ELEC 4700

ASSIGNMENT 4 – Circuit Modelling

Submitted By:

Jarikre Efe Jeffery

Date Submitted:

05/04/2020

Introduction:

Part 1:

By performing the first order linear fit from the previous assignment, we are able to get the value for R3 to be 10.

The differential equations that represent the network in the time domain using KCL (Summation of I=0 at the node) can be found below:

Equations:

$$\begin{aligned}
V_1 &= V_{in} \\
G_1(V_2 - V_1) + C\frac{d(V_2 - V_1)}{dt} + G_2V_2 - I_L &= 0 \\
V_2 - V_3 - L\frac{dI_L}{dt} &= 0 \\
-I_L + G_3V_3 &= 0 \\
V_4 - \alpha I_3 &= 0 \\
G_3V_3 - I_3 &= 0 \\
G_4(V_O - V_4) + G_OV_O &= 0
\end{aligned}$$

Matrices:

$$\mathbf{C} = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ -C & C & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & -L & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \quad \mathbf{G} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ -G_1 & G_1 + G_2 & -1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & -1 & 0 & 0 & 0 \\ 0 & 0 & -1 & G_3 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & -\alpha & 1 & 0 \\ 0 & 0 & 0 & G_3 & -1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & -G_4 & G_4 + G_O \end{bmatrix}$$

$$\mathbf{V} = \begin{bmatrix} V_1 \\ V_2 \\ I_L \\ V_3 \\ I_3 \\ V_4 \\ V_O \end{bmatrix} \quad \mathbf{F} = \begin{bmatrix} V_{in} \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

Equations in the frequency domain can be found below:

In the frequency domain: Date

$V_1 = V_{in}$

$G_1 (V_2 - V_1) + Cj\omega (V_2 - V_1) + G_2 V_2 - I_L = 0$

$V_2 - V_1 - Lj\omega I_L = 0$

$-I_L + G_3 V_3 = 0$

$V_4 - \alpha I_3 = 0$

$G_3 V_3 - I_3 = 0$

$G_4 (V_o - V_4) + G_o V_o = 0$

Programming section:

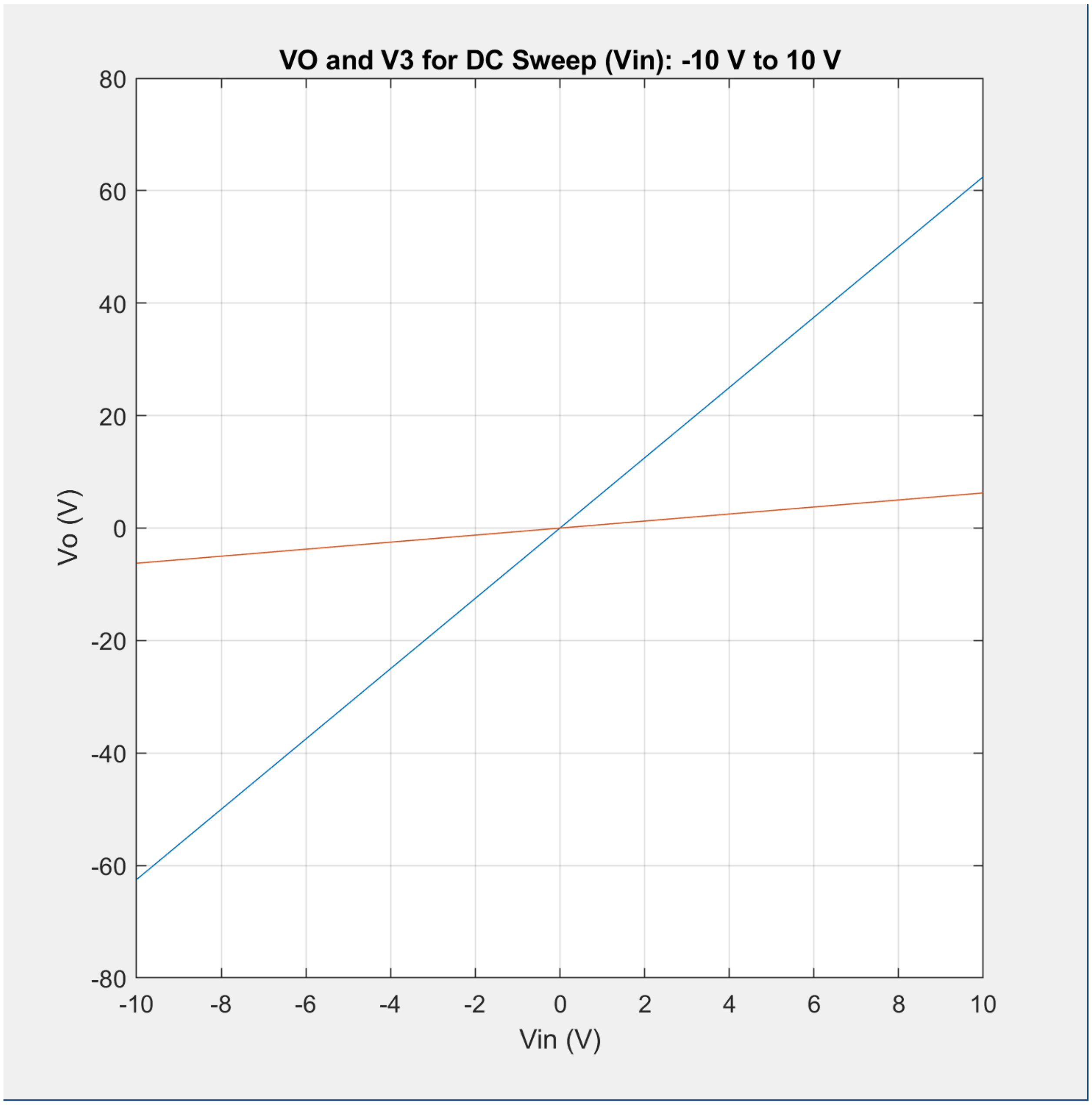


Figure 1: DC Sweep of the input voltage

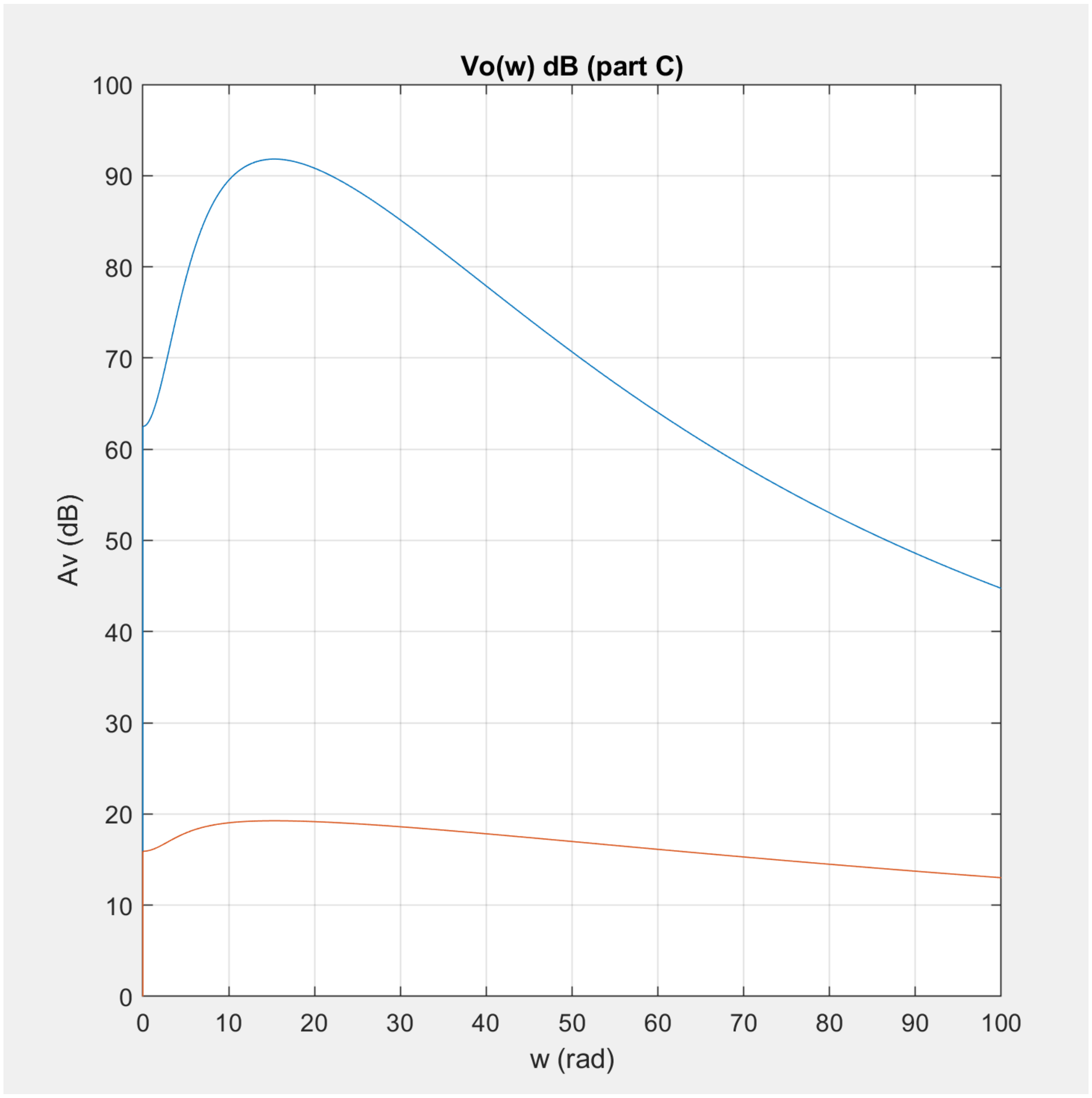


Figure 2: Ac plot of Vo as a fuction of w

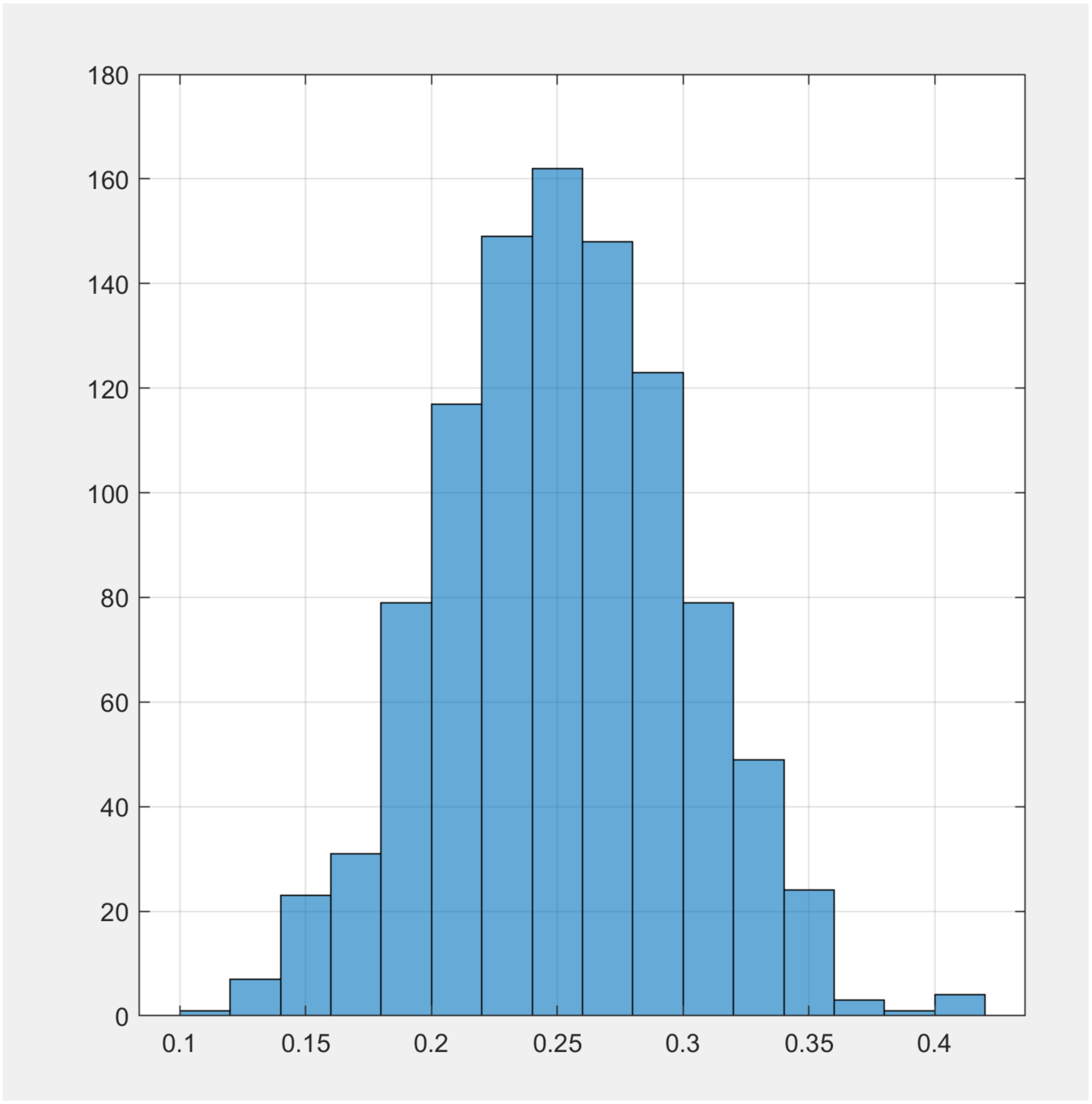


Figure 3: Histogram plot 1

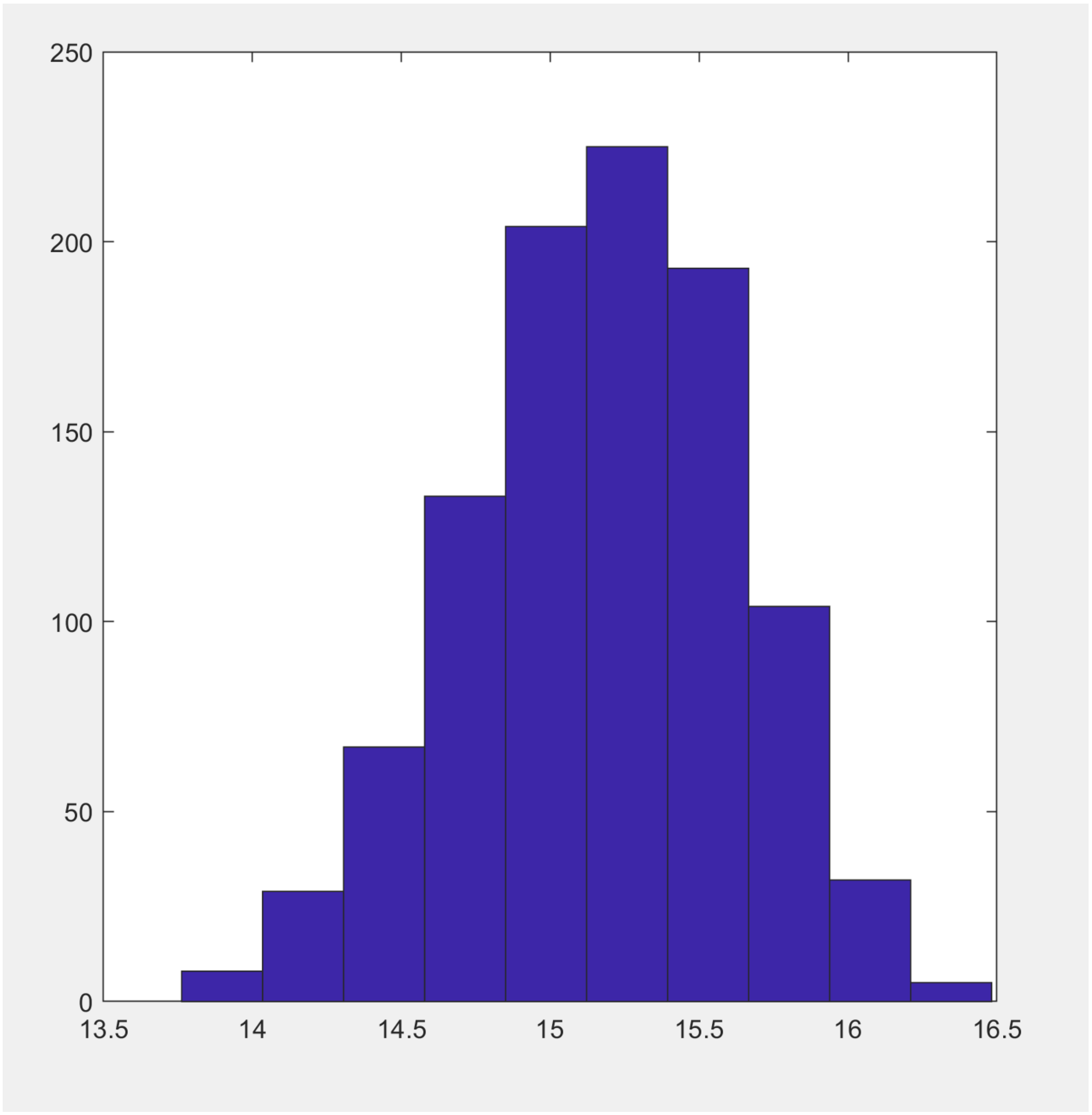


Figure 4: Histogram plot 2

Transient Simulation:

The circuit can be simulated in the time domain by solving the equation of CdV/dt + GV = F

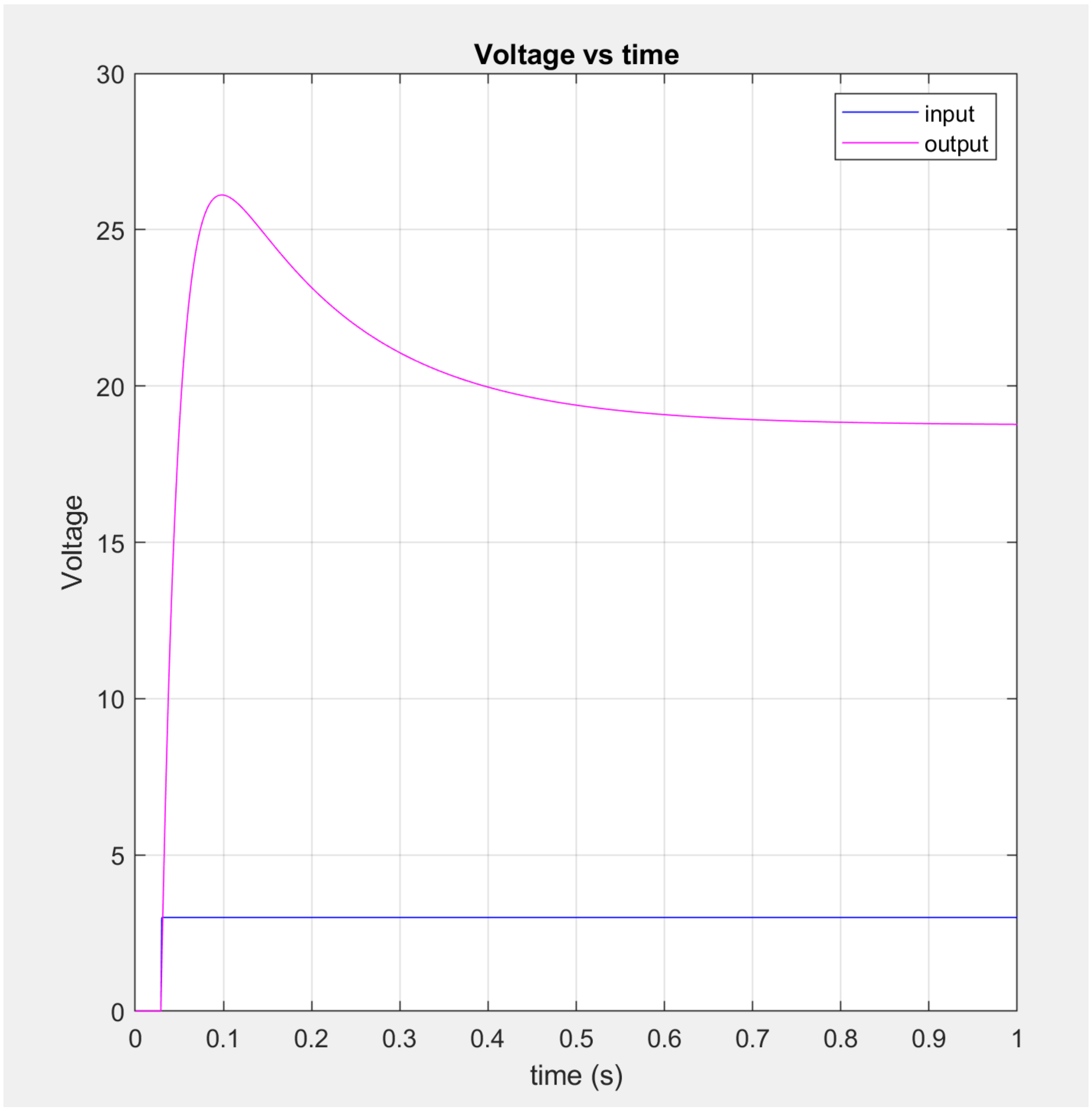


Figure 5: Plot of the voltage vs time

a.) By inspection the circuit is a low pass filter

b.) We should expect the frequency response to cut off high frequencies and allow only the low frequencies to go through.

d.) Part v: As the time step is increased the accuracy of the simulation is decreased.

