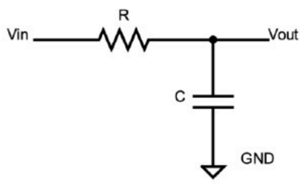
EN. 580.742 NI1 Homework #1 hand written part

Siyu Wang (swang333@jh.edu)

Part I: Low-Pass Filter



1. Derive the differential equation that defines $\frac{dV_{out}}{dt}$ in terms of $V_{out}(t)$, $V_{in}(t)$, R, and C. You should do this outside of MATLAB and show your work.

$\because \; I_c = C\frac{dV_c}{dt} = C\cdot\frac{dV_{out}}{dt}$

$\because \; V_{in} = I\cdot R + V_{out}$

$\therefore \; V_{in} = C\cdot\frac{dV_{out}}{dt}\cdot R + V_{out}$

$\therefore \; V_{in} - V_{out} = C R\cdot\frac{dV_{out}}{dt}$

$$\frac{dV_{out}}{dt} = \frac{V_{in} - V_{out}}{C R}$$

2. Find a value for R such that the maximum current through the RC circuit is 1 mA when a step of $V_{in} = 1$ V is applied.

$\because$ I_{max} is reached the moment when the voltage $V_{in} = 1\,V$ because at that time C acts as a short circuit.

$\therefore$

$\because \; R = \frac{V_{in}}{I_{max}} = \frac{1V}{1mA} = 1000\,\Omega$

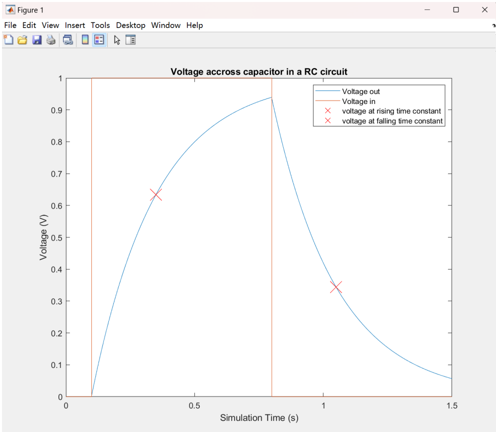
3. Using the value of R calculated above, find a value for C that makes the time constant $\tau = 0.25$ s.

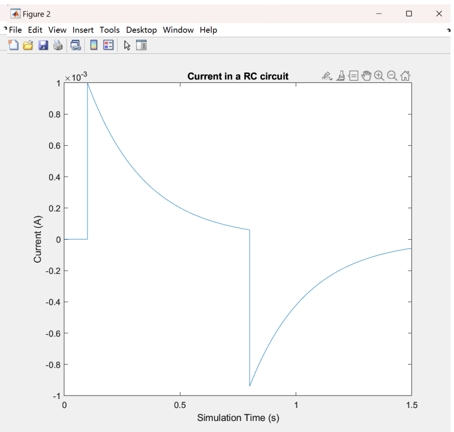
$\because \; \tau = R\cdot C = 0.25\,s$

$\because \; R = 1000\,\Omega$

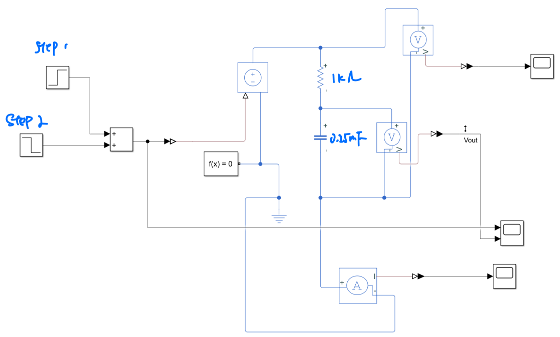
$\therefore \; C = 2.5\times10^{-4}\,F = 0.25\,mF$

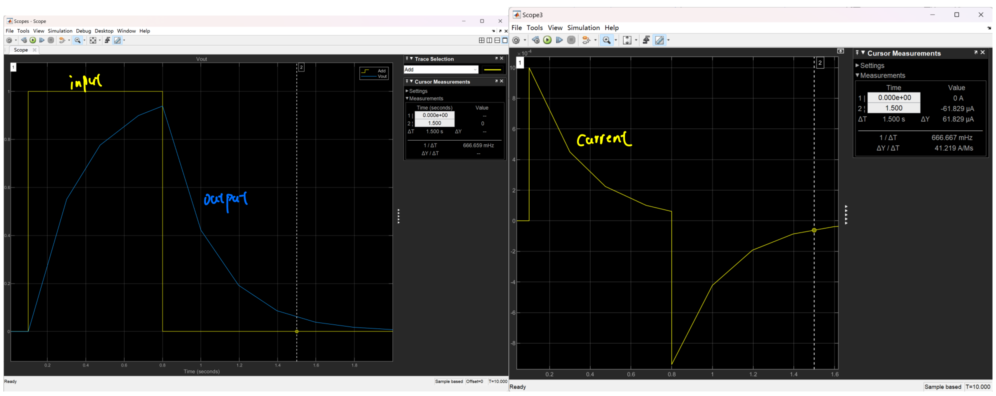
4. With the equation for $\frac{dV_{out}}{dt}$ and the values for R and C that you determined above, find $V_{out}(t)$ when $V_{in}(t)$ is a waveform that starts at 0 V at $t = 0$ s, steps up to 1 V at $t = 0.1$ s, steps back down to 0 V at $t = 0.8$ s, and then ends at $t = 1.5$ s. Use the forward Euler's method to find the solution (**not an ODE solver**). In one figure, plot $V_{in}(t)$ and $V_{out}(t)$ vs. t. Plot two x markers on $V_{out}(t)$ at the timepoints where the rising time constant occurs and where the falling time constant occurs. In a second figure, plot $I(t)$ (the current running through the RC circuit) vs. t.





5. Implement and show a schematic of the circuit in Simulink with the same R, C, and input $V_{in}(t)$ as defined above. Use your model to create the same two figures as described in question 4.

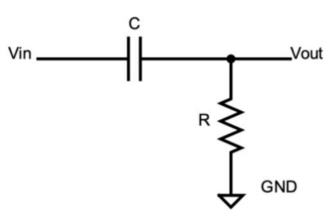




6. Do your results match?

Yes, the simulation result and Simulink result are aligned.
However, the simulink result is not as smooth as the code simulation result.

Part II: High-Pass Filter



1. Derive the equation that defines $\frac{dV_{out}}{dt}$ in terms of $V_{out}(t)$, $V_{in}(t)$, R, and C. You should do this outside of MATLAB and show your work.

$\because \quad I_c = C \cdot \frac{dV_c}{dt}$

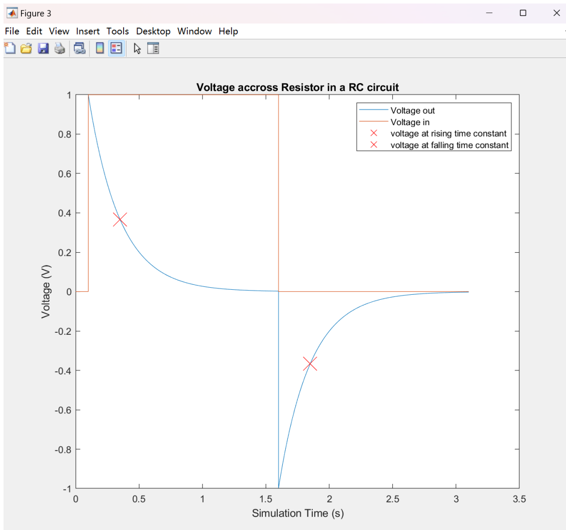
$\because \quad V_{in} = V_c + V_{out} \quad \Rightarrow \quad V_c = V_{in} - V_{out}$

