Assignment 4 - Kyle Poulin 100939284

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Question 1

1:

Time & Frequency: $V_i = V_{in}$

2:

Time: $G_1(V_2 - V_1) + C(\frac{d(V_2-V_1)}{dt}) + G_2V_2 - I_L = 0$

Frequency: $G_1(V_2 - V_1) + C(j\omega(V_2 - V_1)) + G_2V_2 - I_L = 0$

3:

Time: $V_2 - V_3 - L\frac{dI_l}{dt} = 0$$

Frequency: $V_2 - V_3 - L(j\omega)I_l = 0$$

4:

Time & Fequency: $-I_L + G_3V_3 = 0$$

5:

Time & Fequency: $V_4 - \alpha I_3 = 0$$

6:

Time & Fequency: $G_3V_3 - I_3 = 0$$

7:

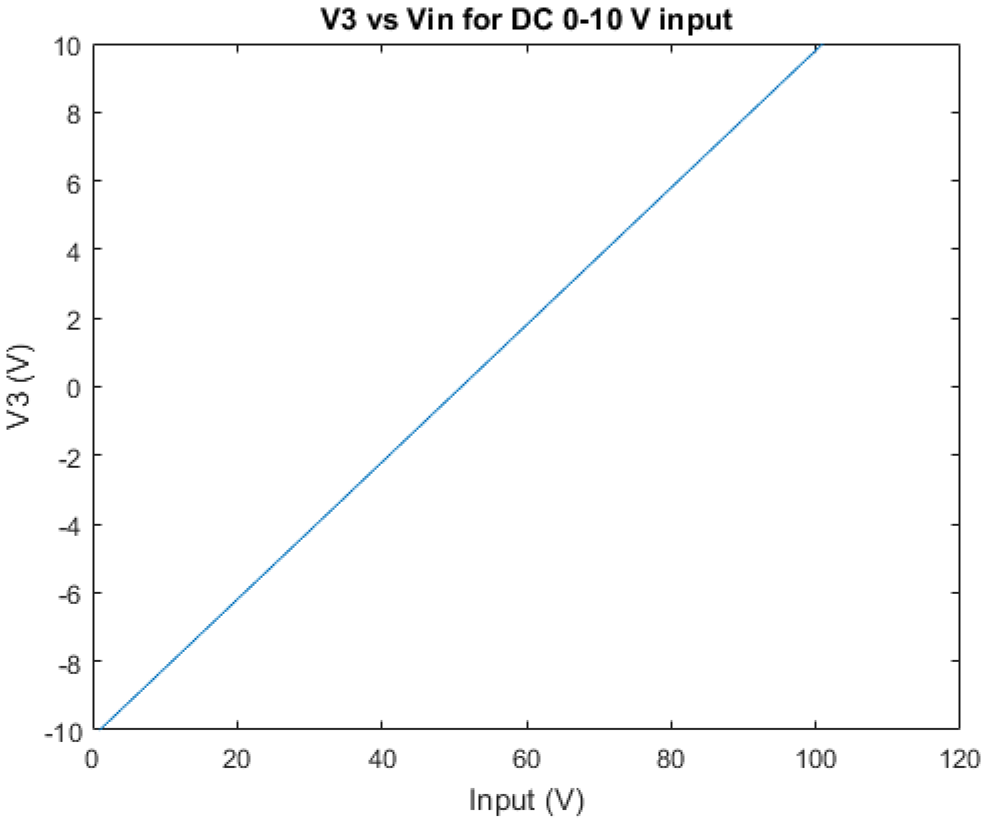
Time & Fequency: $G_4(V_0 - V_4) + G_0V_0 = 0$$

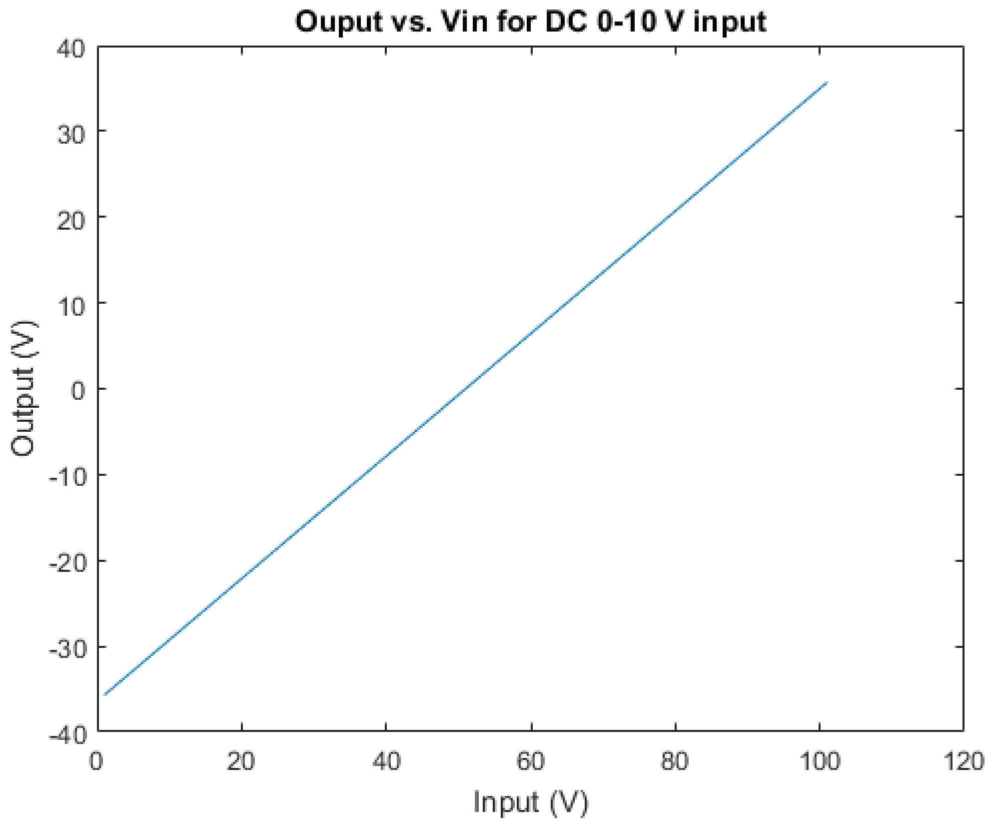
```
C = 0.25;
Cconst = 0.25;
Cstd = 0.05;
L = 0.2;
G1 = 1;
G2 = 0.5;
```

