Assignment 4

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Question 1 and 2 - PA 9 and Transient Circuit Simulation

The simulation was run:

```
MNA_Q1
pause(2);
```

```
C =

         0         0         0         0         0         0
   -0.2500    0.2500         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    0.2000


G =

    1.0000         0         0         0         0         0
   -1.0000    1.5000         0         0         0    1.0000
         0         0    0.1000         0         0   -1.0000
         0         0  -10.0000    1.0000         0         0
         0         0         0  -10.0000   10.0010         0
         0   -1.0000    1.0000         0         0         0
```

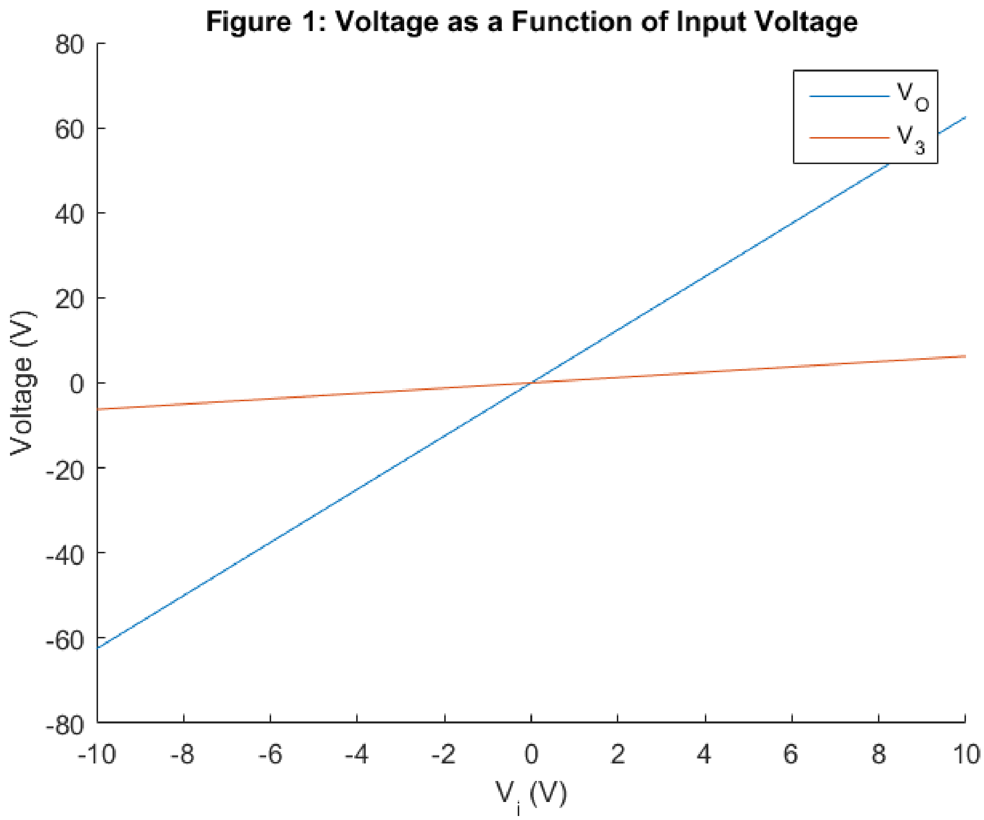


Figure 1: Voltage as a Function of Input Voltage
80
60
40
20
0
-20
-40
-60
-80
Voltage (V)
-10
-8
-6
-4
-2
0
2
4
6
8
10
V i (V)
V O
V 3