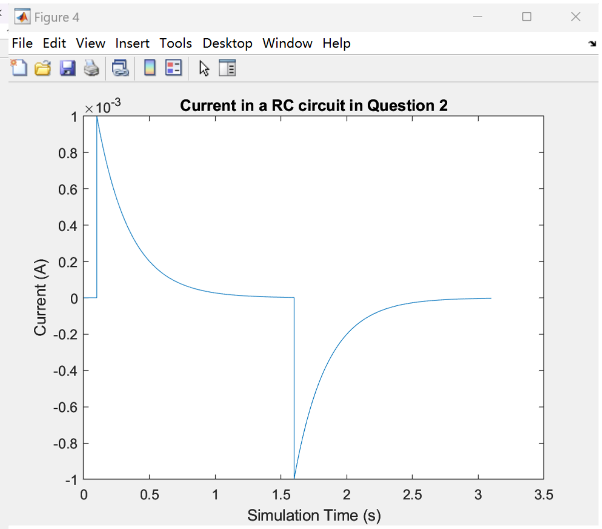
$\because \quad V_{out} = R \cdot C \cdot \frac{dV_c}{dt} \qquad V_{in} - V_c = R \cdot C \cdot \frac{dV_c}{dt} = \frac{dV_c}{dt} = \frac{V_{in} - V_c}{R \cdot C}$

$\therefore \quad \frac{dV_c}{dt} = \frac{V_{out}}{R \cdot C}$

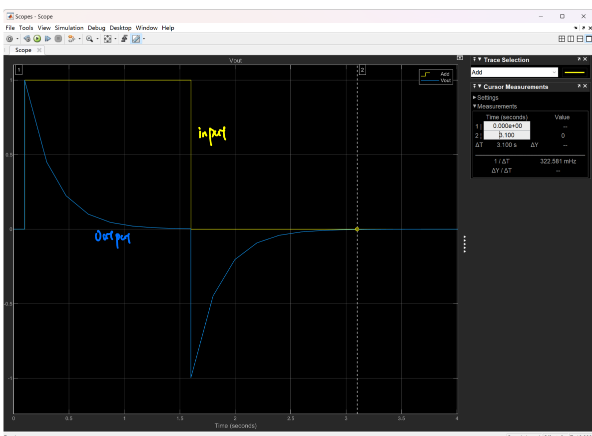
$\frac{dV_{in}}{dt} - \frac{dV_{out}}{dt} = \frac{V_{out}}{R \cdot C} \quad \Rightarrow \quad \boxed{\frac{dV_{out}}{dt} = \frac{dV_{in}}{dt} - \frac{V_{out}}{R \cdot C}} \qquad dV_{out} = dV_{in} - \frac{V_{out}}{R \cdot C}$

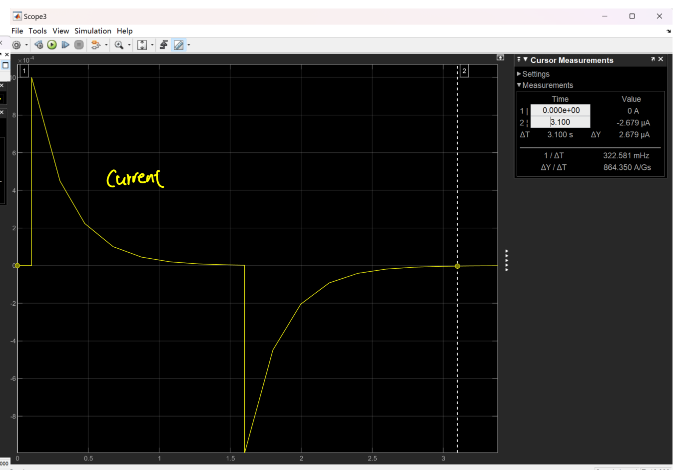
2. With the equation for $\frac{dV_{out}}{dt}$ you determined above and the same values for R and C from Part I, find $V_{out}(t)$ when $V_{in}(t)$ is a waveform that starts at 0 V at $t = 0$ s, steps up to 1 V at $t = 0.1$ s, steps back down to 0 V at $t = 1.6$ s, and then ends at $t = 3.1$ s. Use the forward Euler's method to find the solution (**not an ODE solver**). In one figure, plot $V_{in}(t)$ and $V_{out}(t)$ vs. t. Plot two x markers on $V_{out}(t)$ at the timepoints where the rising time constant occurs and where the falling time constant occurs. In a second figure, plot $I(t)$ (the current running through the RC circuit) vs. t.



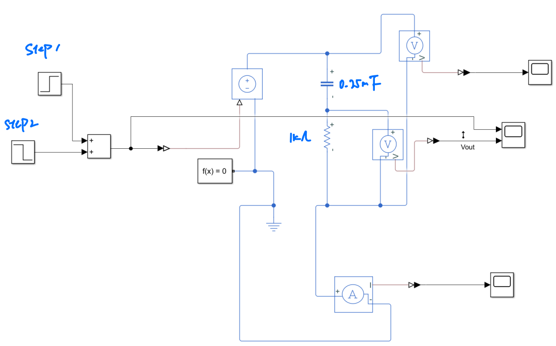


3. Implement and show a schematic of the circuit in Simulink with the same R, C, and input $V_{in}(t)$ as defined above. Use your model to create the same two figures as described in question 3.
4. Do your results match?





The simulation and the Simulink results are aligned.



Part III: Circuit Design

1. Let R and C be equal to the same values determined above. Can you add a single resistor to the circuit from Part 1 such that the maximum $V_{out}(t)$ of the new circuit is half of the maximum $V_{out}(t)$ of the original circuit when the same input waveform is applied? Implement and show a schematic of the new circuit in Simulink. In one figure, plot $V_{in}(t)$ and $V_{out}(t)$ vs. t. In a second figure, plot $I(t)$ (the current running through the RC circuit) vs. t.

$V_{out}(t) = V_{in} + (V_{init} - V_{in}) e^{-\frac{t-t_i}{\tau}}$ $\qquad R = 1k\Omega \qquad C = 0.25\mu F$