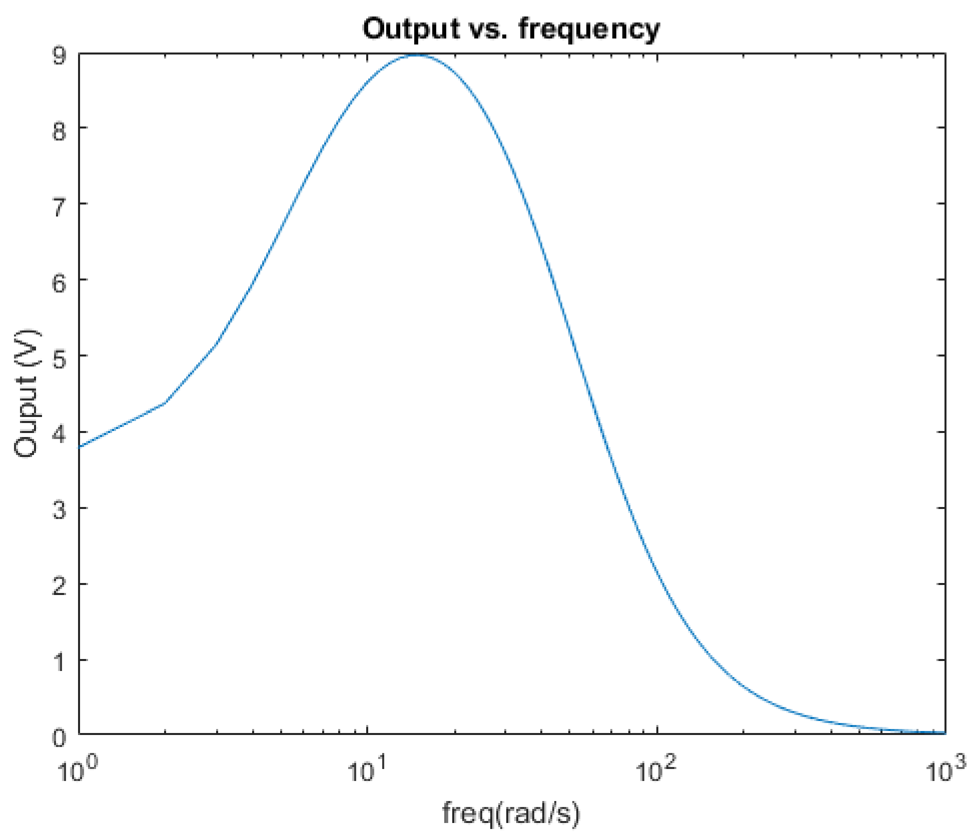
```
G3 = 0.1;
G4 = 10;
G0 = 1/1000;
a = 100;
Vin=1;


Cm = [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];
Gm = [1 0 0 0 0 0 0; -G2 G1+G2 -1 0 0 0 0; 0 1 0 -1 0 0 0; 0 0 -1 G3 0
 0 0; 0 0 0 0 -a 1 0; 0 0 0 G3 -1 0 0; 0 0 0 0 0 -G4 G4+G0];
%V = [V1; V2; IL; V3; I3; V4; V0];
F = [Vin; 0; 0; 0; 0; 0; 0];

V0 = zeros(1,100);
V3 = zeros(1,100);
counter = 1;

for i= -10:0.2:10

   F = [i; 0; 0; 0; 0; 0; 0];
   V = Gm\F;
   V0(1,counter) = V(7);
   V3(1,counter) = V(1);
   counter = counter+1;
end

figure(1);
plot(V3);
title('V3 vs Vin for DC 0-10 V input');
xlabel('Input (V)');
ylabel('V3 (V)');
figure(2);
plot(V0);
title('Ouput vs. Vin for DC 0-10 V input')
xlabel('Input (V)')
ylabel('Output (V)')

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


xaxis = linspace(0,1000,1001);
gain = [];
for i = 0:1000
    V = (Gm+1j*i*Cm)\F;
    gain = [gain, V(7)];
end

%plot(gain);
figure(3);
semilogx(xaxis,gain);
title('Output vs. frequency')
xlabel('freq(rad/s)')
ylabel('Ouput (V)')
```

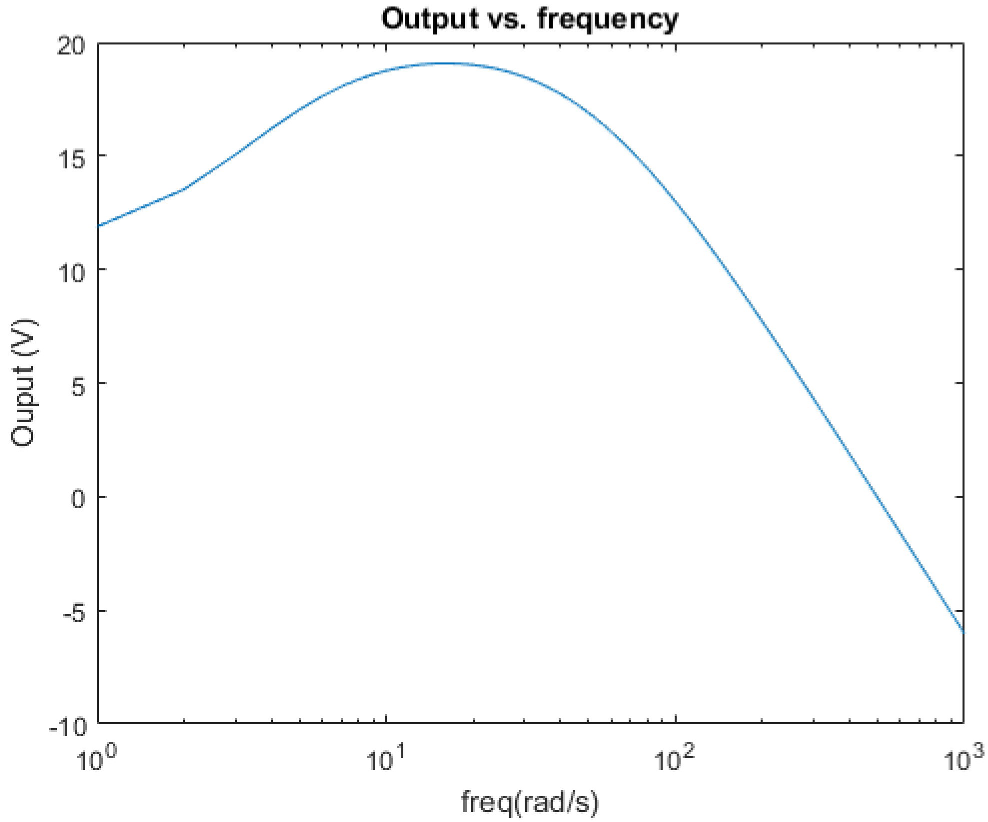
```
figure(4);
semilogx(xaxis,20*log10(gain));
title('Output vs. frequency')
xlabel('freq(rad/s)')
ylabel('Ouput (V)')

F = [Vin; 0; 0; 0; 0; 0; 0];
Gm = [1 0 0 0 0 0 0; -G2 G1+G2 -1 0 0 0 0; 0 1 0 -1 0 0 0; 0 0 -1 G3 0
 0 0; 0 0 0 0 -a 1 0; 0 0 0 G3 -1 0 0; 0 0 0 0 0 -G4 G4+G0];
gain = [];
for i=1:10000
    C = normrnd(Cconst,Cstd);
    Cm = [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];
    V = (Gm+pi*Cm)\F;
    gain = [gain, V(7)];
end

figure(5);
histogram(real(20*log10(gain)));
title('Gain Hist')
xlabel('Gain (dB)')
ylabel('Counts')
```

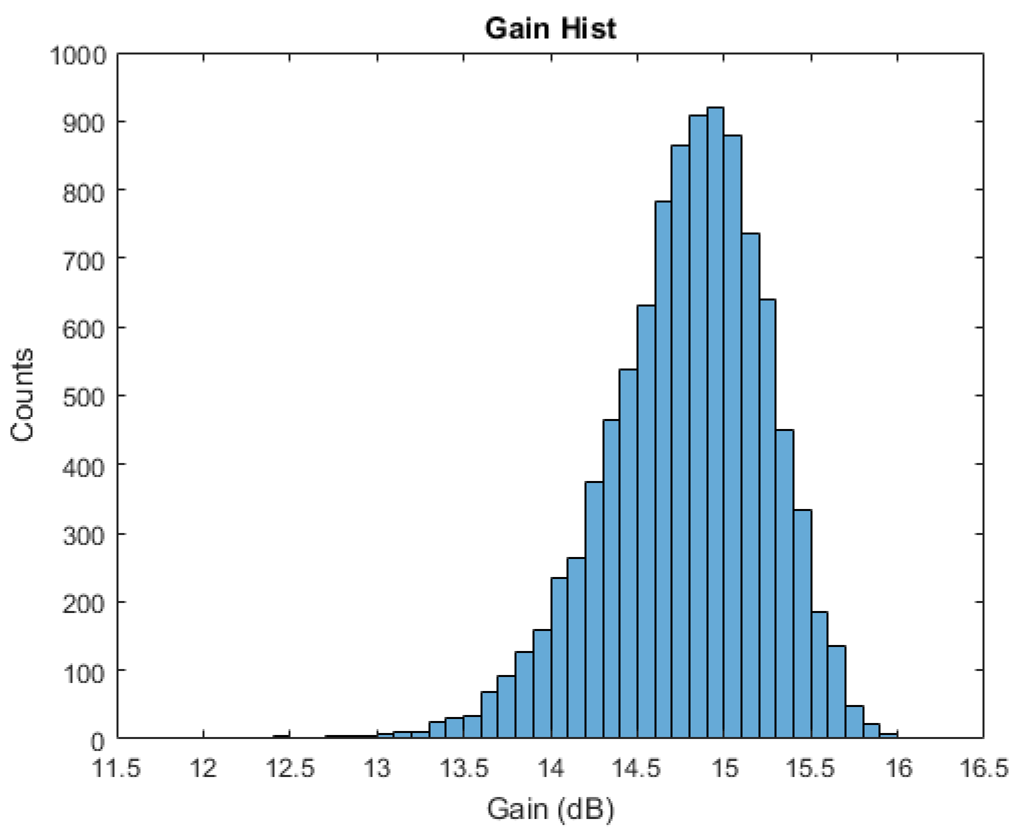
Warning: Imaginary parts of complex X and/or Y arguments ignored
Warning: Imaginary parts of complex X and/or Y arguments ignored