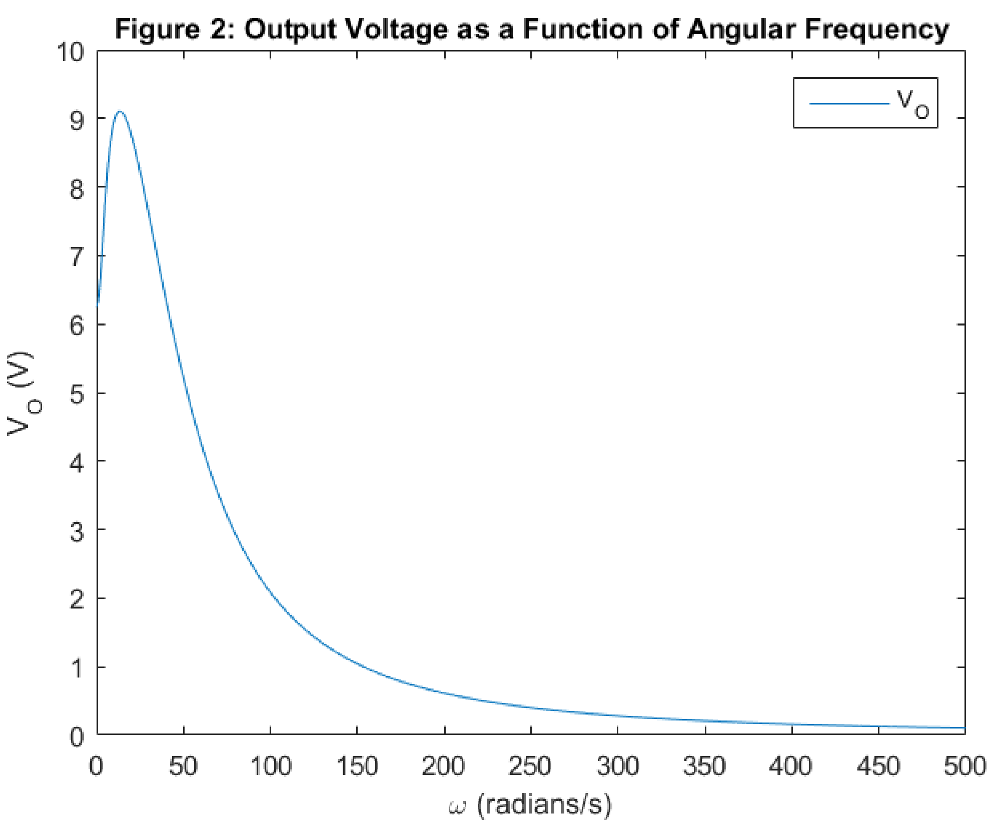


Figure 2: Output Voltage as a Function of Angular Frequency
10
9
8
7
6
5
4
3
2
1
0
V O (V)
0
50
100
150
200
250
300
350
400
450
500
ω (radians/s)
V O

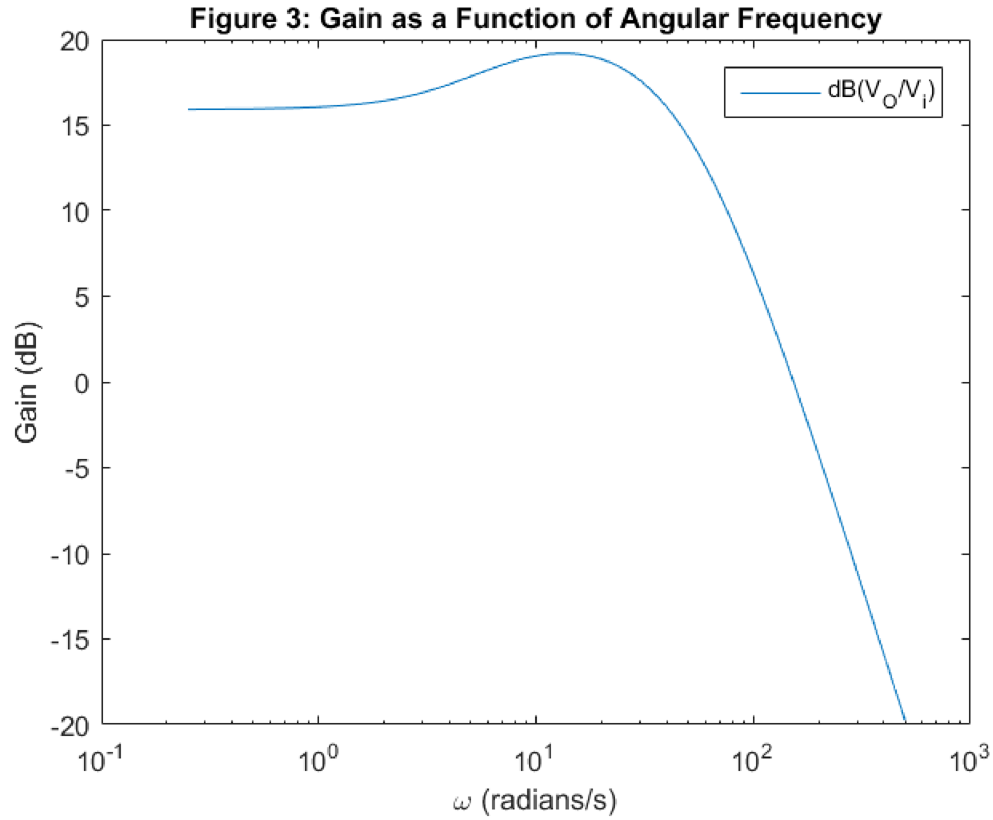


Figure 3: Gain as a Function of Angular Frequency
dB(V$_O$/V$_i$)
Gain (dB)
ω (radians/s)
20
15
10
5
0
-5
-10
-15
-20
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}

