ELEC 4700

Assignment 4

Circuit Modeling

Liam Anderson
100941879
April 5 2020

1. and 2.

```
% My assignment 3 was terrible...
% But if I had the IV data from A3 I would
% find the linear fit and R3 like this:

poly = polyfit(v, i, 1);
fit = poly(1)*v + poly(2);
R3 = poly(1)
```

3.

a.

Eq'ns

① $\frac{1}{R_1}(V_1 - V_2) + i_{in} = 0$

② $\frac{1}{R_1}(V_2 - V_1) + \frac{V_2}{R_2} = 0$

③ $\frac{V_3}{R_3} - i_L = 0$

④ $\frac{1}{R_4}(V_4 - V_5) + i_3 = 0$

⑤ $\frac{1}{R_4}(V_4 - V_5) + \frac{V_5}{R_0} = 0$

⑥ $V_1 = [-10:10]$ SWEEP → linspace

⑦ $V_2 - V_3$

⑧ $-\alpha V_3/R_3$

$$
G = \begin{array}{c|cccccccc}
 & v_1 & v_2 & v_3 & v_4 & v_5 & i_{in}\ 6 & i_L\ 7 & i_3\ 8 \\
\hline
1 & 1/R_1 & -1/R_1 & 0 & 0 & 0 & 1 & 0 & 0 \\
2 & -1/R_1 & \frac{1}{R_1}+\frac{1}{R_2} & 0 & 0 & 0 & 0 & 1 & 0 \\
3 & 0 & 0 & 1/R_3 & 0 & 0 & 0 & -1 & 0 \\
4 & 0 & 0 & 0 & 1/R_4 & -1/R_4 & 0 & 0 & 1 \\
5 & 0 & 0 & 0 & -1/R_4 & \left[1/R_0 + 1/R_4\right] & 0 & 0 & 0 \\
6 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
7 & 0 & 1 & -1 & 0 & 0 & 0 & 0 & 0 \\
8 & 0 & 0 & -\alpha/R_3 & 1 & 0 & 0 & 0 & 0
\end{array}
$$

7+1 nodes

Voltages + Currents

Note: See appendix for finite difference derivations

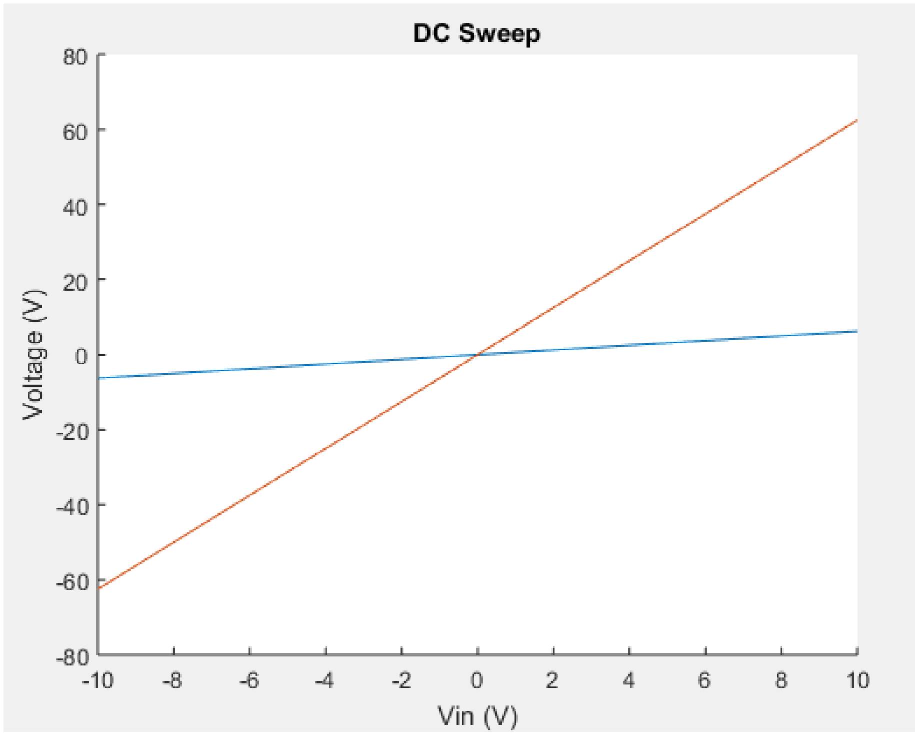
$$C = \begin{array}{c|cccccccc|} & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 \\ 1 & C & -C & 0 & 0 & 0 & 0 & & \\ 2 & -C & C & 0 & & \text{etc.} & & & \\ 3 & 0 & 0 & 0 & & & & & \\ 4 & & & & & & & & \\ 5 & & & & \text{0's} & & & & \\ 6 & & & & & & & & \\ 7 & & & & & & & & \\ 8 & & & & & & & & \end{array}$$

```
G = [
    1.0000   -1.0000         0         0         0         0         0    1.0000    ;
   -1.0000    1.5000         0         0         0    1.0000         0         0    ;
         0         0    0.1000         0         0   -1.0000         0         0    ;
         0         0         0   10.0000  -10.0000         0    1.0000         0    ;
         0         0         0  -10.0000   10.0010         0         0         0    ;
         0    1.0000   -1.0000         0         0         0         0         0    ;
         0         0  -10.0000    1.0000         0         0         0         0    ;
    1.0000         0         0         0         0         0         0         0    ;
    ];
```

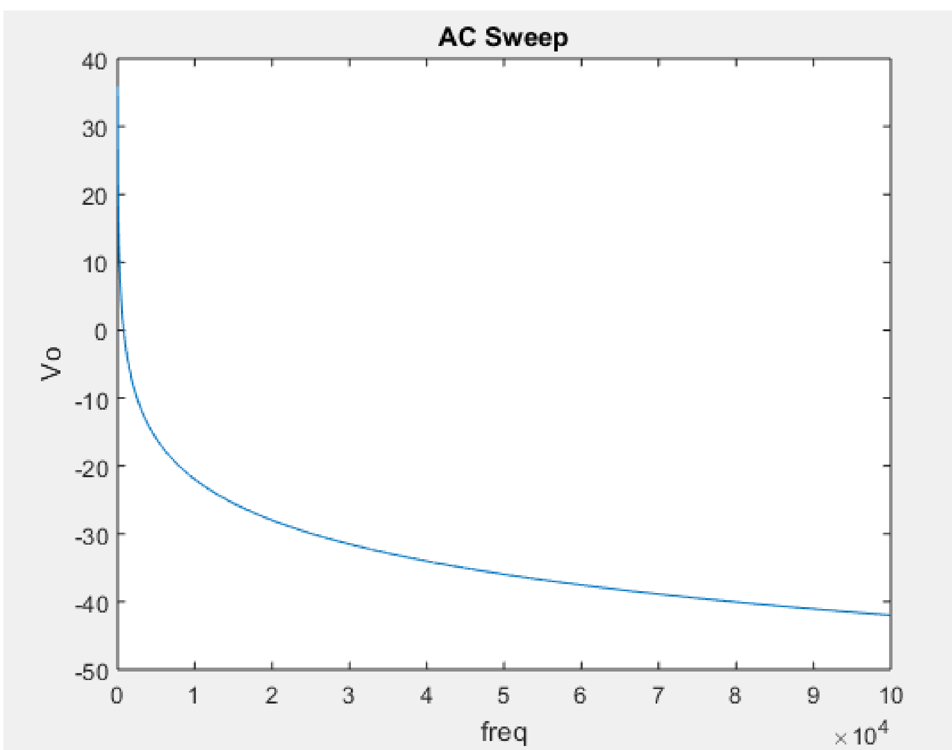
```
C = [
       Cap      -Cap         0         0         0         0         0         0    ;
      -Cap       Cap         0         0         0         0         0         0    ;
         0         0         0         0         0         0         0         0    ;
         0         0         0         0         0         0         0         0    ;
         0         0         0         0         0         0         0         0    ;
         0         0         0         0         0        -L         0         0    ;
         0         0         0         0         0         0         0         0    ;
         0         0         0         0         0         0         0         0    ;
    ];
```