Ouput vs. Vin for DC 0-10 V input
Output (V)
Input (V)
40
30
20
10
0
-10
-20
-30
-40
0
20
40
60
80
100
120


Output vs. frequency
Ouput (V)
freq(rad/s)
9
8
7
6
5
4
3
2
1
0
10^0
10^1
10^2
10^3


Output vs. frequency
Ouput (V)
freq(rad/s)
20
15
10
5
0
-5
-10
10^0
10^1
10^2
10^3

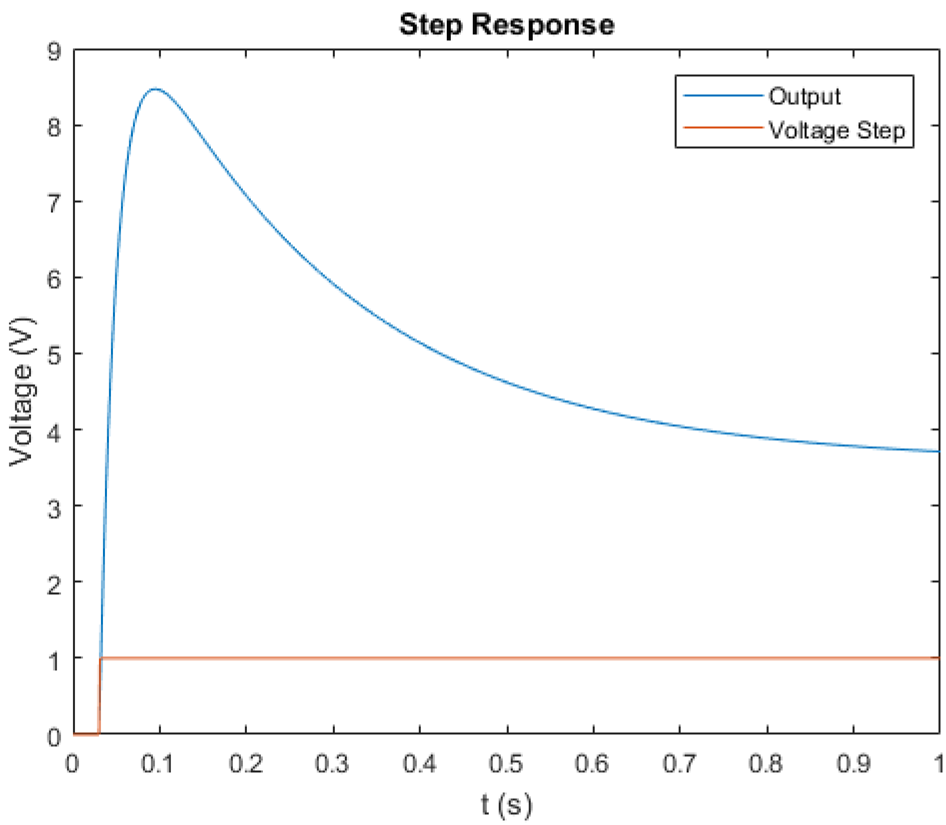

Gain Hist
Counts
Gain (dB)
1000
900
800
700
600
500
400
300
200
100
0
11.5
12
12.5
13
13.5
14
14.5
15
15.5
16
16.5