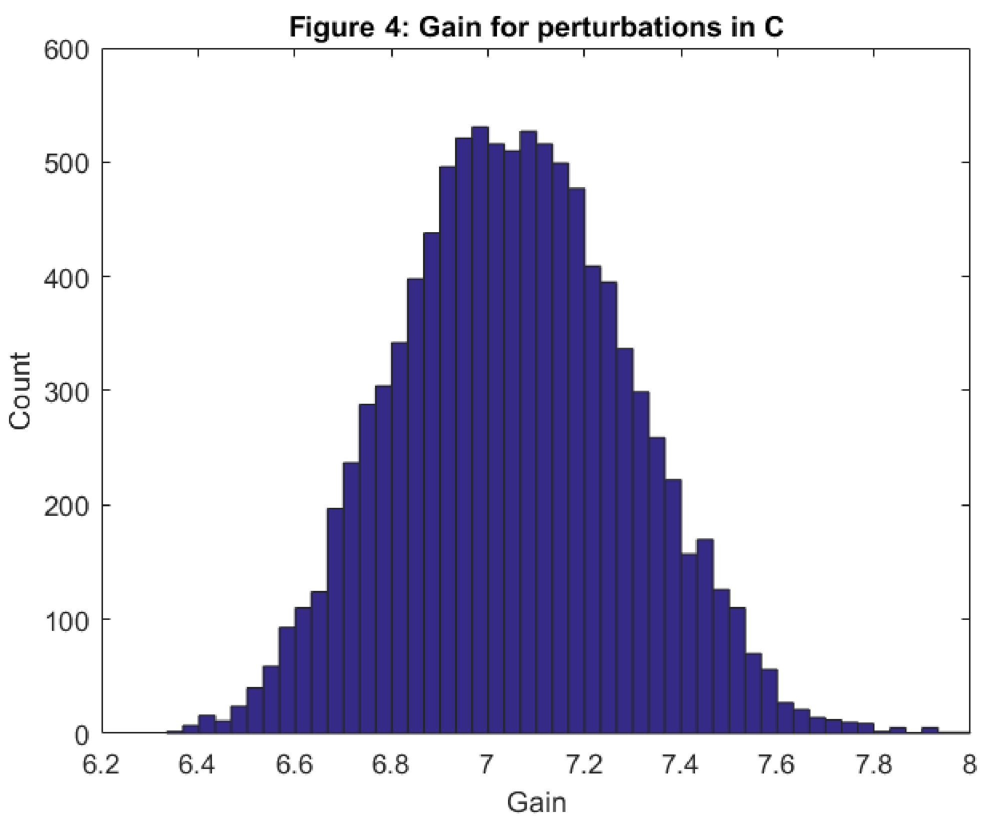


Figure 4: Gain for perturbations in C
Count
Gain
600
500
400
300
200
100
0
6.2
6.4
6.6
6.8
7
7.2
7.4
7.6
7.8
8

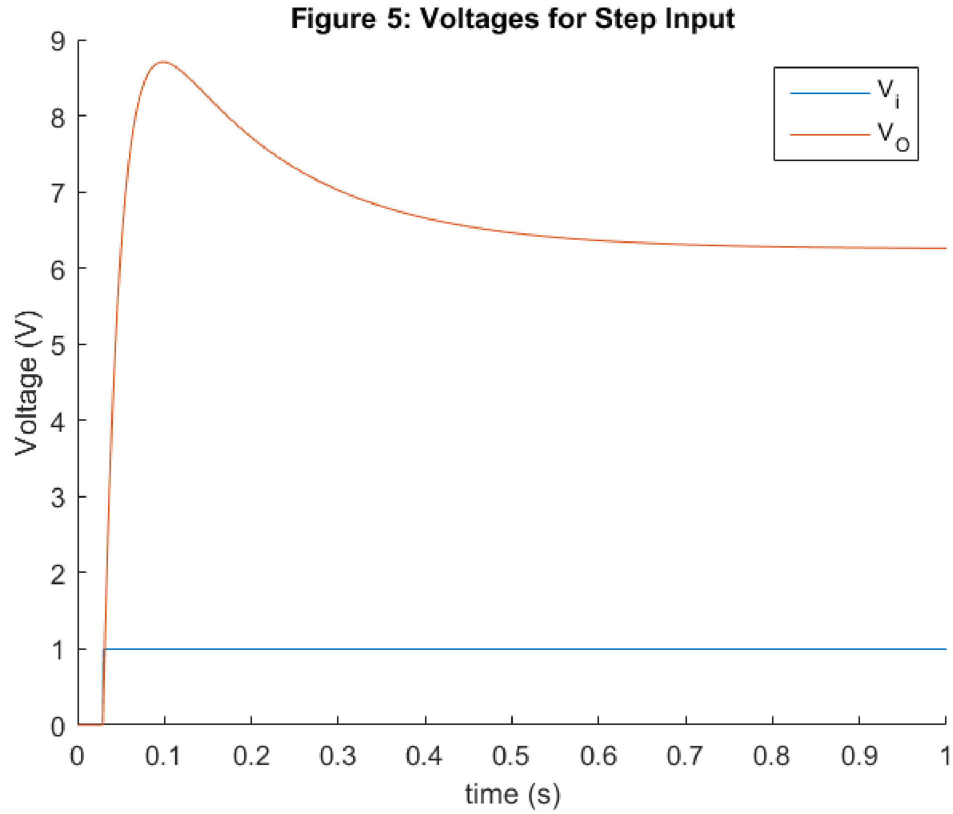


Figure 5: Voltages for Step Input
Voltage (V)
time (s)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
2
3
4
5
6
7
8
9
V_i
V_O