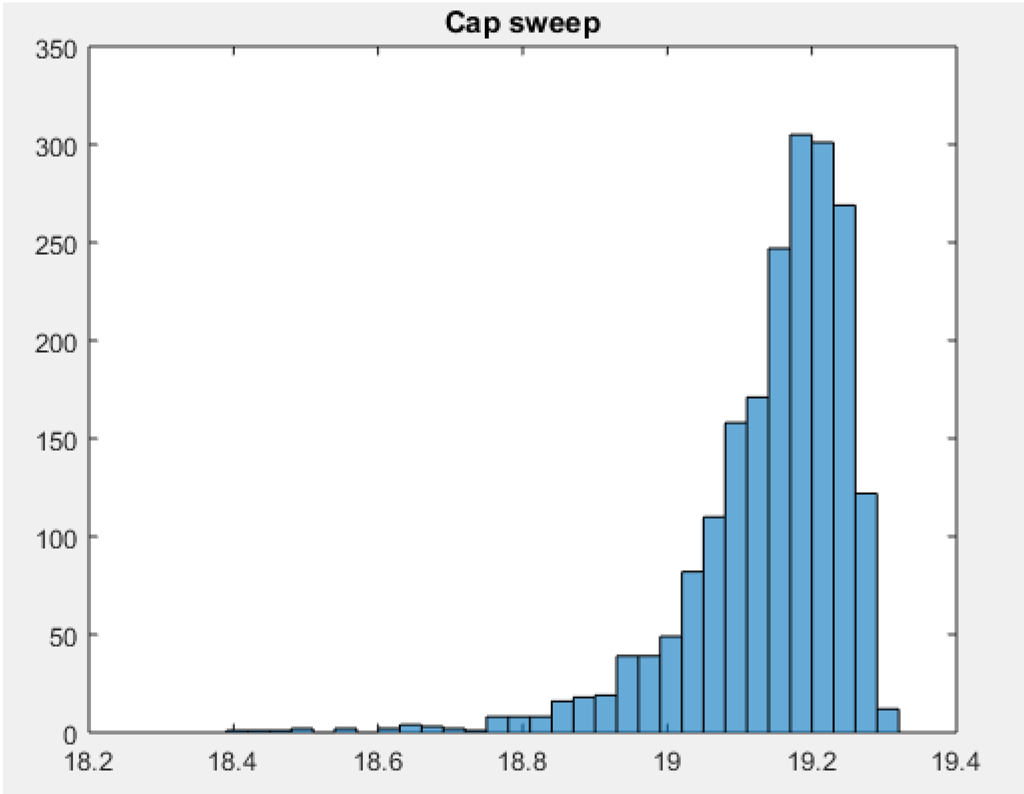
```
F = [
    0   ;
    0   ;
    0   ;
    0   ;
    0   ;
    0   ;
    0   ;
    1   ;
    ];
```

b.



*** For DC above, note that the blue line is V1 and the orange line is Vout**





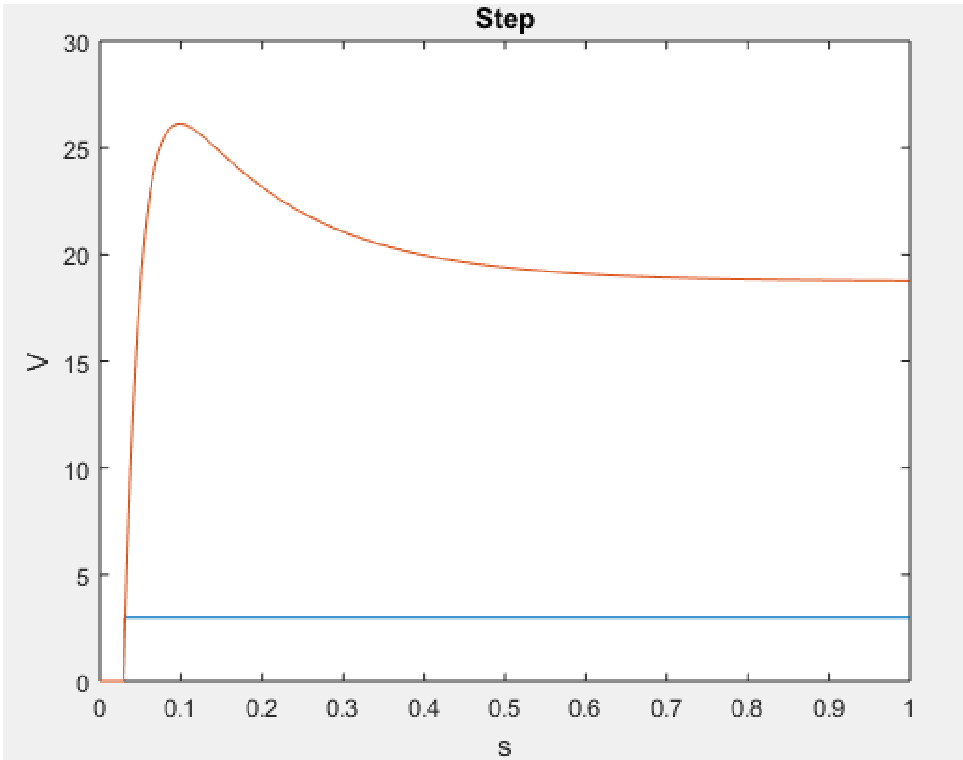
4.

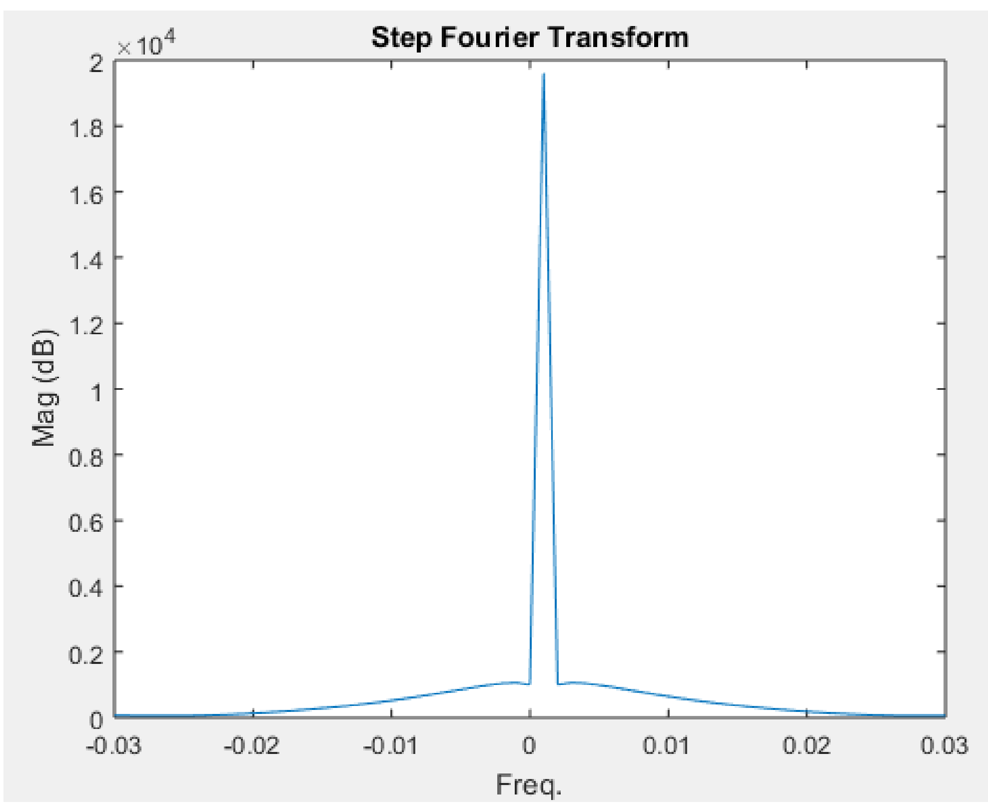
a. This circuit is a <u>low-pass filter</u>. This is proven by the AC Sweep graph. It is also predictable, given the presence of the inductor.