$V_{out}(0.8s) = 1V + (0V - 1V) e^{-\frac{0.7}{R\cdot C}}$

$= 1V - e^{-\frac{0.7}{0.25}} V$

$= 0.9392 V$

$\therefore \frac{1}{2} V_{out}(0.8s) = 0.4696 V = V_{out\,new}(0.8s)$

$\therefore V_{out}(t) = V_{in} + (V_{init} - V_{in}) e^{-\frac{t-t_i}{\tau}}$

$V_{out\,new}(0.8s) = 1V - e^{-\frac{0.7}{R\times 0.25\mu F}} = 0.4696V$

$e^{-\frac{0.7}{R\times 0.25\mu F}} = 0.5304V$

$-\frac{0.7}{R\times 0.25\mu F} = -0.6341$

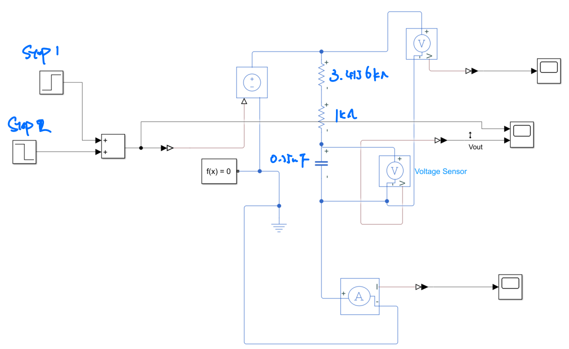
$R\times 0.25\mu F = 1.1039$

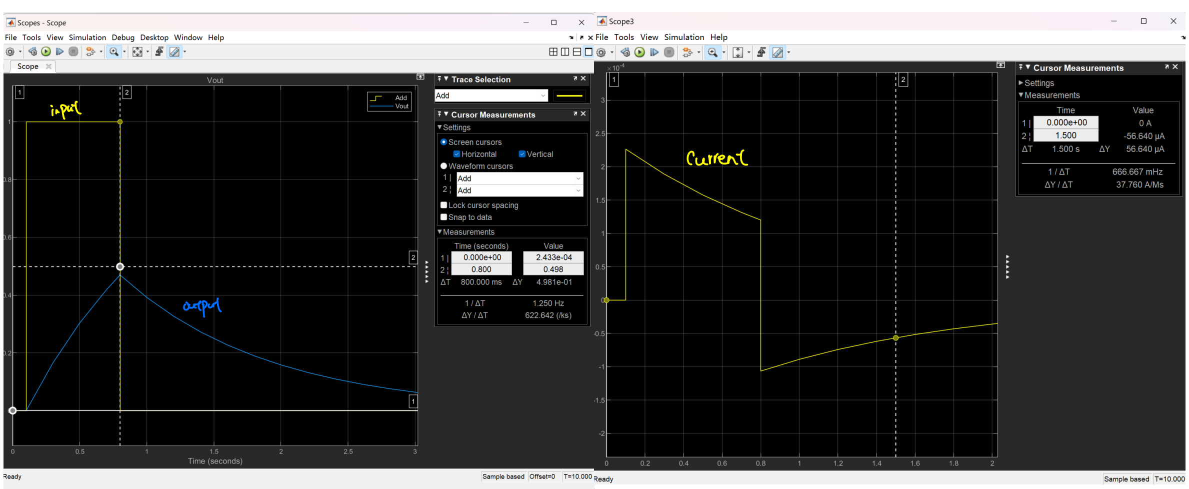
$R = 4415.6\Omega$

$1 - e^{-\frac{0.7}{\tau'}} = 0.4696$

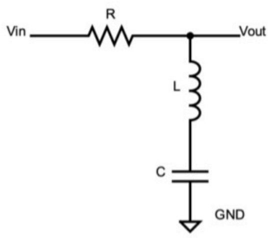
$e^{-\frac{0.7}{\tau'}} = 0.5304$

$\therefore$ add 3415.6Ω resistor in series with the 1kΩ resistor





Part IV: Band-Stop Filter



1. Derive the frequency-domain transfer function $H(j\omega)$ for $\frac{V_{out}}{V_{in}}$. You should do this outside of MATLAB and show your work.

$$Z_L = j\omega L$$

$$Z_C = \frac{1}{j\omega C}$$

$$Z_L + Z_C = j\omega L + \frac{1}{j\omega C} = \frac{1 - \omega^2 LC}{j\omega C}$$

$$Z_L + Z_C + R = j\omega L + \frac{1}{j\omega C} + R = \frac{1 - \omega^2 LC + j\omega C \cdot R}{j\omega C}$$

$$\therefore \frac{V_{out}}{V_{in}} = \frac{1 - \omega^2 LC}{1 - \omega^2 LC + j\omega C \cdot R}$$

2. Given $C = 1\text{ nF} = 10^{-9}$ F, and starting from the transfer function you derived, find values for R and L such that the center frequency is 50 kHz and the bandwidth is 20 kHz. Note, the bandwidth is defined as the difference between the upper and lower cutoff frequencies (-3 dB points). The center frequency is located halfway between the upper and lower cutoff frequencies and corresponds to the frequency with the most attenuation. You should do this outside of MATLAB and show your work. Hint – you should be able to solve this using only the material you learned in the lectures. Any additional equations you use should be explained/derived accordingly.

$$\frac{1}{LC} = \omega^2$$

$$\omega = \frac{1}{\sqrt{LC}}$$

let $j\omega = s$

$$Z_L + Z_C = sL + \frac{1}{sC} = \frac{s^2 LC + 1}{sC}$$

$$Z_L + Z_C + R = sL + \frac{1}{sC} + R = \frac{s^2 LC + 1 + sCR}{sC} = \frac{s^2 LC + sCR + 1}{sC}$$

$$\frac{V_{out}}{V_{in}} = \frac{s^2 \cdot LC + 1}{s^2 LC + sCR + 1} = \frac{s^2 + \frac{1}{LC}}{s^2 + \frac{R}{L}s + \frac{1}{LC}}$$

$\because$ largest attenuation occurs @ $s^2 + \frac{1}{LC} = 0$ $\quad \frac{1}{LC} - \omega^2 = 0 \quad \omega^2 = \frac{1}{LC}$

$$\therefore \frac{1}{LC} = \omega_0^2$$

$$LC = \frac{1}{\omega_0^2}$$

$$\boxed{L = \frac{1}{C\omega_0^2} = \frac{1}{1\times 10^{-9} \times (2\pi \times 50k)^2} = 0.0101 \quad H}$$

$\because$ -3dB point

$$\therefore \left|\frac{V_{out}}{V_{in}}\right| = \frac{1}{\sqrt{2}}$$

$$\therefore \left| \frac{s^2 + \frac{1}{LC}}{s^2 + \frac{R}{L}s + \frac{1}{LC}} \right| = \frac{1}{\sqrt{2}}$$

$$= \frac{\frac{1}{LC} - w^2}{-w^2 + jw\frac{R}{L} + \frac{1}{LC}}$$

$$= \frac{\frac{1}{LC} - w^2}{\left(-w^2 + \frac{1}{LC}\right) + jw\frac{R}{L}}$$

$$= \frac{1}{1 + \frac{jw\frac{R}{L}}{-w^2 + \frac{1}{LC}}}$$

$$\because \left\| 1 + j\frac{w\frac{R}{L}}{-w^2 + \frac{1}{LC}} \right\| = \sqrt{2}$$

$$\therefore \frac{w\frac{R}{L}}{-w^2 + \frac{1}{LC}} = \pm 1$$

$\therefore$ ① $w\frac{R}{L} = -w^2 + \frac{1}{LC}$

$$w^2 + \frac{R}{L}w - \frac{1}{LC} = 0$$

$$w_1 = \frac{-\frac{R}{L} + \sqrt{\left(\frac{R}{L}\right)^2 + \frac{4}{LC}}}{2}$$

$$w_2 = \frac{-\frac{R}{L} - \sqrt{\left(\frac{R}{L}\right)^2 + \frac{4}{LC}}}{2}$$

② $w\frac{R}{L} = w^2 - \frac{1}{LC}$

$$w^2 - \frac{R}{L}w - \frac{1}{LC} = 0$$

$$w_3 = \frac{\frac{R}{L} + \sqrt{\left(\frac{R}{L}\right)^2 + \frac{4}{LC}}}{2}$$

$$w_4 = \frac{\frac{R}{L} - \sqrt{\left(\frac{R}{L}\right)^2 + \frac{4}{LC}}}{2}$$

$\because$ w can not be negative

$\therefore$ w_2 and w_4 are disgarded

$$\therefore \quad \omega_L = \frac{-\frac{R}{L} + \sqrt{\left(\frac{R}{L}\right)^2 + \frac{4}{LC}}}{2}$$

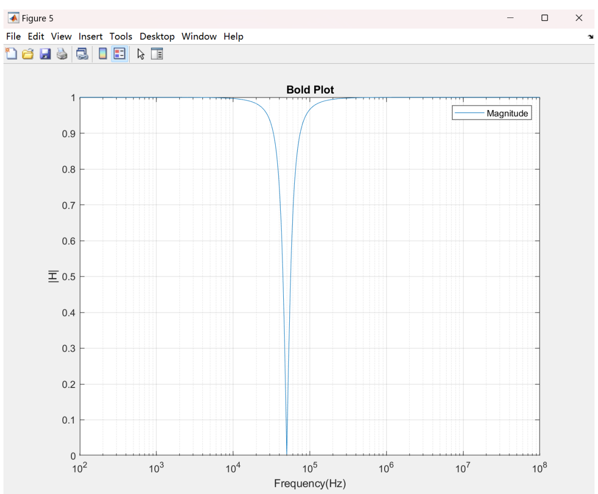
$$\omega_H = \frac{\frac{R}{L} + \sqrt{\left(\frac{R}{L}\right)^2 + \frac{4}{LC}}}{2}$$

