ELEC 4700

Assignment 4

Circuit Modeling

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Date: Sunday, April 11, 2021.

Introduction

In assignment 4, an electrical circuit was modelled and simulated with the goal of understanding its properties.

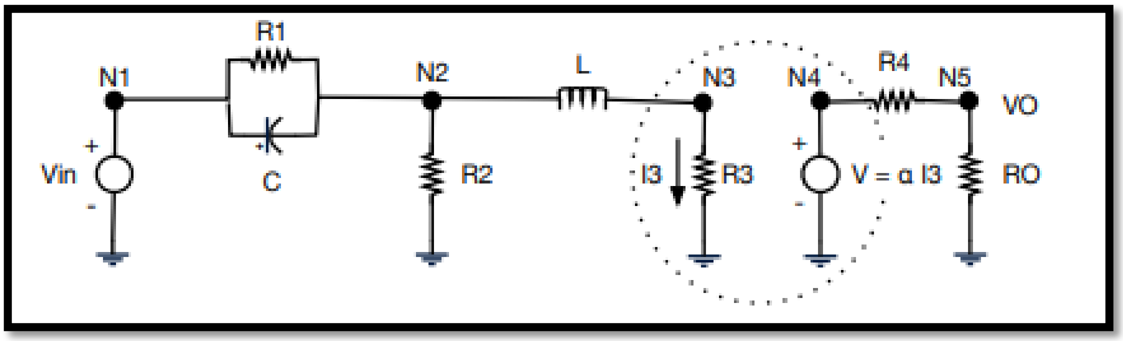


Figure 1: Circuit Diagram

The circuit diagram in figure 1 was modelled using various software techniques.

The Voltage Sweep to Determine the R_3 Resistor

From assignment 3 techniques, a voltage sweep was performed on the device and a plot of the current was derived for each test case in the x-direction. Furthermore, the resistance value from the linear fit of the current and voltage, was used to represent the R_3 resistor.

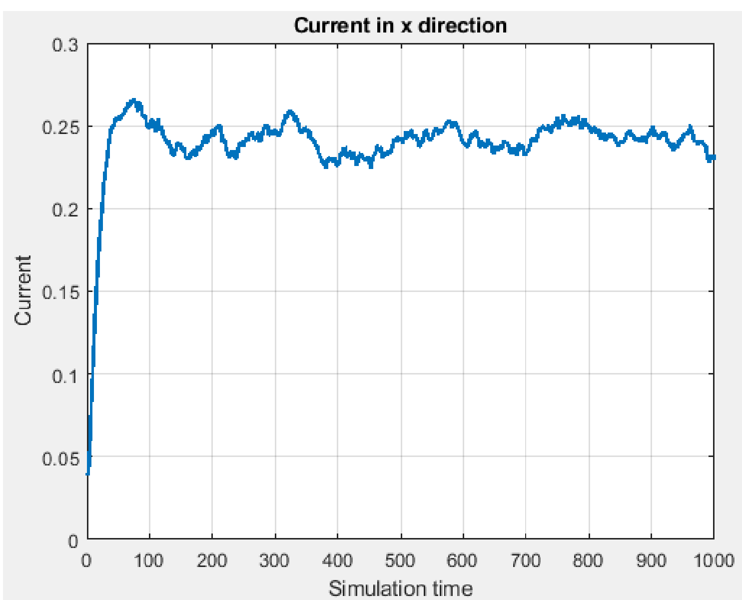


Figure 2: Current in the x-direction for the applied voltage

From figure 2 above, shows the current in the x-direction for the applied voltage of 10V. The average current for each applied voltage in the range of 0.1V to 10V was calculated and these average current values were plotted using a linear fit to model the current values for the voltage sweep.

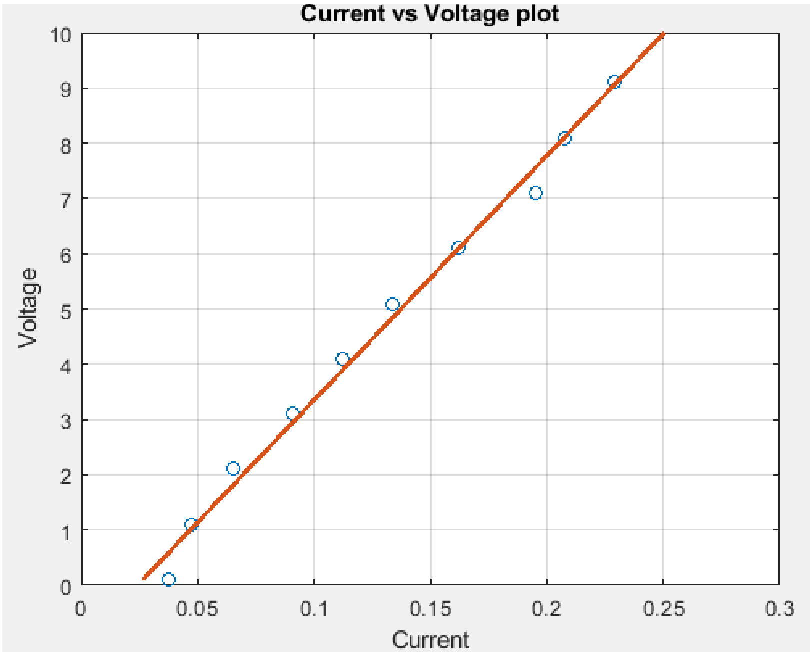


Figure 3: Linear Fit for the Current values for each case in the applied voltage sweep

Using the equation for a line to model the slope;

Where;

$$Y = mx + b, where\ m = resistance$$

$$m = 10.23 => R_3 = 10.23\Omega$$

The value from the slope was used to represent the resistance value for the R_3 resistor.

Circuit Simulation

The G matrix from the circuit shown in Figure 1 above, is shown below:

G =

1.0000	-1.0000	0	0	0	0	1.0000	0
-1.0000	1.5000	0	0	0	1.0000	0	0
0	0	0.0226	0	0	-1.0000	0	0
0	0	0	10.0000	-10.0000	0	0	1.0000
0	0	0	-10.0000	10.0010	0	0	0
0	1.0000	-1.0000	0	0	0	0	0
1.0000	0	0	0	0	0	0	0
0	0	-10.0000	1.0000	0	0	0	0

Furthermore, the C matrix is shown below:

C =

0.2500	-0.2500	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	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

DC Sweep

In this part, the DC sweep was performed from the input to the output voltage and was solved for each case.