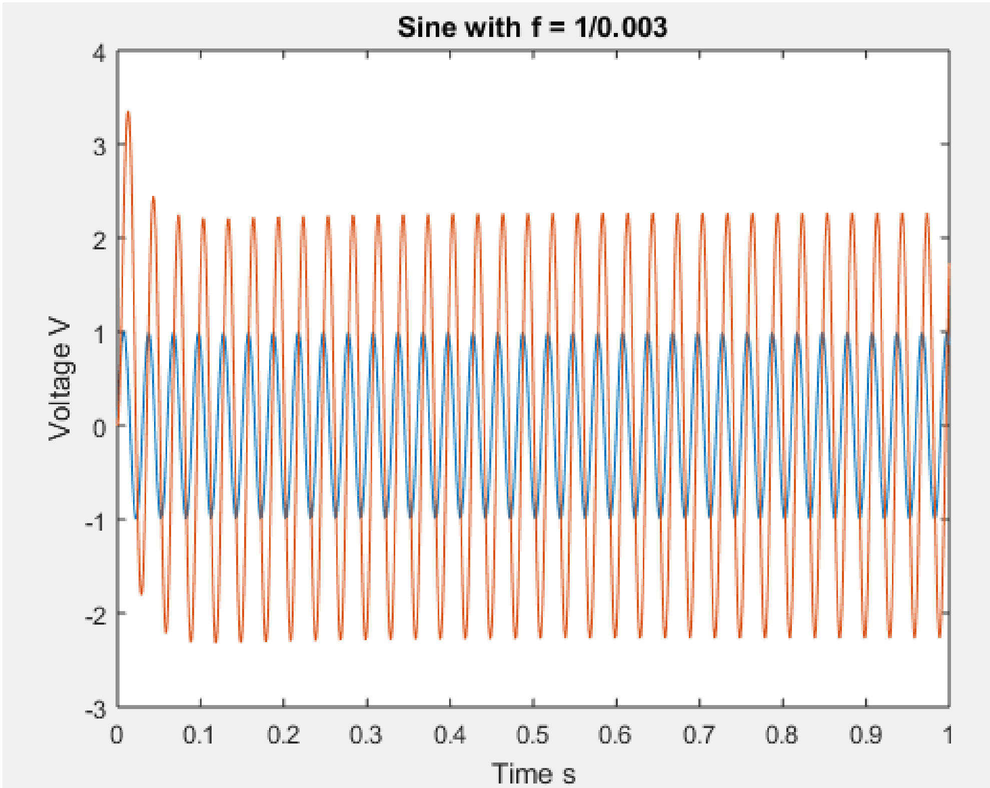
b. If it behaves like a normal filter, then it would have a <u>high gain at low frequencies</u>, up to the chosen <u>cut-off frequency where it should drop by 3dB</u> and then begin to drop sharply, again how sharp is dependent on the design.

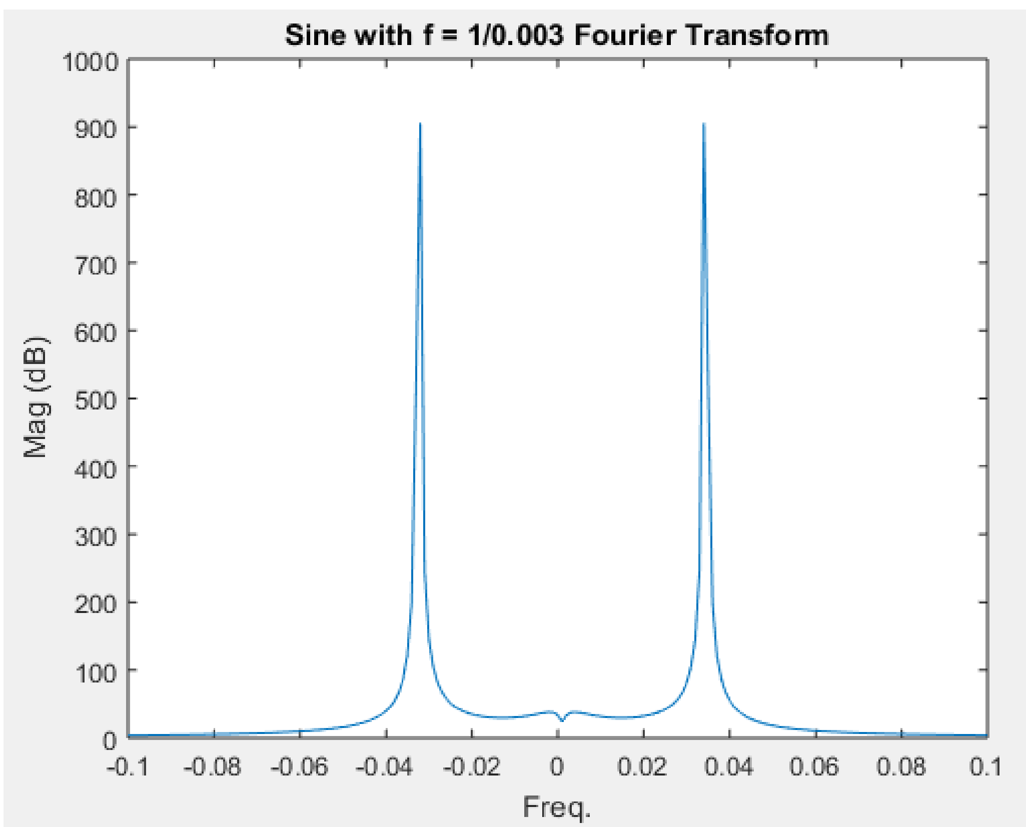
c. See appendix for finite difference derivations

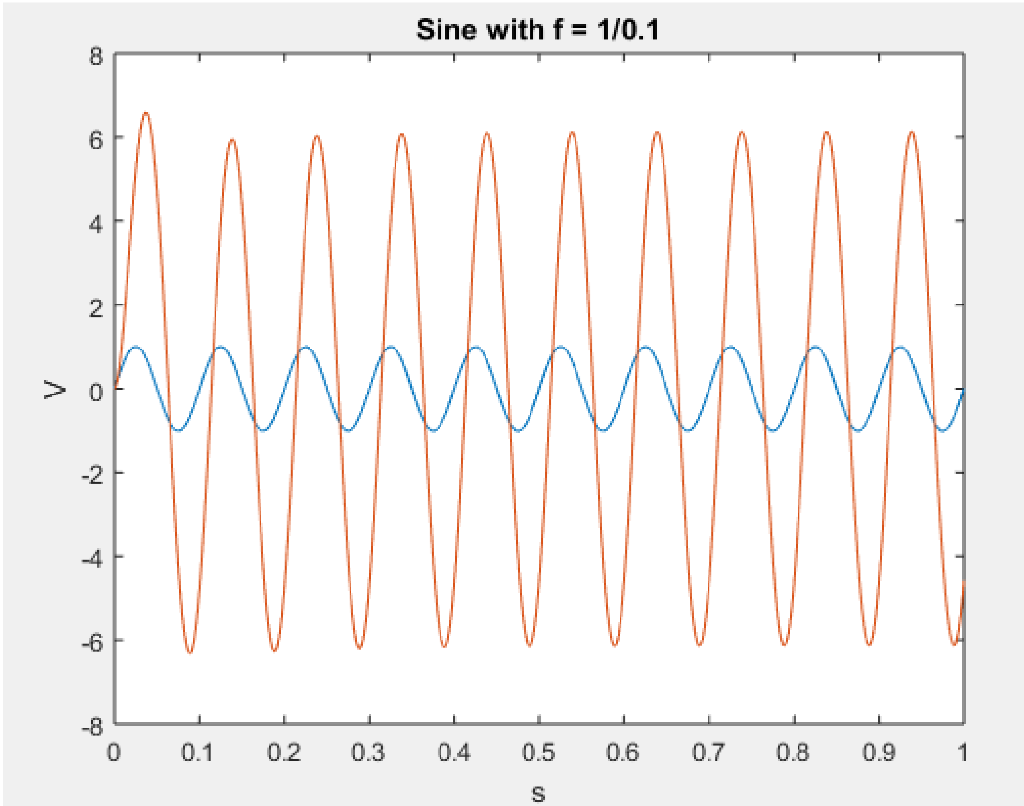
d.