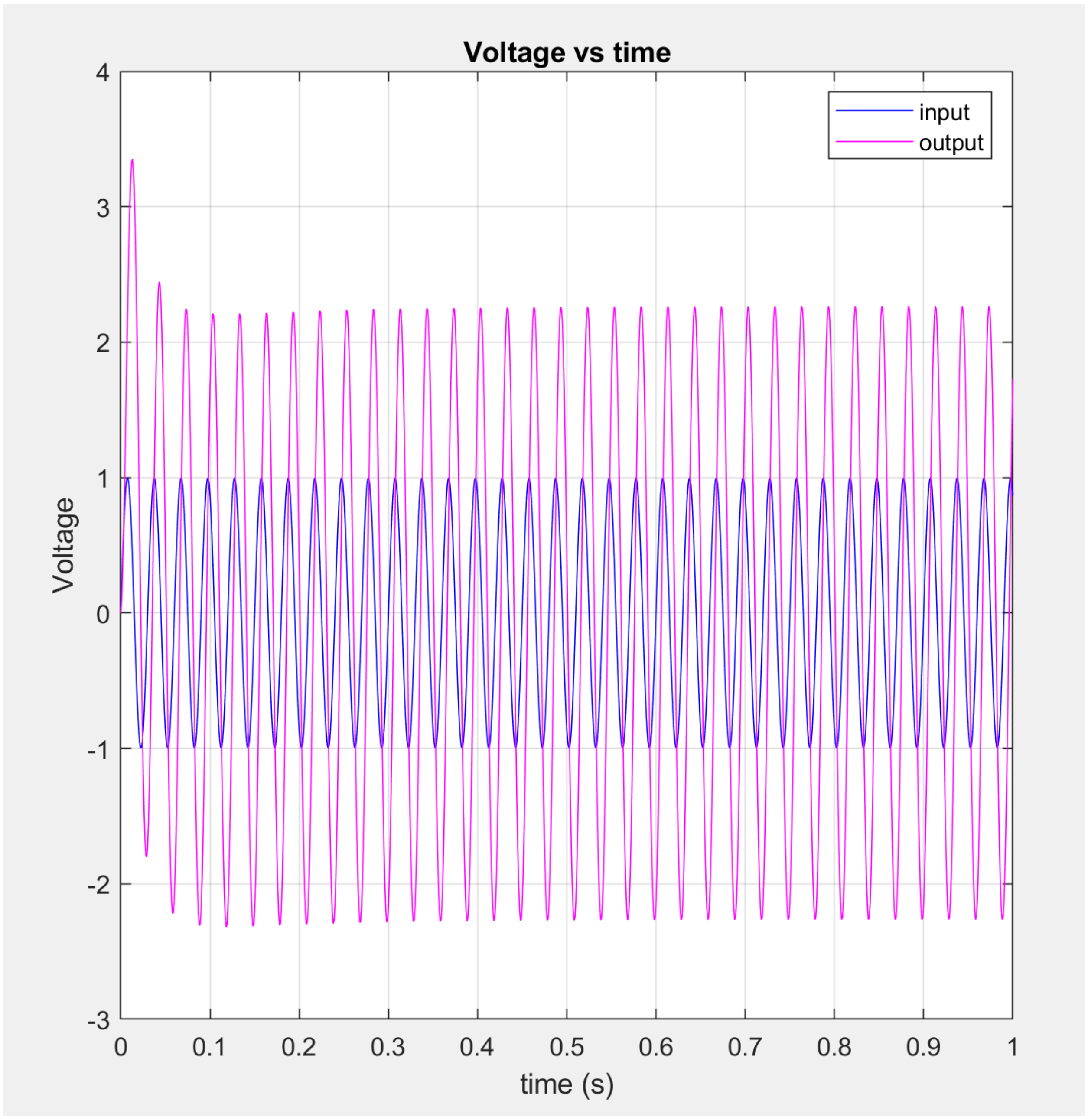


Figure 6: voltage vs time input and output sinusoid

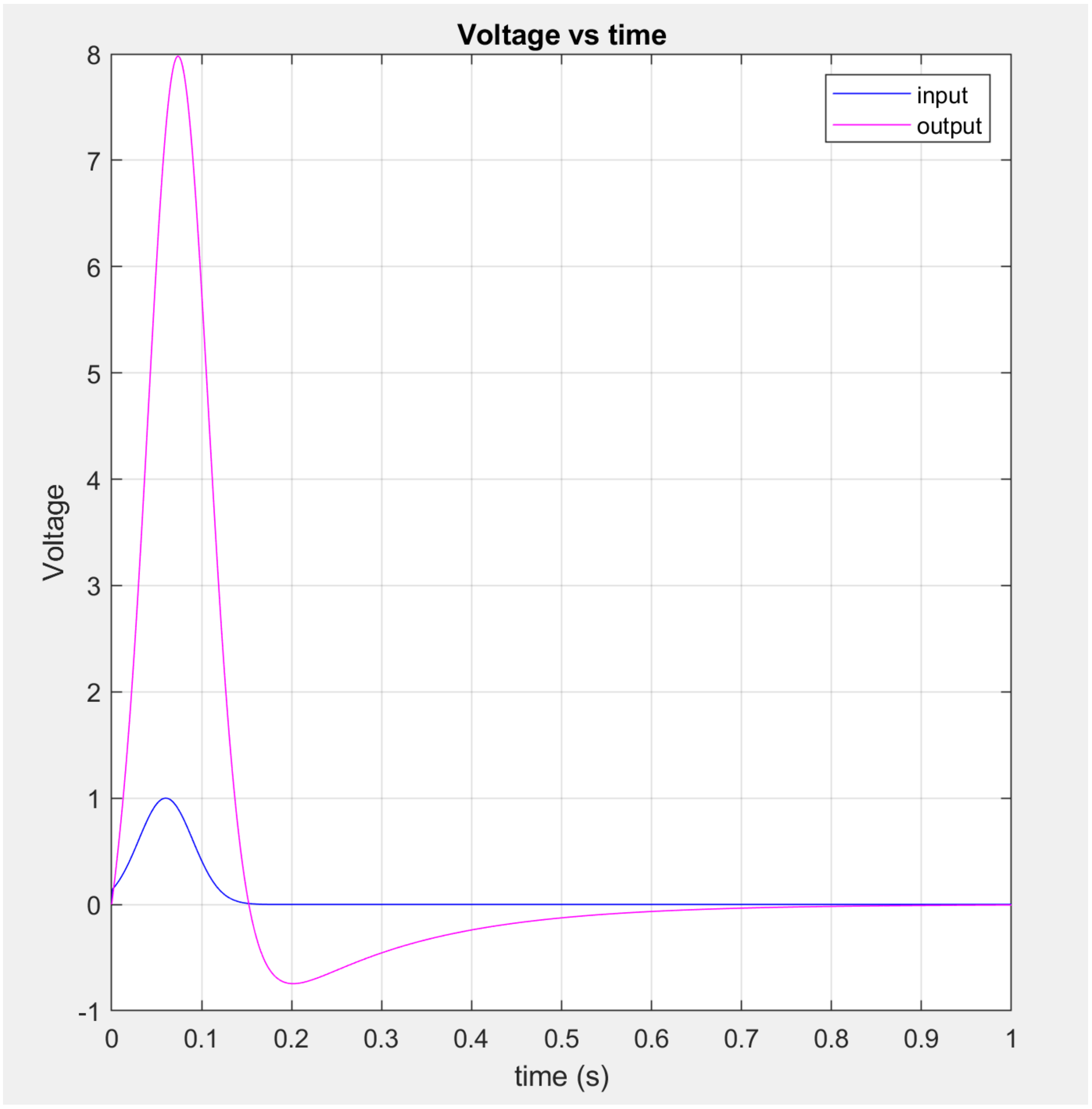


Figure 7: voltage vs time with input and output

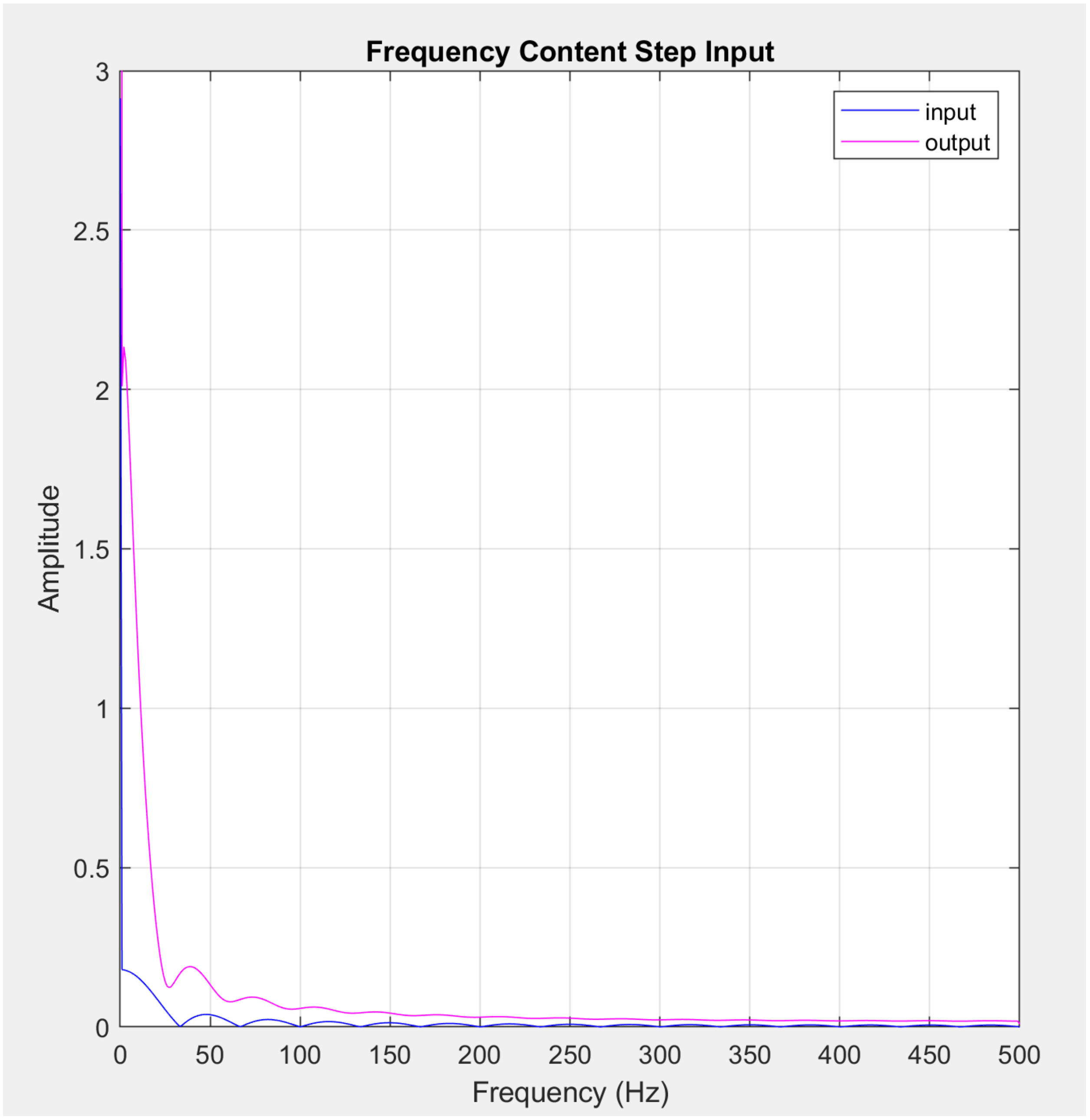


Figure 8: frequency content step input

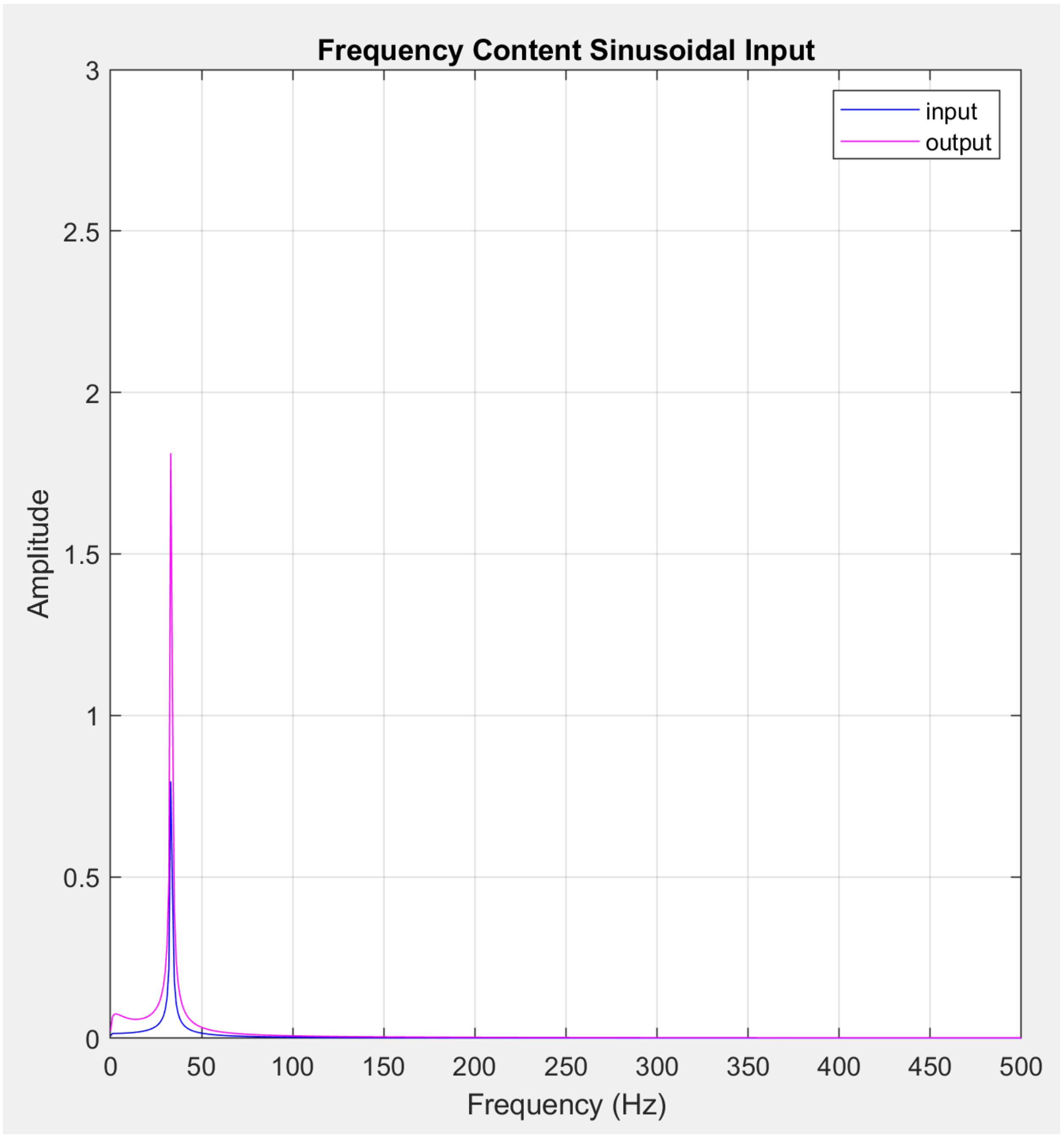


Figure 9: Frequency content sinuisoidal input

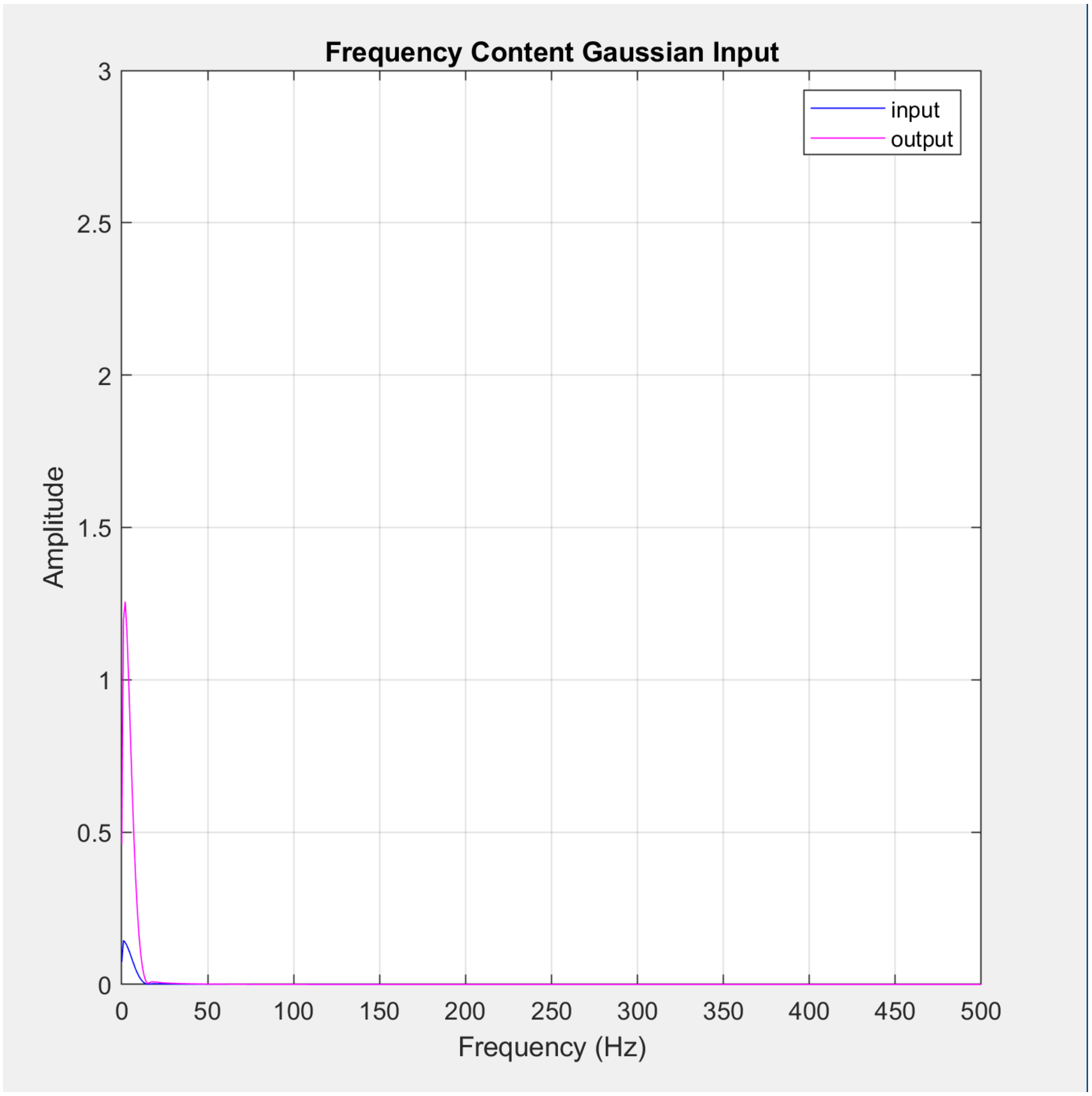


Figure 10: Frequency content Gaussian input

C matrix:

```
C1 =

    0.2500   -0.2500         0         0         0         0         0         0
   -0.2500    0.2500         0         0         0         0         0         0