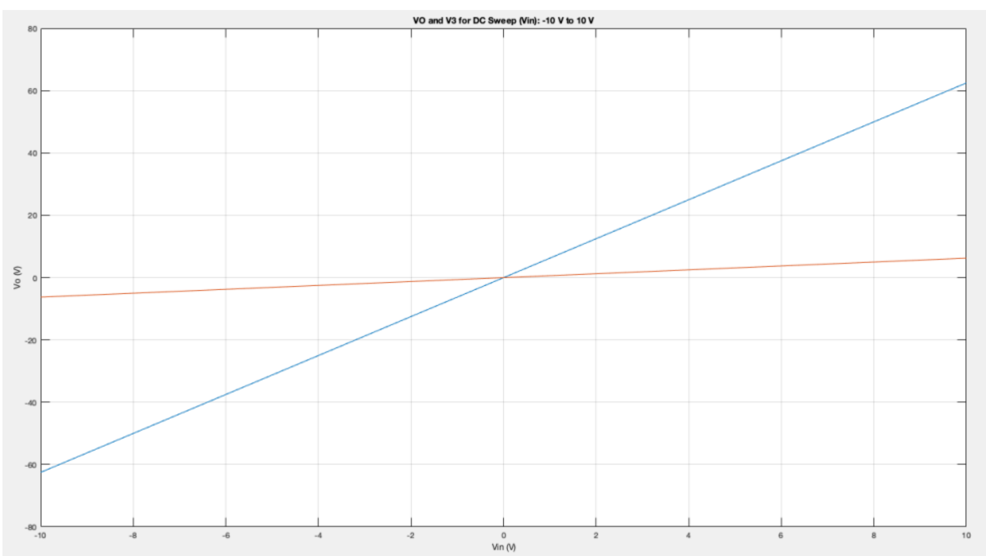
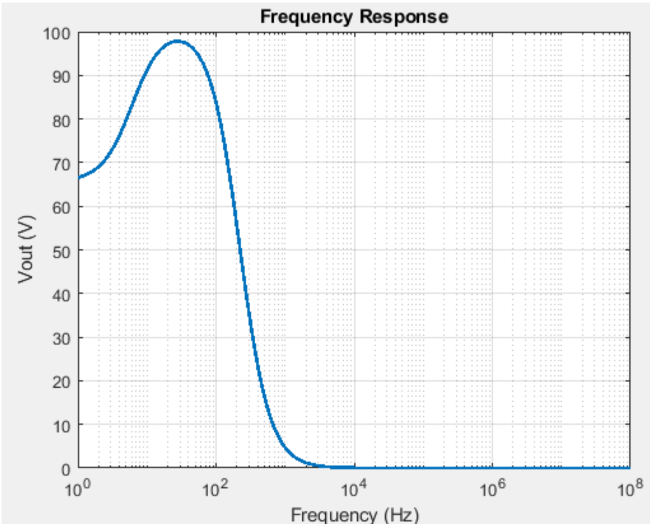


Figure 4: The DC sweep from the input to the output voltage

AC Case of Gain

The gain and the output voltage for the AC gain case of the applied input voltage of 10V, is shown below:



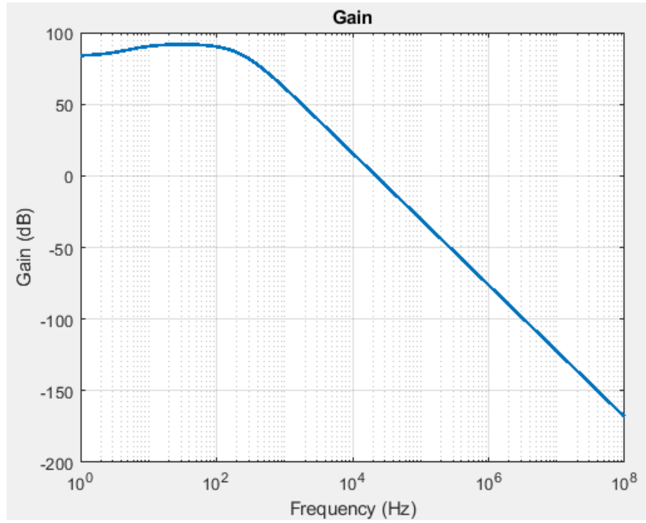


Figure 5: Showing the AC Frequency Response and Gain

From figure 5 above, having the AC frequency response and gain, we see the output voltages for various frequencies and we can use this to determine the 3dB point and filter types.

Histogram Gain

Using the normal distribution with std = .05 at w = π, the histogram of the gain is shown below:

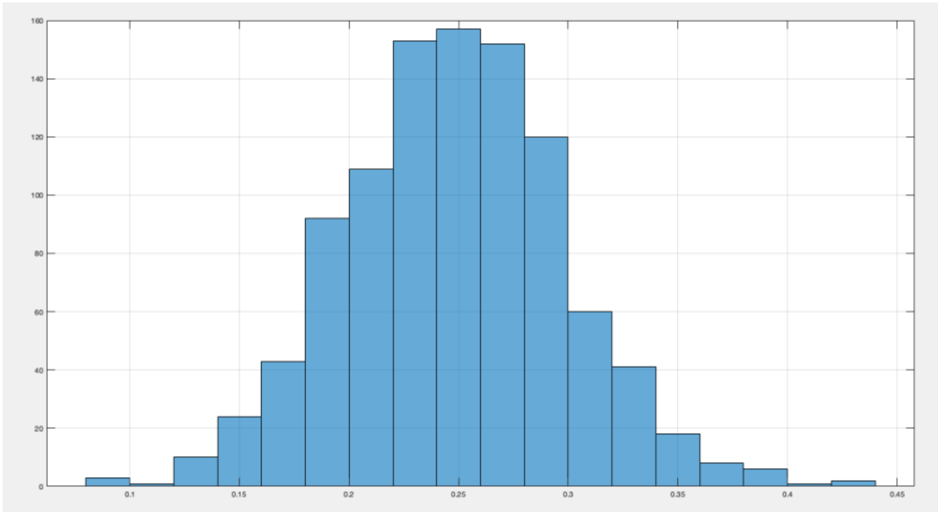


Figure 6: Histogram distribution for gain

From the histogram distribution in Figure 6 above, the gain is centered at 0.25.