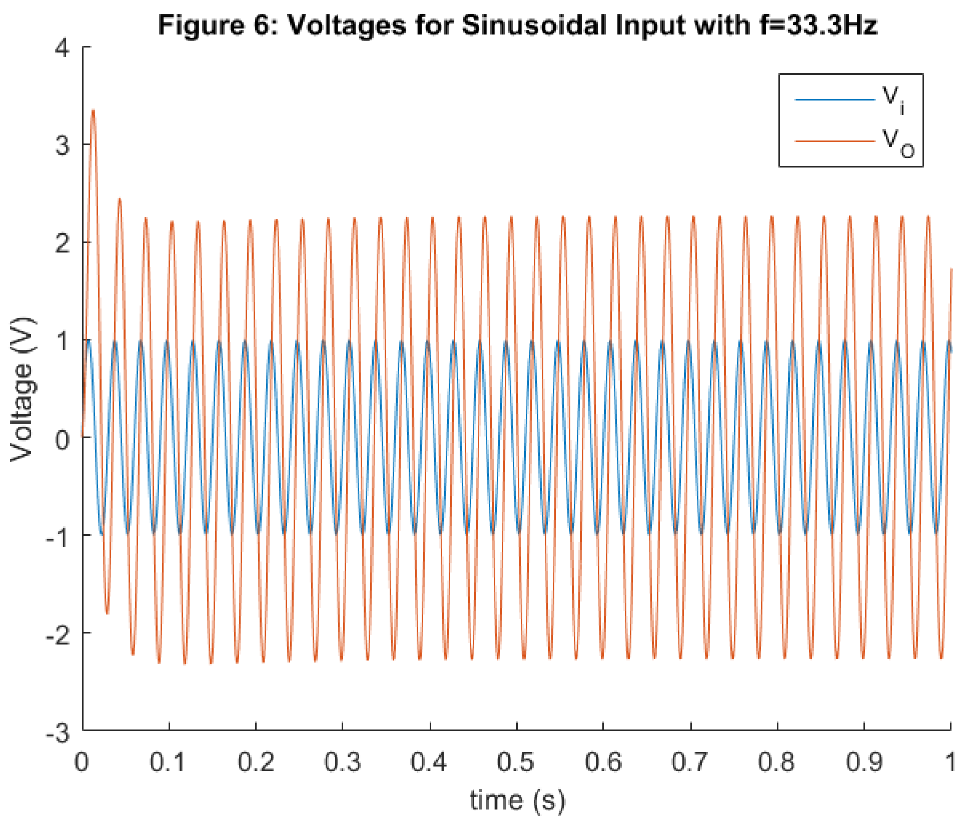


Figure 6: Voltages for Sinusoidal Input with f=33.3Hz
Voltage (V)
time (s)
-3
-2
-1
0
1
2
3
4
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
V_i
V_O

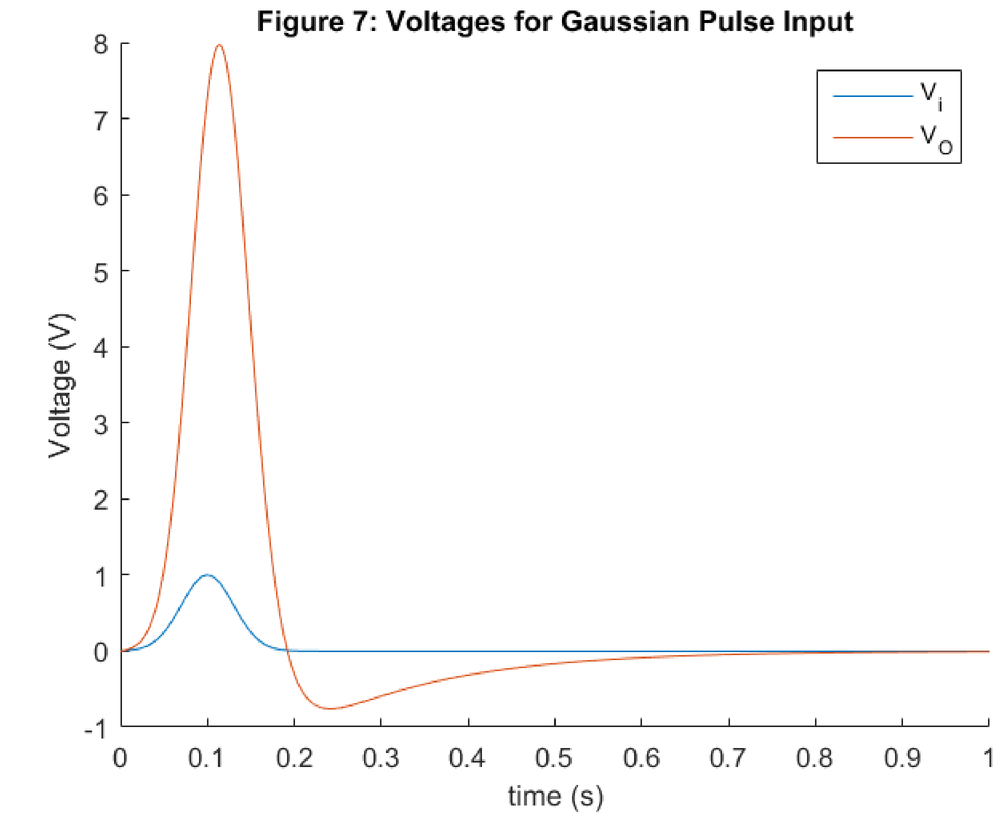


Figure 7: Voltages for Gaussian Pulse Input
Voltage (V)
time (s)
8
7
6
5
4
3
2
1
0
-1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
V_i
V_O