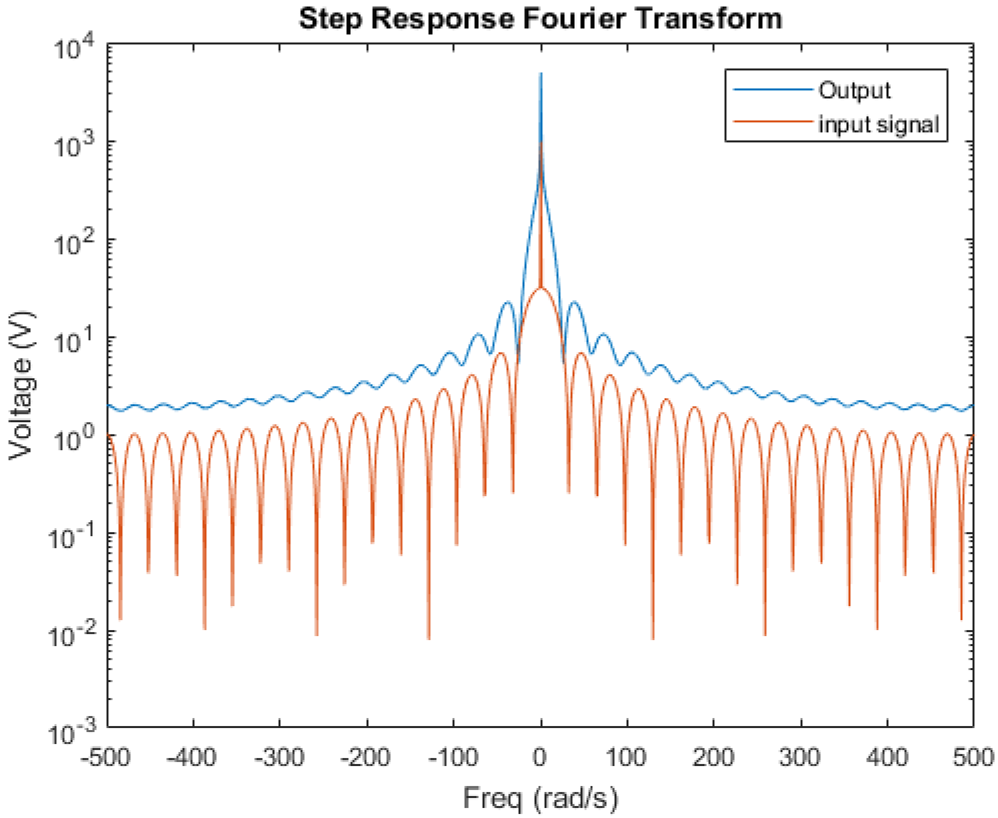
Question 2

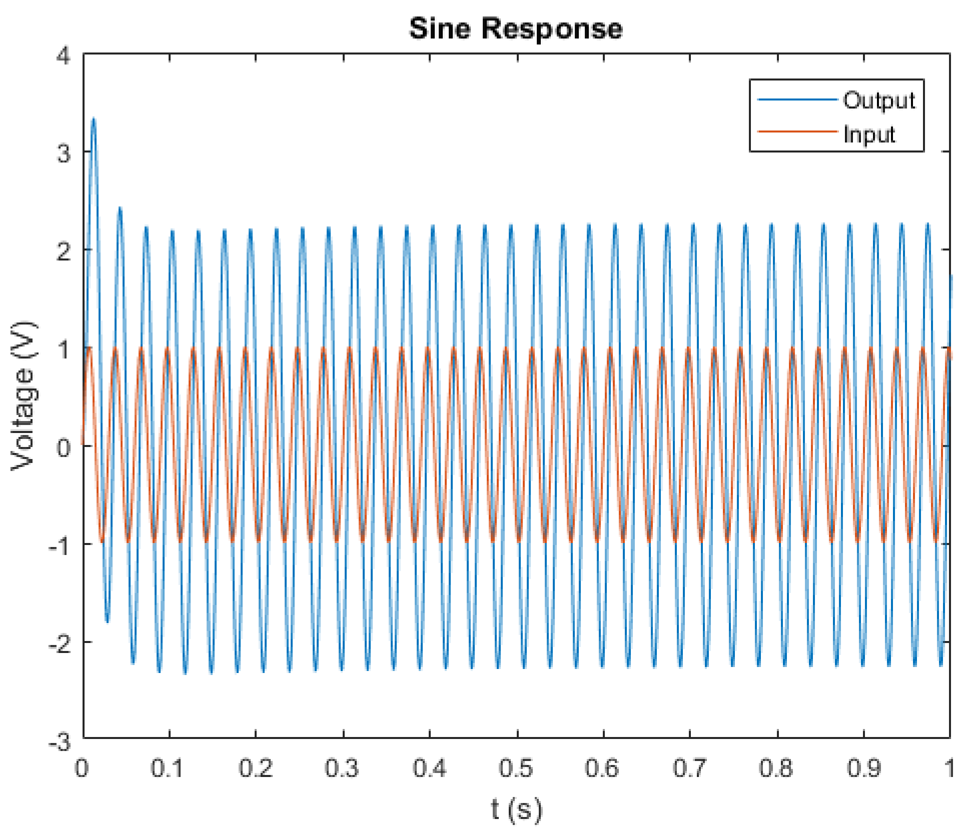
```
% Step Response:
vin = 1;
F1 = 0;
V1=0;
t = linspace(0,1,1000);
dt = 0.001;


for i=1:31
    F1(i,1:7) = [0;0;0;0;0;0;0];
end
for i=32:1000
    F1(i,1:7) = [vin;0;0;0;0;0;0];
end

V1(1:7,1) = (Cm/dt+Gm)^-1 *(F1(1,:)');
for i=2:1000
    V1(:,i) = (Cm/dt+Gm)^-1 *(Cm*V1(:,i-1)/dt+F1(i,:)');
end

figure(6);
plot(t,V1(7,:));
hold on
plot(t,F1(:,1));
title('Step Response')
xlabel('t (s)')
ylabel('Voltage (V)')
legend('Output','Voltage Step')

figure(7)
semilogy(linspace(-500,500,1000),fftshift(abs(fft(V1(7,:)))))
hold on
semilogy(linspace(-500,500,1000),fftshift(abs(fft(F1(:,1)))))

title('Step Response Fourier Transform')
xlabel('Freq (rad/s)')
ylabel('Voltage (V)')
legend('Output','input signal')

% Sine input
V2 = 0;
freq = 1/0.03;
F2=0;
for i=1:1000
    F2(i,1:7) = [sin(2*pi*freq*t(i)),0,0,0,0,0,0];
end


V2(1:7,1) = (Cm/dt+Gm)^-1 *(F2(1,:)');
for i=2:1000
    V2(:,i)=(Cm/dt+Gm)^-1 *(Cm*V2(:,i-1)/dt+F2(i,:)');
```

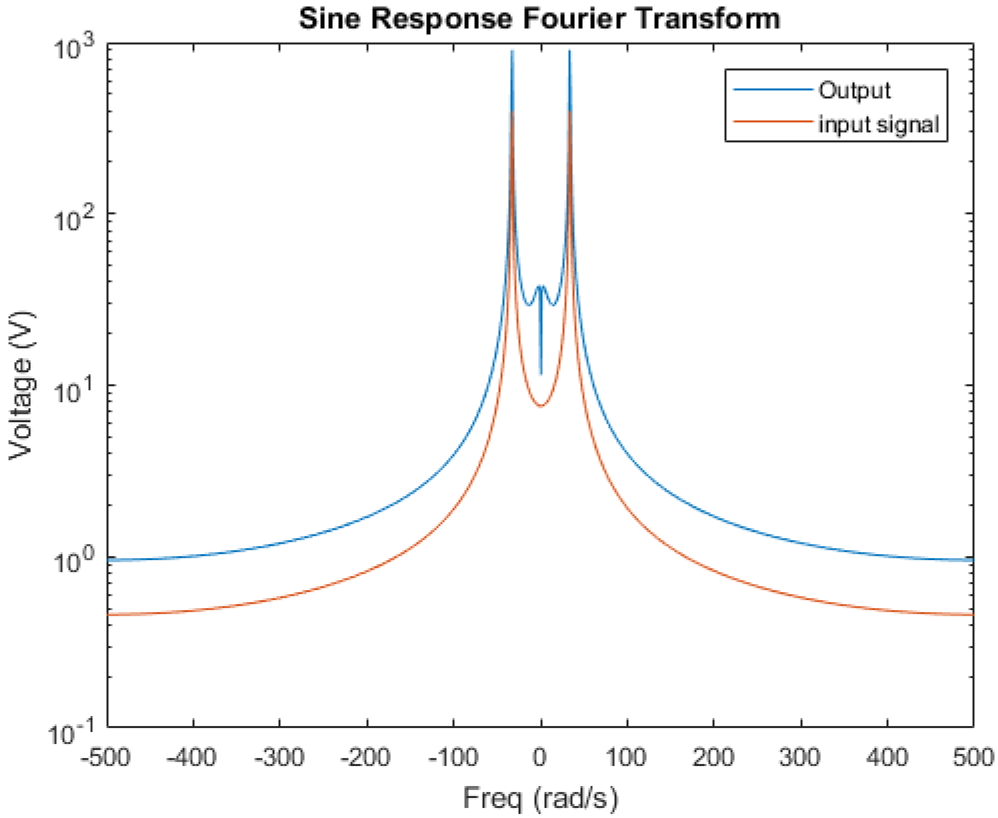
```
end

% Plot the response
figure(8)
plot(t,V2(7,:))
hold on
plot(t,F2(:,1))

title('Sine Response')
xlabel('t (s)')
ylabel('Voltage (V)')
legend('Output','Input')

figure(9)
semilogy(linspace(-500,500,1000),fftshift(abs(fft(V2(7,:)))))
hold on
semilogy(linspace(-500,500,1000),fftshift(abs(fft(F2(:,1)))))

title('Sine Response Fourier Transform')
xlabel('Freq (rad/s)')
ylabel('Voltage (V)')
legend('Output','input signal')

% Gauss response
V3 = 0;
F3 = 0;
for i=1:1000
    F3(i,1:7)=[exp(-1/2*((t(i)-0.06)*freq)^2),0,0,0,0,0,0];
end

V3(1:7,1) = (Cm/dt+Gm)^-1 *(F3(1,:)');
for i=2:1000
    V3(:,i)=(Cm/dt+Gm)^-1 *(Cm*V3(:,i-1)/dt+F3(i,:)');
end


figure(10)
plot(t,V3(7,:))
hold on
plot(t,F3(:,1))

title('Guassian Response')
xlabel('t (s)')
ylabel('Voltage (V)')
legend('Output','Input')

figure(11)
semilogy(linspace(-500,500,1000),fftshift(abs(fft(V3(7,:)))))
hold on
semilogy(linspace(-500,500,1000),fftshift(abs(fft(F3(:,1)))))

title('Guassian Response Fourier Transform')
xlabel('Freq (rad/s)')
ylabel('Voltage (V)')
```

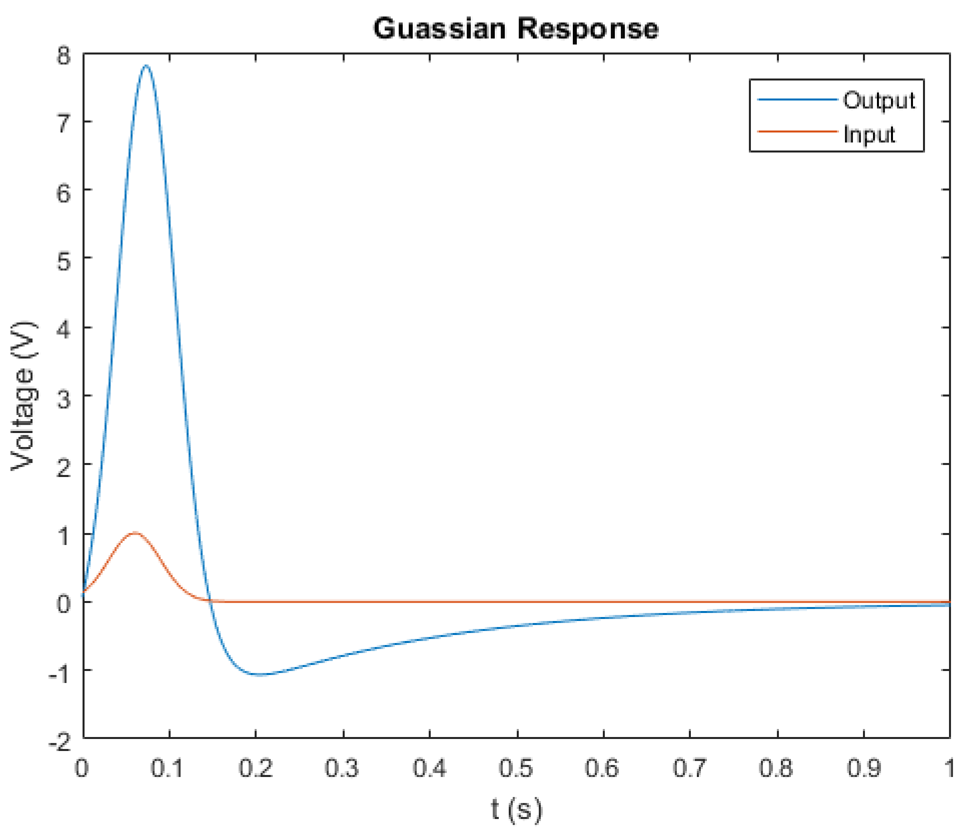
```
legend('Output','input signal')

% Larger Timestep
V4 = 0;
t = linspace(0,1,100);

V4(1:7,1)=(Cm/dt+Gm)^-1 *(F3(1,:)');
for i=2:100
    V4(:,i)=(Cm/dt+Gm)^-1 *(Cm*V3(:,i-1)/dt+F3(i,:)');
end

figure(12)
plot(t,V4(7,:))
hold on
t = linspace(0,1,1000);
plot(t,F3(:,1))
legend('Vout','input signal')
title('DC Guassian responce')
xlabel('Time (s)')
ylabel('Voltage (V)')

% The longer time step can be seen in figure 12. When acting on the
% gaussian input, the peak widens and gets pushed back in time.
```