Transient Circuit Simulation

The circuit was simulated in the time-domain by solving the equation:

$$F = C\frac{dV}{dt} + (G \times V)$$

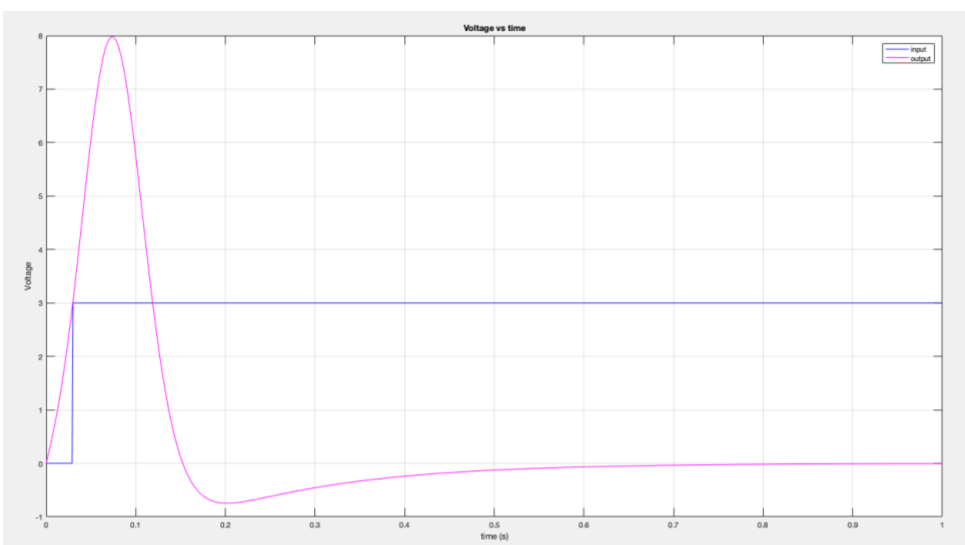


Figure 7: Plot of AC voltage for the step function

a) By inspection, this circuit is a low-pass filter

b) We expect the frequency response to cutoff high frequencies and allow low frequencies to pass. Furthermore, above certain frequencies, the corner frequency attenuation occurs.