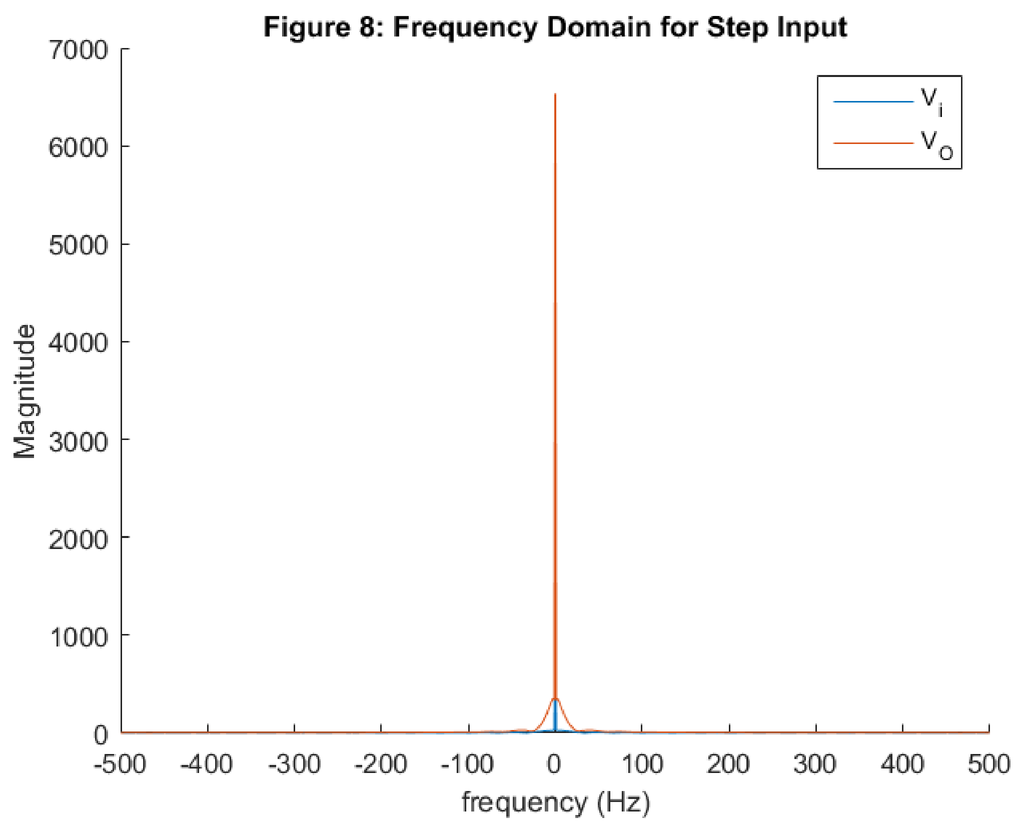


Figure 8: Frequency Domain for Step Input
Magnitude
frequency (Hz)
7000
6000
5000
4000
3000
2000
1000
0
-500
-400
-300
-200
-100
0
100
200
300
400
500
V_i
V_O

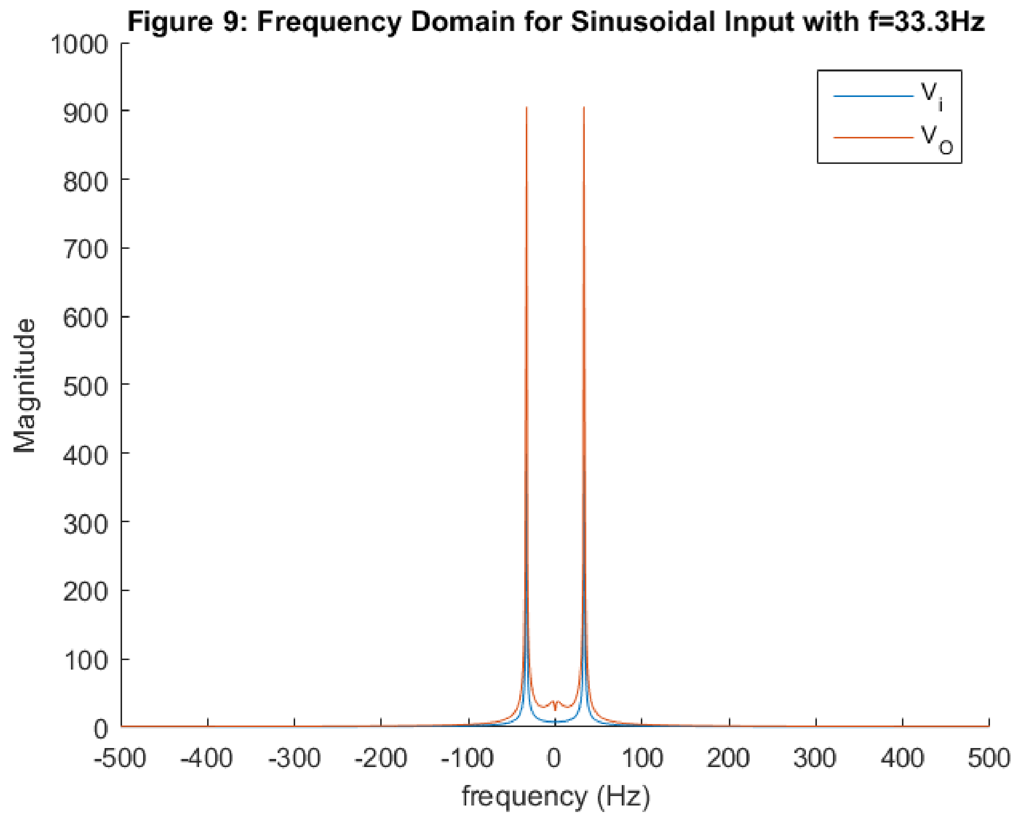


Figure 9: Frequency Domain for Sinusoidal Input with f=33.3Hz
Magnitude
frequency (Hz)
1000
900
800
700
600
500
400
300
200
100
0
-500
-400
-300
-200
-100
0
100
200
300
400
500
V_i
V_O