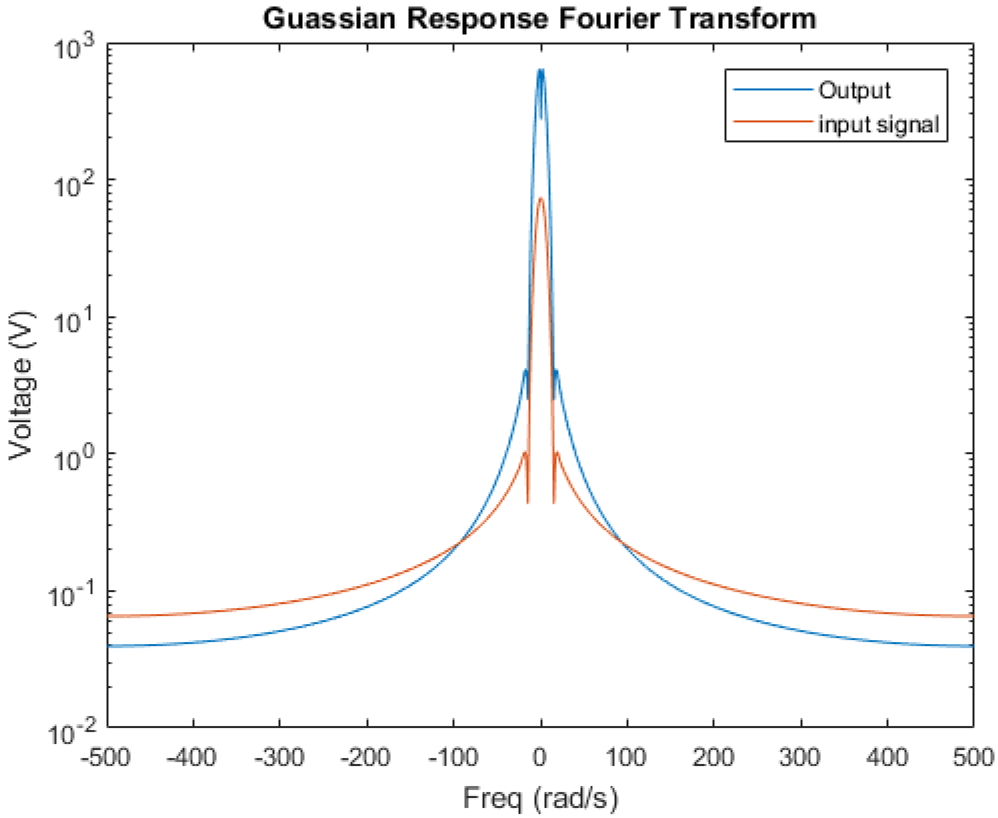


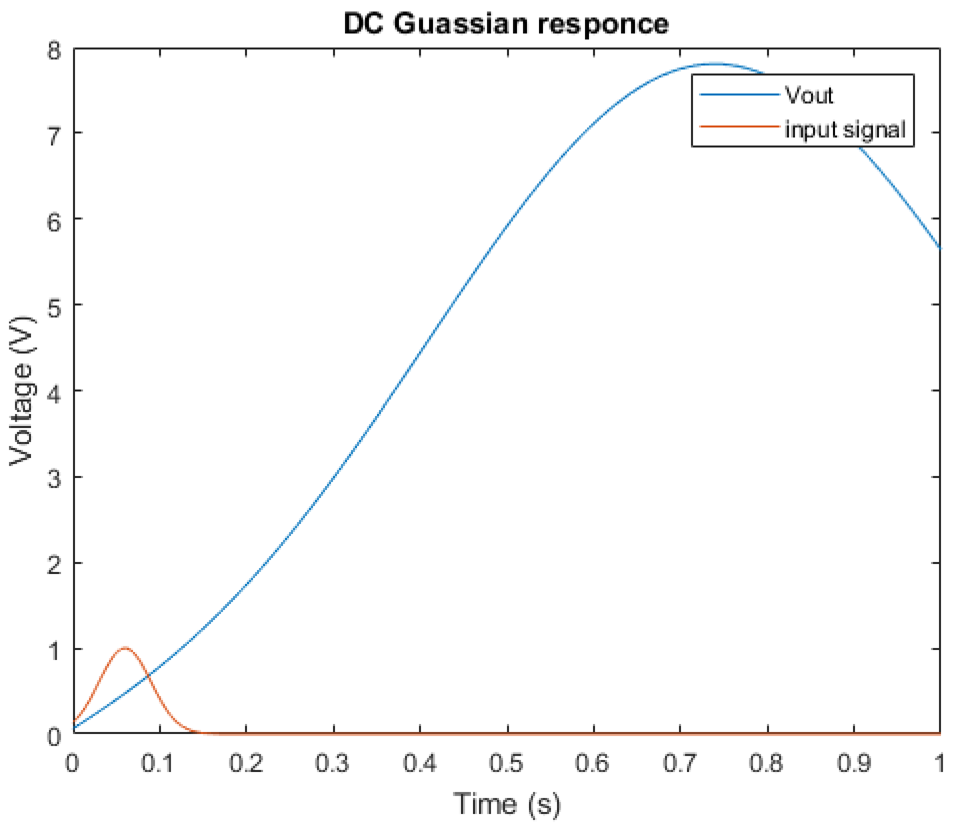

Step Response Fourier Transform
Output
input signal
Voltage (V)
Freq (rad/s)
-500
-400
-300
-200
-100
0
100
200
300
400
500


Sine Response
Output
Input
Voltage (V)
t (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 Response Fourier Transform
Output
input signal
Voltage (V)
Freq (rad/s)
10^{3}
10^{2}
10^{1}
10^{0}
10^{-1}
-500
-400
-300
-200
-100
0
100
200
300
400
500


Guassian Response
Output
Input
Voltage (V)
t (s)
8
7
6
5
4
3
2
1
0
-1
-2
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1


Guassian Response Fourier Transform
Output
input signal
Voltage (V)
Freq (rad/s)
10^3
10^2
10^1
10^0
10^{-1}
10^{-2}
-500
-400
-300
-200
-100
0
100
200
300
400
500


DC Guassian responce
Vout
input signal
Voltage (V)
Time (s)
0
1
2
3
4
5
6
7
8
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

