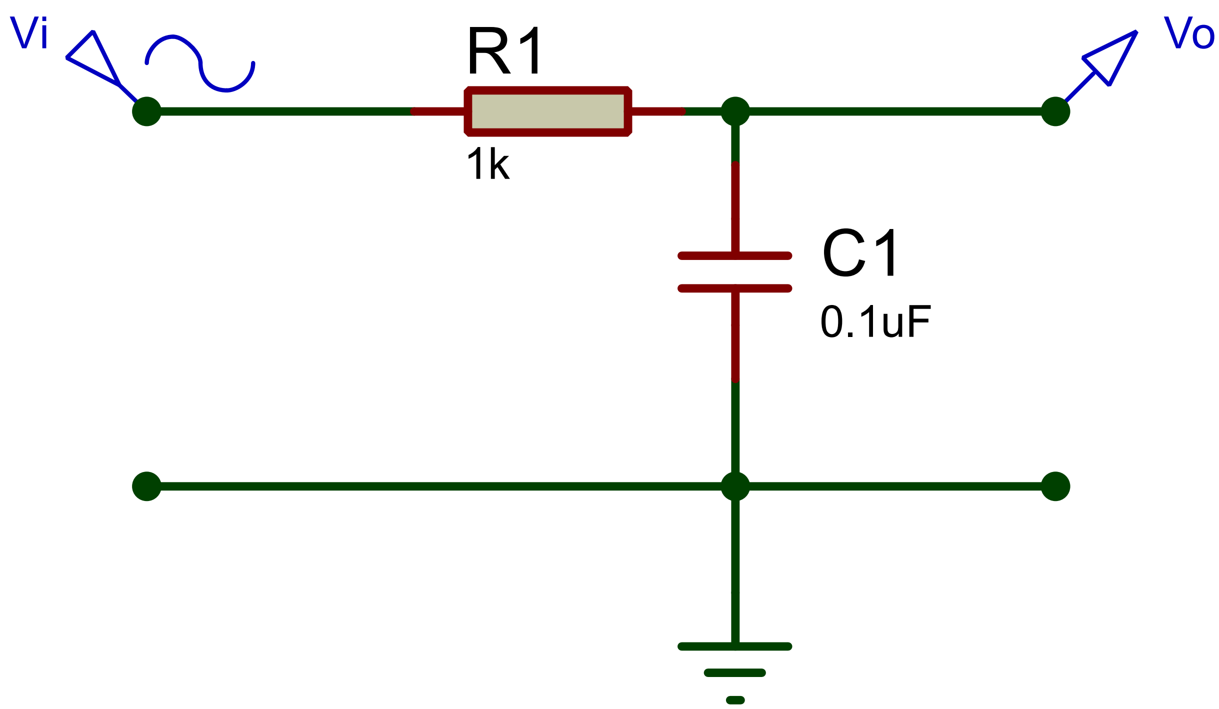
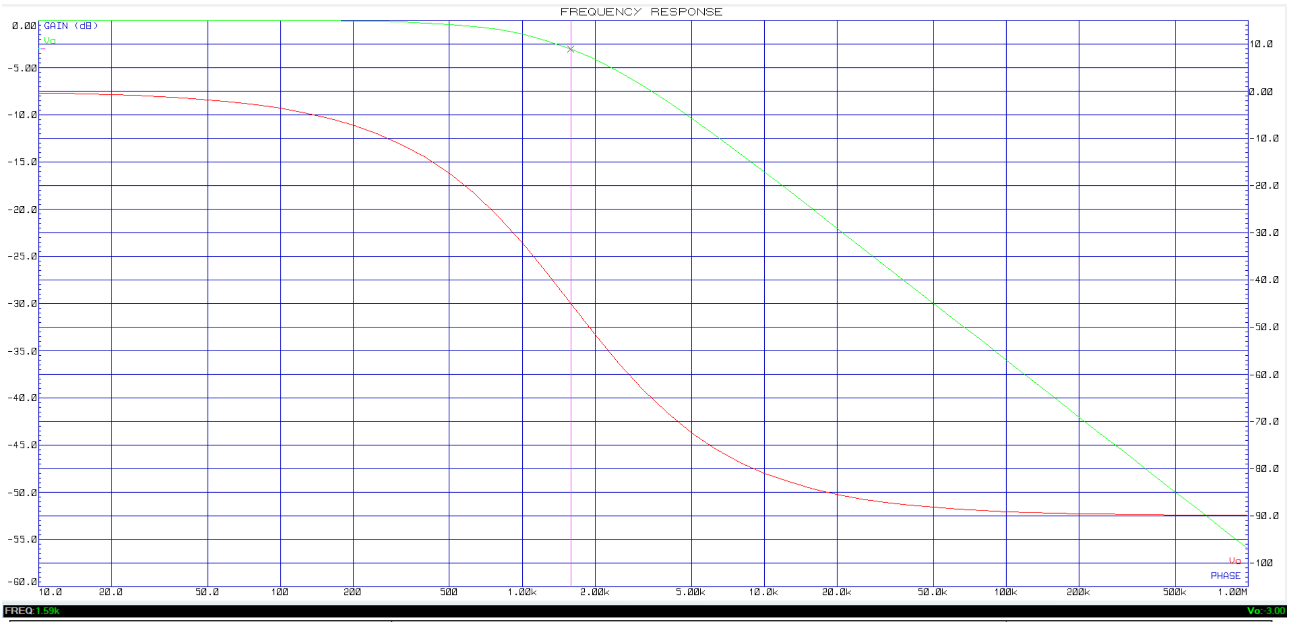


Figure 13: Proteus Circuit Figure a



Gain in passband	Half power frequency / frequencies	Bandwidth
0 dB	(1.59) KHz	1.59 KHz