         0         0    0.0000         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   -0.2000         0         0
         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0
```

Note That Cn1 = 0.00001

```
C1(1,:)=[C -C 0 0 0 0 0 0];
C1(2,:)=[-C C 0 0 0 0 0 0];
C1(3,:)=[0 0 cn1 0 0 0 0 0];
C1(4,:)=[0 0 0 0 0 0 0 0];
C1(5,:)=[0 0 0 0 0 0 0 0];
C1(6,:)=[0 0 0 0 0 -L 0 0];
C1(7,:)=[0 0 0 0 0 0 0 0];
C1(8,:)=[0 0 0 0 0 0 0 0];
```

Varying Cn:

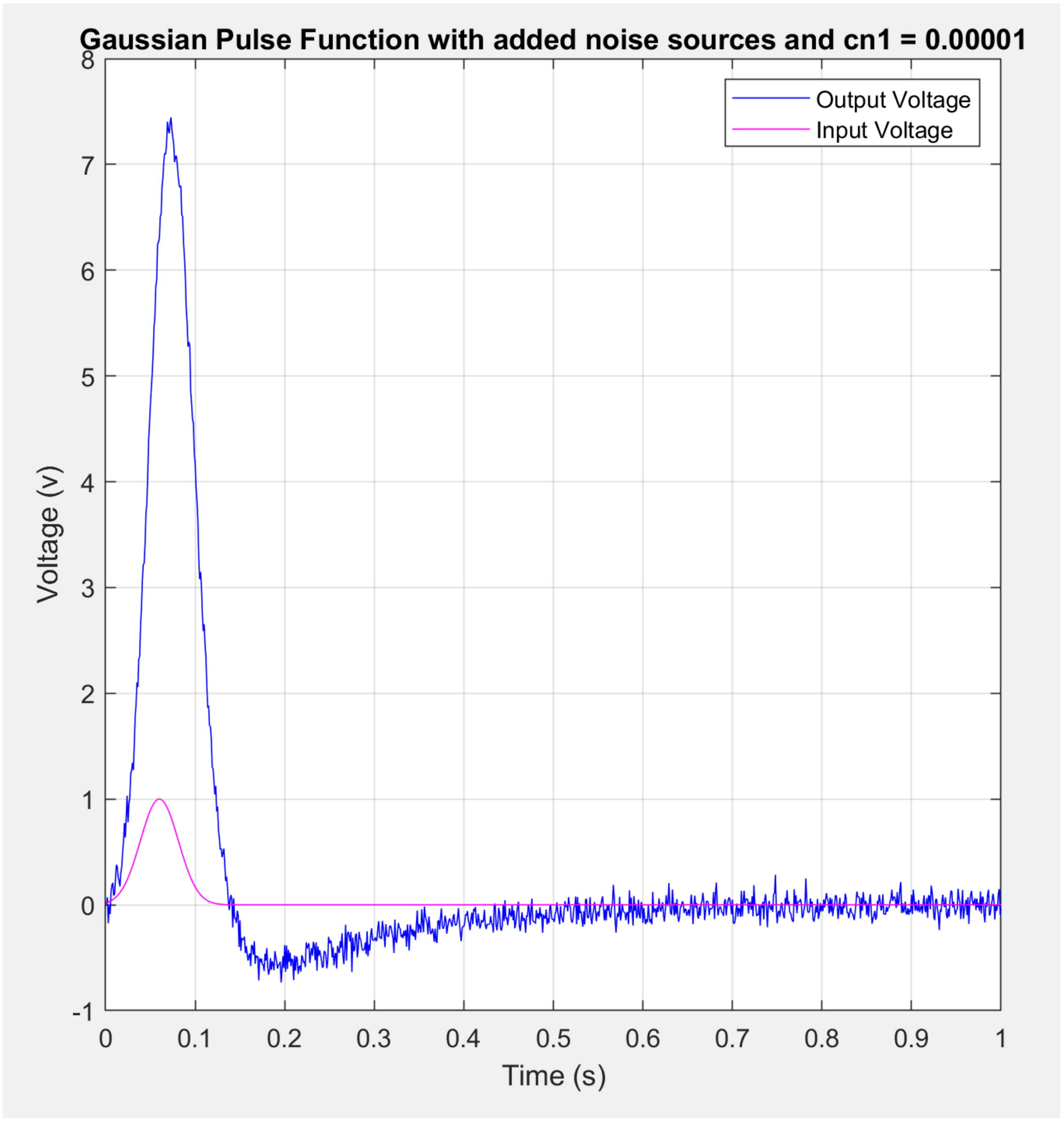


Figure 11: Gaussian Pulse function with added noise sources and cn1 = 0.00001

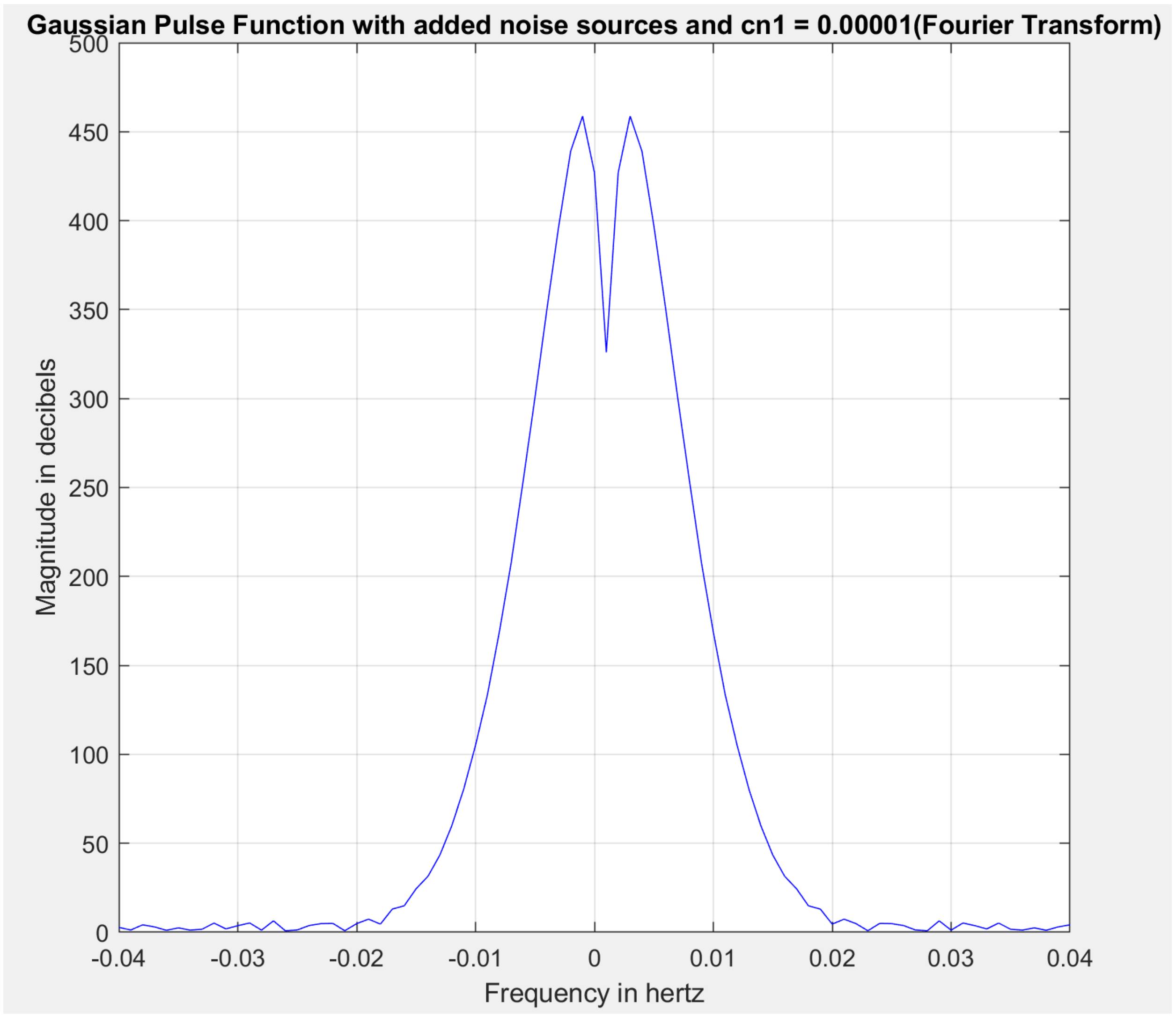


Figure 12: Gaussian Pulse function with added noise sources and cn1=0.00001 fourier transform