Step
30
25
20
15
10
5
0
V
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
s

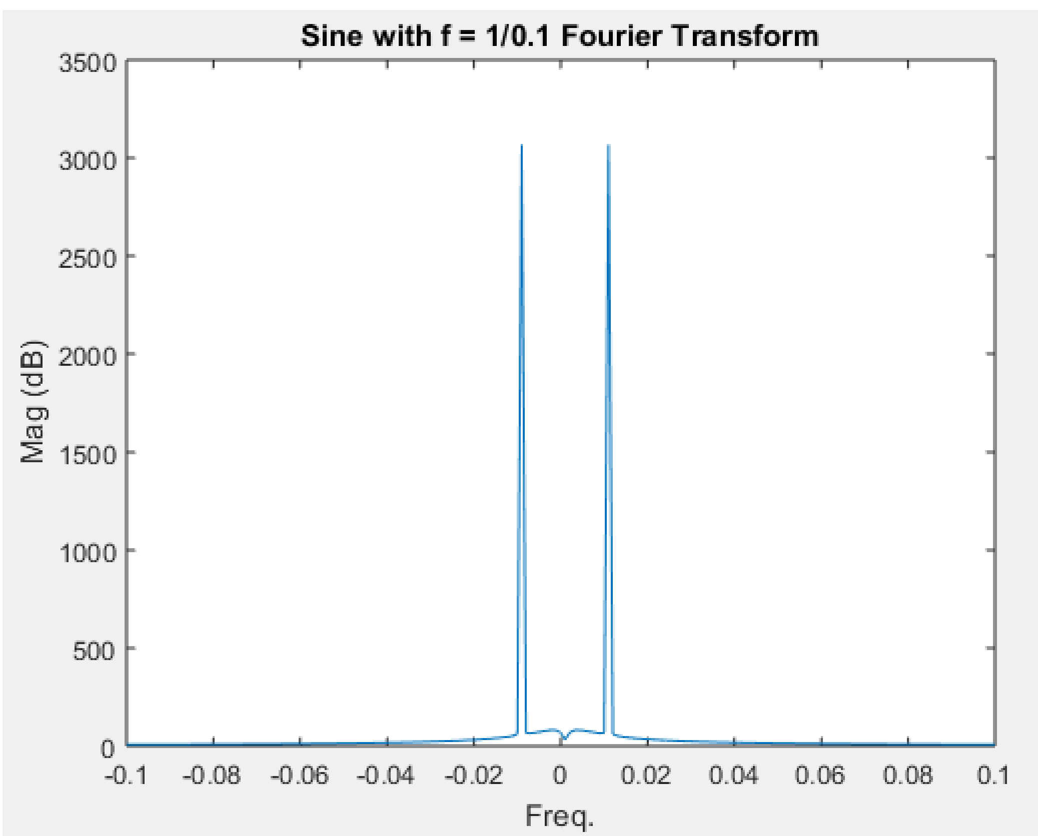

Step Fourier Transform
×10^4
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Mag (dB)
-0.03
-0.02
-0.01
0
0.01
0.02
0.03
Freq.


Sine with f = 1/0.003
Voltage V
Time s
4
3
2
1
0
-1
-2
-3
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

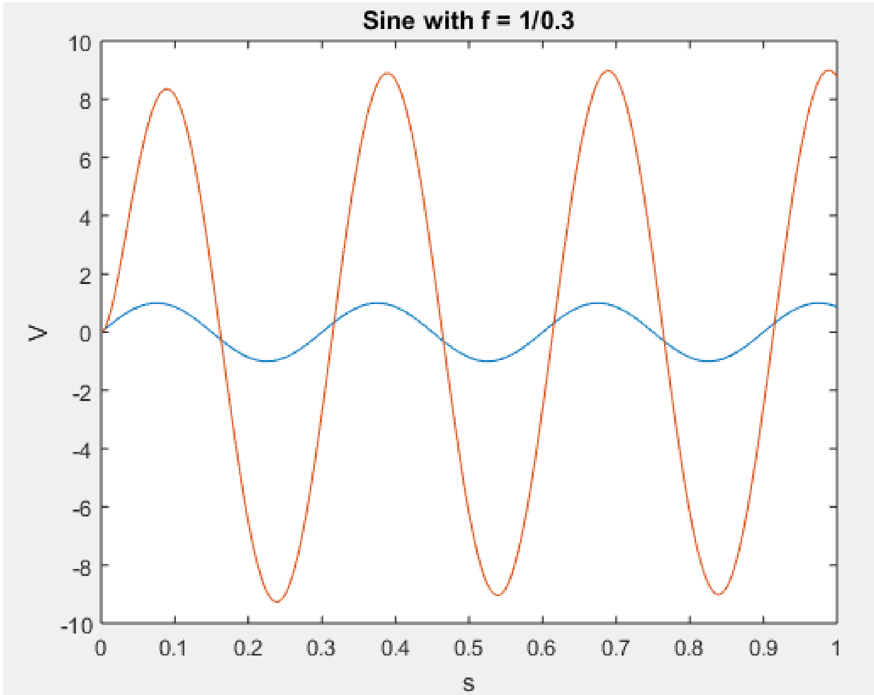

Sine with f = 1/0.003 Fourier Transform
Mag (dB)
Freq.
1000
900
800
700
600
500
400
300
200
100
0
-0.1
-0.08
-0.06
-0.04
-0.02
0
0.02
0.04
0.06
0.08
0.1