d) The accuracy of the simulation is decreased as the time-step is increased

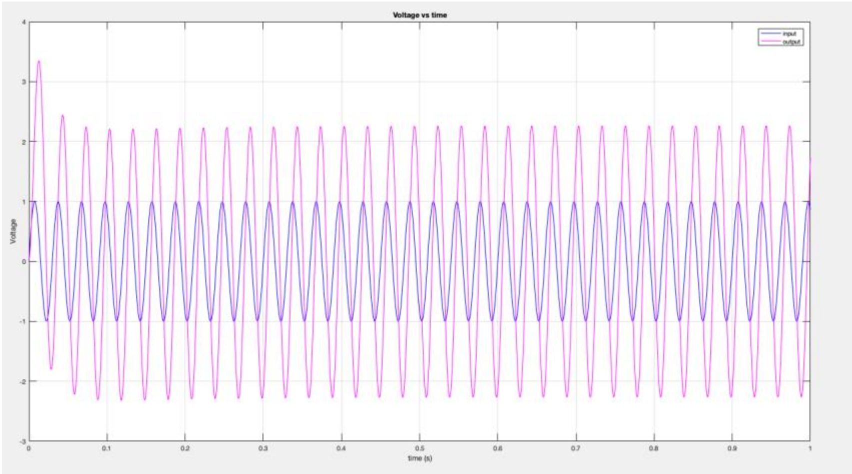


Figure 8: AC response for the sine signal

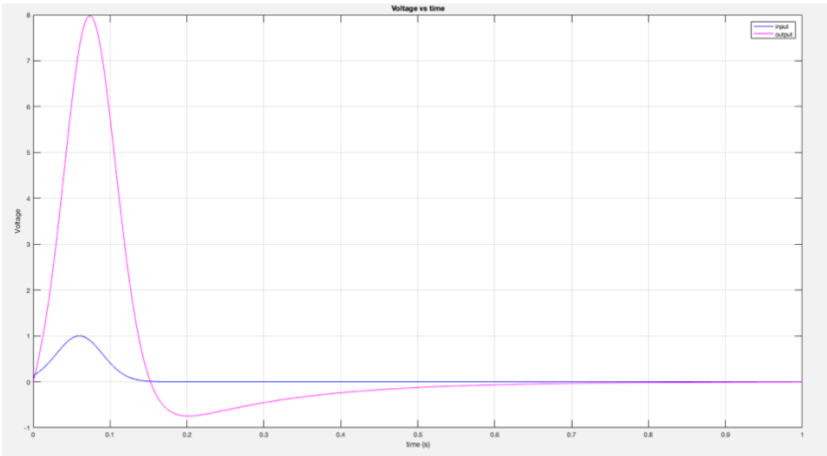


Figure 9: Plot of voltage vs time with input and output

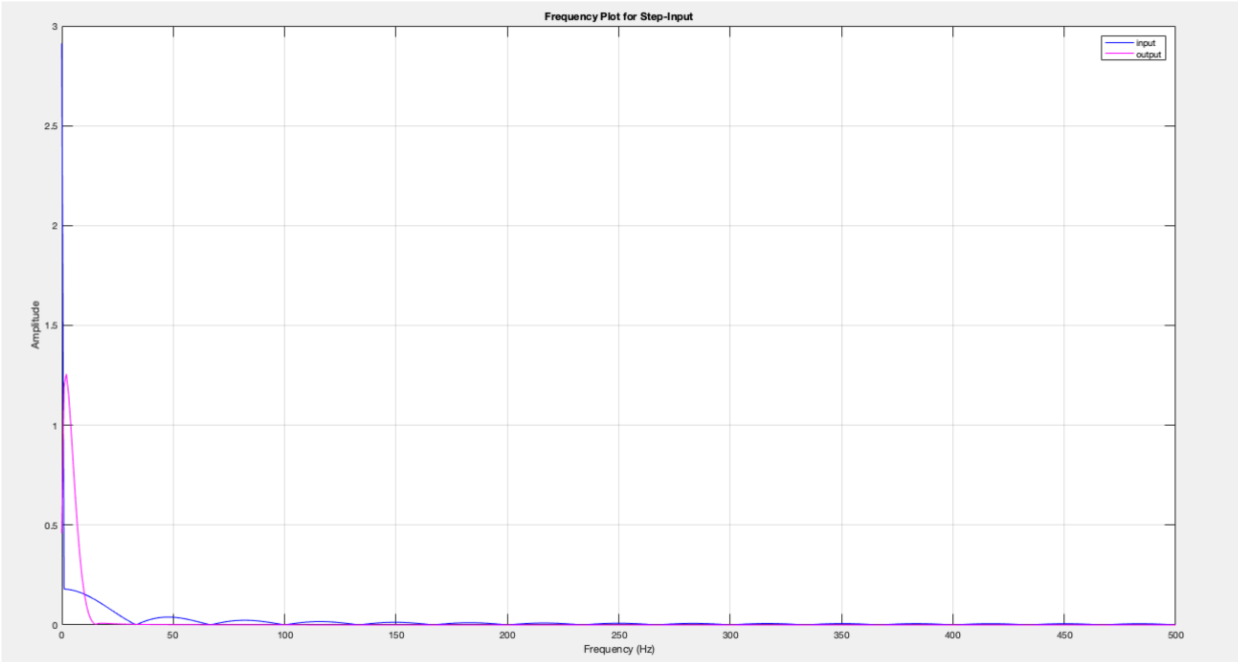


Figure 10: Plot of amplitude vs frequency for given step-inputs