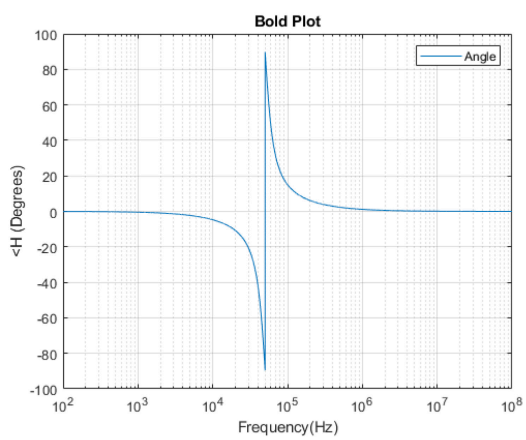
$$\therefore \quad \boxed{BW = \omega_H - \omega_L = \frac{R}{L}}$$

$$\frac{R}{L} = 20\,\text{kHz}$$

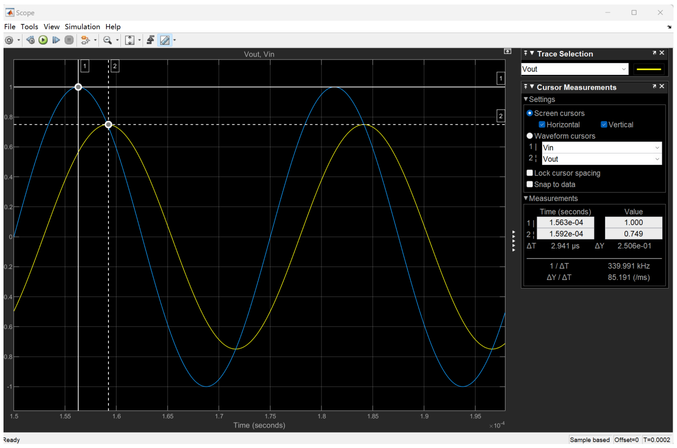
$$\boxed{R = 2\pi \cdot 20\,\text{kHz} \cdot 0.0101\,H = 1273.24\,\Omega}$$

3. In MATLAB, use the transfer function and the values of R, L, and C from above to solve for $H(j\omega)$ for frequencies $f = 10^{2:0.001:8}$ Hz. In one or two figures, create a bode plot including a plot of the magnitude (as a decimal between 0 and 1) vs. frequency (in Hz) and a second plot of the phase shift (in Hz) vs. frequency (in Hz). In both plots, the x-axis should be displayed on a log scale. Function hints – **abs**, **angle**, **semilogx**.





4. Open the provided Simulink model for this circuit. This model has specific timing, timestep, and scope parameters set to make sure you are able to do some calculations based on the output plot. Update the values for the resistor and inductor in the model to the R and L values established above. In this model, $V_{in} = \sin(2\pi(40{,}000))$. Both the V_{in} and V_{out} are displayed on the scope. **Use this scope output** (not the derived transfer function) to calculate the gain and phase shift of V_{out} at this frequency. You should do these calculations outside of MATLAB and show your work. You don't need to include a snapshot of the model, but you should include a picture of the scope output. Note – if your MATLAB/Simulink version is giving you issues to open the file, please email celia@jhmi.edu with your MATLAB/Simulink version and we'll help you open the model.



$$\boxed{\text{Gain} = \frac{V_{out}}{V_{in}} = \frac{0.749}{1} = 0.749}$$

$\because \Delta T = -2.941\ \mu S$

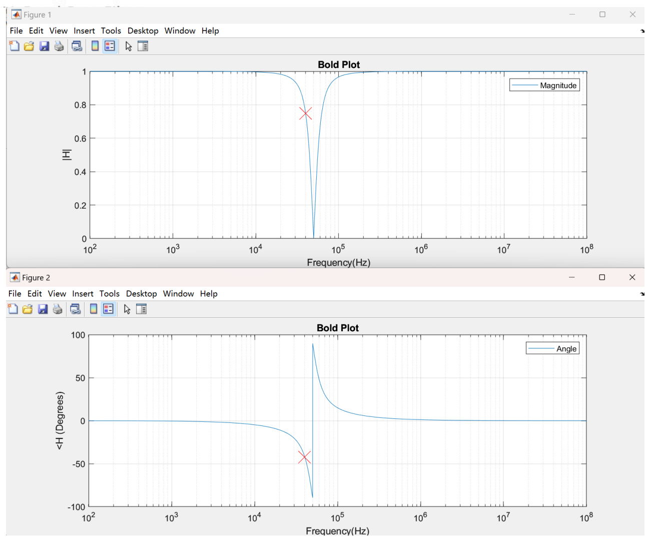
$\because f = 40000\ Hz$

$\therefore \text{period} = \frac{1}{f} = 25\ \mu S$

$\therefore \text{Phase} = -\frac{2.941\ \mu S}{25\ \mu S} \times 360^\circ$

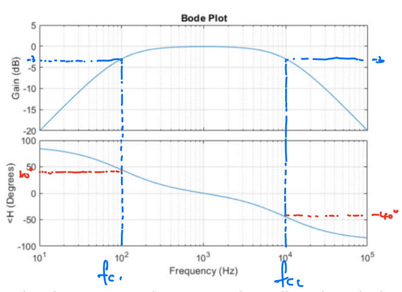
$$\boxed{= -42.35^\circ}$$

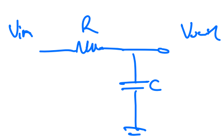
5. Plot your calculated gain and phase shift for $f = 40{,}000$ Hz from Q4 as an 'x' on both plots from Q3. Do these points fall on the bode plot lines?



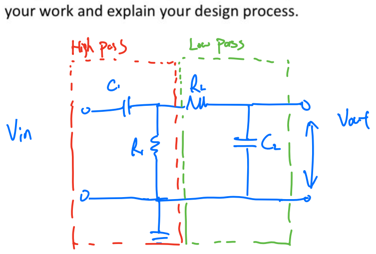
The points fall on the bode plot lines

Part V: Band-Pass Filter





1. Design a circuit with only resistors and capacitors that will produce the bode plot above. Show your work and explain your design process.