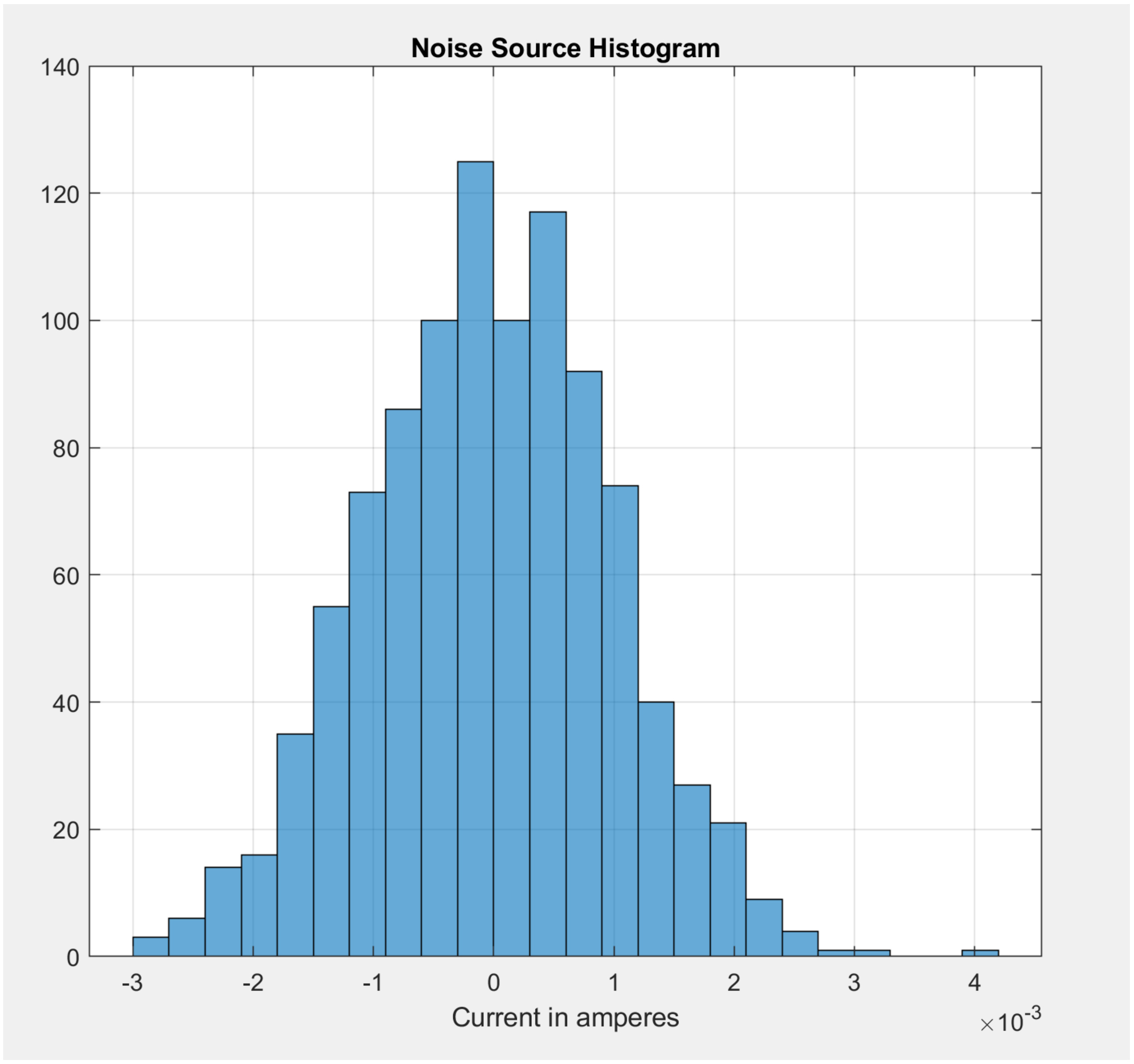


Figure 13: Noise Source Histogram

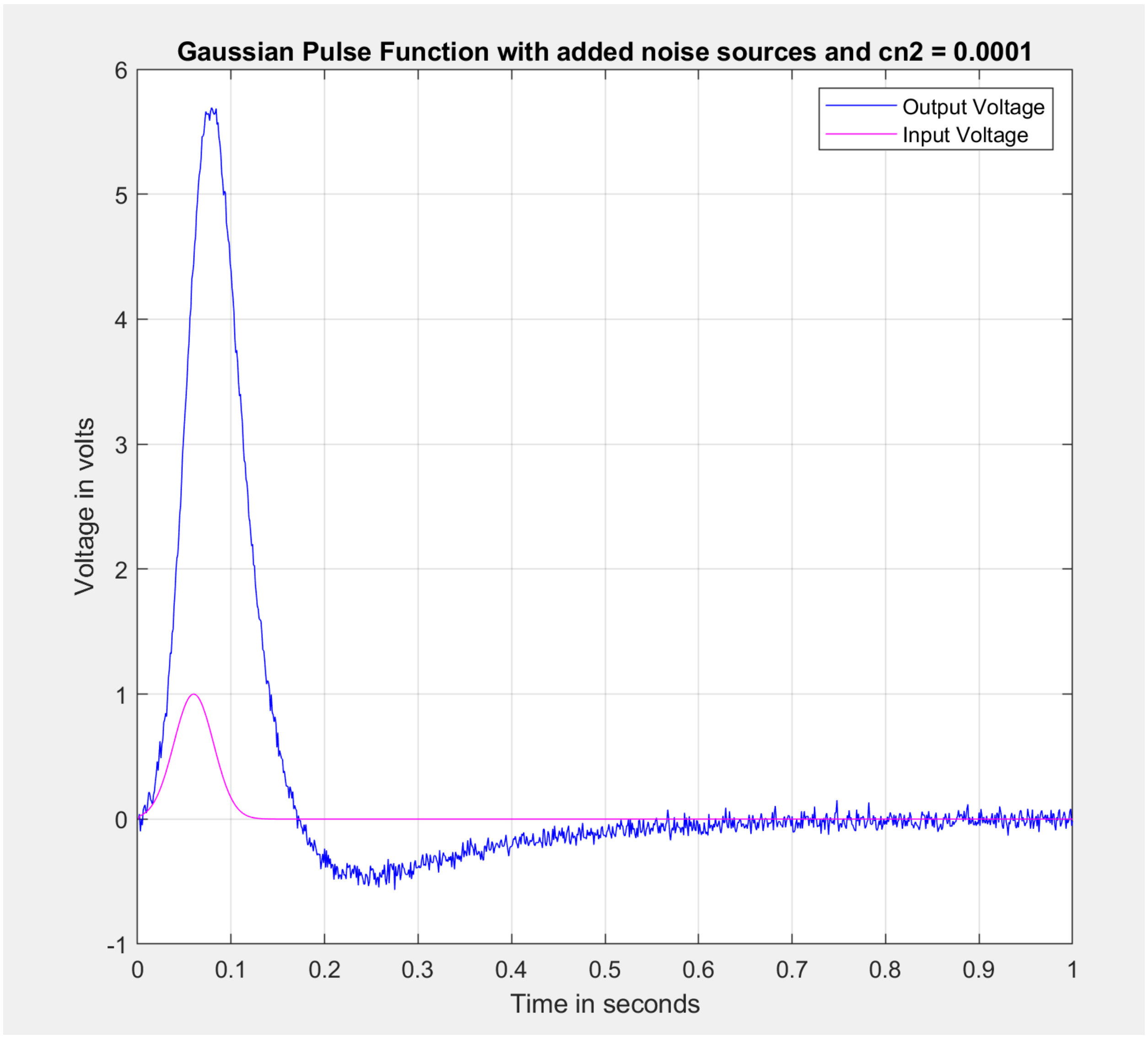


Figure 14: Gaussian Pulse function with added noise sources and cn2=0.0001

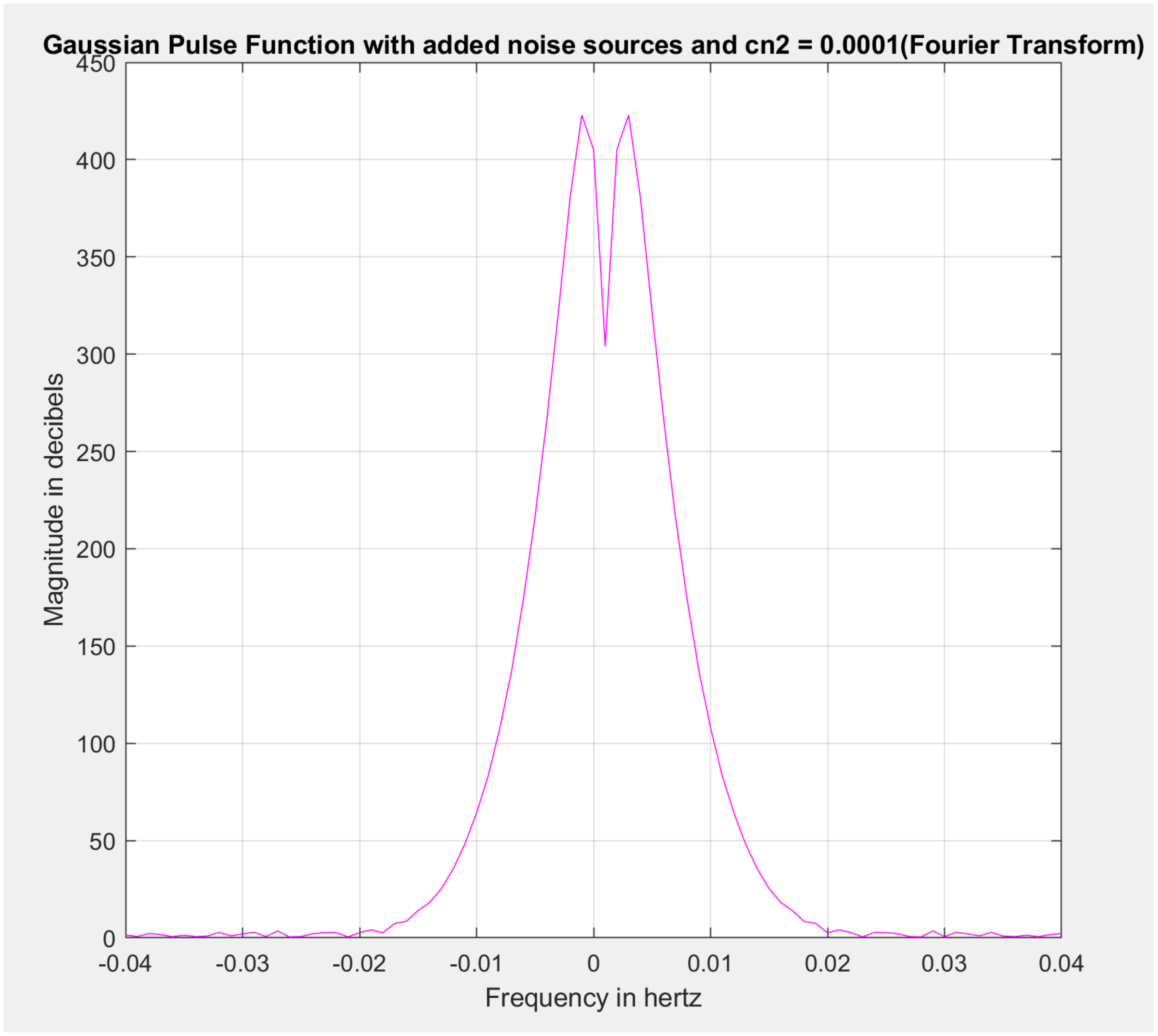


Figure 15: Gaussian Pulse Function with added noise sources and cn2 =0.0001 fourier transform