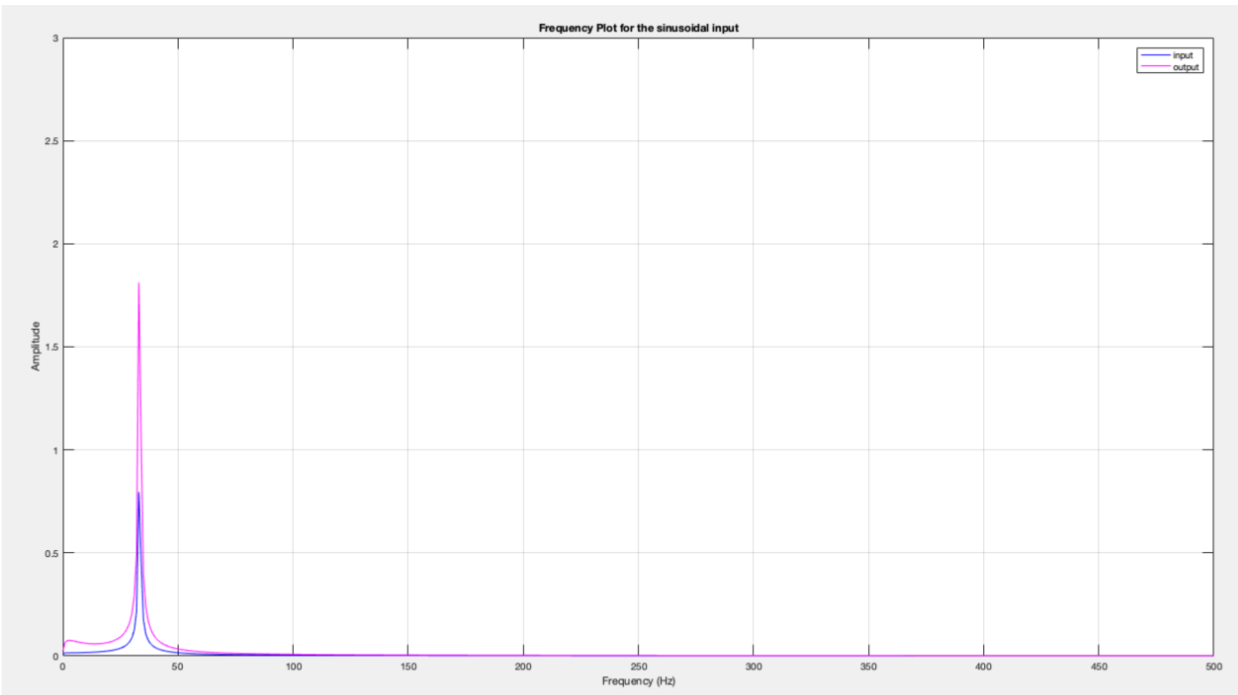


Figure 11: Plot of amplitude vs frequency for given sinusoidal-inputs

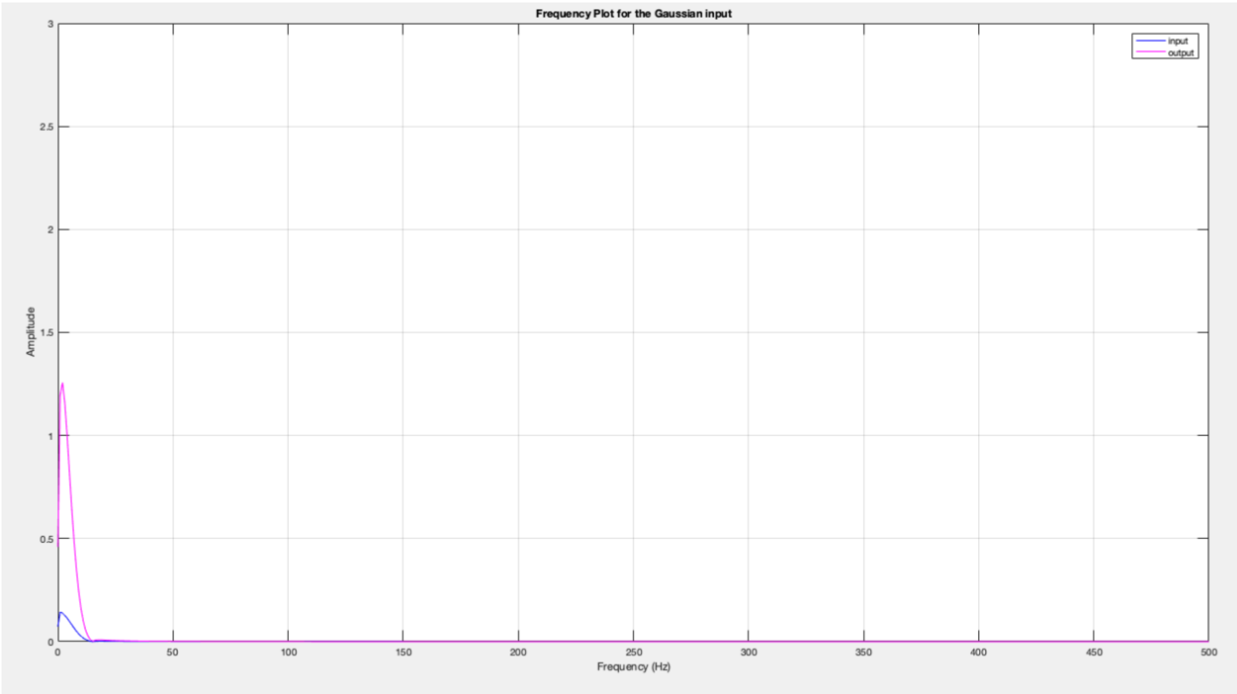


Figure 12: Plot of amplitude vs frequency for given Gaussian-inputs

Updated 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
```

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];
```