Figure 14: Proteus Observation Figure a

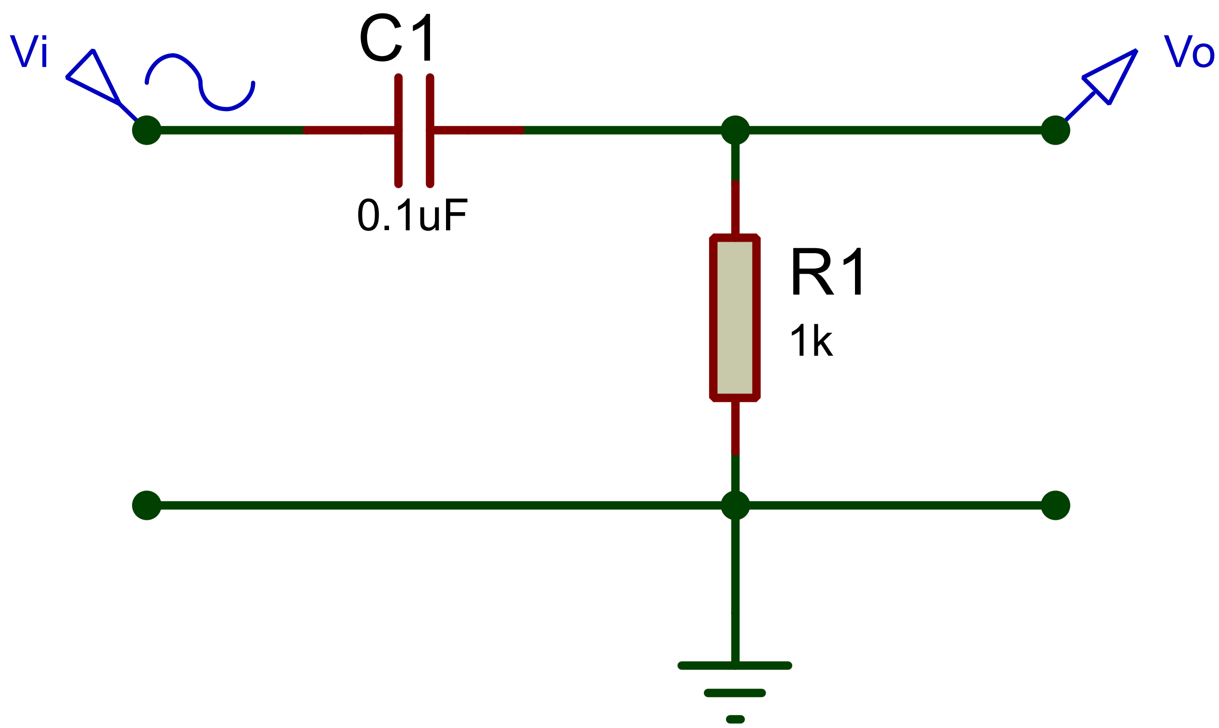
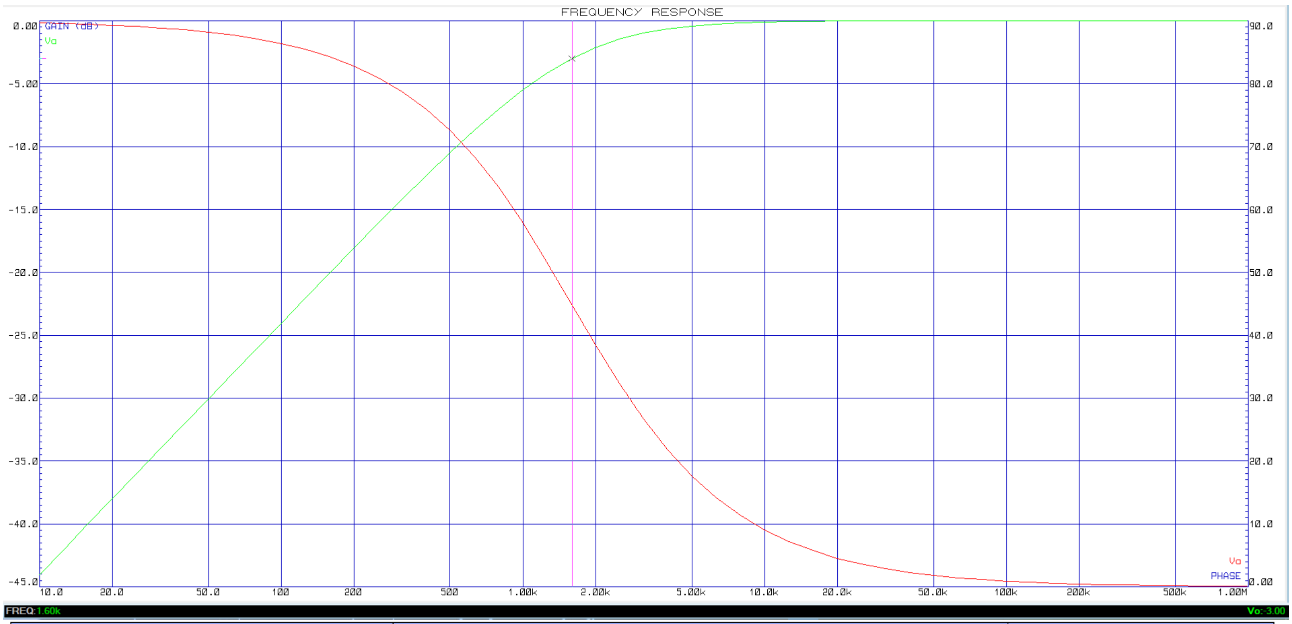


Figure 15: Proteus Circuit Figure b



Gain in passband	Half power frequency / frequencies	Bandwidth
0 dB	(1.60) KHz	1.60 KHz

Figure 16: Proteus Observation Figure b

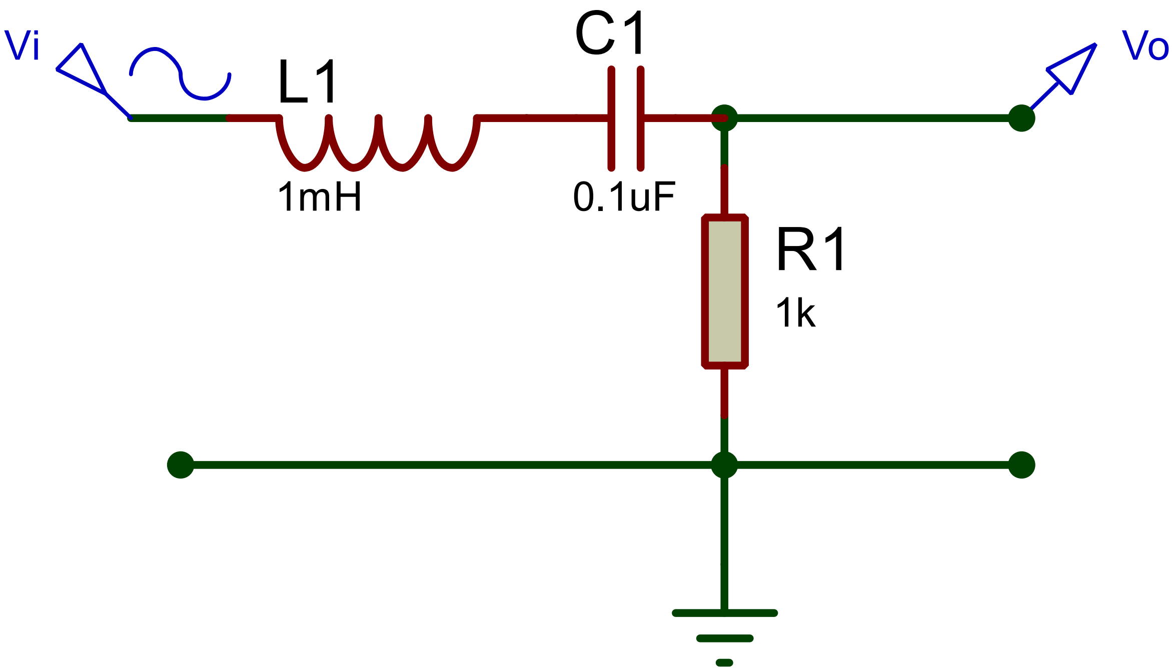
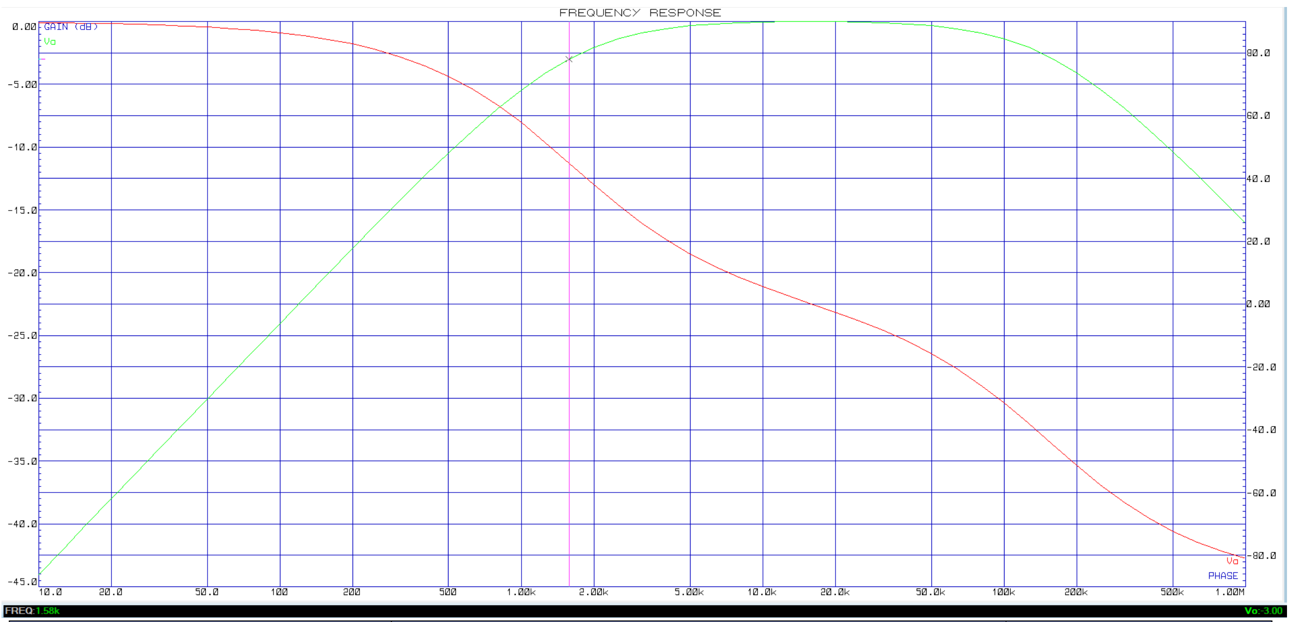