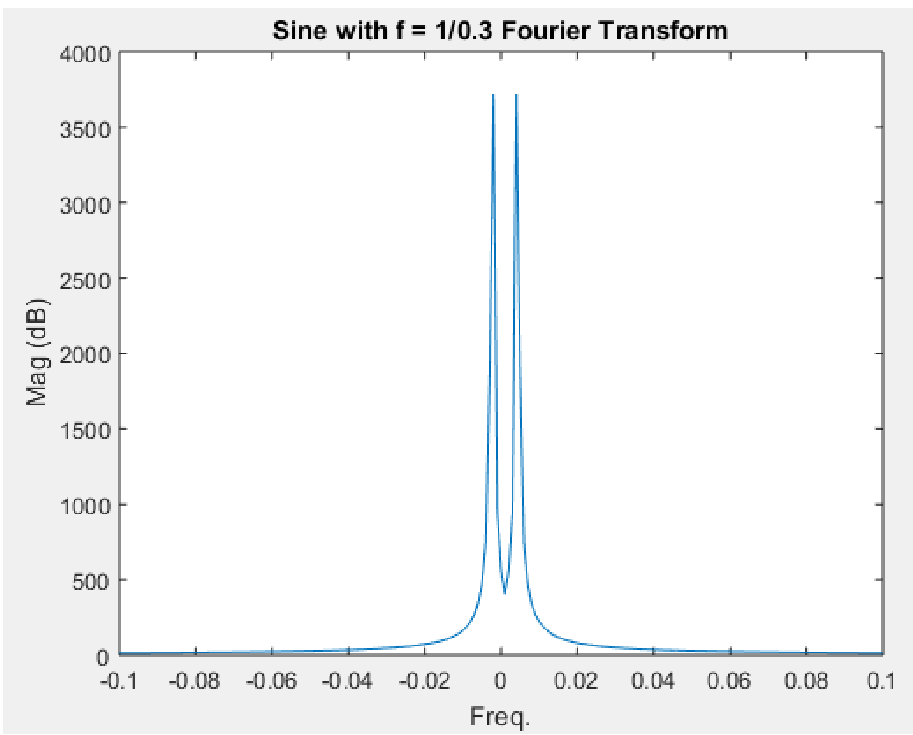


Sine with f = 1/0.1
V
s

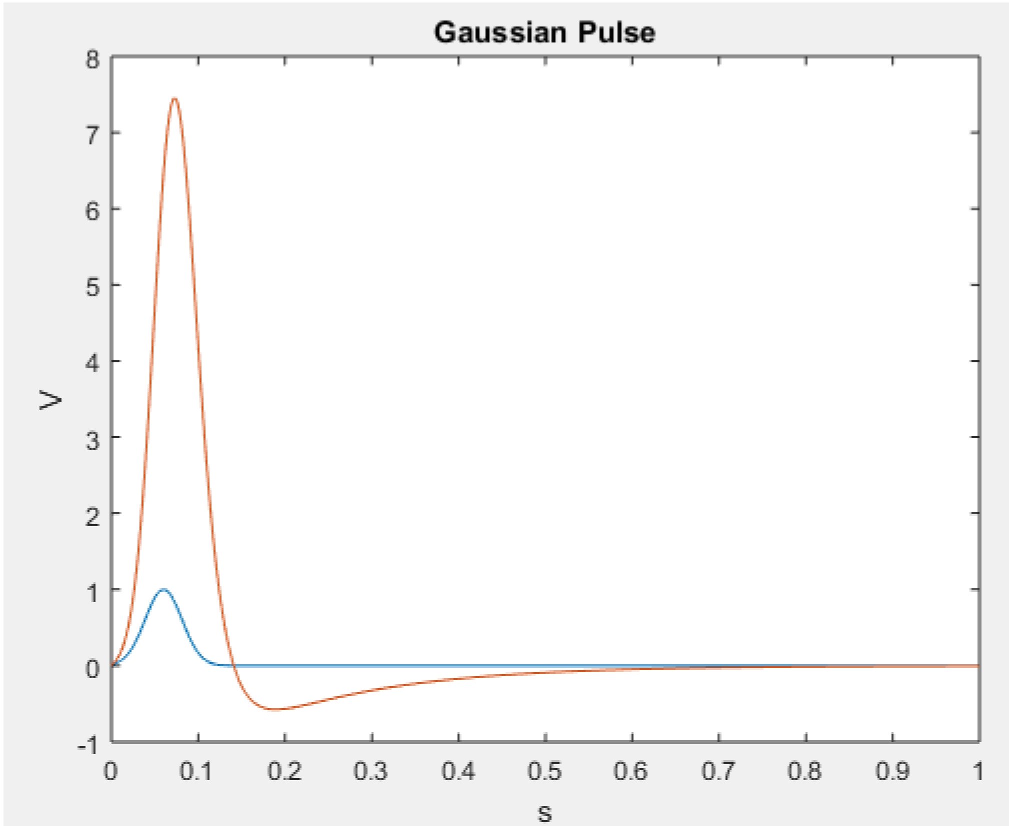


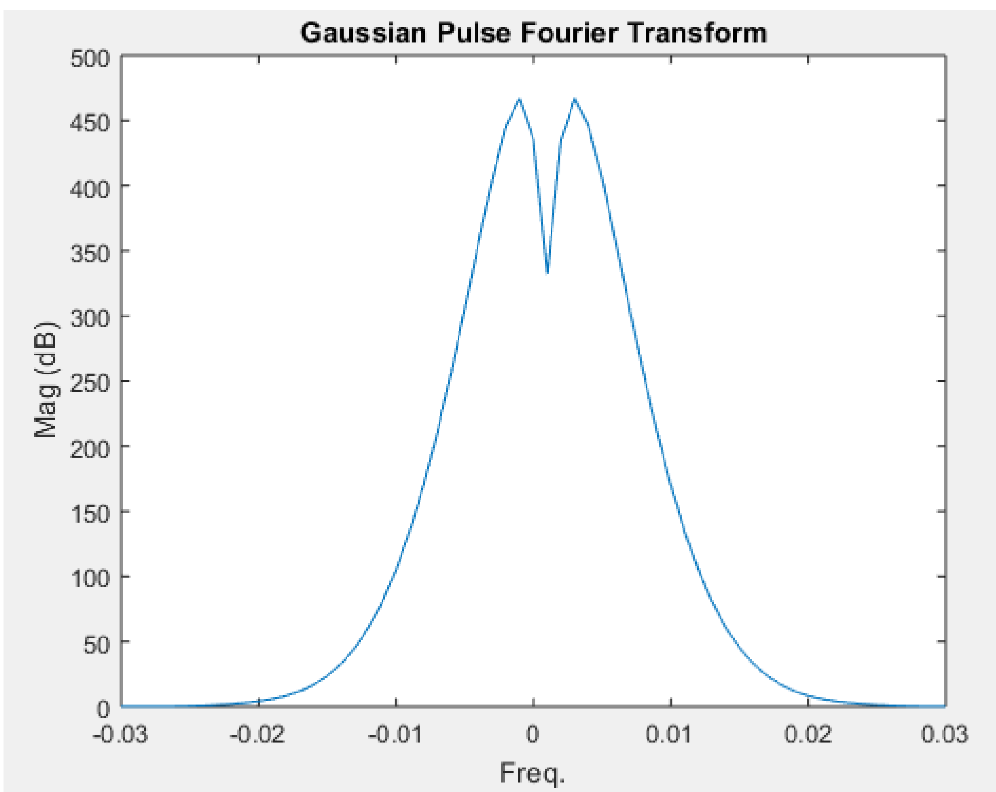
Sine with f = 1/0.1 Fourier Transform
Mag (dB)
Freq.





- It appears that as the frequency is decreased (slowed down), the <u>gain increases</u>. It can be assumed that the opposite would be true for increasing frequency.