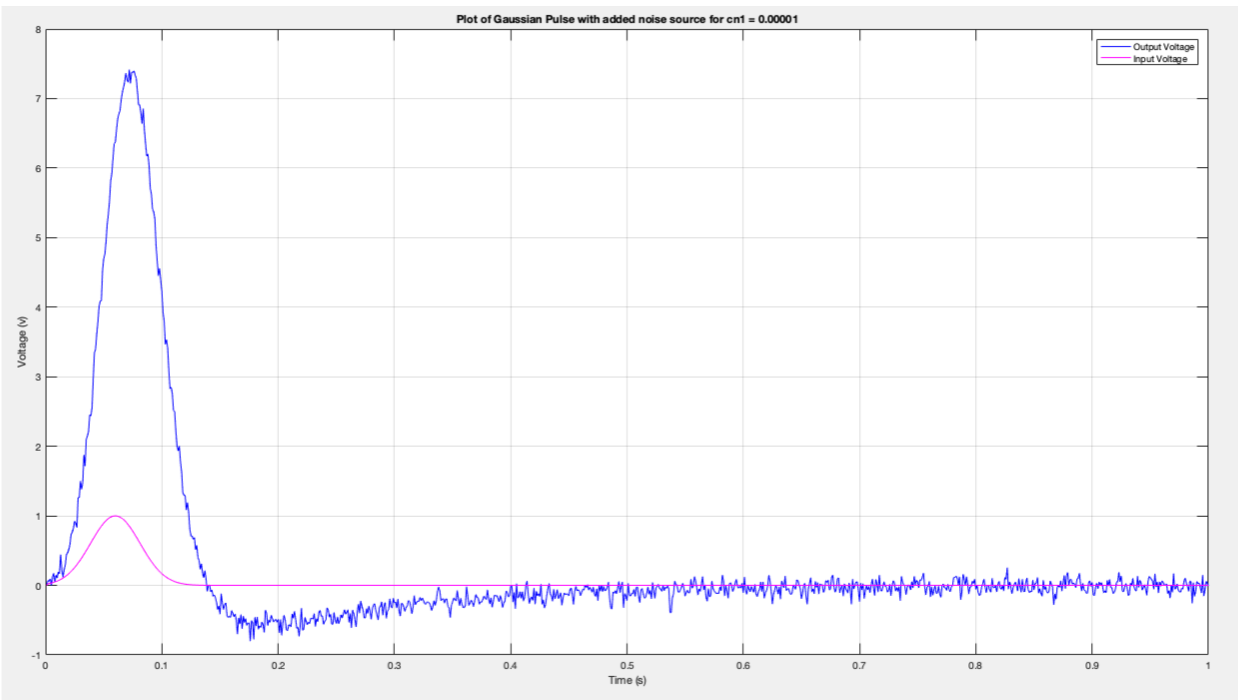


Figure 13: Voltage vs time plot for added noise sources and cn1 = 0.00001

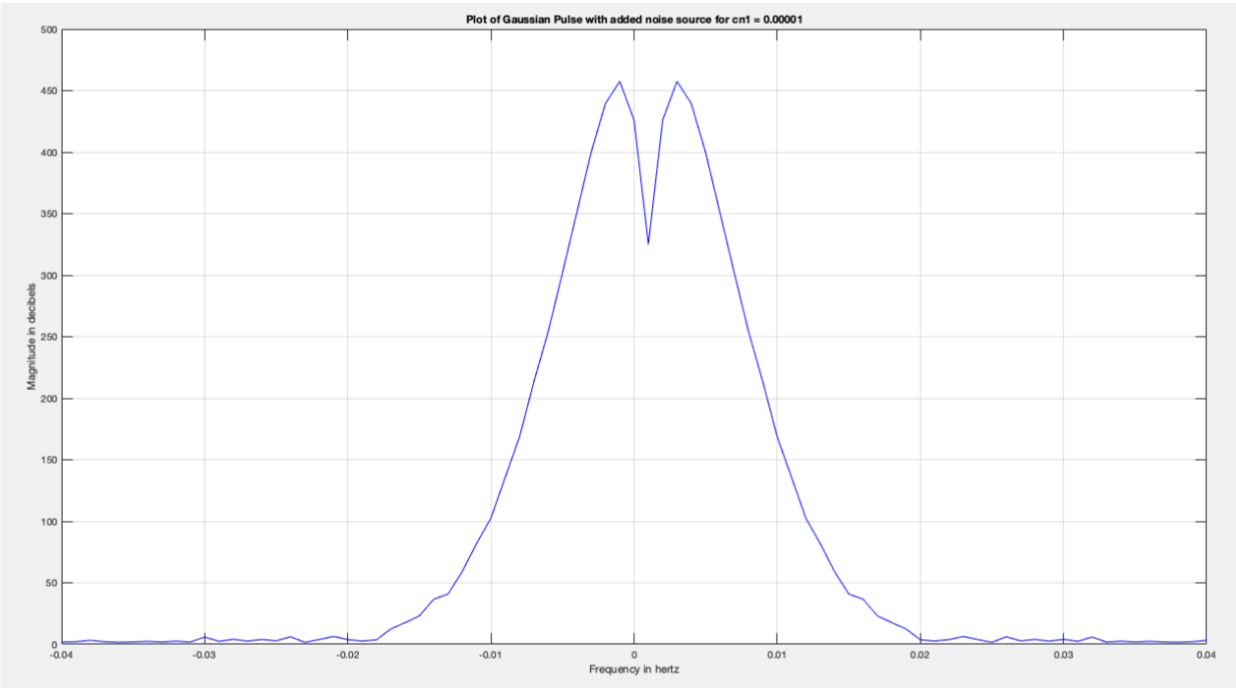


Figure 14: Plot of Gaussian plot with Fourier transform for cn1

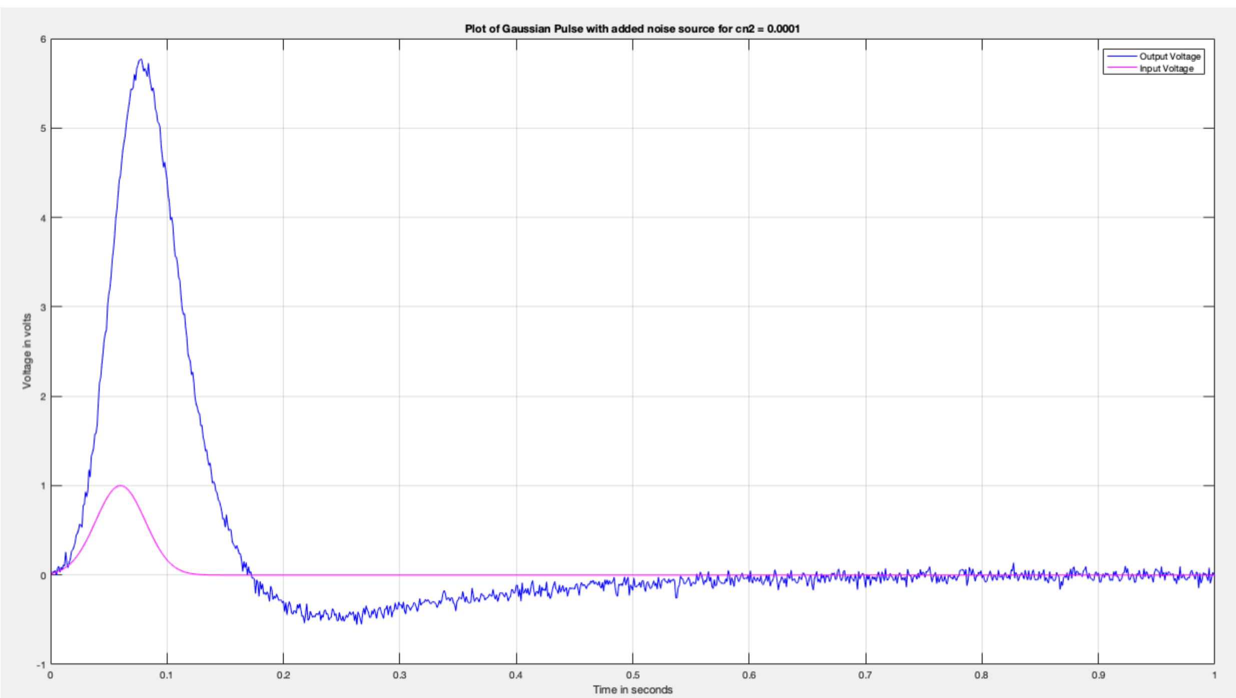


Figure 15: Voltage vs time plot for added noise sources and cn2 = 0.00001

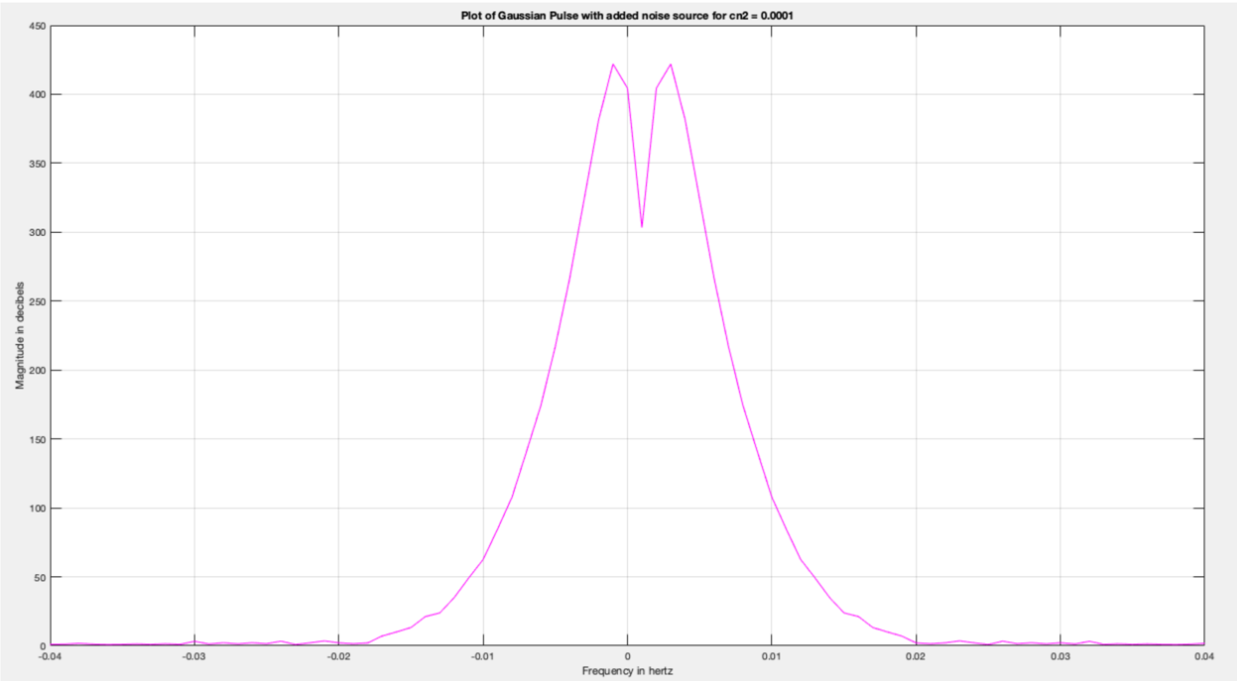