Figure 17: Proteus Circuit Figure c



Gain in passband	Half power frequency / frequencies	Bandwidth
0 dB	(1.58 & 160) KHz	158.42 KHz

Figure 18: Proteus Observation Figure c

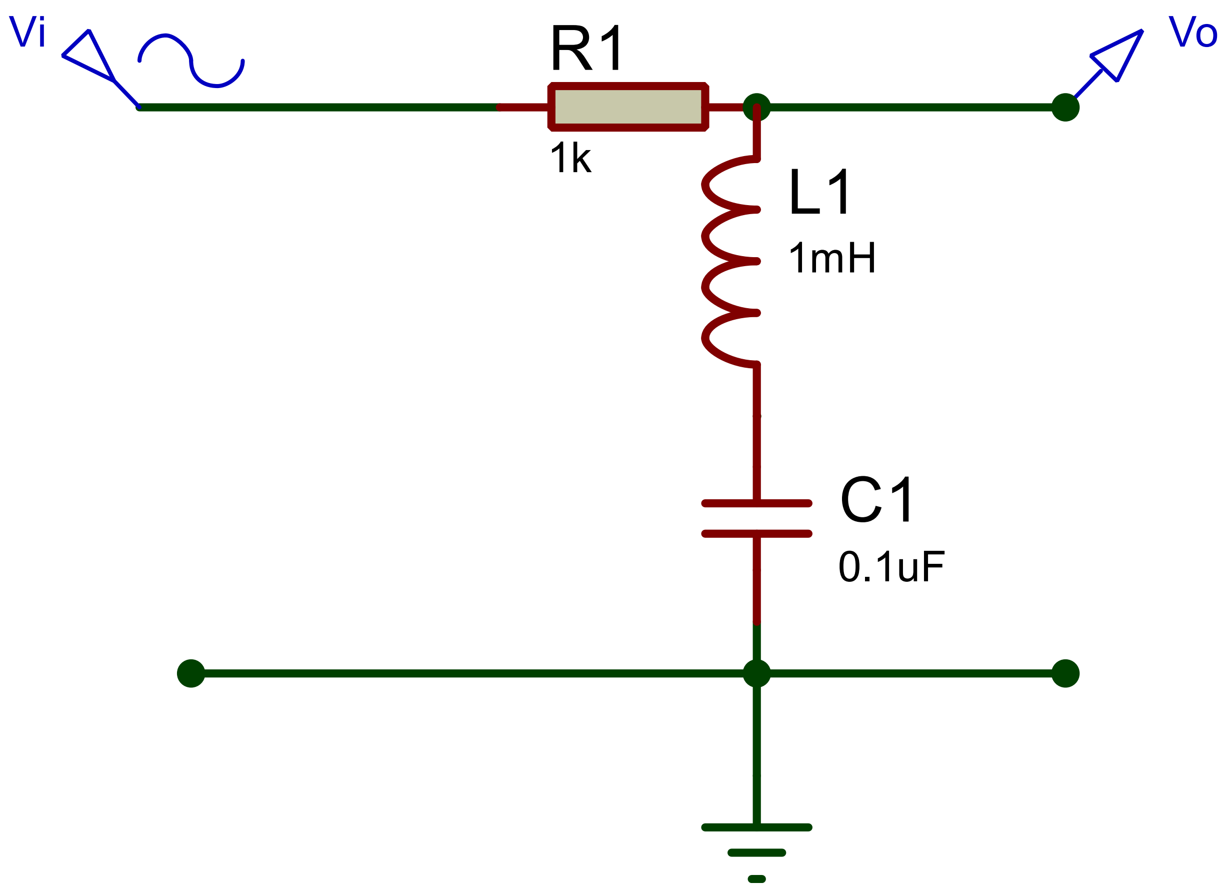
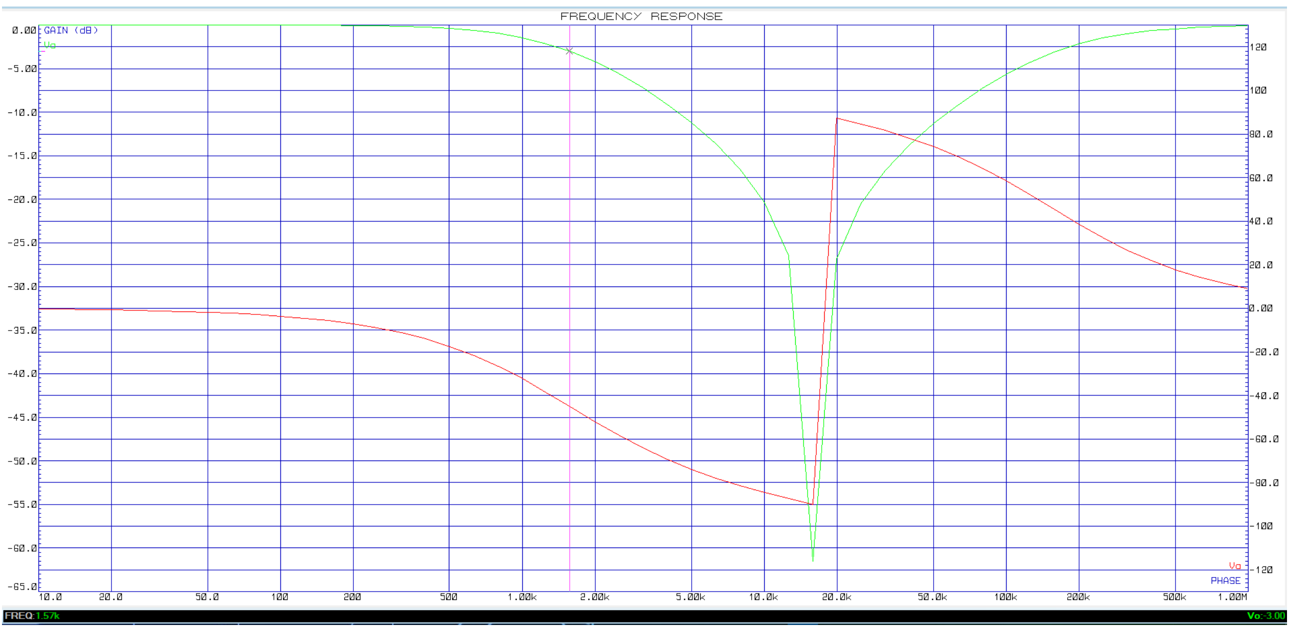


Figure 19: Proteus Circuit Figure d



Gain in passband	Half power frequency / frequencies	Bandwidth
0 dB	(1.57 & 161) KHz	159.43 KHz