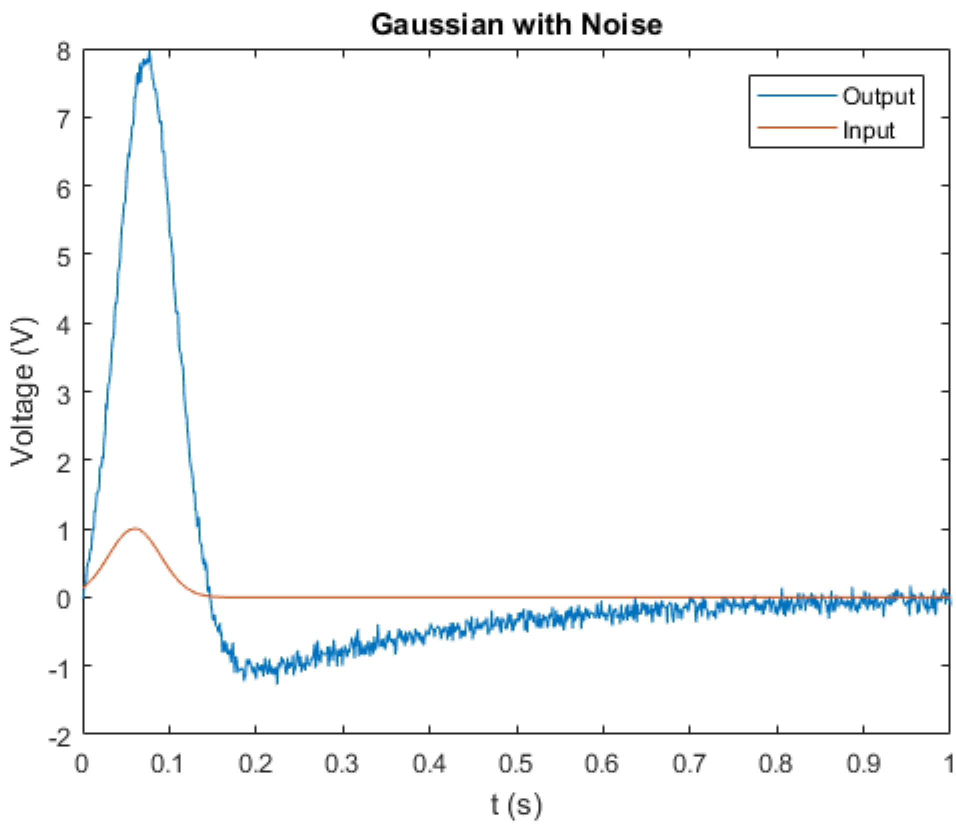
Question 3

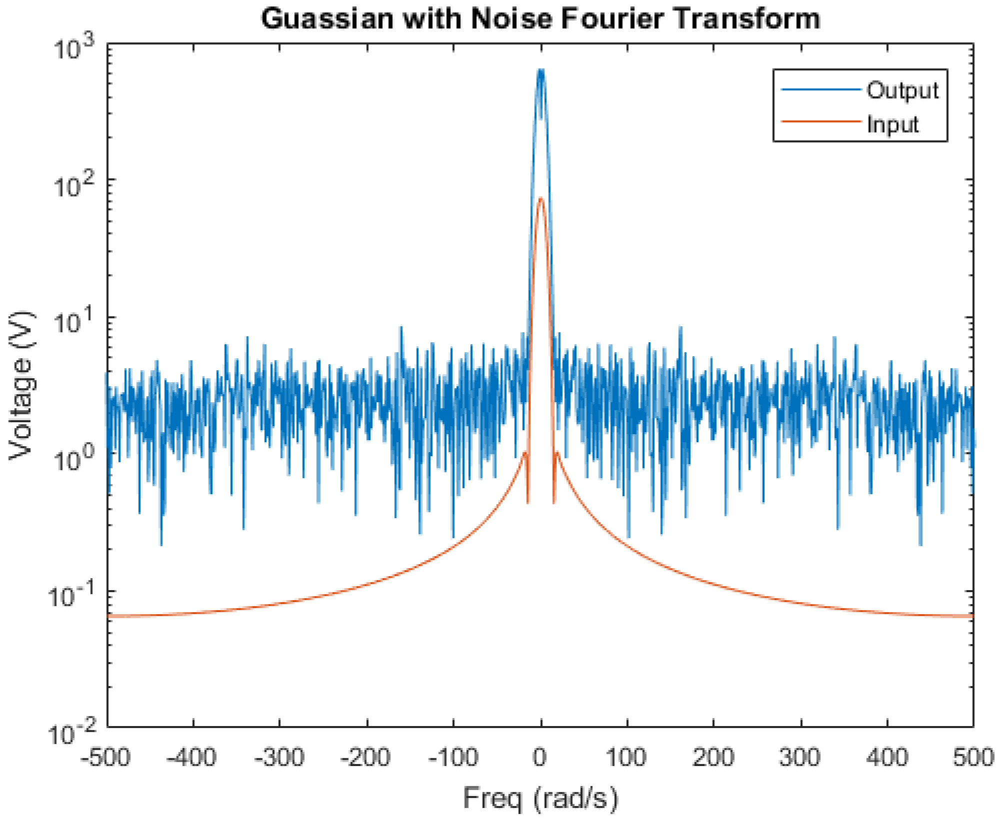
```
% Redefine C and G matrixes to be 8x8 to account for the new junction
In = 0.001*randn();
Cn = 0.00001;

Cm = [0 0 0 0 0 0 0 0; -C C 0 0 0 0 0 0; 0 0 -L 0 0 0 0 0; 0 0 0 Cn 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 0];
Gm = [1 0 0 0 0 0 0 0; -G2 G1+G2 -1 0 0 0 0 0; 0 1 0 -1 0 0 0 0; 0 0
 -1 G3 0 0 0 -1; 0 0 0 0 -a 1 0 0; 0 0 0 G3 -1 0 0 0; 0 0 0 0 0 -G4
 G4+G0 0; 0 0 0 0 0 0 0 1];
F = [Vin; 0; 0; 0; 0; 0; 0; In];

V1 = 0;
F1 = 0;

for i=1:1000
    In = dt*randn();
    F1(i,1:8)=[exp(-1/2*((t(i)-0.06)*freq)^2),0,0,0,0,0,0,In];
end

V1(1:8,1)=(Cm/dt+Gm)^-1*(F1(1,:)');
for i=2:1000
    V1(:,i)=(Cm/dt+Gm)^-1*(Cm*V1(:,i-1)/dt+F1(i,:)');
end

figure(13)
plot(t,V1(7,:))
hold on
plot(t,F1(:,1))

title('Gaussian with Noise')
xlabel('t (s)')
ylabel('Voltage (V)')
legend('Output','Input')

figure(14)
semilogy(linspace(-500,500,1000),fftshift(abs(fft(V1(7,:)))))
hold on
semilogy(linspace(-500,500,1000),fftshift(abs(fft(F3(:,1)))))

title('Guassian with Noise Fourier Transform')
xlabel('Freq (rad/s)')
ylabel('Voltage (V)')
legend('Output','Input')


Cn = 0.00002;
Cm = [0 0 0 0 0 0 0 0; -C C 0 0 0 0 0 0; 0 0 -L 0 0 0 0 0; 0 0 0 Cn 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 0];
```