$\because$ The cut-off frequency happens on time constant τ

$\because \tau = R \cdot C$

$\therefore f_c = \frac{1}{2\pi R \cdot C}$

$\therefore f_{c_1} = \frac{1}{2\pi R_1 \cdot C_1} = 100\ Hz$

$f_{c_2} = \frac{1}{2\pi R_2 \cdot C_2} = 10000\ Hz$

$\therefore R_1 \cdot C_1 = \frac{1}{2\pi \cdot 100} = \frac{1}{200\pi}$

$R_2 \cdot C_2 = \frac{1}{2\pi\ 10000} = \frac{1}{20000\ \pi}$

if $R_1 = 100k\Omega$, $R_2 = 100k\Omega$

$1 \times 10^4 \Omega \cdot C_1 = \frac{1}{200\ \pi}$

$C_1 = \frac{1}{2 \times 10^6\ \pi} = 1.592 \times 10^{-8}\ F = 15.92\ nF$

$1 \times 10^4 \Omega \cdot C_2 = \frac{1}{20000\ \pi}$

$C_2 = \frac{1}{2 \times 10^8\ \pi} = 1.592 \times 10^{-10}\ F = 0.1592\ nF$

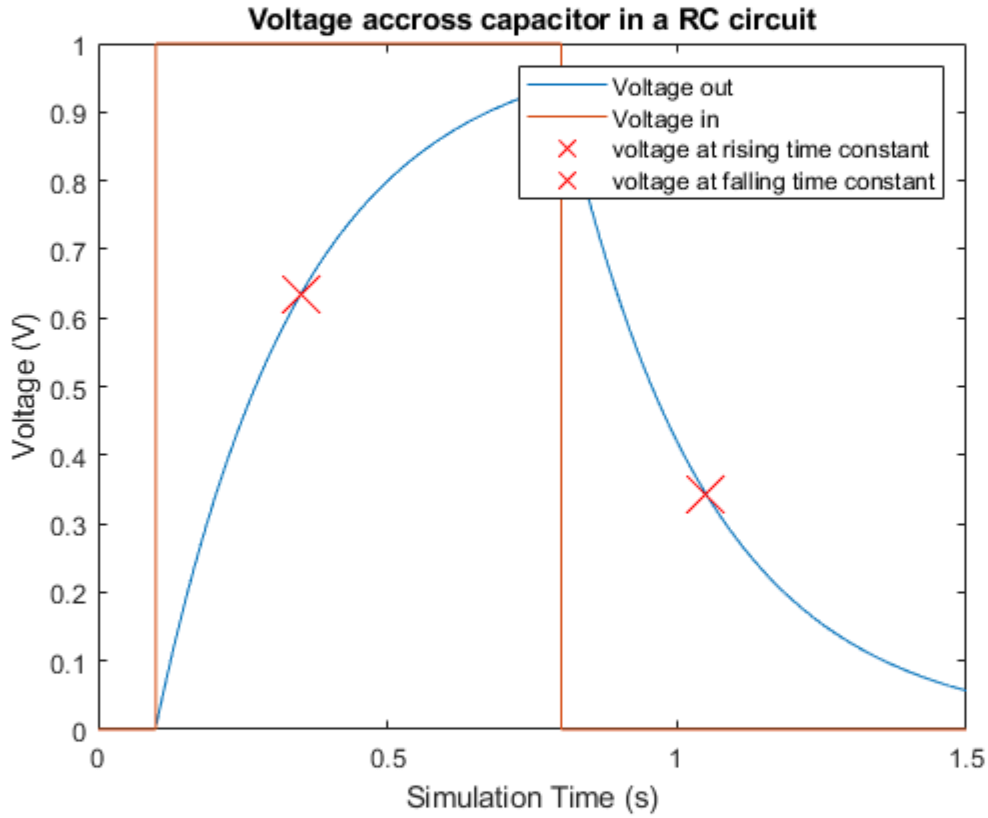
Homework I

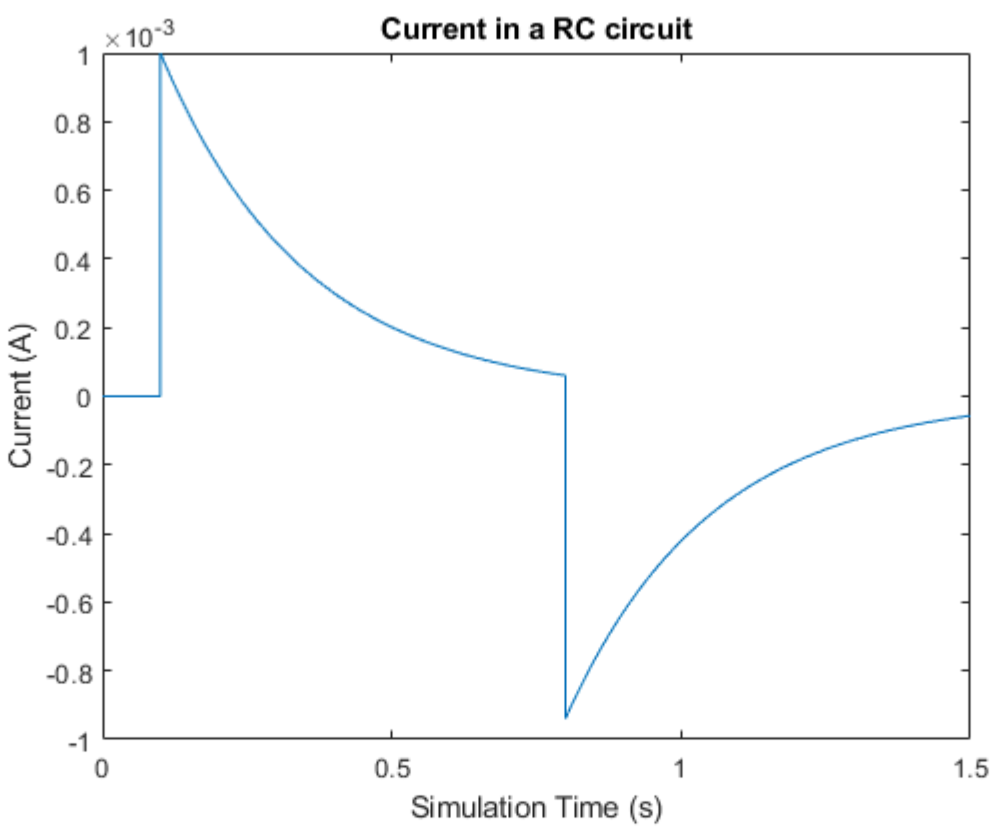
Table of Contents

Siyu Wang (swang333)

Question 1.4 R-C circuit on capcitor simulation

```
[TimeAllList, VoutAllList, iAllList, VinAllList, VtList] =
 RC_circuit_Q1(1000,0.00025);
figure();
plot(TimeAllList,VoutAllList);
hold on
plot(TimeAllList,VinAllList);
hold on
plot(0.35, VtList(1), 'xr', 'MarkerSize',20)
hold on
plot(1.05, VtList(2), 'xr', 'MarkerSize',20)
hold on
title("Voltage accross capacitor in a RC circuit"); % set figure title
legend("Voltage out","Voltage in", "voltage at rising time constant", "voltage
 at falling time constant"); % set legend
xlabel("Simulation Time (s)"); % set x label
ylabel("Voltage (V)"); % set y label

figure();
plot(TimeAllList,iAllList);
title("Current in a RC circuit"); % set figure title
xlabel("Simulation Time (s)"); % set x label
ylabel("Current (A)"); % set y label
```

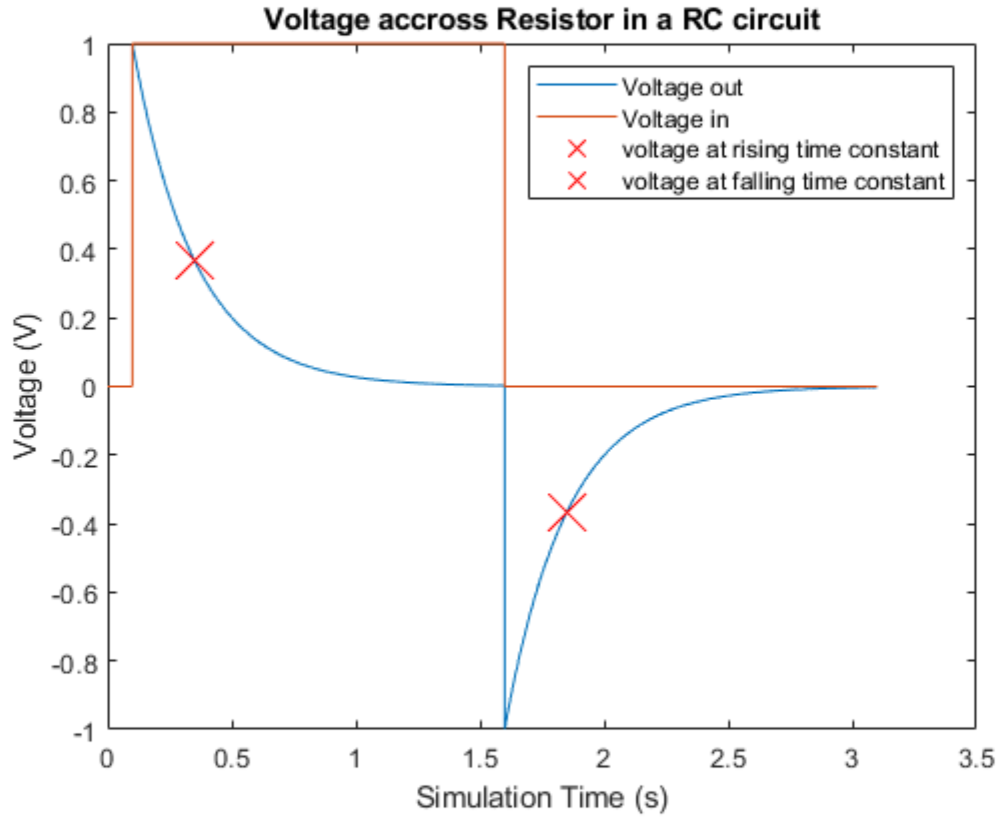

Voltage accross capacitor in a RC circuit
Voltage (V)
Simulation Time (s)
Voltage out
Voltage in
voltage at rising time constant
voltage at falling time constant
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
0.5
1
1.5