Figure 16: Plot of Gaussian plot with Fourier transform for cn2

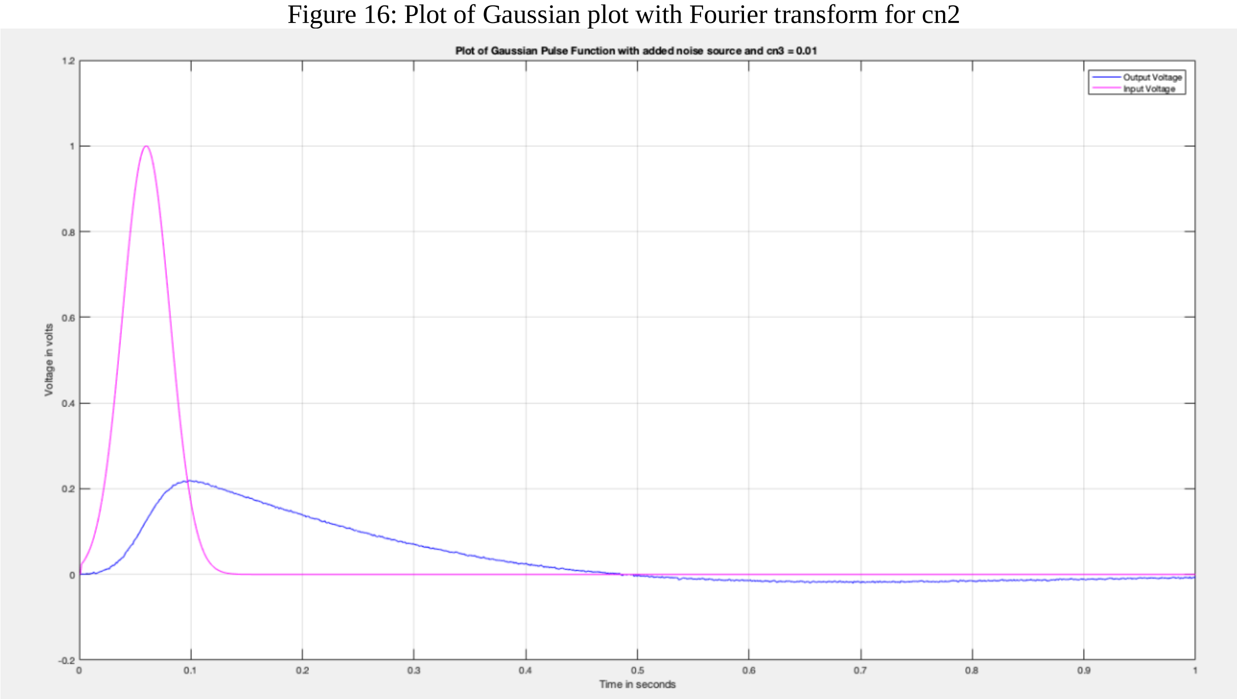


Figure 17: Plot of Gaussian pulse function for cn3

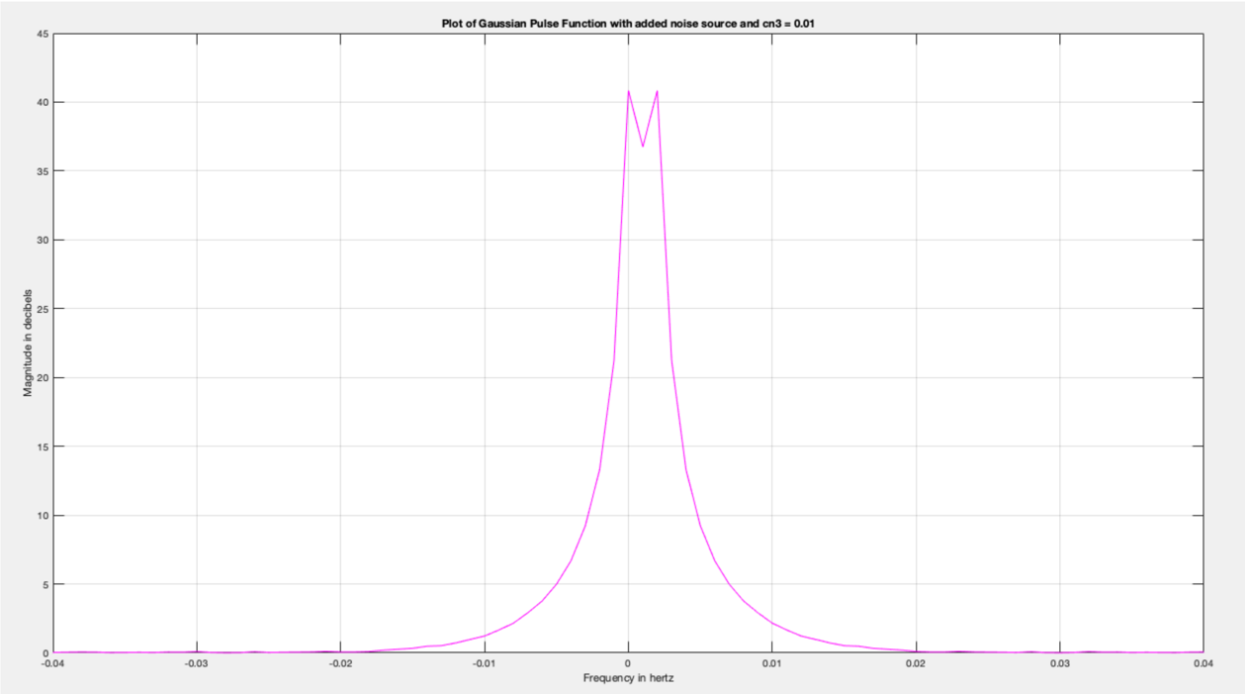


Figure 18: Plot of Gaussian plot with Fourier transform for cn3

Conclusion

- As cn gets larger, the bandwidth tends to decrease and get smaller.