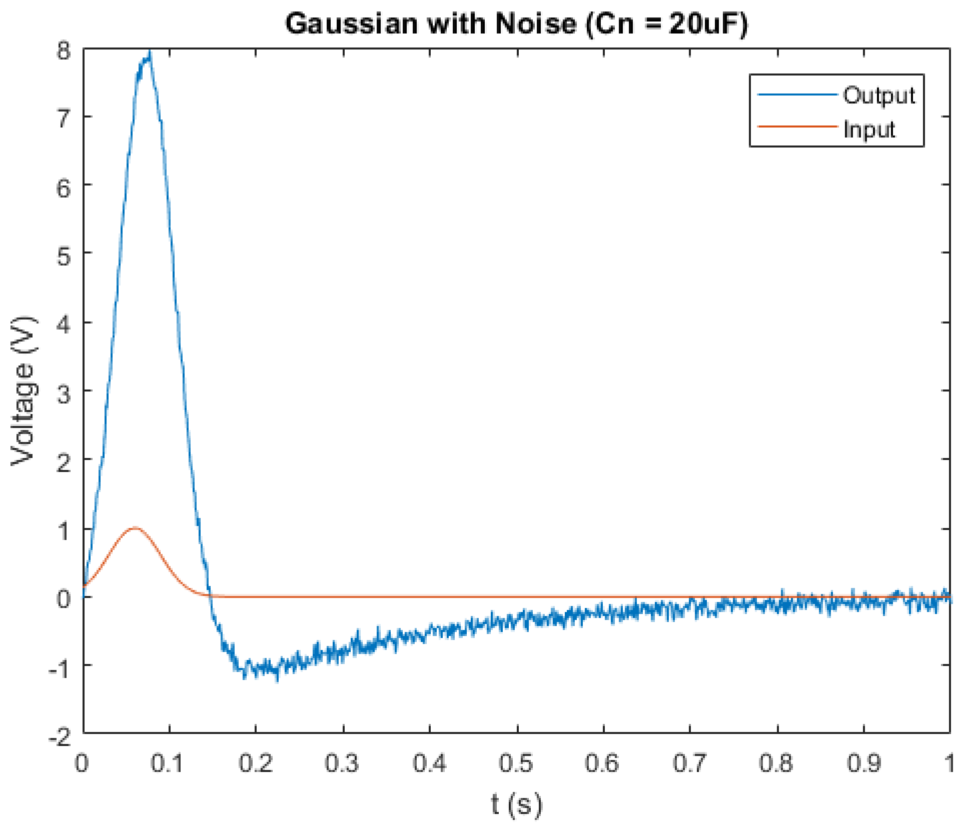
```
V2(1:8,1)=(Cm/dt+Gm)^-1*(F1(1,:)');
for i=2:1000
    V2(:,i)=(Cm/dt+Gm)^-1*(Cm*V2(:,i-1)/dt+F1(i,:)');
end

figure(15)
plot(t,V2(7,:))
hold on
plot(t,F1(:,1))

title('Gaussian with Noise (Cn = 20uF)')
xlabel('t (s)')
ylabel('Voltage (V)')
legend('Output','Input')


Cn = 0.0002;
Cm = [0 0 0 0 0 0 0 0; -C C 0 0 0 0 0 0; 0 0 -L 0 0 0 0 0; 0 0 0 Cn 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 0];

V3(1:8,1)=(Cm/dt+Gm)^-1*(F1(1,:)');
for i=2:1000
    V3(:,i)=(Cm/dt+Gm)^-1*(Cm*V3(:,i-1)/dt+F1(i,:)');
end

figure(16)
plot(t,V3(7,:))
hold on
plot(t,F1(:,1))

title('Gaussian with Noise (Cn = 200uF)')
xlabel('t (s)')
ylabel('Voltage (V)')
legend('Output','Input')


Cn = 0.002;
Cm = [0 0 0 0 0 0 0 0; -C C 0 0 0 0 0 0; 0 0 -L 0 0 0 0 0; 0 0 0 Cn 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 0];

V4(1:8,1)=(Cm/dt+Gm)^-1*(F1(1,:)');
for i=2:1000
    V4(:,i)=(Cm/dt+Gm)^-1*(Cm*V4(:,i-1)/dt+F1(i,:)');
end

figure(17)
plot(t,V4(7,:))
hold on
plot(t,F1(:,1))

title('Gaussian with Noise (Cn = 2mF)')
xlabel('t (s)')
```

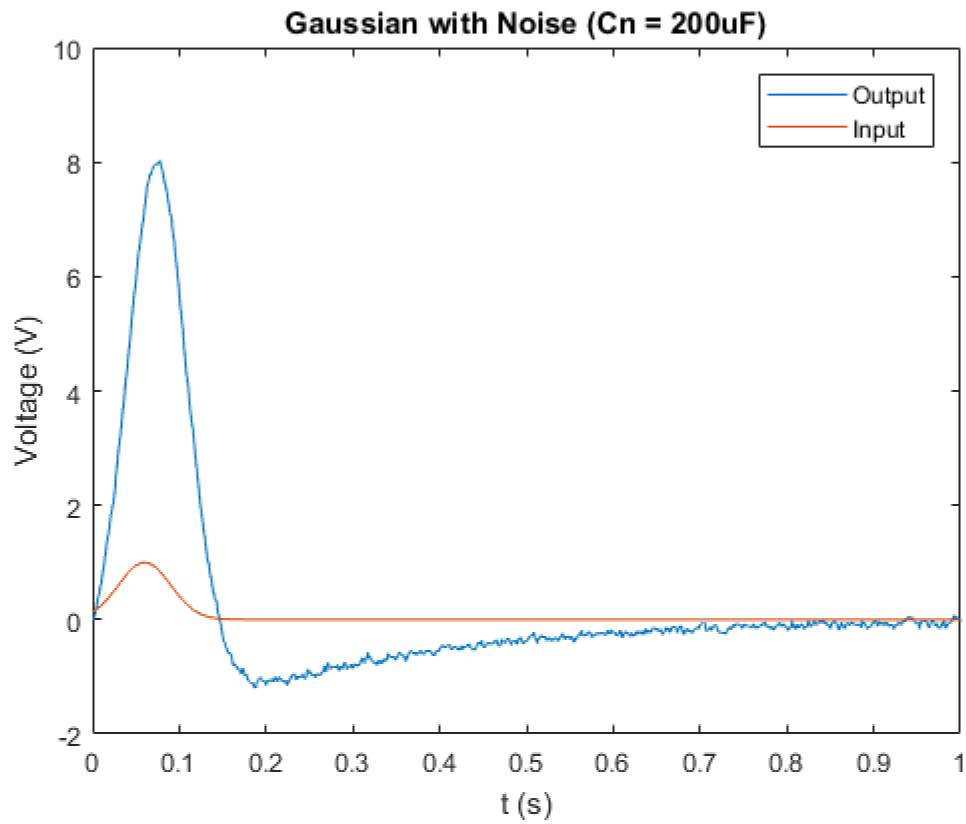
```
ylabel('Voltage (V)')
legend('Output','Input')

% Return the Cn value to default
Cn = 0.00001;
Cm = [0 0 0 0 0 0 0 0; -C C 0 0 0 0 0 0; 0 0 -L 0 0 0 0 0; 0 0 0 Cn 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 0];

% It can be seen that increasing the capacitor value decreases the
 noise.
% Once the value has been increased to 2mF, the noise is negligable.

V5 = 0;
F2 = 0;

t = linspace(0,1,800);
dt = 0.00125;

for i=1:800
    In = 0.001*randn();
    F2(i,1:8)=[exp(-1/2*((t(i)-0.06)*freq)^2),0,0,0,0,0,0,In];
end

V5(1:8,1)=(Cm/dt+Gm)^-1*(F2(1,:)');
for i=2:800
    V5(:,i)=(Cm/dt+Gm)^-1*(Cm*V5(:,i-1)/dt+F2(i,:)');
end

figure(18)
plot(t,V5(7,:))
hold on
plot(t,F2(:,1))

title('Gaussian with Noise (dt = 1.25ms)')
xlabel('t (s)')
ylabel('Voltage (V)')
legend('Output','Input')



V6 = 0;
F3 = 0;

t = linspace(0,1,500);
dt = 0.1;

for i=1:500
    In = 0.001*randn();
    F3(i,1:8)=[exp(-1/2*((t(i)-0.06)*freq)^2),0,0,0,0,0,0,In];
end

V6(1:8,1)=(Cm/dt+Gm)^-1*(F3(1,:)');
for i=2:500
```