Current in a RC circuit
×10^-3
Current (A)
Simulation Time (s)
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
0
0.5
1
1.5

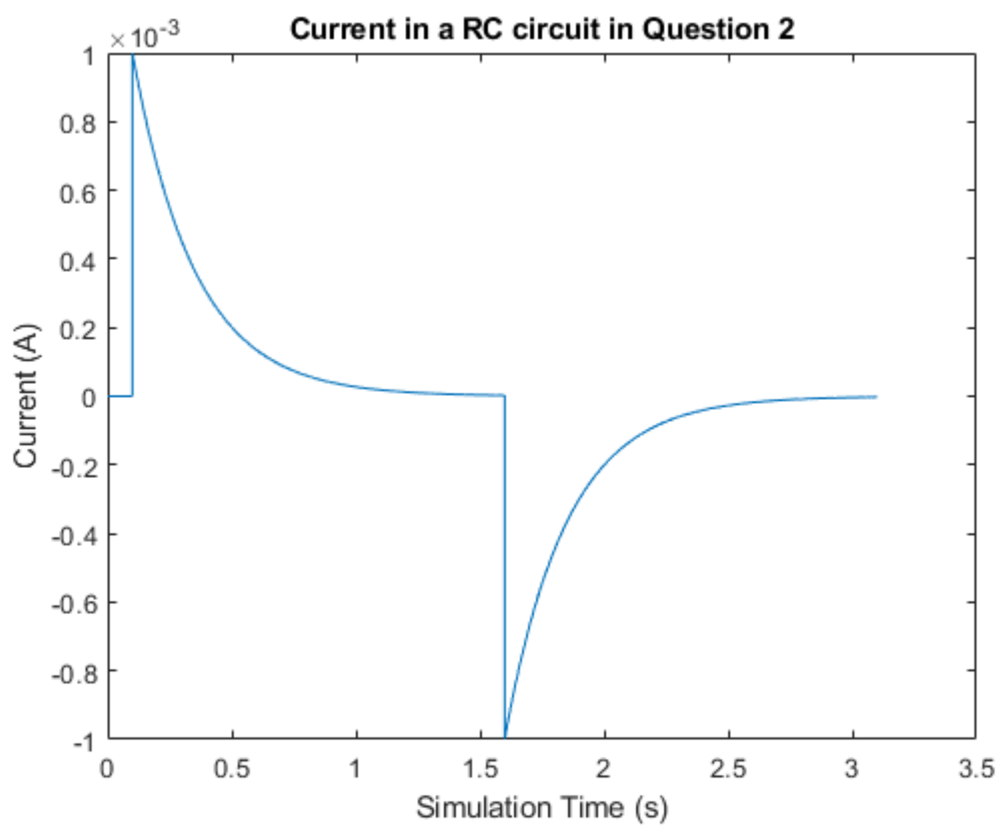
Question 2.2 R-C circuit on resistor simulation

```
[TimeAllList, VoutAllList, VinAllList, iAllList, VtList] =
 RC_circuit_Q2(1000,0.00025);
figure();
plot(TimeAllList,VoutAllList);
hold on
plot(TimeAllList,VinAllList);
hold on
plot(0.35, VtList(1), 'xr', 'MarkerSize',20)
hold on
plot(1.85, VtList(2), 'xr', 'MarkerSize',20)
hold on
title("Voltage accross Resistor in a RC circuit"); % set figure title
legend("Voltage out","Voltage in", "voltage at rising time constant", "voltage
 at falling time constant"); % set legend
xlabel("Simulation Time (s)"); % set x label
ylabel("Voltage (V)"); % set y label

figure();
plot(TimeAllList,iAllList);
title("Current in a RC circuit in Question 2"); % set figure title
xlabel("Simulation Time (s)"); % set x label
ylabel("Current (A)"); % set y label
```

```
Vin_current_list =

     []
```



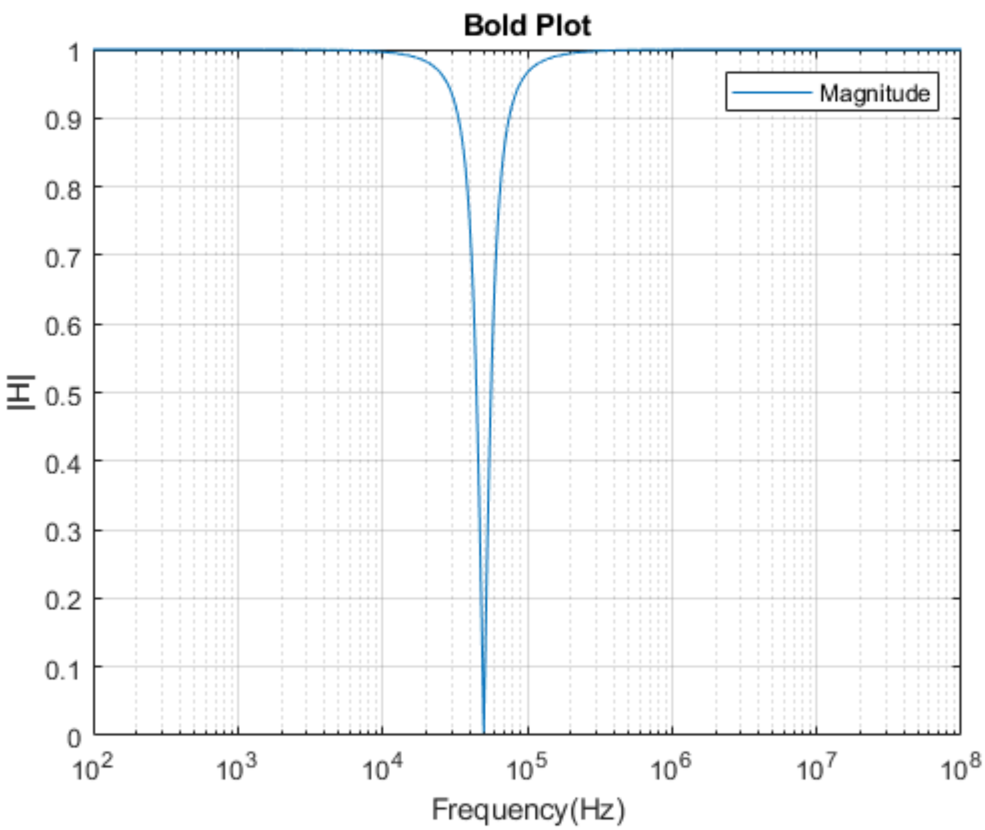
Voltage accross Resistor in a RC circuit
Voltage out
Voltage in
voltage at rising time constant
voltage at falling time constant
Voltage (V)
Simulation Time (s)