Figure 20: Proteus Observation Figure d

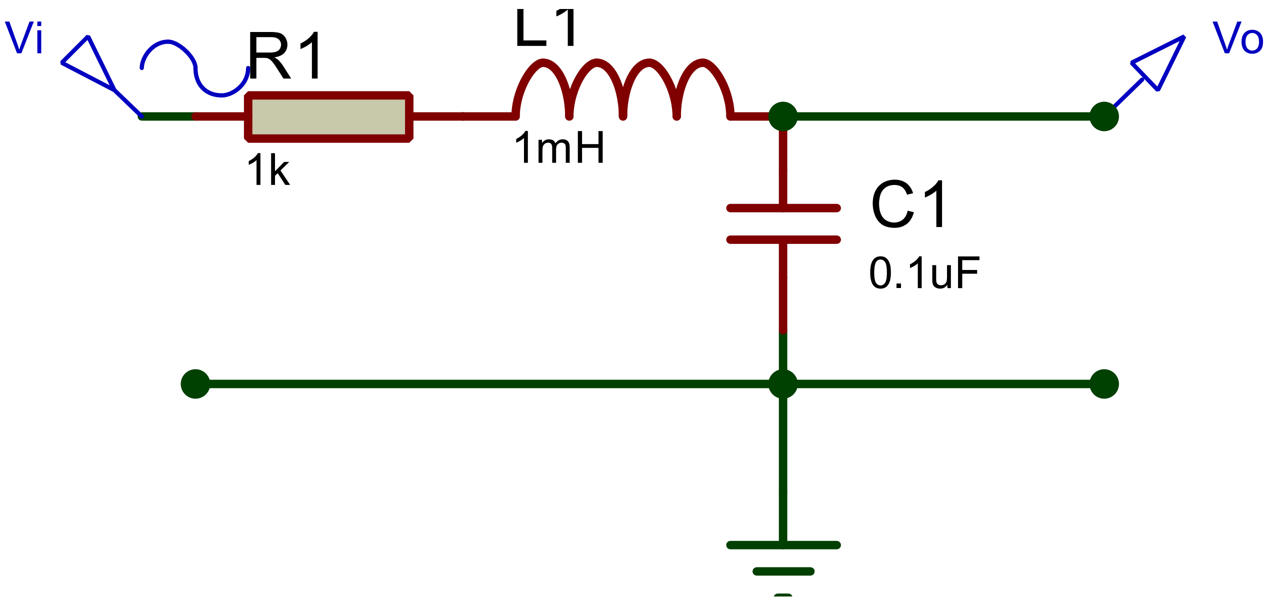
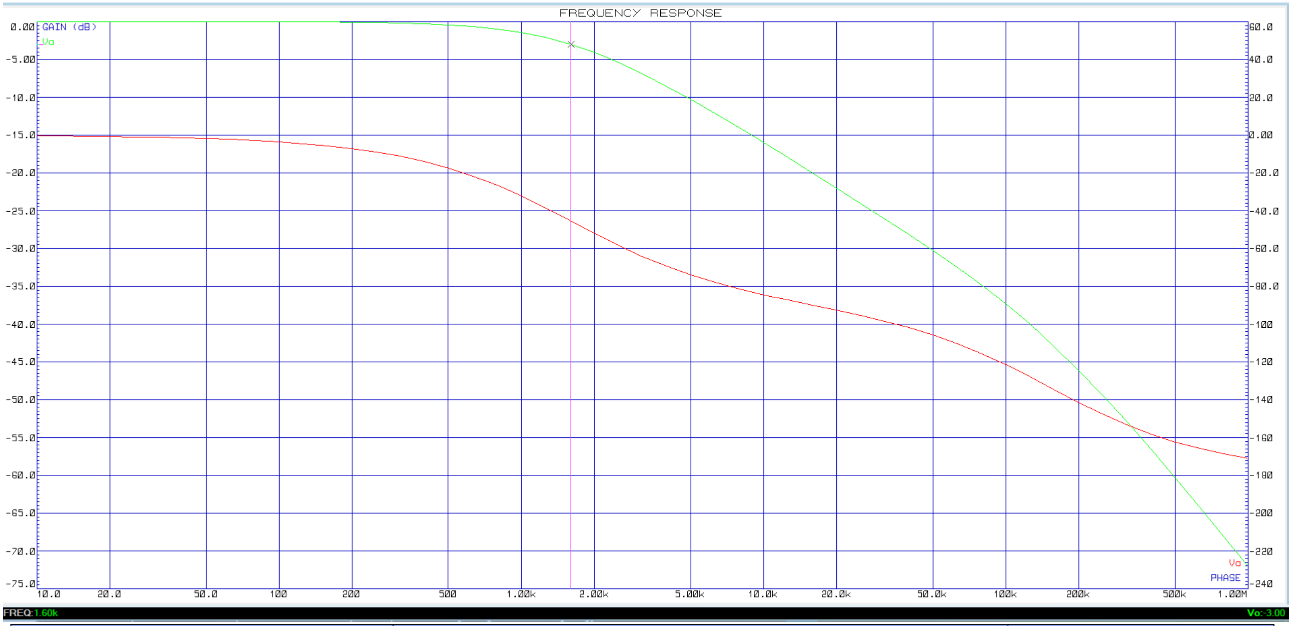


Figure 21: Proteus Circuit Figure e



Gain in passband	Half power frequency / frequencies	Bandwidth
0 dB	(1.6) KHz	1.6 KHz