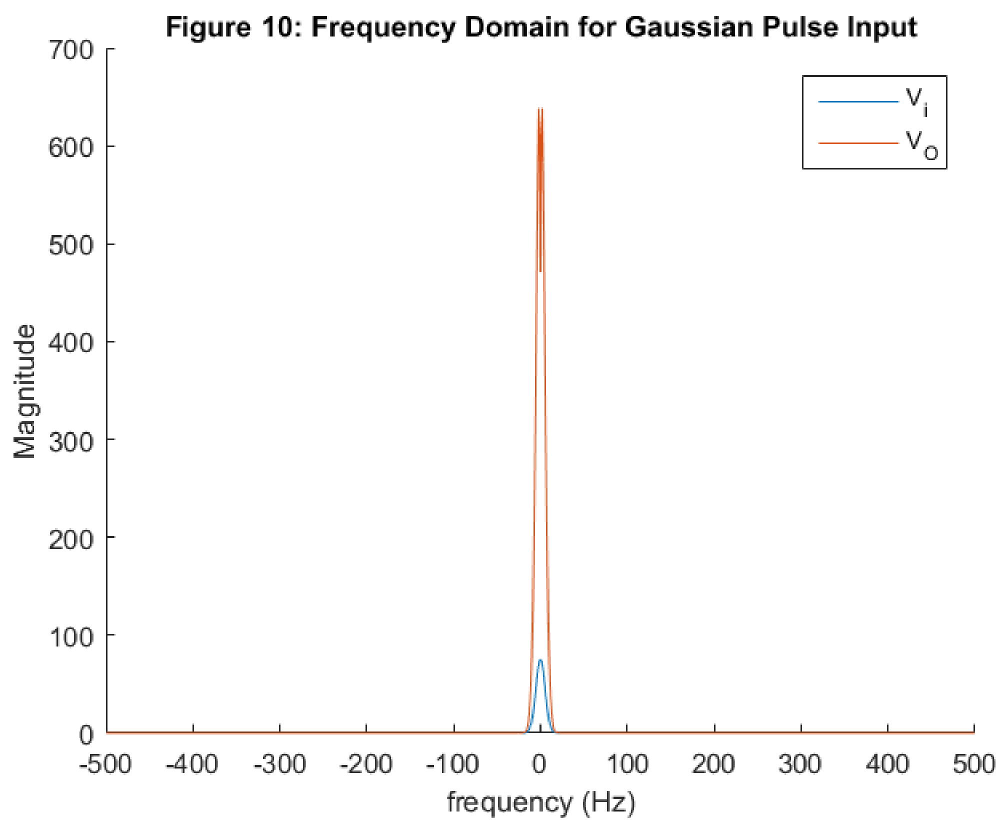


Figure 10: Frequency Domain for Gaussian Pulse Input
Magnitude
frequency (Hz)
700
600
500
400
300
200
100
0
-500
-400
-300
-200
-100
0
100
200
300
400
500
V_i
V_O

(a)

The values of the C and G matrices are shown above.

The G matrix is:

$$
\begin{matrix}
1 & 0 & 0 & 0 & 0 & 0 \\
-\frac{1}{R_1} & \left(\frac{1}{R_2}+\frac{1}{R_1}\right) & 0 & 0 & 0 & 1 \\
0 & 0 & \frac{1}{R_3} & 0 & 0 & -1 \\
0 & 0 & -\frac{\alpha}{R_3} & 1 & 0 & 0 \\
0 & 0 & 0 & -\frac{1}{R_4} & \left(\frac{1}{R_4}+\frac{1}{R_O}\right) & 0 \\
0 & -1 & 1 & 0 & 0 & 0
\end{matrix}
$$

The C matrix is:

$$
\begin{matrix}
0 & 0 & 0 & 0 & 0 & 0 \\
-C_1 & C_1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & L_1
\end{matrix}
$$

The V matrix is:

$$
\begin{matrix}
V_1 \\
V_2 \\
V_3 \\
V_4 \\
V_5 \\
I_L
\end{matrix}
$$

(b)

Figure 1 shows a plot of the DC sweep. The relationship of V_O and V_3 to V_i is linear.

(c)

Figure 2 shows the output voltage as a function of the angular frequency. Figure 3 shows the gain as a function of the angular frequency. The ciruit acts like a low pass filter.

Figure 4 shows a histogram of Gain for pertubation in C. It has a normal distribution just like the perturbation in C.

(d)

Figure 5 shows the input and output voltage for a step input. The output voltage overshoots and then exponentialy approaches a final votage.

Figure 6 shows the input and output voltage for a sinusoidal input. The output voltage is also a sinusoidal signal but it has a higher amplitude and a phase shift. There is some irregularity since the input voltage starts from a steady state of 0V.

Figure 7 shows the input and output voltage for a Gaussian pulse input. The output voltage resembles the Gaussian input but overshoots below 0V before gradually returning to 0V.

(e)

Figure 8 shows the frequency domain for the step input. The input and output both resemble a dirac-delta centred at a frequency of 0Hz. The output is a slighty worse dirac-delta.

Figure 9 shows the frequency domain for the sinsoidal input. The input and output both resemble two dirac-delta at -33.3Hz and 33.3Hz. The output is a slighty worse pair of dirac-deltas.

Figure 10 shows the frequency domain for the Gaussian pulse input. The input and output both resemble Gaussian distributions. The output has larger magnitude.