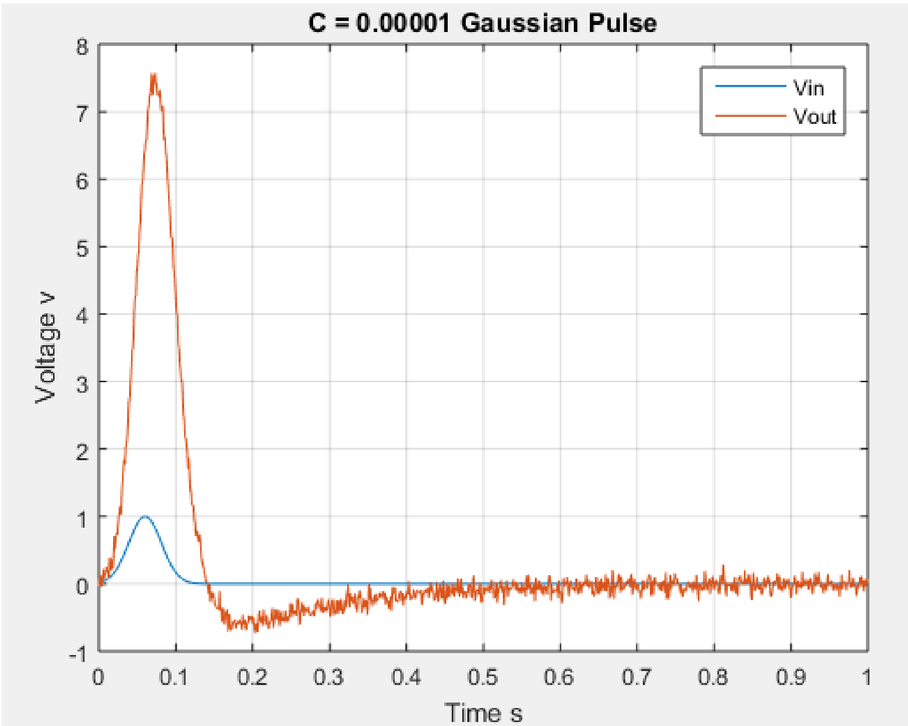


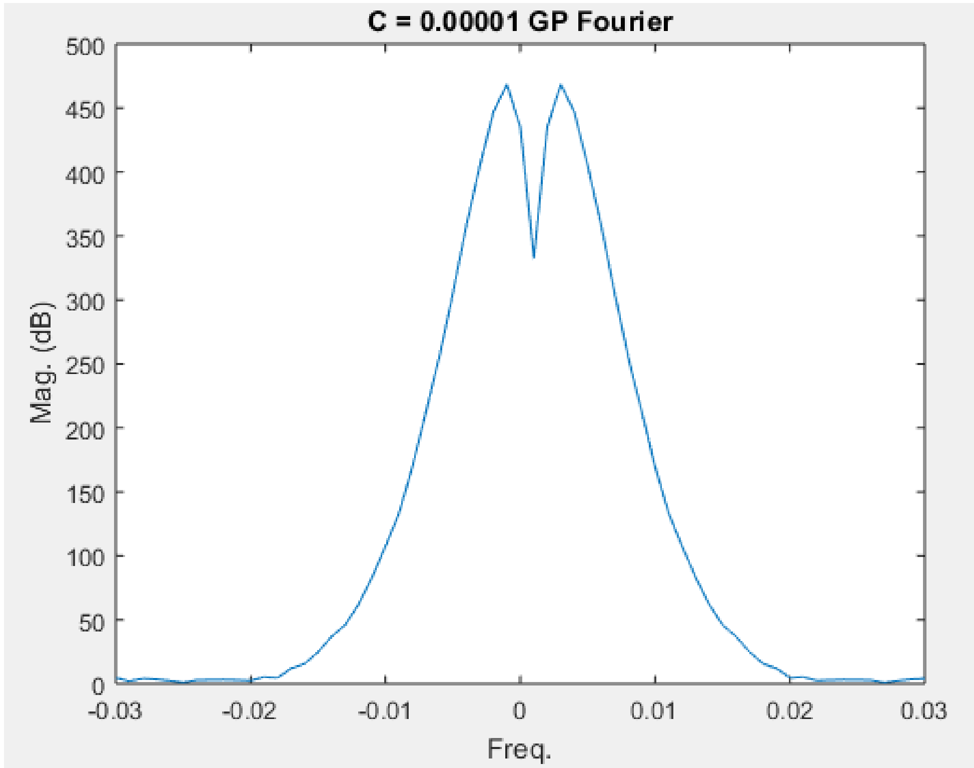


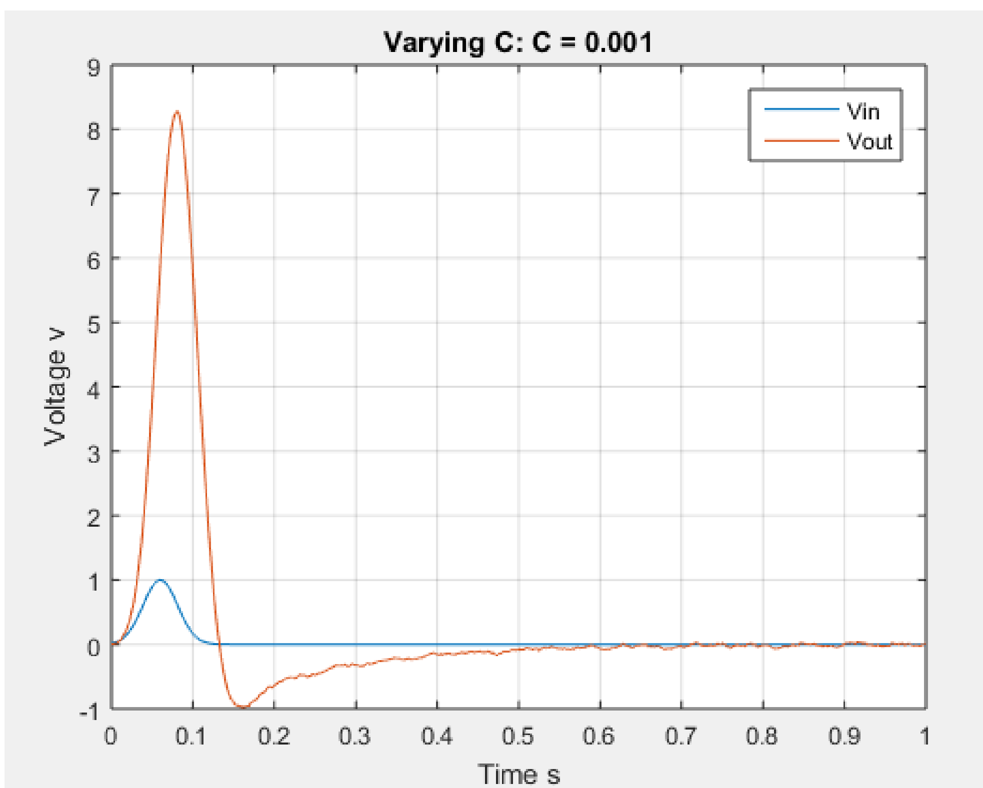
Decreasing the timestep will make the simulation more detailed (see Q5)

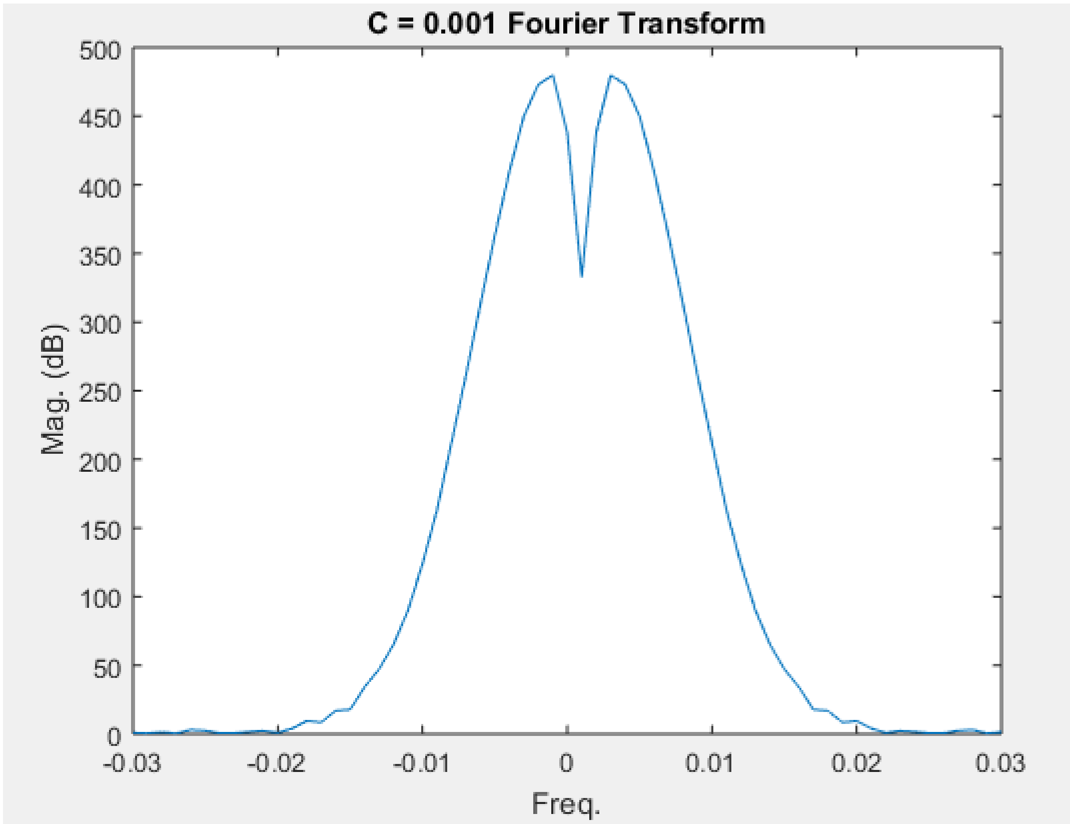
5.

```
C = [
    Cap     -Cap    0       0   0   0   0   0   ;
    -Cap    Cap     0       0   0   0   0   0   ;
    0       0       Cnew    0   0   0   0   0   ;
    0       0       0       0   0   0   0   0   ;
    0       0       0       0   0   0   0   0   ;
    0       0       0       0   0   -L  0   0   ;
    0       0       0       0   0   0   0   0   ;
    0       0       0       0   0   0   0   0   ;
    ];
```