Figure 22: Proteus Observation Figure e

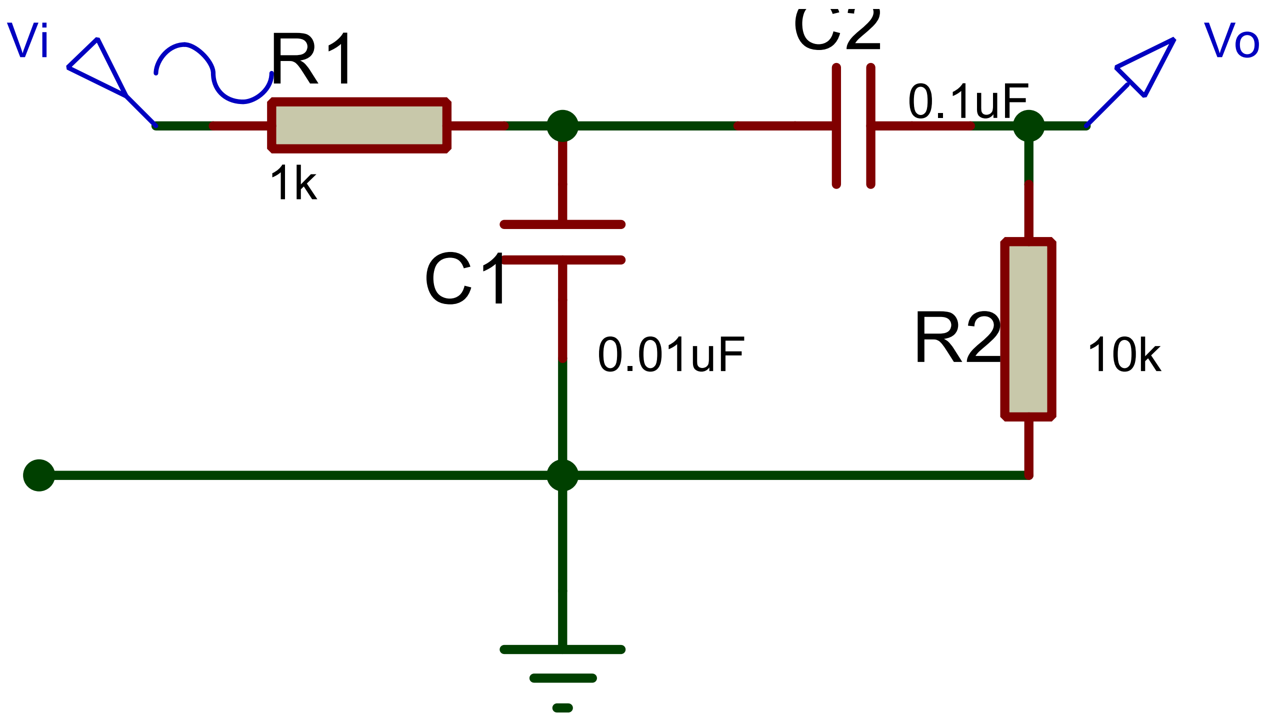
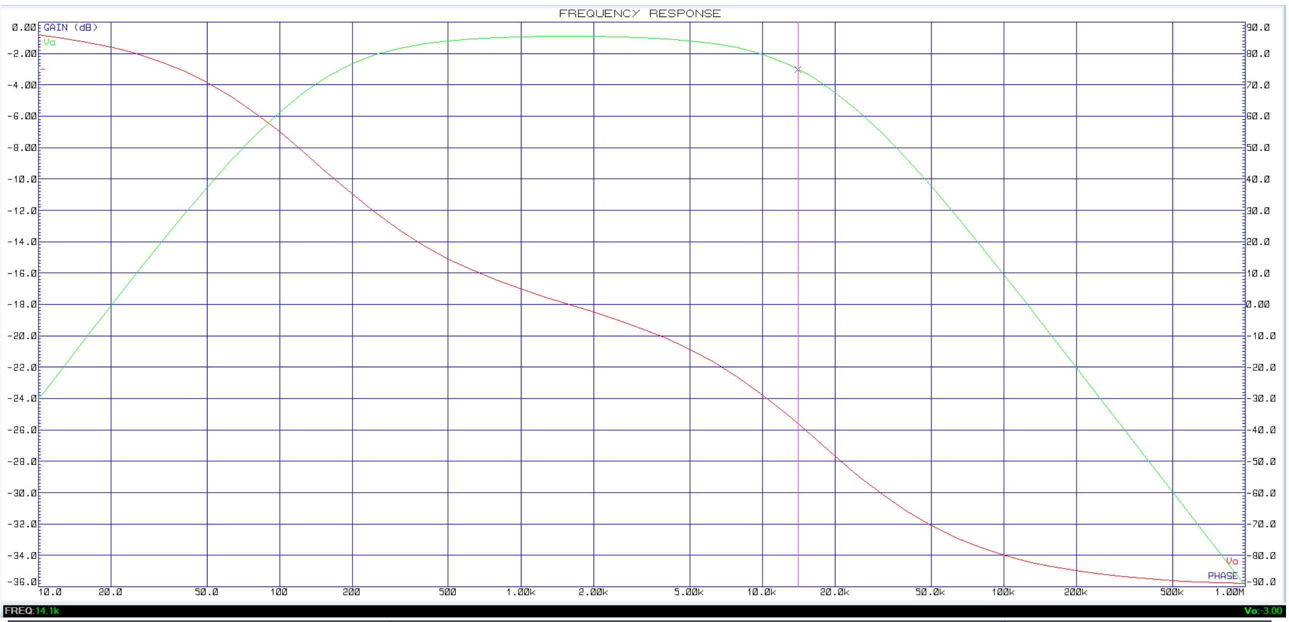


Figure 23: Proteus Circuit Figure f



Gain in passband	Half power frequency / frequencies	Bandwidth
-0.907 dB	(0.18 & 14.1) KHz	13.92 KHz

Figure 24: Proteus Observation Figure f

5.4 Question -4

Observe the effect in magnitude response of above networks by changing the element values as:

- **When resistance is increased or decreased**
- **When inductance is increased or decreased**

- **When capacitance is increased or decreased**

Comment on your results for each of the given filter network.

5.4.1 Observation with varying component values

Value of each component is varied to 25 and 75 percentage of original value in both increasing and decreasing direction.

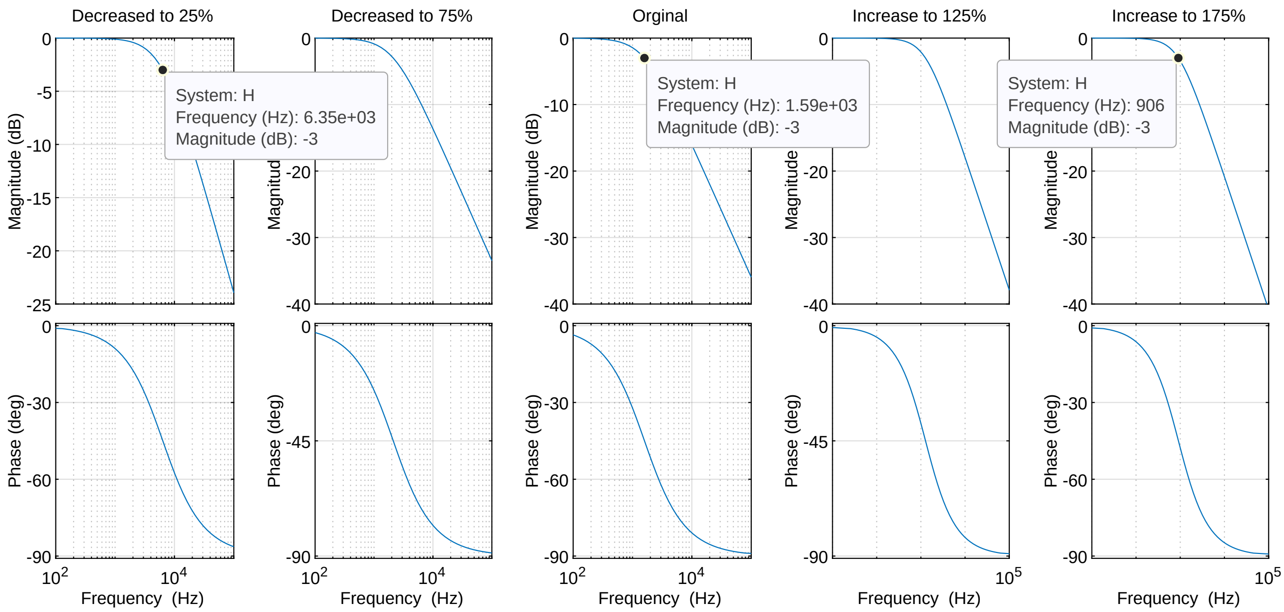


Figure 25: Observation for varying R in Figure a

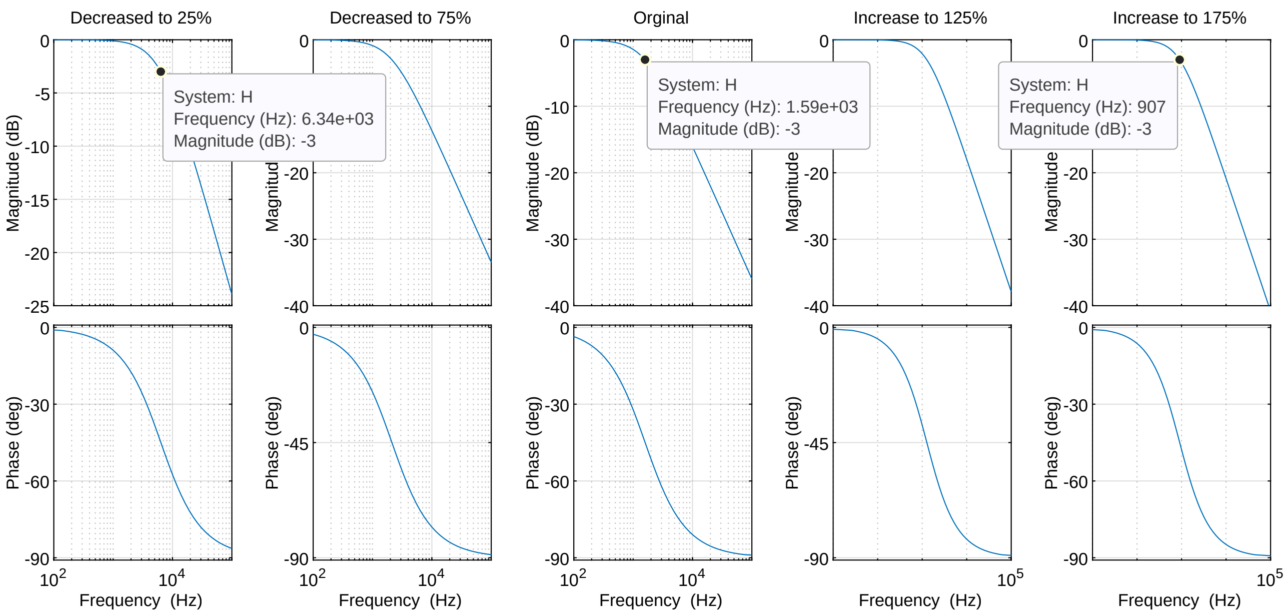


Figure 26: Observation for varying C in Figure a

It is clear from the above plots that for decrease (25% & 75%) in value of resistance and capacitor in **figure a** has increased the half power frequency as well as bandwidth whereas for increase (25%