Question 3 - Circuit with Noise

The simulation was run:

```
MNA_Q3
pause(2);


C =

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

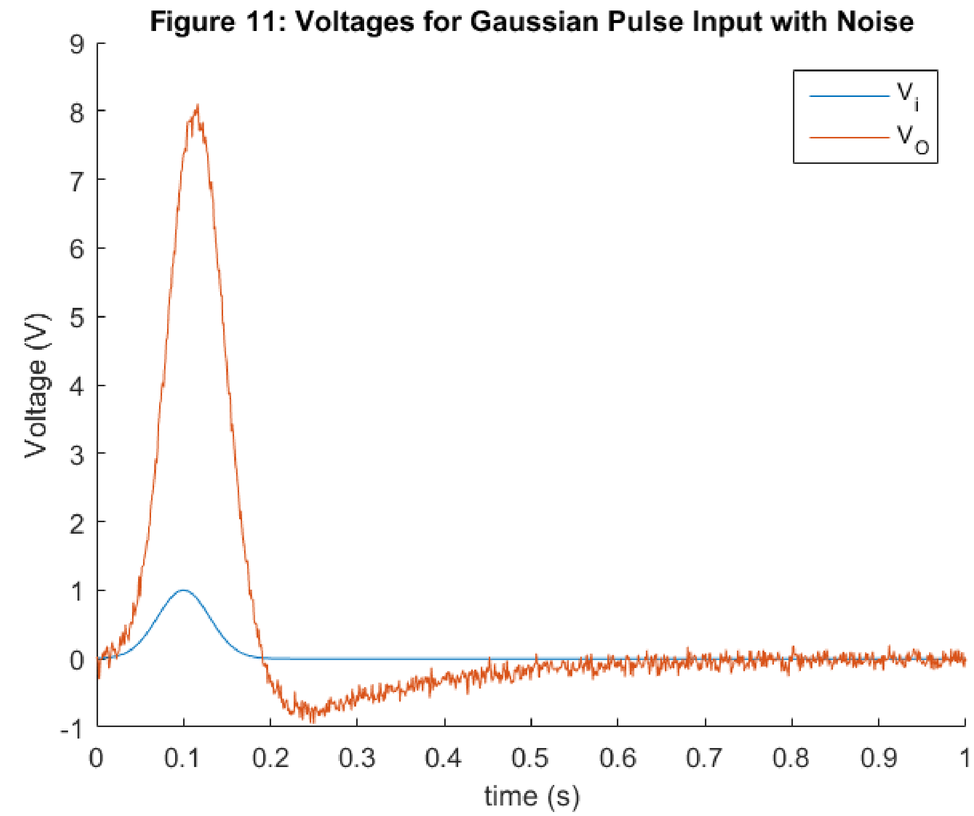


Figure 11: Voltages for Gaussian Pulse Input with Noise
Voltage (V)
time (s)
V_i
V_O

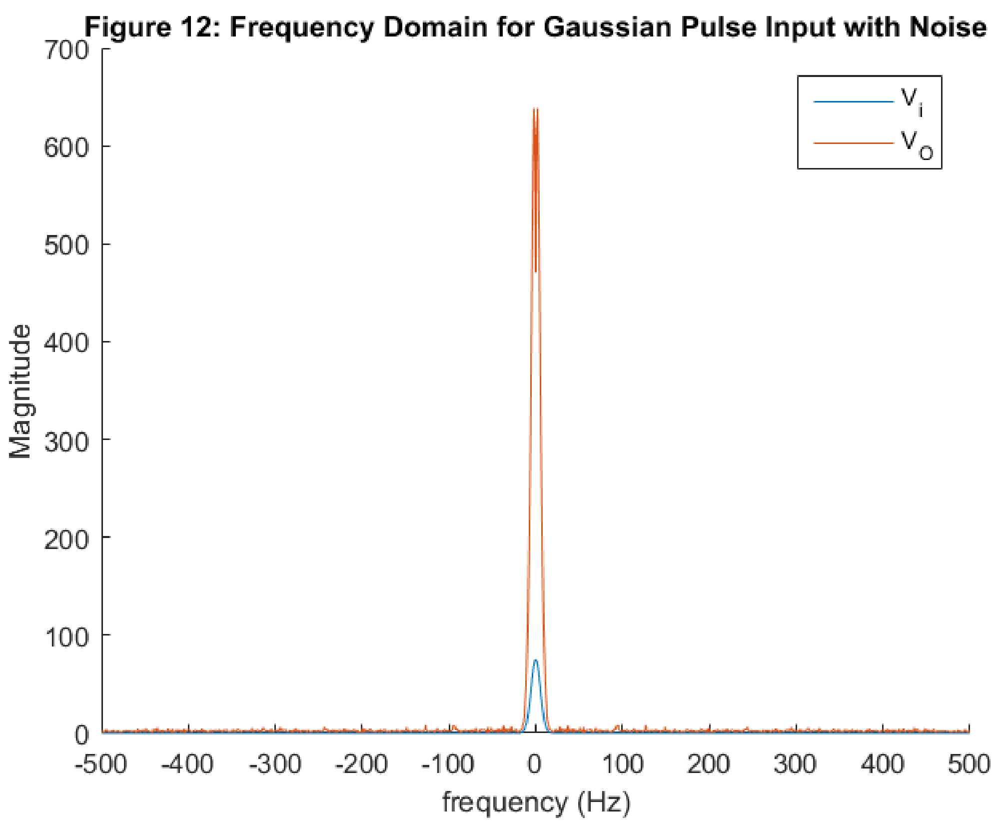


Figure 12: Frequency Domain for Gaussian Pulse Input with Noise
Magnitude
frequency (Hz)
V_i
V_O

Figure 13: Voltages with Noise for Different Cn

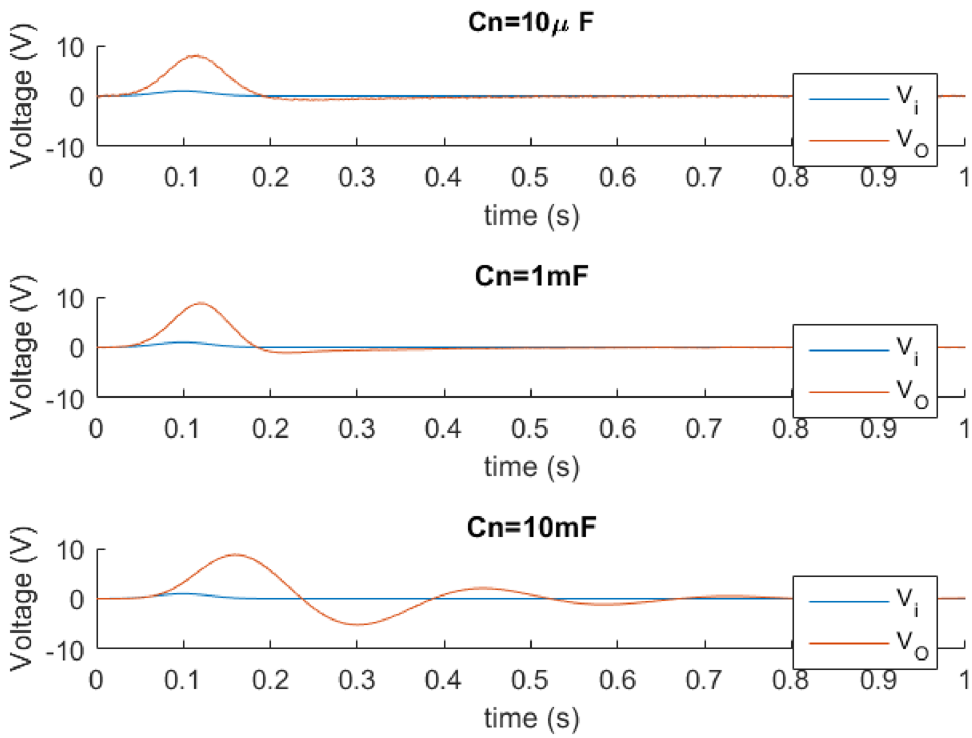
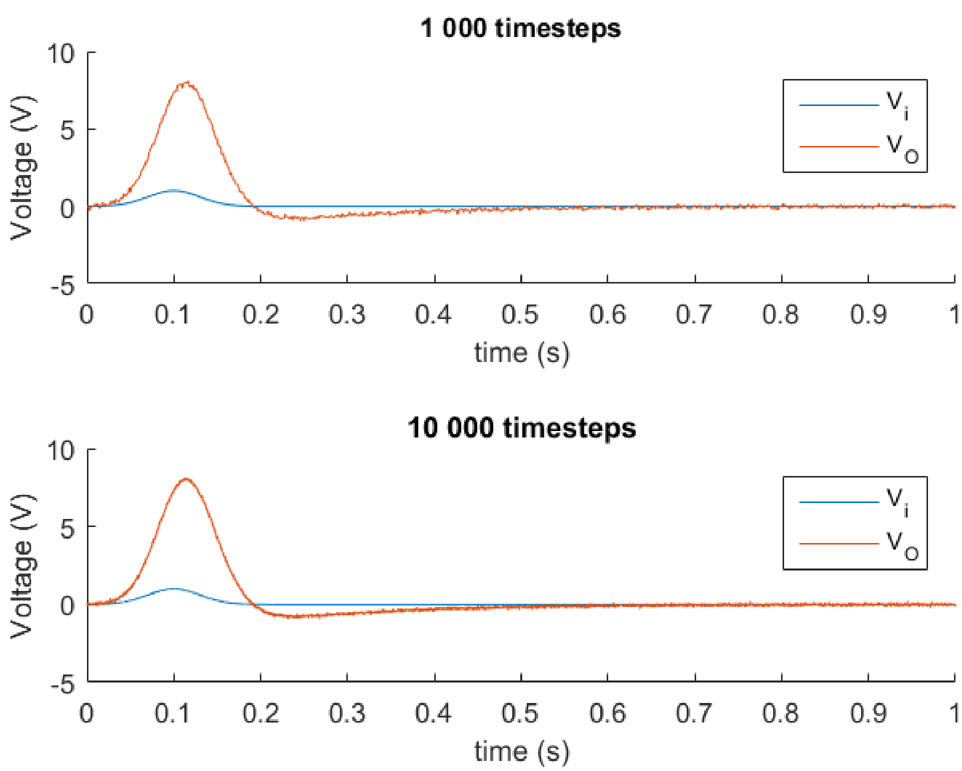


Figure 14: Voltages with Noise for Different Timesteps



(a)

The value of the new C matrix is shown above.

The new C matrix is:

$$\begin{matrix} 0 & 0 & 0 & 0 & 0 & 0 \\ -C_1 & C_1 & 0 & 0 & 0 & 0 \\ 0 & 0 & C_n & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & L_1 \end{matrix}$$

(b)

Figure 11 shows the input and output voltages for added noise.

(c)

Figure 12 shows the frequency domain for added noise.

(d)

Figure 13 shows the input and output voltages for different values of Cn. The initial Cn used was 10\mu F which has noise visible on the output signal. For the middle subplot, a larger Cn of 1mF which eliminated most of the noise. For the bottom subplot, an even larger Cn of 10mF resulted in the output signal oscillating.

(e)

Figure 14 shows the input and output voltages for different numbers of timesteps. The upper subplot has 1000 timesteps. The lower subplot has 10 000 timesteps. The subplot with more timestpes appears to be more noisy. This is due to the higher sampling rate.

Question 4 - Non-linearity

(a)

In order to implement a non-linear output stage voltage, the B matrix would need to be used. The new MNA equation that should be used is:

$$C\frac{dV}{dt} + GV + B\left(V\right) = F\left(t\right)$$

(b) The MNA equation should be rearranged to the form:

$$\left(\frac{C}{\Delta t} + G\right)V_n - \frac{C}{\Delta t}V_{n-1} + -B\left(V\right) - F\left(t\right) = 0$$

Newton Raphson would need to be solved iteratively. I would create a H matrix. This H matrix would be used to iteratively solve for the V matrix.

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