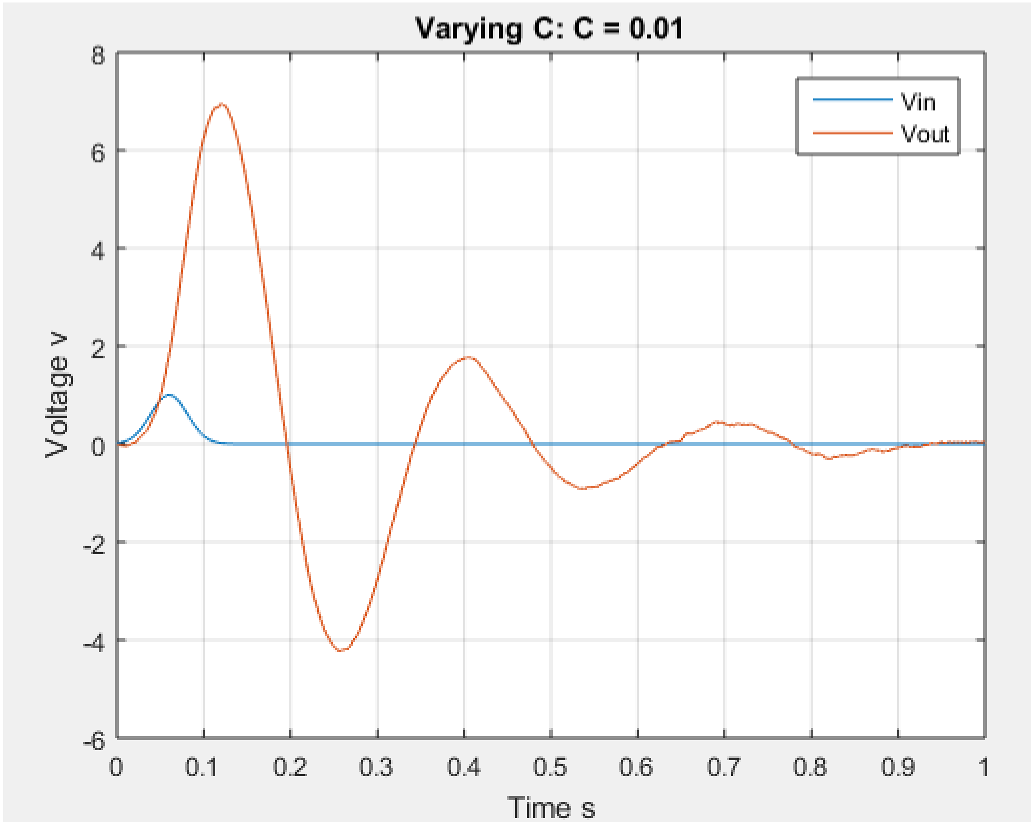



C = 0.00001 GP Fourier
Mag. (dB)
500
450
400
350
300
250
200
150
100
50
0
-0.03
-0.02
-0.01
0
0.01
0.02
0.03
Freq.

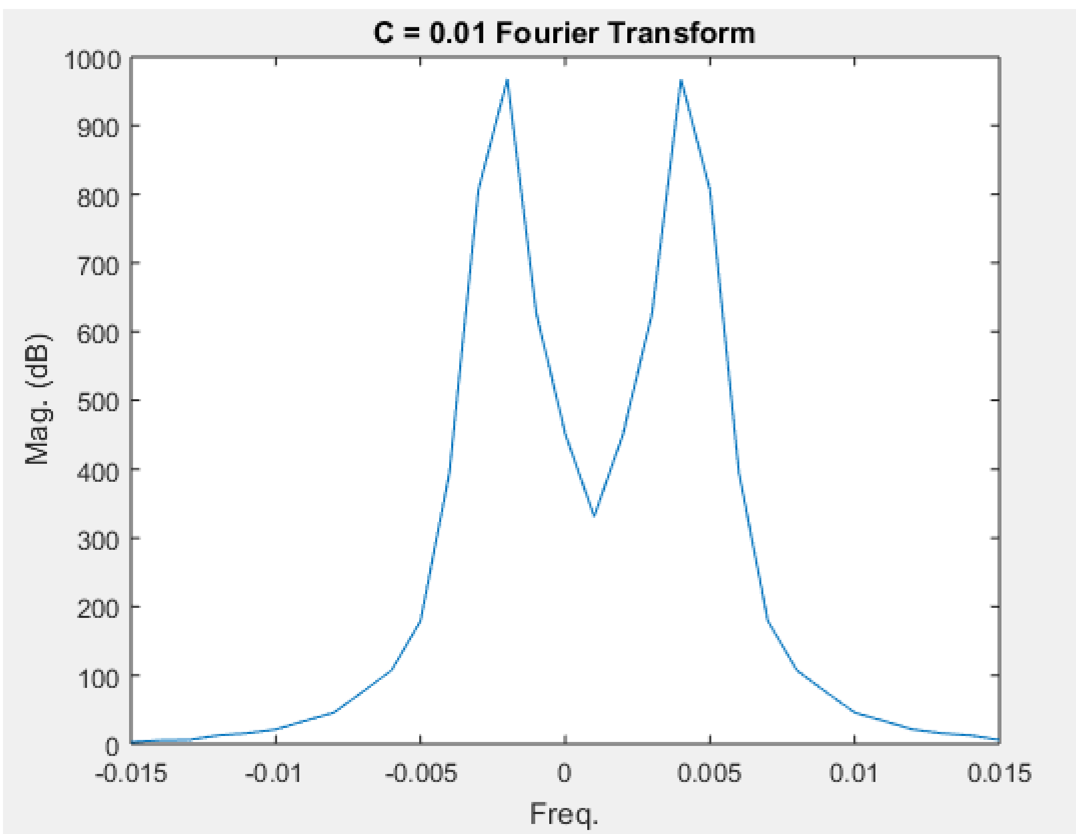

Varying C: C = 0.001
Vin
Vout
Voltage v
9
8
7
6
5
4
3
2
1
0
-1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Time s



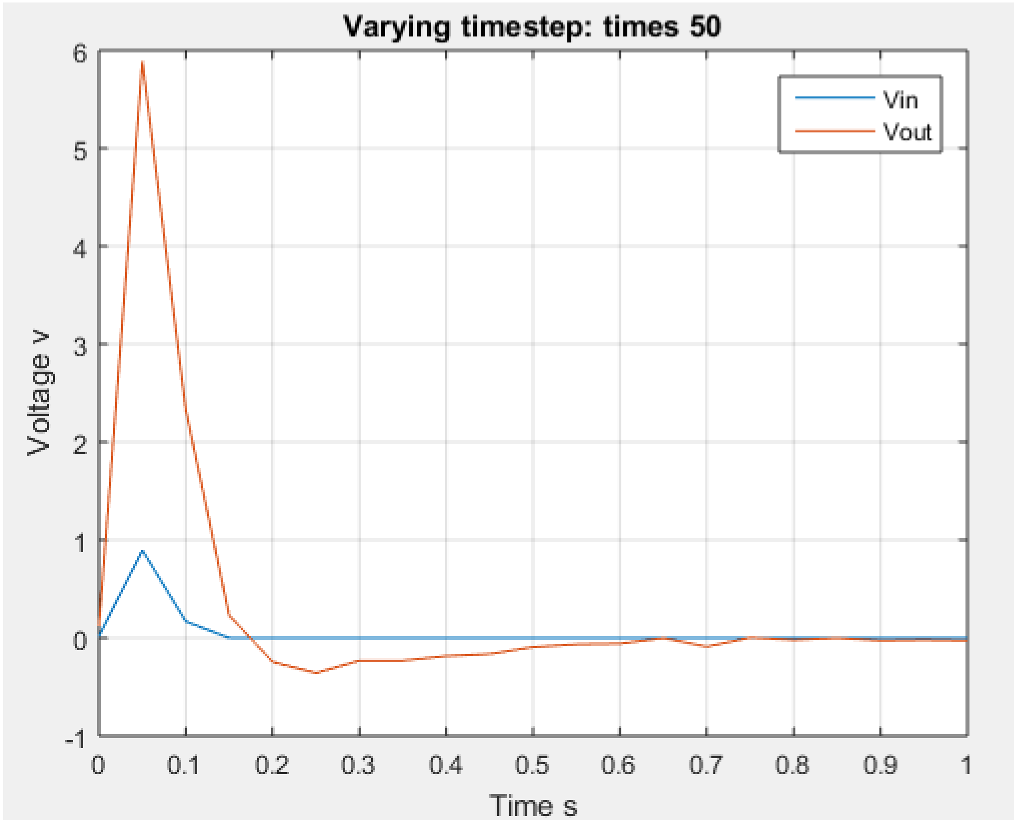
C = 0.001 Fourier Transform
Mag. (dB)
Freq.
500
450
400
350
300
250
200
150
100
50
0
-0.03
-0.02
-0.01
0
0.01
0.02
0.03