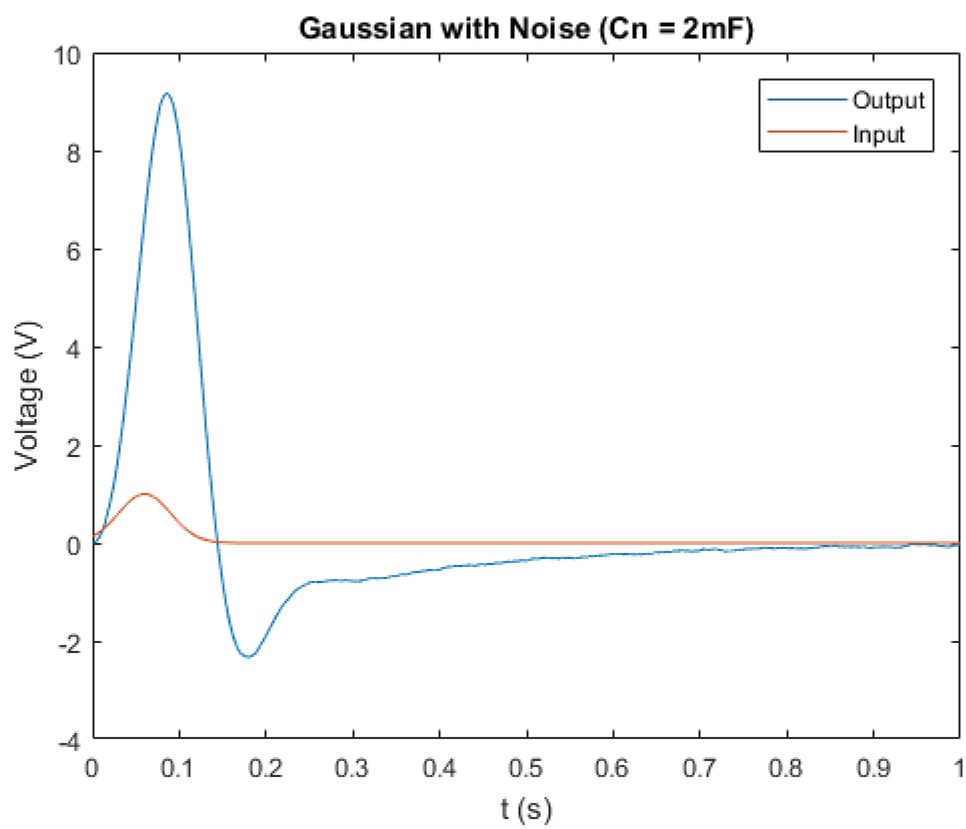
```
    V6(:,i)=(Cm/dt+Gm)^-1*(Cm*V6(:,i-1)/dt+F3(i,:)');
end

figure(19)
plot(t,V6(7,:))
hold on
plot(t,F3(:,1))

title('Gaussian with Noise (dt = 0.1s)')
xlabel('t (s)')
ylabel('Voltage (V)')
legend('Output','Input')

% With an increase in the timestep, we see that the output shape does
 not
% dip as far into the negative voltage range. The output signal is
 also
% slightly less noisy (figure 19) as compared to that of a smaller
 time
% step (figure 18).
```

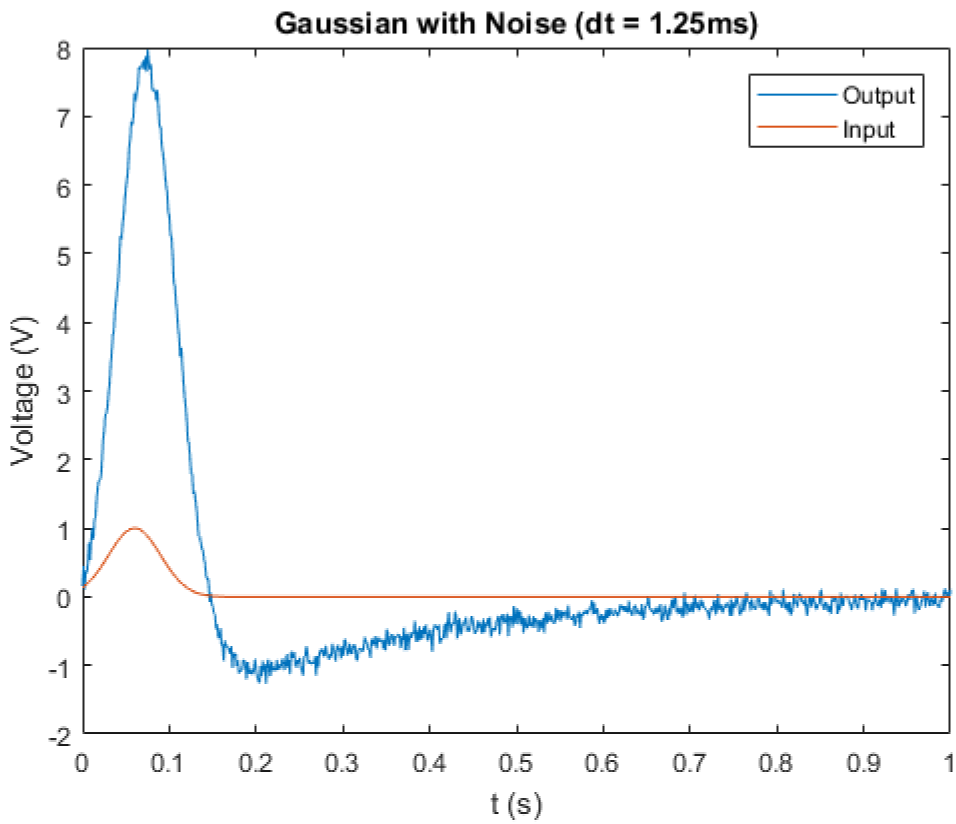


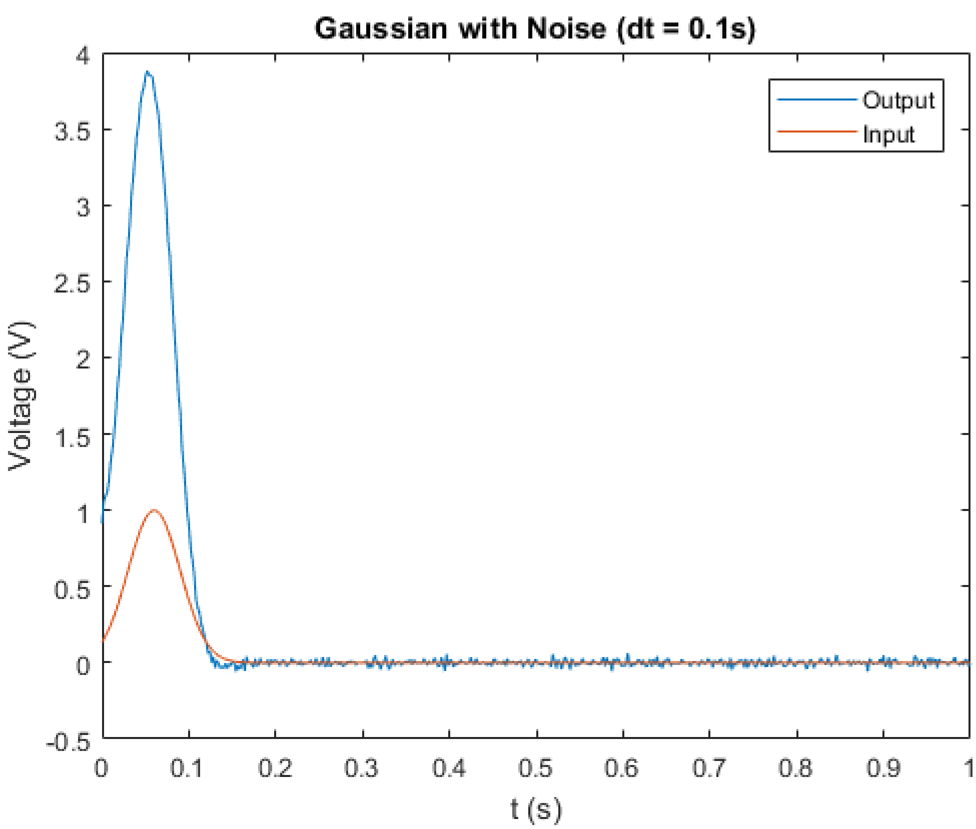

Guassian with Noise Fourier Transform
Output
Input
Voltage (V)
Freq (rad/s)
10^3
10^2
10^1
10^0
10^-1
10^-2
-500
-400
-300
-200
-100
0
100
200
300
400
500


Gaussian with Noise (Cn = 20uF)
Output
Input
Voltage (V)
t (s)
8
7
6
5
4
3
2
1
0
-1
-2
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1


Gaussian with Noise (Cn = 200uF)
Output
Input
Voltage (V)
t (s)
10
8
6
4
2
0
-2
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1


Gaussian with Noise (Cn = 2mF)
Output
Input
Voltage (V)
t (s)
10
8
6
4
2
0
-2
-4
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1


Gaussian with Noise (dt = 1.25ms)
Output
Input
Voltage (V)
t (s)
8
7
6
5
4
3
2
1
0
-1
-2
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1


Gaussian with Noise (dt = 0.1s)
Output
Input
Voltage (V)
t (s)
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

Question 4

If you want to implement the non-linearity, you would have to keep track of the non-linear components using another vector. This would change the G matrix. This makes the time domain equation:

$$C\frac{dV}{dt} + GV + B = F$$

Where B is the non-linear component-holding vector. In order to converge on a value for B, the simulation will have to not only iterate over time but also in each timestep.

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