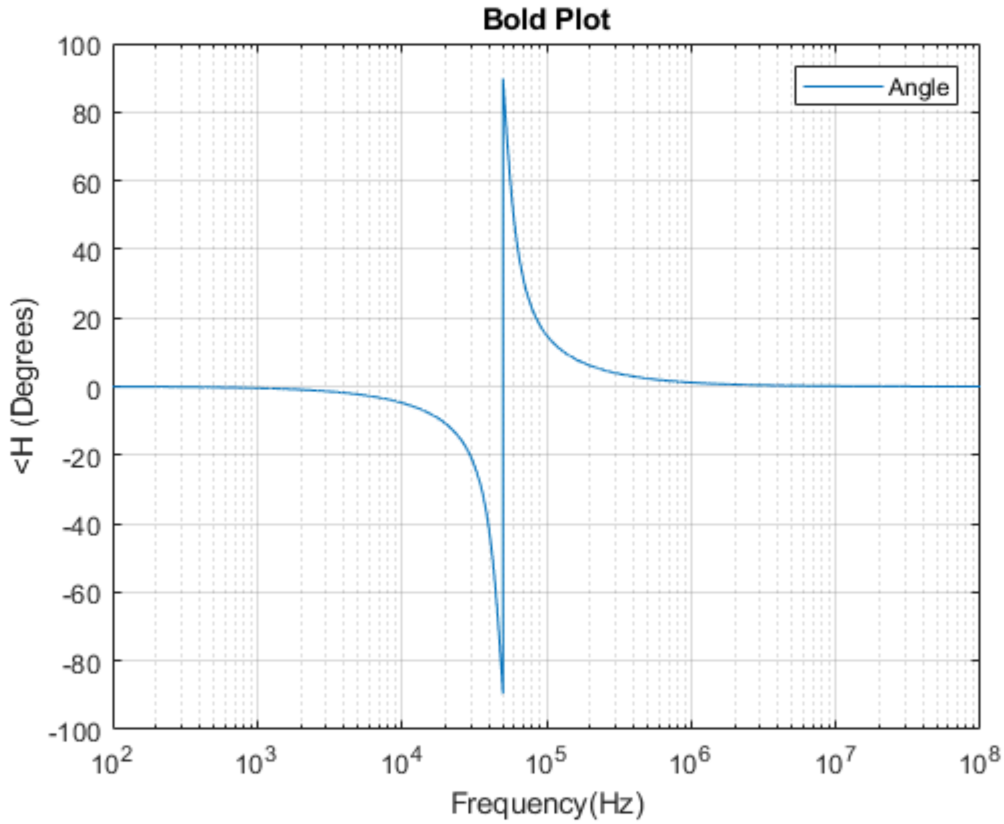


Current in a RC circuit in Question 2
×10^-3
Current (A)
Simulation Time (s)

Question 4.3 RCL circuit Band-stop filter

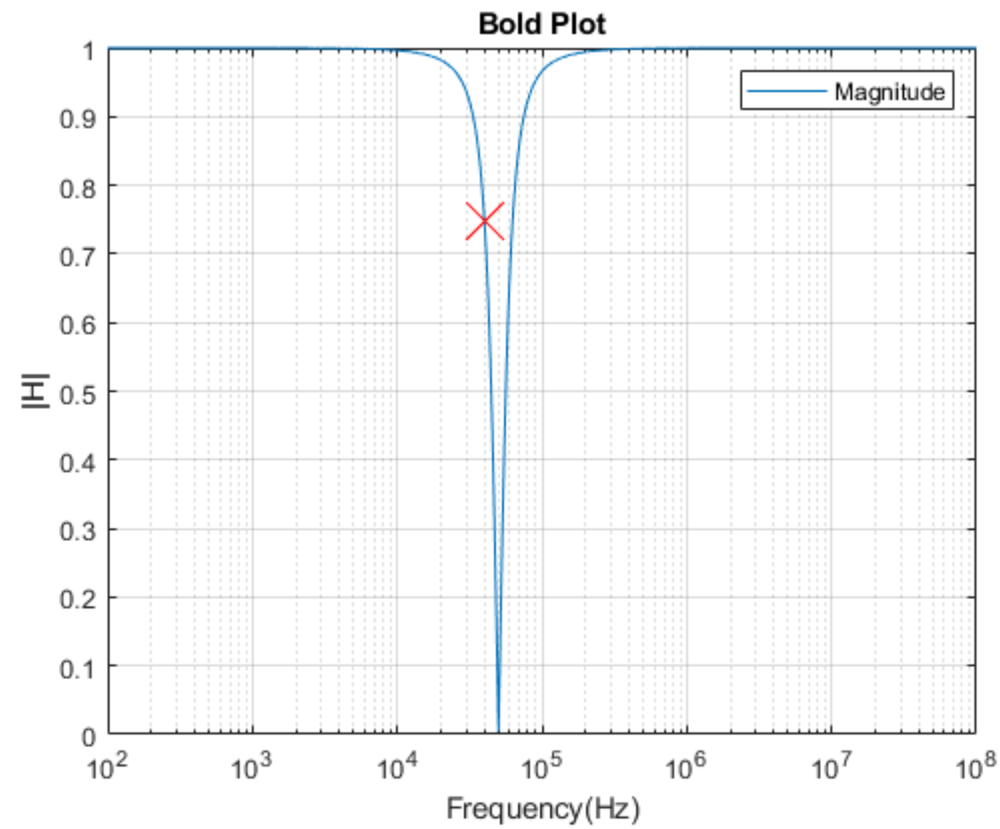
```
L = 0.0101;
C = 1e-9;
R = 1273.24;
[f_list,angle_list,mag_list] = RCL_circuit_Q4(R,C,L);
figure();
semilogx(f_list,mag_list);
title("Bold Plot"); % set figure title
legend("Magnitude"); % set legend
xlabel("Frequency(Hz)");
ylabel("|H|");
grid on;
figure();
semilogx(f_list,angle_list);
title("Bold Plot"); % set figure title
legend("Angle"); % set legend
xlabel("Frequency(Hz)");
ylabel("<H (Degrees)");
grid on;
```

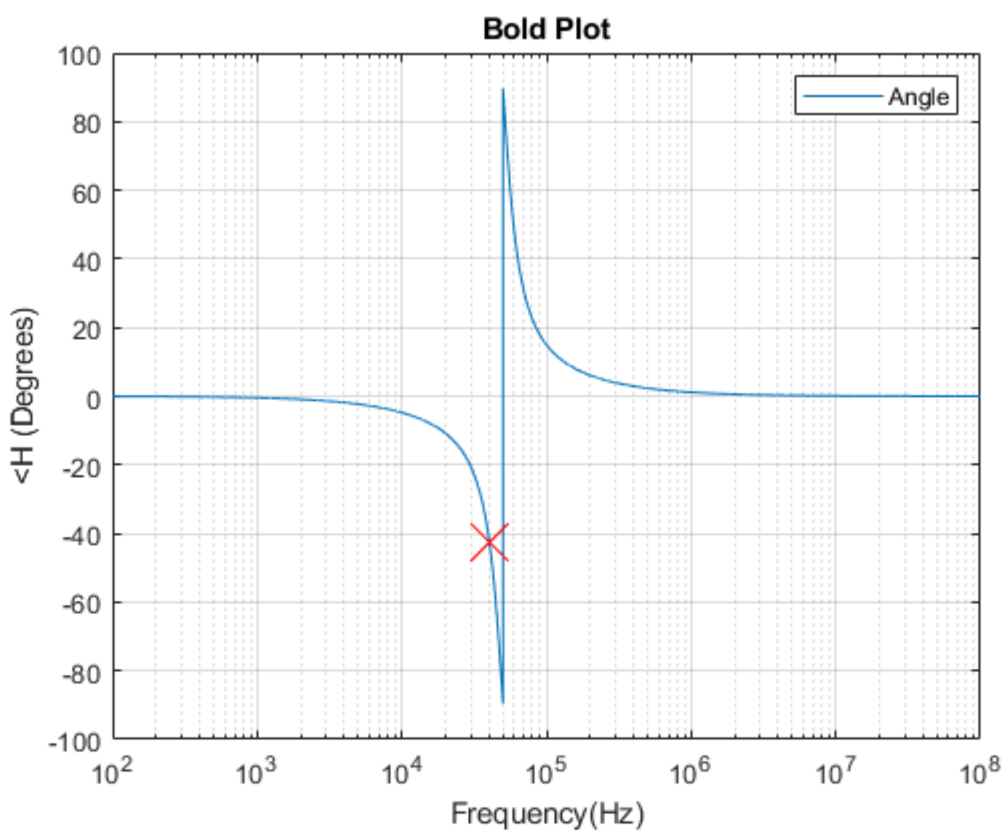




Question 4.5 RCL circuit freq @ 40000 Hz

```
figure();
semilogx(f_list,mag_list);
hold on
semilogx(40000,0.749,'xr', 'MarkerSize',20);
hold on
title("Bold Plot"); % set figure title
legend("Magnitude"); % set legend
xlabel("Frequency(Hz)");
ylabel("|H|");
grid on;
figure();
semilogx(f_list,angle_list);
hold on
semilogx(40000,-42.35,'xr', 'MarkerSize',20);
hold on
title("Bold Plot"); % set figure title
legend("Angle"); % set legend
xlabel("Frequency(Hz)");
ylabel("<H (Degrees)");
grid on;
```