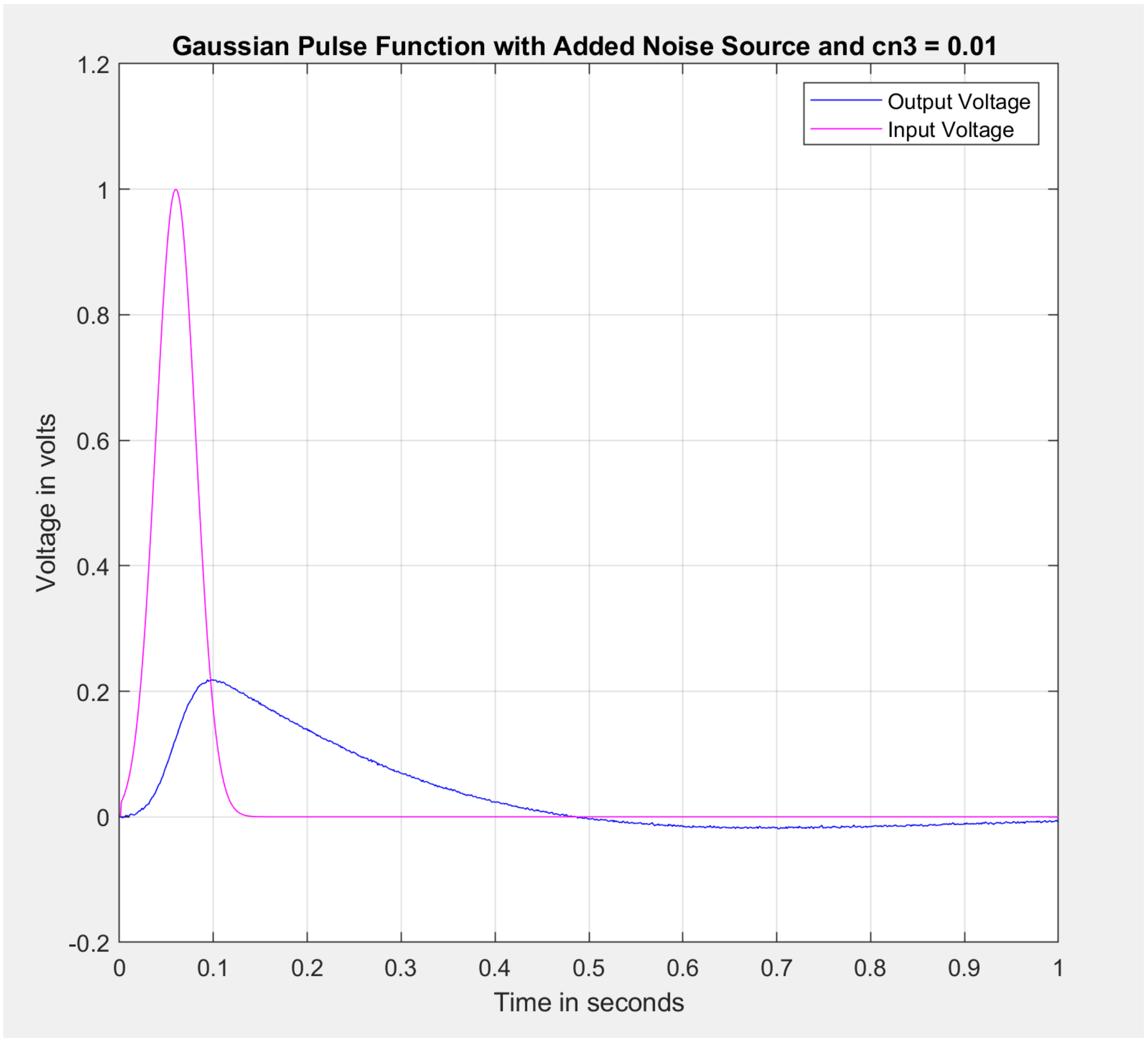


Figure 16: Gaussian Pulse function with added noise sources and cn3=0.01

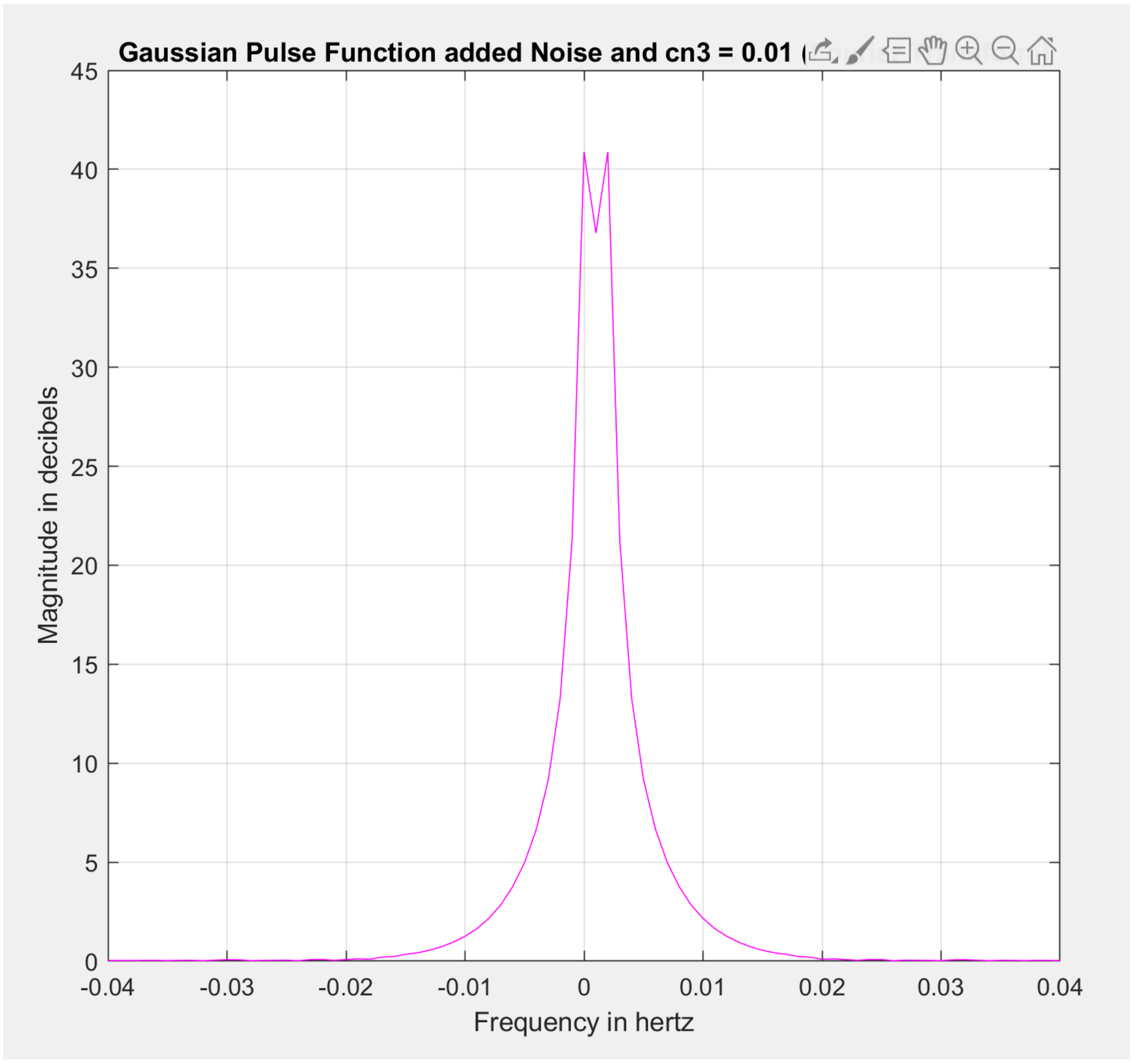


Figure 17: Gaussian Pulse function with added noise sources and cn3=0.01 fourier transform

We can conclude that as cn gets larger the bandwidth tends to get smaller.

Varying the timestep:

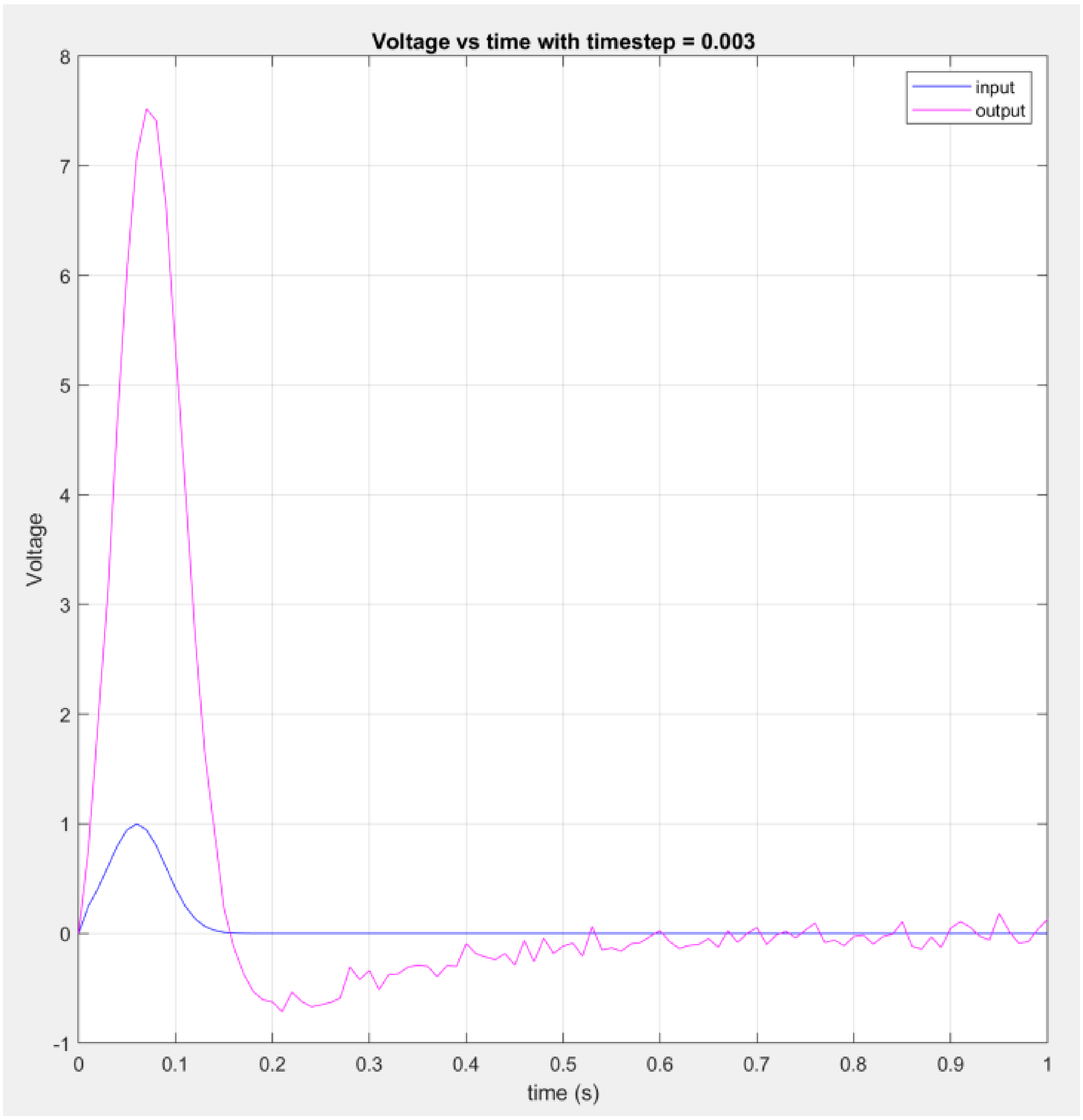
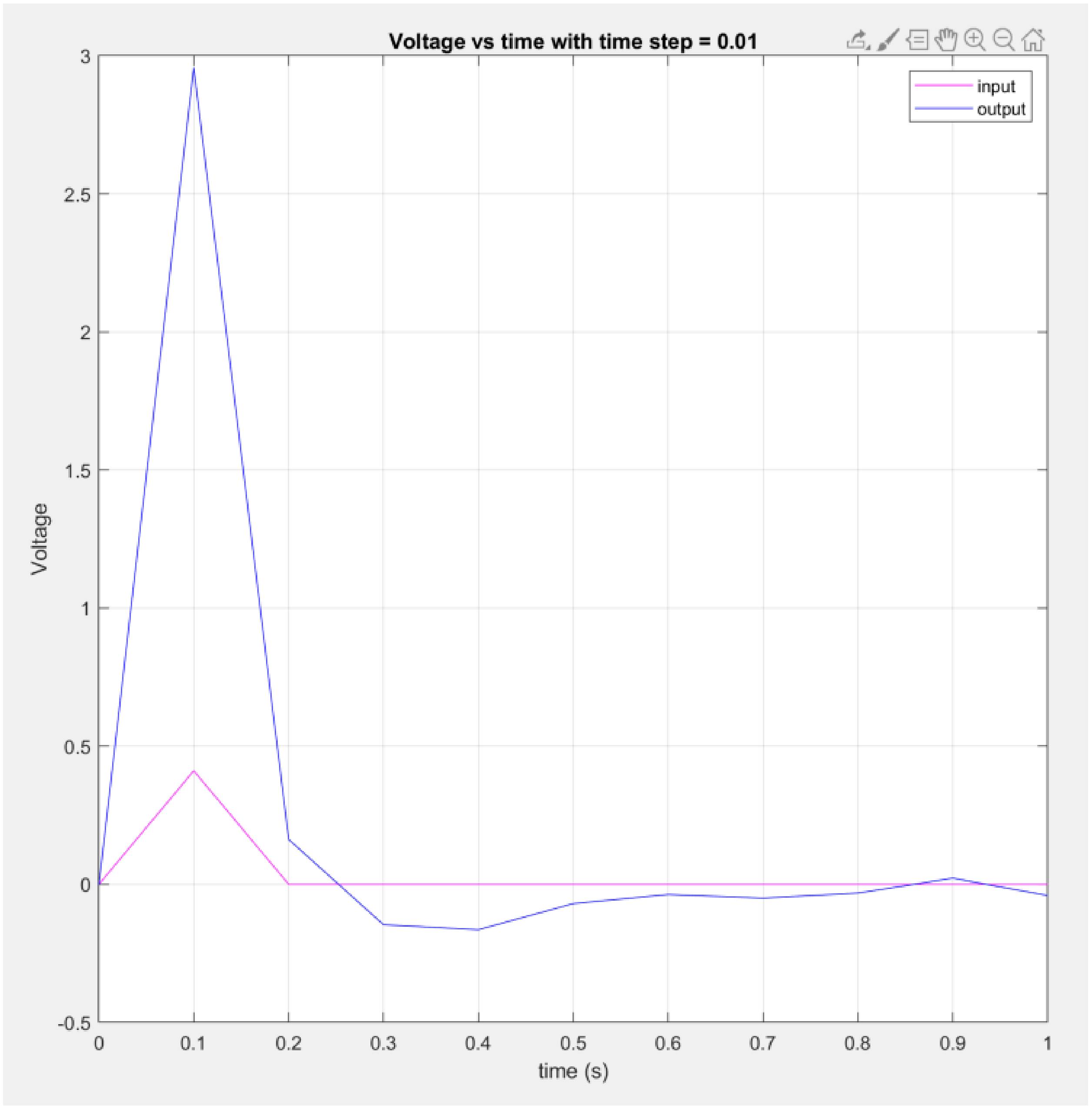


Figure 18: Plot when time step equals 0.003



<u>Figure19: Plot when timestep equals 0.01</u>

What I seemed to have observed was that as the time step is increased the accuracy of the simulation decreases.

<u>Non-Linearity:</u>

In order to implement this in MATLAB we would need to add another matrix to represent or contain the equations for the non-linear elements. A column vector B(V) would need to be added. When that has been added, because the system is now non-linear it can't be solved by simple gaussian elimination and instead the newton Raphson numerical method would need to be used instead.