& 75%) in value of resistance and capacitor both terms has decreased.Gain fot this **Low pass filter** remain constant i.e. zero throughout the variation.

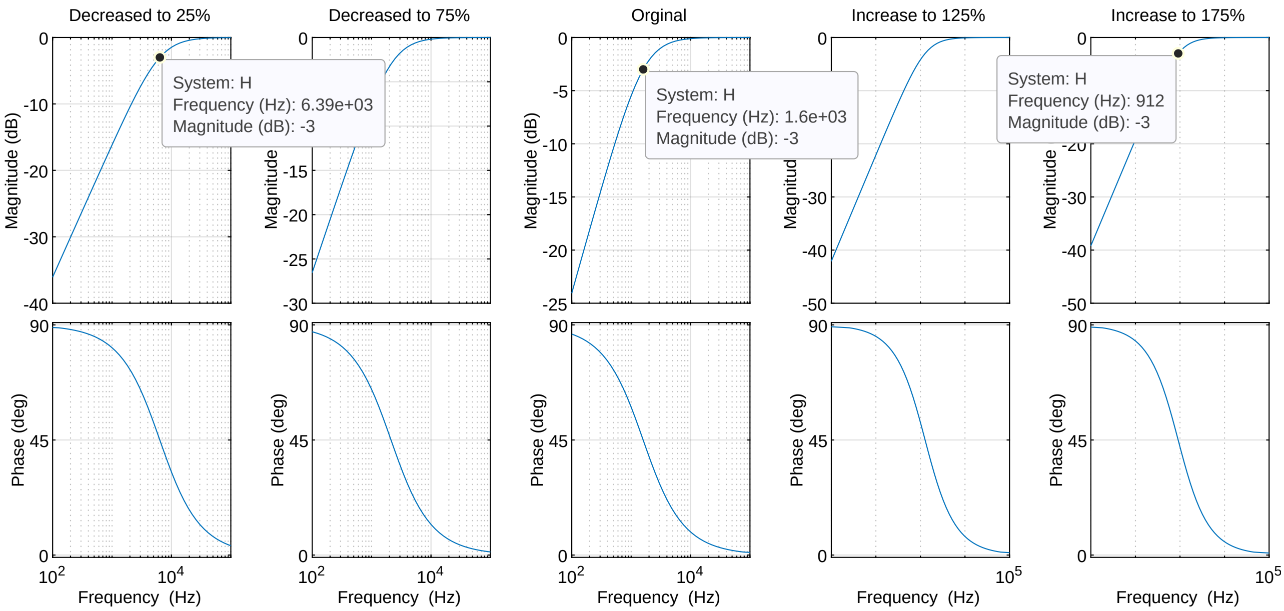


Figure 27: Observation for varying R in Figure b

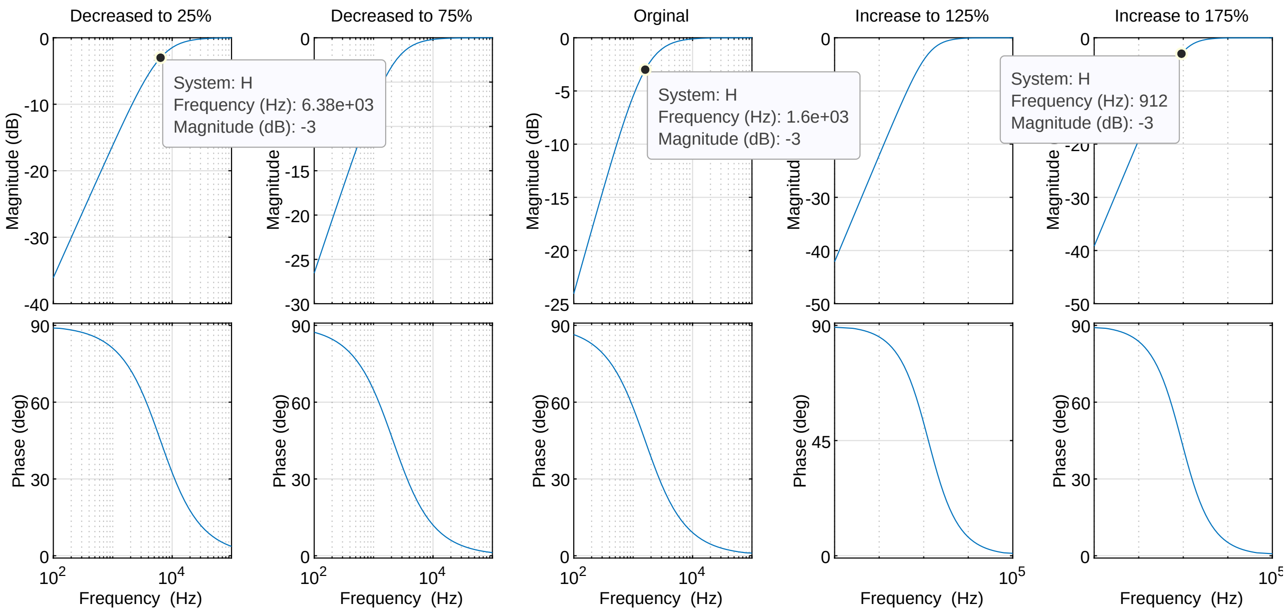


Figure 28: Observation for varying C in Figure b

It is clear from the above plots that for decrease (25% & 75%) in value of resistance and capacitor in **figure b** has increased the half power frequency as well as bandwidth whereas for increase (25% & 75%) in value of resistance and capacitor both terms has decreased.Gain fot this **High pass filter** remain constant i.e. zero throughout the variation.