Bold Plot
Magnitude
|H|
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
10^2
10^3
10^4
10^5
10^6
10^7
10^8
Frequency(Hz)


Bold Plot
Angle
<H (Degrees)
100
80
60
40
20
0
-20
-40
-60
-80
-100
10^2
10^3
10^4
10^5
10^6
10^7
10^8
Frequency(Hz)

```
%-------------------- Question 1 helper function --------------
function [Time_all_list,Vout_all_list, i_all_list, Vin_all_list, Vt_list]=
 RC_circuit_Q1(R,C)
    % 0v at t = 0s
    % steps up to 1v at t = 0.1s
    % steps backdown to 0v at 1.6s
    % ends at 3.1s
    Time_all_list = [];
    Vout_all_list = [];
    Vin_all_list = [];
    i_all_list = [];
    Time_current_list = [];
    Vout_current_list = [];
    Vt_list = [];

    Vin = 0;
    Vout_prev = 0;
    Time_prev=0;
    [Time_current_list, i_current_list, Vin_current_list, Time_prev,
 Vout_current_list, Vout_prev] = RC_step_C(R,C,Vout_prev,Vin, Time_prev,0.1);
    Time_all_list = [Time_all_list,Time_current_list];
    Vout_all_list = [Vout_all_list, Vout_current_list];
    i_all_list = [i_all_list,i_current_list];
    Vin_all_list = [Vin_all_list,Vin_current_list];

    Vin = 1;
    [Time_current_list, i_current_list, Vin_current_list,
 Time_prev, Vout_current_list, Vout_prev, Voltage_at_TimeConstant] =
 RC_step_C(R,C,Vout_prev,Vin, Time_prev,0.7);
    Time_all_list = [Time_all_list,Time_current_list];
    Vout_all_list = [Vout_all_list, Vout_current_list];
    i_all_list = [i_all_list,i_current_list];
    Vin_all_list = [Vin_all_list,Vin_current_list];
    Vt_list = [Vt_list,Voltage_at_TimeConstant];

    Vin = 0;
    [Time_current_list, i_current_list, Vin_current_list,
 Time_prev, Vout_current_list, Vout_prev, Voltage_at_TimeConstant] =
 RC_step_C(R,C,Vout_prev,Vin, Time_prev,0.7);
    Time_all_list = [Time_all_list,Time_current_list];
    Vout_all_list = [Vout_all_list, Vout_current_list];
    i_all_list = [i_all_list,i_current_list];
    Vin_all_list = [Vin_all_list,Vin_current_list];
    Vt_list = [Vt_list,Voltage_at_TimeConstant];
end

% This function models the Vout in a step voltage
function [Time_list, i_list, Vin_list, Time_last, Vout_list, Vout,
 Voltage_at_TimeConstant]=RC_step_C(R,C,Vout_prev, Vin, Time_prev, duration)
    dt = 0.001;
    Vout = Vout_prev; %initilazation
    Time_list = [];
    Vout_list = [];
    Vin_list = [];
```

```
    i_list = [];
    for t=0:dt:duration
        dVout = dt*((Vin-Vout)/(R*C));
        i = C*(dVout/dt);
        Vout = Vout + dVout;
        Time_list = [Time_list,t+Time_prev];
        Time_last = t+Time_prev;
        Vout_list = [Vout_list, Vout];
        i_list = [i_list,i];
        Vin_list = [Vin_list,Vin];
        if t == 0.25
            Voltage_at_TimeConstant = Vout;
        end
    end
end

%-------------------- Question 2 helper function --------------
function [Time_all_list,Vout_all_list, Vin_all_list, i_all_list, Vt_list]=
 RC_circuit_Q2(R,C)
    % 0v at t = 0s
    % steps up to 1v at t = 0.1s
    % steps backdown to 0v at 0.8s
    % ends at 1.5s
    Time_all_list = [];
    Vout_all_list = [];
    Vin_all_list = [];
    i_all_list = [];
    Time_current_list = [];
    Vout_current_list = [];
    Vin_current_list = []
    Vt_list = [];

    Vin = 0;
    Vout_prev = 0;
    Vc_prev = 0;
    Time_prev=0;
    [Time_current_list, i_current_list, Vin_current_list, Time_prev,
 Vout_current_list, Vout_prev, Vc_prev] = RC_step_R(R,C,Vout_prev,Vc_prev,
 Vin,0, Time_prev,0.1);
    Time_all_list = [Time_all_list,Time_current_list];
    Vout_all_list = [Vout_all_list, Vout_current_list];
    Vin_all_list = [Vin_all_list,Vin_current_list];
    i_all_list = [i_all_list,i_current_list];

    Vin = 1;
    [Time_current_list, i_current_list, Vin_current_list, Time_prev,
 Vout_current_list, Vout_prev, Vc_prev, Voltage_at_TimeConstant] =
 RC_step_R(R,C,Vout_prev,Vc_prev, Vin,1, Time_prev,1.5);
    Time_all_list = [Time_all_list,Time_current_list];
    Vout_all_list = [Vout_all_list, Vout_current_list];
    Vin_all_list = [Vin_all_list,Vin_current_list];
    i_all_list = [i_all_list,i_current_list];
    Vt_list = [Vt_list,Voltage_at_TimeConstant];
```

```
    Vin = 0;
    [Time_current_list, i_current_list, Vin_current_list, Time_prev,
 Vout_current_list, Vout_prev, Vc_prev, Voltage_at_TimeConstant] =
 RC_step_R(R,C,Vout_prev,Vc_prev, Vin,-1, Time_prev,1.5);
    Time_all_list = [Time_all_list,Time_current_list];
    Vout_all_list = [Vout_all_list, Vout_current_list];
    Vin_all_list = [Vin_all_list,Vin_current_list];
    i_all_list = [i_all_list,i_current_list];
    Vt_list = [Vt_list,Voltage_at_TimeConstant];
end

% This function models the Vout in a step voltage
function [Time_list, i_list, Vin_list, Time_last, Vout_list, Vout, Vc,
 Voltage_at_TimeConstant]=RC_step_R(R,C,Vout_prev, Vc_prev, Vin, dVin,
 Time_prev, duration)
    dt = 0.001;
    Vout = Vout_prev; %initilazation
    Vc = Vc_prev;
    Time_list = [];
    Vout_list = [];
    Vin_list = [];
    i_list = [];
    for t=0:dt:duration
        if t==0
            dVout = dVin-dt*(Vout/(R*C));
        else
            dVout = -dt*(Vout/(R*C));
        end
        dVc = dt*((Vin-Vc)/(R*C));
        i = C*(dVc/dt);
        Vout = Vout + dVout;
        Vc = Vc + dVc;
        Time_list = [Time_list,t+Time_prev];
        Time_last = t+Time_prev;
        Vout_list = [Vout_list, Vout];
        i_list = [i_list,i];
        Vin_list = [Vin_list,Vin];
        if t == 0.25
            Voltage_at_TimeConstant = Vout;
        end
    end
end

%-------------------- Question 4 helper function --------------
function [f_list,angle_list, mag_list]= RCL_circuit_Q4(R,C,L)
    mag_list = [];
    angle_list = [];
    f_list = [];
    for f_exp=2:0.001:8
        f = 10^f_exp;
        w = 2*pi*f;
        H = (1-L*C*w^2)/(complex(1-L*C*w^2,w*C*R));
        mag = abs(H);
        phase = angle(H)*180/pi;
```

```
        f_list = [f_list,f];
        mag_list = [mag_list, mag];
        angle_list = [angle_list,phase];
    end
end
```

Published with MATLAB® R2022b