Appendix section:

```
clc
clear
clearvars
set(0,'DefaultFigureWindowStyle','docked')
% Name:Jarikre Efe Jeffery
% Student Number: 101008461

%Determining the time step
voltage = linspace(0.1, 10);
current = linspace(0.1, 100);
p = polyfit(voltage, current, 1);    % order 1 linear fit
fit = p(1)*voltage+p(2);
R3 = p(1);

% By taking the slope of the linear ft plot we can get the value of R3 to
% be 10.
figure(22)
plot(voltage, current, 'm.')
hold on
plot(voltage, fit)
title('Linear Fit')
grid on


clc
clear
clearvars
set(0,'DefaultFigureWindowStyle','docked')
% Name:Jarikre Efe Jeffery
% Student Number: 101008461
% Part 3: Programming

G = zeros(6, 6);

%Resistances:
R1 = 1;
R2 = 2;
R3 = 10;
```

```
R4 = 0.1;
R0 = 1000;

%Conductances:
G1 = 1/R1;
G2 = 1/R2;
G3 = 1/R3;
G4 = 1/R4;
G0 = 1/R0;

%Additional Parameters:
a = 100;
Cval = 0.25;
L = 0.2;
vi = zeros(100, 1);
vo = zeros(100, 1);
v3 = zeros(100, 1);

G(1, 1) = 1;
G(2, 1) = G1; G(2, 2) = -(G1 + G2); G(2, 6) = -1;
G(3 ,3) = -G3; G(3, 6) = 1;
G(4, 3) = -a*G3; G(4, 4) = 1;
G(5, 5) = -(G4+G0); G(5, 4) = G4;
G(6, 2) = -1; G(6, 3) = 1;


C = zeros(6, 6);

C(2, 1) = Cval; C(2, 2) = -Cval;
C(6, 6) = L;

F = zeros(6, 1);
v = 0;

for vin = -10:0.1:10
  v = v + 1;
  F(1) = vin;
  Vm = G\F;
  vi(v) = vin;
  vo(v) = Vm(5);
  v3(v) = Vm(3);
end

figure(1)
```

```
plot(vi, vo);
hold on;
plot(vi, v3);
title('VO and V3 for DC Sweep (Vin): -10 V to 10 V');
xlabel('Vin (V)')
ylabel('Vo (V)')
grid on


vo2 = zeros(1000, 1);
W = zeros(1000, 1);

Avlog = zeros(1000, 1);

for freq = linspace(0, 100, 1000)
   v = v+1;
   Vm2 = (G+1j*freq*C)\F;
   W(v) = freq;
   vo2(v) = norm(Vm2(5));

   Avlog(v) = 20*log10(norm(Vm2(5))/10);
end

figure(3)
plot(W, vo2)
hold on;
plot(W, Avlog)
grid on
title('Vo(w) dB (part C)')
xlabel('w (rad)')
ylabel('Av (dB)')

figure(4)
semilogx(W,vo2)
title('Vo(w) dB (part C)')
xlabel('w (rad)')
ylabel('Av (dB)')
grid on

w = pi;
CC = zeros(1000,1);
GG = zeros(1000,1);

for i = 1:1000
```

```
    crand = Cval + 0.05*randn();
    C(2, 1) = crand;
    C(2, 2) = -crand;
    C(3, 3) = L;
    Vm3 = (G+(1i*w*C))\F;
    CC(i) = crand;
    GG(i) = 20*log10(abs(Vm3(5))/10);
end

figure(5)
histogram(CC)
grid on
figure(6)
grid on
hist(GG)

clc
clear
clearvars
set(0,'DefaultFigureWindowStyle','docked')
% Transient simulation
R1 = 1;
R2 = 2;
C = 0.25;
L = 0.2;
R3 = 10;
a = 100;
R4 = 0.1;
R0 = 1000;
G = zeros(7,7);
Cm = zeros(7,7);
% Conductance value
G(1,1) = 1;
G(2,1) = -1/R1;
G(2,2) = 1/R1 + 1/R2;
G(2,6) = 1;
G(3,3) = 1/R3;
G(3,6) = -1;
G(4,3) = 1/R3;
G(4,7) = -1;
G(5,4) = -1/R4;
G(5,5) = 1/R4 + 1/R0;
G(6,2) = 1;
G(6,3) = -1;
```

```
G(7,4) = 1;
G(7,7) = -a;
% Capacitance value
Cm(2,1) = -C;
Cm(2,2) = C;
Cm(6,6) = -L;
V1 = zeros(7,1);
V2 = zeros(7,1);
V3 = zeros(7,1);
V_node1(1) = 0;
V_node2(1) = 0;
V_node3(1) = 0;
delta = 0.001;
A = (Cm/delta) + G;
F_index1 = zeros(7,1);
F_index2 = zeros(7,1);
F_index33 = zeros(7,1);
Vo_node1(1) = 0;
Vo_node2(1) = 0;
Vo_node3(1) = 0;

i = 1;
for j = delta:delta:1
    if j >= 0.03
        F_index1(1) = 3;
    end
    F_index2(1) = sin(2*pi*j/0.03);
    F_index33(1) = exp(-0.5*((j - 0.06)/0.03)^2);
    V1 = A\(Cm*V1/delta + F_index1);
    V2 = A\(Cm*V2/delta + F_index2);
    V3 = A\(Cm*V3/delta + F_index33);
    V_node1(i+1) = V1(1);
    V_node2(i+1) = V2(1);
    V_node3(i+1) = V3(1);
    Vo_node1(i+1) = V1(5);
    Vo_node2(i+1) = V2(5);
    Vo_node3(i+1) = V3(5);
    i = i+1;
end

figure(7)
plot(0:delta:1,V_node1,'b')
hold on
plot(0:delta:1,Vo_node1,'m')
```

```
title('Voltage vs time')
xlabel('time (s)')
ylabel('Voltage')
legend('input','output')
grid on
figure(8)
plot(0:delta:1,V_node2,'b')
hold on
plot(0:delta:1,Vo_node2,'m')
title('Voltage vs time')
xlabel('time (s)')
ylabel('Voltage')
legend('input','output')
grid on
figure(9)
plot(0:delta:1,V_node3,'b')
hold on
plot(0:delta:1,Vo_node3,'m')
title('Voltage vs time')
xlabel('time (s)')
ylabel('Voltage')
legend('input','output')
grid on

% Convert to frequency domain by taking the fourier transform
step_in = fft(V_node1); %fft -> Fast fourier transform
P_mag2_in = abs(step_in/1000);
P_1_in = P_mag2_in(1:1000/2+1);
P_1_in(2:end-1) = 2*P_1_in(2:end-1);
sample_f = (1/delta)*(0:(1000/2))/1000;
% Plot figure
figure(10)
plot(sample_f,P_1_in,'b')
step_out = fft(Vo_node1);
P2_out = abs(step_out/1000);
P1_out = P2_out(1:1000/2+1);
P1_out(2:end-1) = 2*P1_out(2:end-1);
sample_f = (1/delta)*(0:(1000/2))/1000;
hold on
plot(sample_f,P1_out,'m')
title('Frequency Content Step Input')
xlabel('Frequency (Hz)')
ylabel('Amplitude')
ylim([0 3])
```

```
legend('input','output')
grid on
% The fourier transform of the step input signal givess us a sinc function.
% This makes sense as we know that by taking the fourier transform of a step signal we should
get a sinc function.
% The High Frequency components are attenuated due to the fact that the filter
% is a low pass filter

step_in = fft(V_node2); %Take fourier transform
P_mag2_in = abs(step_in/1000);
P_1_in = P_mag2_in(1:1000/2+1);
P_1_in(2:end-1) = 2*P_1_in(2:end-1); % Calculate singel ended spectrum
figure(11)
plot(sample_f,P_1_in,'b')
grid on
step_out = fft(Vo_node2);
P2_out = abs(step_out/1000);
P1_out = P2_out(1:1000/2+1);
P1_out(2:end-1) = 2*P1_out(2:end-1);
hold on
plot(sample_f,P1_out,'m')
title('Frequency Content Sinusoidal Input')
xlabel('Frequency (Hz)')
ylabel('Amplitude')
ylim([0 3])
legend('input','output')
step_in = fft(V_node3); %Take fourier transform
P_mag2_in = abs(step_in/1000);
P_1_in = P_mag2_in(1:1000/2+1);
P_1_in(2:end-1) = 2*P_1_in(2:end-1); % Calculate singel ended spectrum
figure(12)
plot(sample_f,P_1_in,'b')
grid on
step_out = fft(Vo_node3);
P2_out = abs(step_out/1000);
P1_out = P2_out(1:1000/2+1);
P1_out(2:end-1) = 2*P1_out(2:end-1);
hold on
plot(sample_f,P1_out,'m')
title('Frequency Content Gaussian Input')
xlabel('Frequency (Hz)')
ylabel('Amplitude')
ylim([0 3])
legend('input','output')
```

```
clc
clearvars
set(0,'DefaultFigureWindowStyle','docked')

R1 = 1;
R2 = 2;
R3 = 10;
R4 = 0.1;
Ro = 1000;
C = 0.25;
L = 0.2;
a = 100;
cn1 = 0.00001;
cn2 = 0.0001;
cn3 = 0.01;

C1(1,:)=[C -C 0 0 0 0 0 0];
C1(2,:)=[-C C 0 0 0 0 0 0];
C1(3,:)=[0 0 cn1 0 0 0 0 0];
C1(4,:)=[0 0 0 0 0 0 0 0];
C1(5,:)=[0 0 0 0 0 0 0 0];
C1(6,:)=[0 0 0 0 0 -L 0 0];
C1(7,:)=[0 0 0 0 0 0 0 0];
C1(8,:)=[0 0 0 0 0 0 0 0];

C1

C2(1,:)=[C -C 0 0 0 0 0 0];
C2(2,:)=[-C C 0 0 0 0 0 0];
C2(3,:)=[0 0 cn2 0 0 0 0 0];
C2(4,:)=[0 0 0 0 0 0 0 0];
C2(5,:)=[0 0 0 0 0 0 0 0];
C2(6,:)=[0 0 0 0 0 -L 0 0];
C2(7,:)=[0 0 0 0 0 0 0 0];
C2(8,:)=[0 0 0 0 0 0 0 0];

C2

C3(1,:)=[C -C 0 0 0 0 0 0];
C3(2,:)=[-C C 0 0 0 0 0 0];
C3(3,:)=[0 0 cn3 0 0 0 0 0];
C3(4,:)=[0 0 0 0 0 0 0 0];
C3(5,:)=[0 0 0 0 0 0 0 0];
```

```
C3(6,:)=[0 0 0 0 0 -L 0 0];
C3(7,:)=[0 0 0 0 0 0 0 0];
C3(8,:)=[0 0 0 0 0 0 0 0];

C3

G(1,:)=[1 -1 0 0 0 0 0 1];
G(2,:)=[-1 1.5 0 0 0 1 0 0];
G(3,:)=[0 0 0.1 0 0 -1 0 0];
G(4,:)=[0 0 0 10 -10 0 1 0];
G(5,:)=[0 0 0 -10 10.0010 0 0 0];
G(6,:)=[0 1 -1 0 0 -L 0 0];
G(7,:)=[0 0 -10 1 0 0 0 0];
G(8,:)=[1 0 0 0 0 0 0 0];

G

F = [
   0   ;
   0   ;
   0   ;
   0   ;
   0   ;
   0   ;
   0   ;
   0   ;
   ];

% Given these values from lab manual
delta = 0.001;
standard_deviation = 0.03;
d = 0.06;
m = 1;
c_s = zeros(1,1000);
f_l = zeros(8,1,1000);

for i=1:1:1000
   f_l(8,1,i) = exp(-((i*delta - d)/standard_deviation)^2);
   f_l(3,1,i) = -0.001*randn;
   c_s(i) = f_l(3,1,i);
end

VL_1 = zeros(8,1,1000);
VL_2 = zeros(8,1,1000);
```

```
VL_3 = zeros(8,1,1000);

for i = 2:1:1000
   index1 = C1/delta + G;
   index2 = C2/delta + G;
   index3 = C3/delta + G;

   VL_1(:,:,i) = index1\(C1*VL_1(:,:,i-1)/delta +f_l(:,:,i));
   VL_2(:,:,i) = index2\(C1*VL_2(:,:,i-1)/delta +f_l(:,:,i));
   VL_3(:,:,i) = index3\(C1*VL_3(:,:,i-1)/delta +f_l(:,:,i));
end


VoL_1(1,:) = VL_1(5,1,:);
ViL_1(1,:) = VL_1(1,1,:);

VoL_2(1,:) = VL_2(5,1,:);
ViL_2(1,:) = VL_2(1,1,:);

VoL_3(1,:) = VL_3(5,1,:);
ViL_3(1,:) = VL_3(1,1,:);


figure(13)
plot((1:1000).*delta, VoL_1(1,:),'b')
hold on
plot((1:1000).*delta, ViL_1(1,:),'m')
title('Gaussian Pulse Function with added noise sources and cn1 = 0.00001')
xlabel('Time (s)')
ylabel('Voltage (v)')
grid on
legend('Output Voltage','Input Voltage')
hold off

figure(14)
histogram(c_s)
title('Noise Source Histogram')
grid on
xlabel('Current in amperes')

figure(15)
FF = abs(fftshift(fft(VoL_1(1,:))));
plot(((1:length(FF))/1000)-0.5,FF,'b')
xlabel('Frequency in hertz')
```

```
ylabel('Magnitude in decibels')
grid on
xlim([-0.04 0.04])
title('Gaussian Pulse Function with added noise sources and cn1 = 0.00001(Fourier Transform)')

% CN 2 ------------------------------------------

figure(16)
plot((1:1000).*delta, VoL_2(1,:),'b')
hold on
plot((1:1000).*delta, ViL_2(1,:),'m')
title('Gaussian Pulse Function with added noise sources and cn2 = 0.0001')
xlabel('Time in seconds')
ylabel('Voltage in volts')
grid on
legend('Output Voltage','Input Voltage')
hold off

figure(17)
FF = abs(fftshift(fft(VoL_2(1,:))));
plot(((1:length(FF))/1000)-0.5,FF,'m')
xlabel('Frequency in hertz')
ylabel('Magnitude in decibels')
grid on
xlim([-0.04 0.04])
title('Gaussian Pulse Function with added noise sources and cn2 = 0.0001(Fourier Transform)')

figure(18)
plot((1:1000).*delta, VoL_3(1,:),'b')
hold on
plot((1:1000).*delta, ViL_3(1,:),'m')
title('Gaussian Pulse Function with Added Noise Source and cn3 = 0.01 ')
xlabel('Time in seconds')
ylabel('Voltage in volts')
grid on
legend('Output Voltage','Input Voltage')
hold off

figure(19)
FF = abs(fftshift(fft(VoL_3(1,:))));
plot(((1:length(FF))/1000)-0.5,FF,'m')
xlabel('Frequency in hertz')
ylabel('Magnitude in decibels')
grid on
```

```
xlim([-0.04 0.04])
title('Gaussian Pulse Function added Noise and cn3 = 0.01 (Fourier Transform)')
% Varying timestep
%Varying timestep:
clc
clear
clearvars
set(0,'DefaultFigureWindowStyle','docked')
R1 = 1;
R2 = 2;
C = 0.25;
L = 0.2;
R3 = 10;
a = 100;
R4 = 0.1;
R0 = 1000;

G = zeros(7,7);
C_mat = zeros(7,7);
G(1,1) = 1;
G(2,1) = -1/R1;
G(2,2) = 1/R1 + 1/R2;
G(2,6) = 1;
G(3,3) = 1/R3;
G(3,6) = -1;
G(4,3) = 1/R3;
G(4,7) = -1;
G(5,4) = -1/R4;
G(5,5) = 1/R4 + 1/R0;
G(6,2) = 1;
G(6,3) = -1;
G(7,4) = 1;
G(7,7) = -a;
C_mat(2,1) = -C;
C_mat(2,2) = C;
C_mat(6,6) = -L;

G
C_mat

F = zeros(7,1);
V = zeros(7,1);

%Circuit with noise
```

```
In = 0.001; % as provided in assignment manual
Cn = 0.00001; % as provided in assignment manual
C_mat(3,3) = Cn;
G
C_mat

delta = 0.001;
A_transpse = C_mat/delta + G;

F = zeros(7,1);
V = zeros(7,1);
Vo_index(1) = 0;
Vi_index(1) = 0;

ii = 1;
for t = delta:delta:1
   F(1) = exp(-0.5*((t - 0.06)/0.03)^2);
   F(3) = In*normrnd(0,1);
    V = A_transpse\(C_mat*V/delta + F);
    Vi_index(ii + 1) = F(1);
    Vo_index(ii + 1) = V(5);
    ii = ii + 1;
end

X_input = fft(Vi_index);
P2_input = abs(X_input/1000);
P1_input = P2_input(1:1000/2+1);
P1_input(2:end-1) = 2*P1_input(2:end-1);
f = (1/delta)*(0:(1000/2))/1000;

X_output = fft(Vo_index);
P2_output = abs(X_output/1000);
P1_output = P2_output(1:1000/2+1);
P1_output(2:end-1) = 2*P1_output(2:end-1);
f = (1/delta)*(0:(1000/2))/1000;

C_sml = C_mat;
C_med = C_mat;
C_big = C_mat;
C_sml(3,3) = 0;
C_med(3,3) = 0.001;
C_big(3,3) = 0.1;
V_sml = zeros(7,1);
V_med = zeros(7,1);
```

```
V_big = zeros(7,1);
Vo_sml(1) = 0;
Voutput_med(1) = 0;
Vout_big(1) = 0;
Vi_index(1) = 0;
ii = 1;
for t = delta:delta:1
    F(1) = exp(-0.5*((t - 0.06)/0.03)^2);
    F(3) = In*normrnd(0,1);
    V_sml = (C_sml/delta + G)\(C_sml*V_sml/delta + F);
    V_med = (C_med/delta + G)\(C_med*V_med/delta + F);
    V_big = (C_big/delta + G)\(C_big*V_big/delta + F);
    Vo_sml(ii + 1) = V_sml(5);
    Voutput_med(ii + 1) = V_med(5);
    Vout_big(ii + 1) = V_big(5);
    Vi_index(ii + 1) = F(1);
    ii = ii + 1;
end

delta1 = 0.01;
Vinput_SmlStep(1) = 0;
Voutput_SmlStep(1) = 0;
V = zeros(7,1);
ii = 1;
for t = delta1:delta1:1
    F(1) = exp(-0.5*((t - 0.06)/0.03)^2);
    F(3) = In*normrnd(0,1);
    V = (C_mat/delta1 + G)\(C_mat*V/delta1 + F);
    Voutput_SmlStep(ii + 1) = V(5);
    Vinput_SmlStep(ii + 1) = F(1);
    ii = ii + 1;
end

delta2 = 0.1;
Vinput_bigStep(1) = 0;
Voutput_bigStep(1) = 0;
V = zeros(7,1);
ii = 1;
for t = delta2:delta2:1
    F(1) = exp(-0.5*((t - 0.06)/0.03)^2);
    F(3) = In*normrnd(0,1);
    V = (C_mat/delta2 + G)\(C_mat*V/delta2 + F);
    Voutput_bigStep(ii + 1) = V(5);
    Vinput_bigStep(ii + 1) = F(1);
    ii = ii + 1;
end

figure(20)
plot(0:delta1:1,Vinput_SmlStep,'b')
hold on
plot(0:delta1:1,Voutput_SmlStep,'m')
title('Voltage vs time with timestep = 0.003')
xlabel('time (s)')
ylabel('Voltage')
legend('input','output')
grid on

figure(21)
plot(0:delta2:1,Vinput_bigStep,'m')
hold on
plot(0:delta2:1,Voutput_bigStep,'b')
title('Voltage vs time with time step = 0.01')
xlabel('time (s)')
ylabel('Voltage')
legend('input','output')
grid on
```