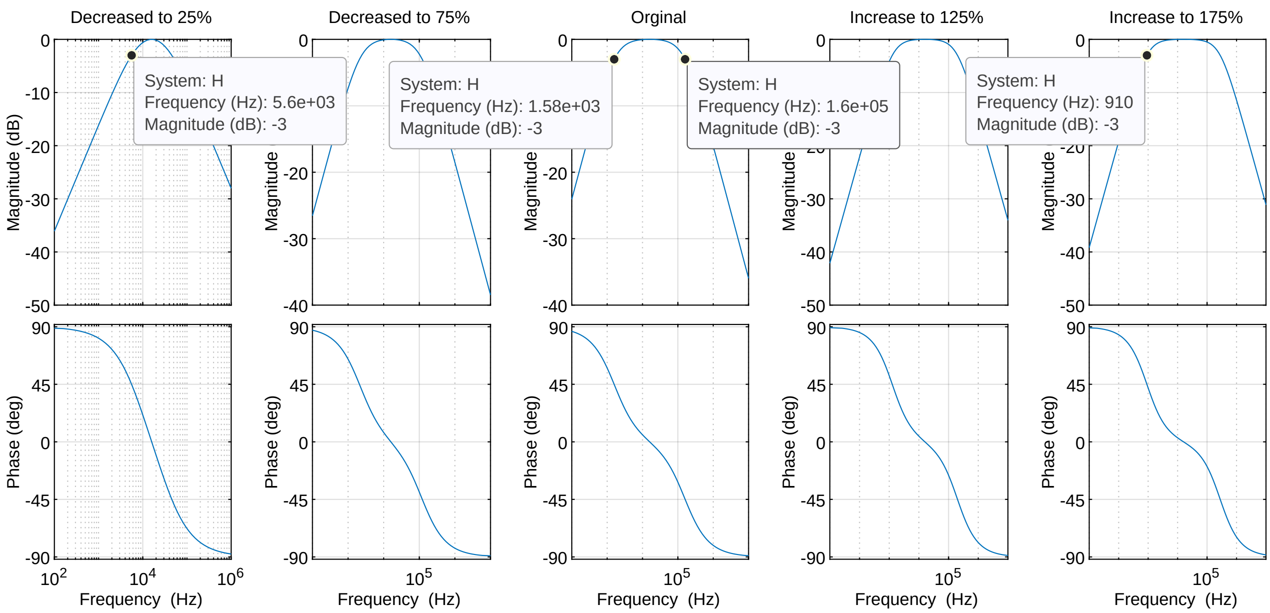


Figure 29: Observation for varying R in Figure c

For decreasing values of Resistance, the first half power frequency has increased but decreased the second half power frequency resulting in decreasing Bandwidth similarly, for increasing values of R the Bandwidth is also increasing.The gain remains constant i.e. zero throughout the variation.

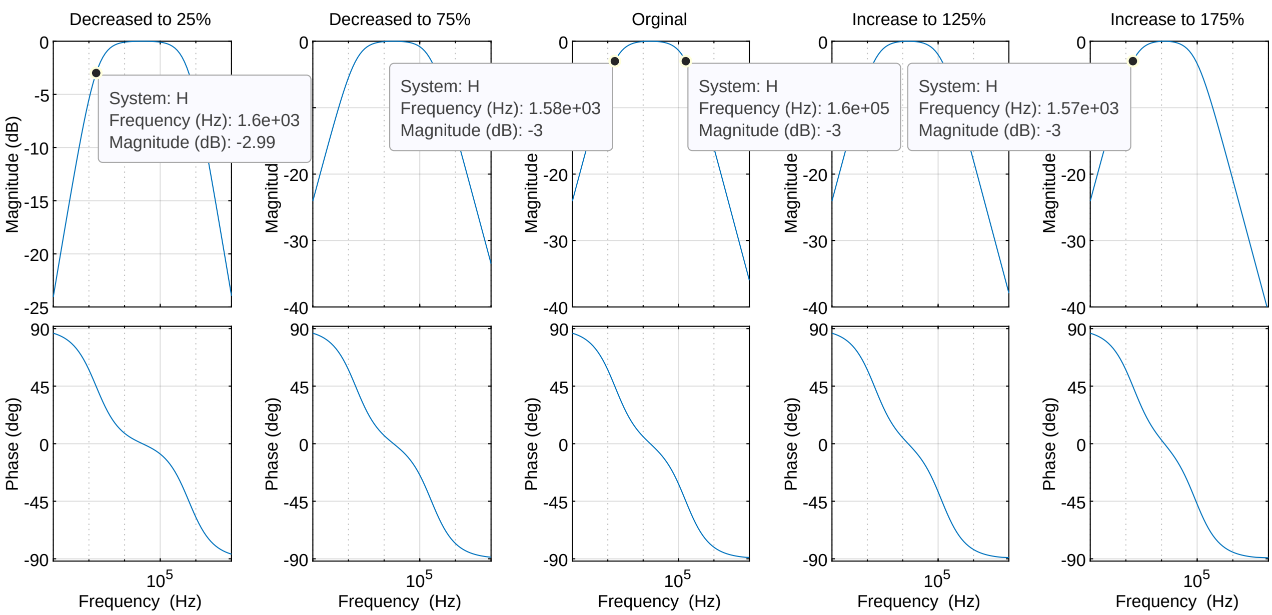


Figure 30: Observation for varying L in Figure c

For decreasing values of Inductance , the bandwidth is increasing as second half power frequency keep on increasing but for increasing values ,the bandwidth is decreasing.The gain remains constant i.e. zero throughout the variation.

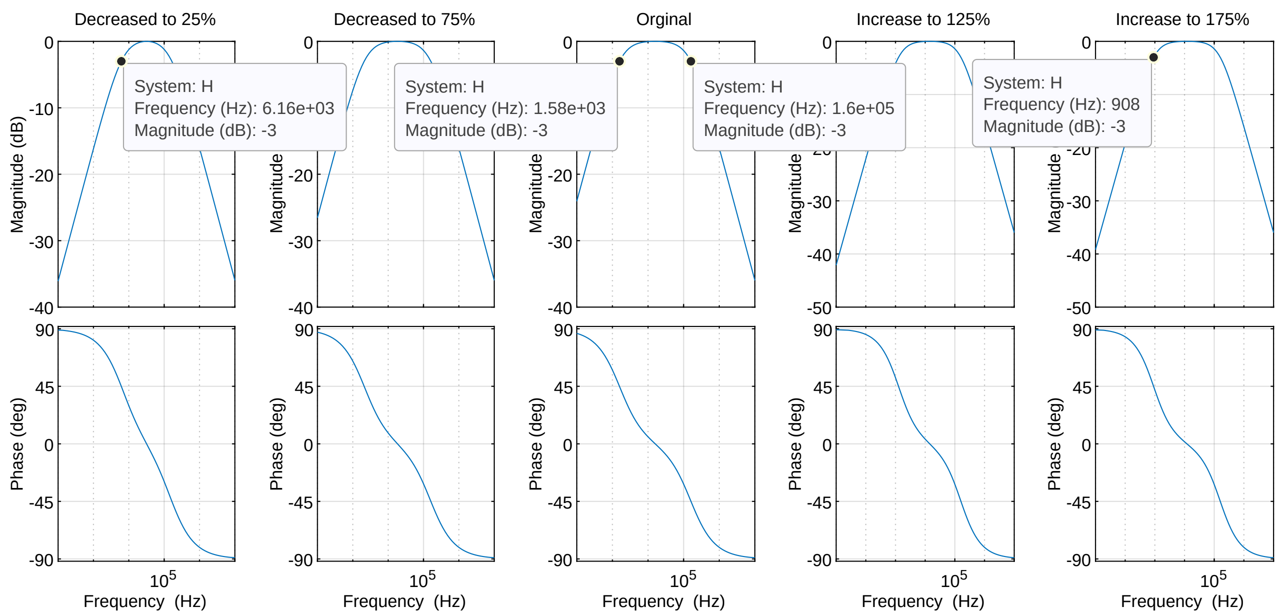


Figure 31: Observation for varying C in Figure c

For decreasing values of Capacitance , the bandwidth is decreasing as first half power frequency keep on increasing , similarly for increasing values ,the bandwidth is increasing.The gain remains constant i.e. zero throughout the variation.