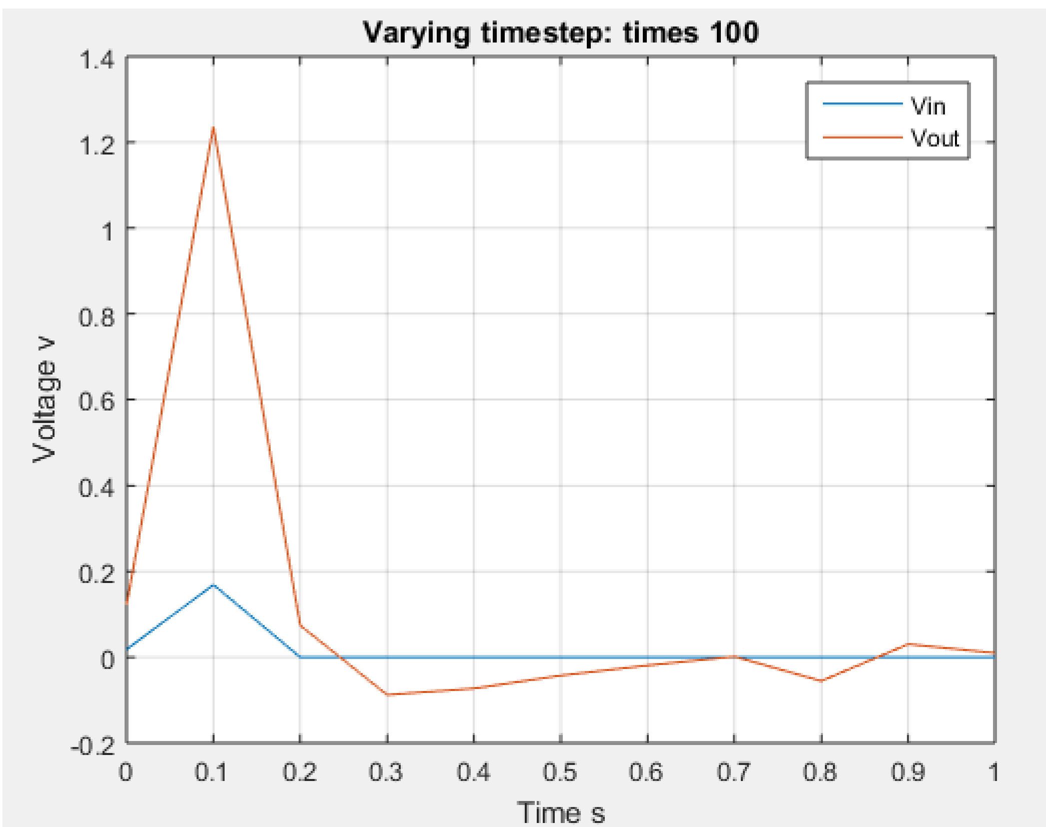


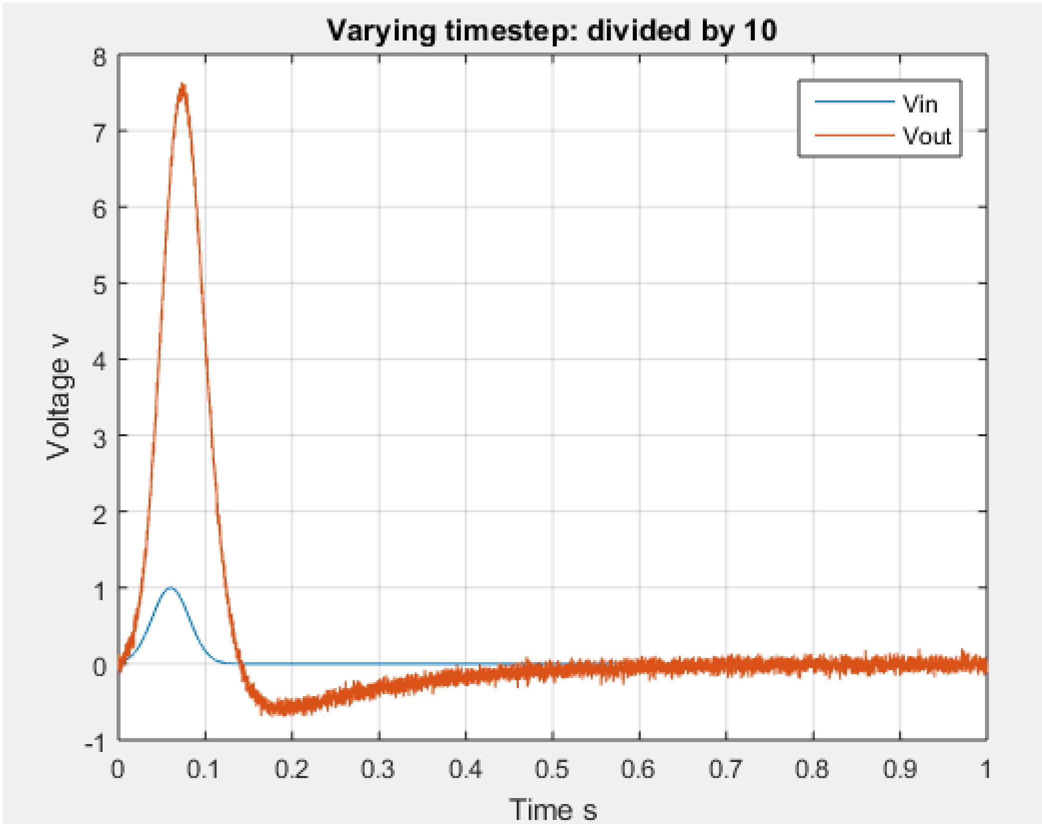
Varying C: C = 0.01
Vin
Vout
Voltage v
Time s
8
6
4
2
0
-2
-4
-6
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1



C = 0.01 Fourier Transform
Mag. (dB)
Freq.
1000
900
800
700
600
500
400
300
200
100
0
-0.015
-0.01
-0.005
0
0.005
0.01
0.015


Varying timestep: times 50
Vin
Vout
Voltage v
Time s


Varying timestep: times 100
Vin
Vout
Voltage v
Time s



- Increasing C seems to increase the (positive) value of the pass frequency, approximately matching C (for example f_{pass} ~= 0.01 Hz for C = 0.01). This is seen on the Fourier Transform graphs.
- Increasing C seems to lower or "dampen" the circuit output.

- The larger the timestep, the less detailed the resulting simulation is. When the timestep is made very small (/10) the curve gets very erratic.

6.

```
% The simulation now needs to deal with nonlinearity.
% A new vector would be added to the matrix equation.
% Gaussian can no longer be used for this non-linear
% problem so some other algorithm would have to be used.
```

Appendix

Time Domain Derivations

DC: $GV = f \rightarrow$ SOLVE

AC: $(j\omega C + G)V = f(\omega) \rightarrow$ SOLVE

Transient: $(C/dt + G)\,V(j) = CV(j-1)/dt + f(t(j))$

References

[1] A. Branicki, GH Repository.
<https://github.com/andrewbranicki/assignment4 > 3-Apr-2019.

[2] L. Jones, “Monte Carlo simulation for two dimensional particles in the NVT ensemble-Lennard Jones interaction - MATLAB Central,” Monte Carlo simulation for two dimensional particles in the NVT ensemble-Lennard Jones interaction - [Online]. Available: https://www.mathworks.com/matlabcentral/fileexchange/55266-monte-carlo-simulation-fortwo-dimensional-particles-in-the-nvt-ensemble-lennard-jones-interaction. 15-Mar-2020.

[3] B. Bogosel, “Finite Difference Method for 2D Laplace equation,” *Beni Bogoşels blog*, 27-Oct-2014. [Online]. Available: https://mathproblems123.wordpress.com/2012/10/19/finite-difference-method-for-2d-laplace-equation/. [Accessed: 15-Mar-2020].

[5] L. Munro, “assignment4.m,” GH Repository.
<https://github.com/Munro-L/ELEC-4700_Assignment4/blob/master/assignment4.m>3-Apr-2019.