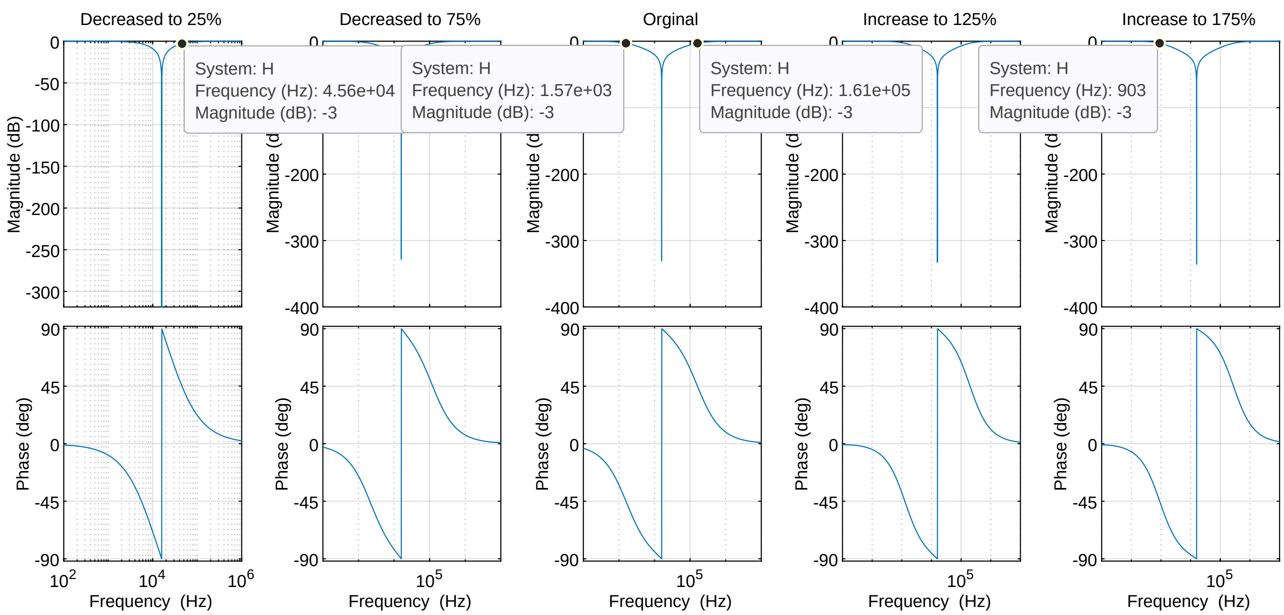


Figure 32: Observation for varying R in Figure d

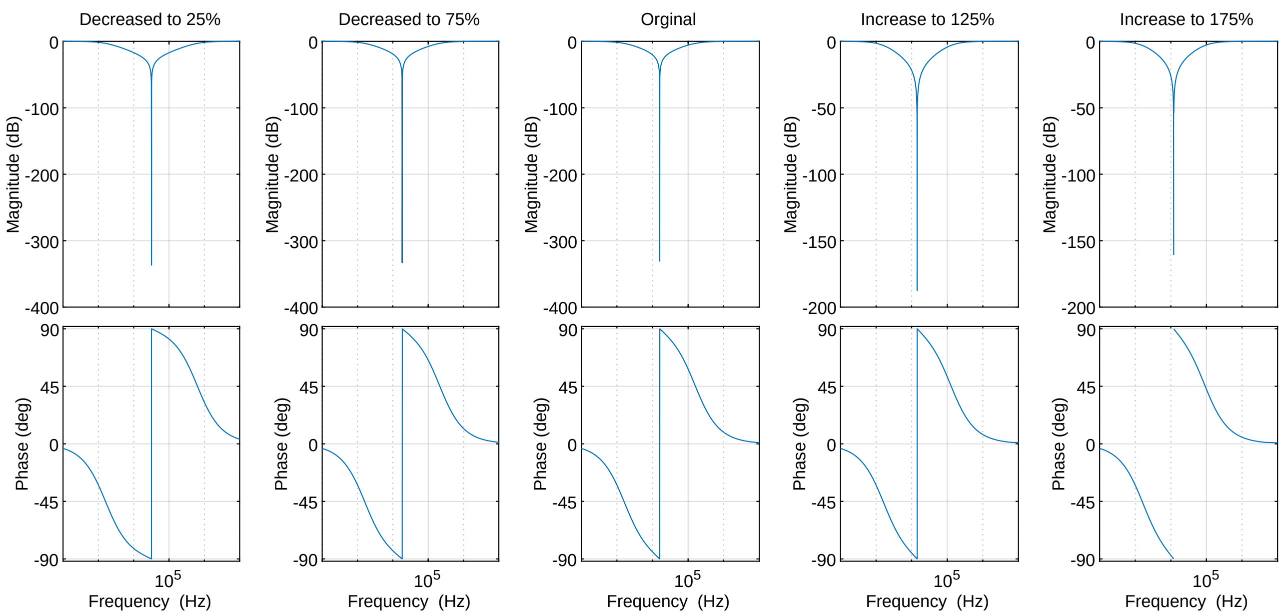


Figure 33: Observation for varying L in Figure d

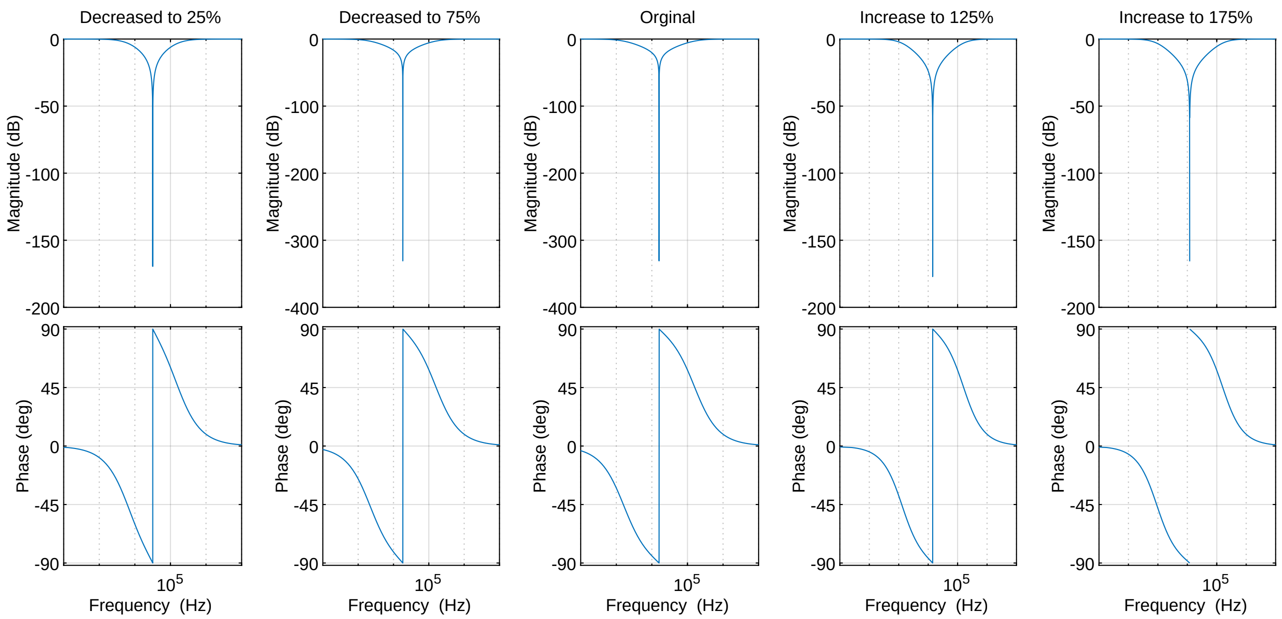


Figure 34: Observation for varying C in Figure d

This **Band stop filter** shows identical relationship as in above **Band pass filter**.

For **figure e** i.e. **Low pass filter** variation in Resistance and Capacitance shows similar relation as shown by **Low pass filter** or **figure a** . For variation in Inductance almost no change is observed .

For **figure f** i.e. **Band pass filter** decrease in Resistance R_1 increase bandwidth but increasing it decreases the bandwidth, Similar result is obtained for capacitor C_1 and opposite result with R_1. For C_2 remain almost unchanged.

6 Conclusion

In this Lab we did Analysis of Filter Networks. We used MATLAB and Proteus design suite to plot Transfer function and design and plot frequency response for the circuit and also compared their observation. We also observe the effect of varying network component like resistor, capacitor and inductor in Gain, Half power frequency and Bandwidth.