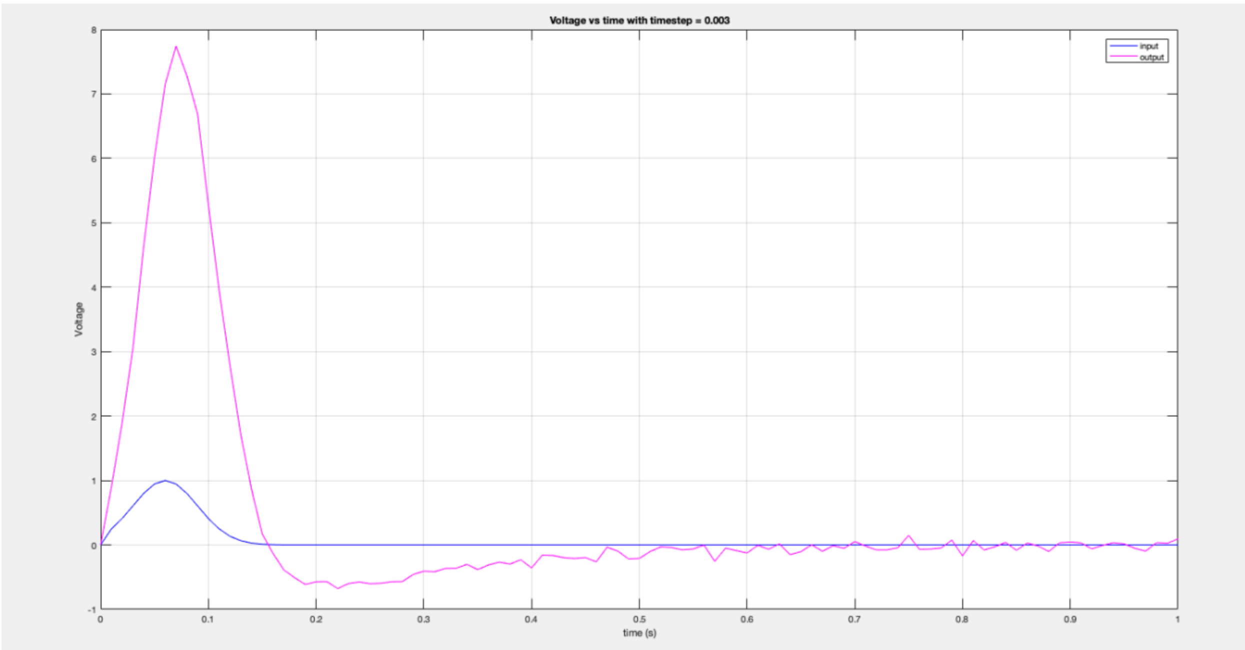


Figure 19: Plot of voltage vs time for the given time-step of 0.003

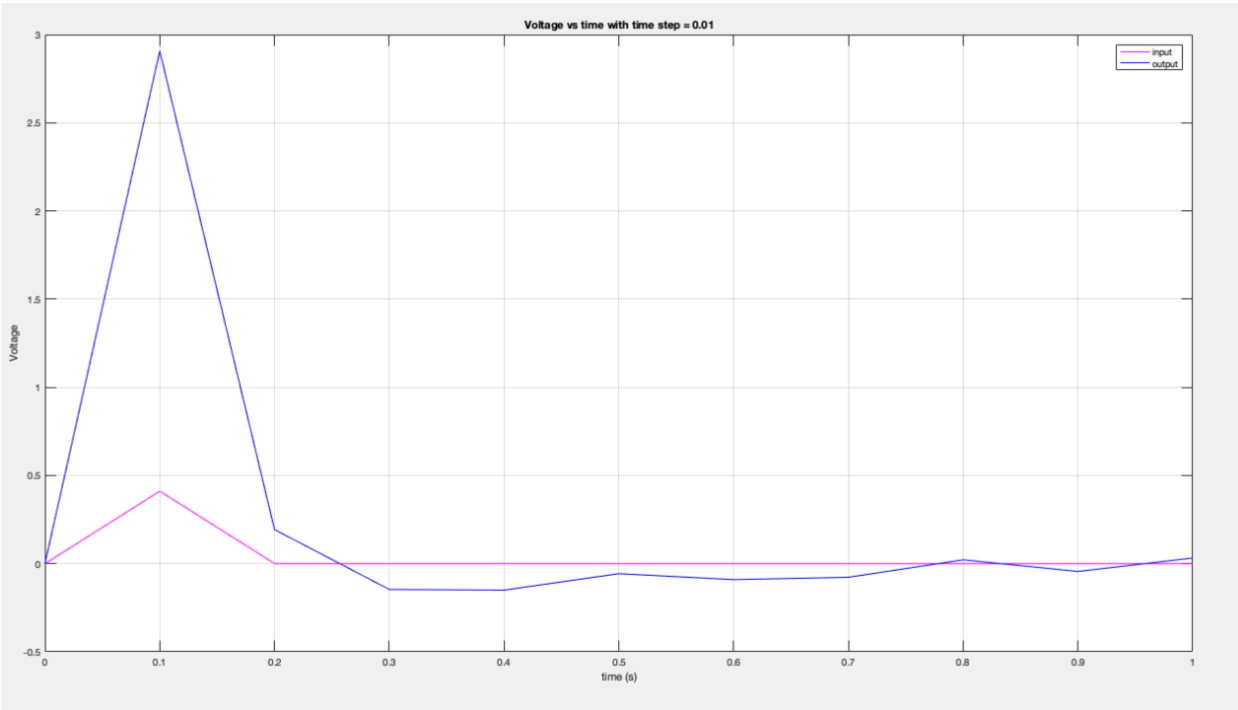


Figure 20: Plot of voltage vs time for the given time-step of 0.01

Conclusion:

- **Observation:** As the time-step increases, the accuracy of the simulation decreases.
- **Non-linearity:** In other to implement the non-linearity in MATLAB, an additional matrix would be needed to stamp the non-linear elements of the circuit and this would mean a new column vector of B(v) added. Furthermore, Newton Raphson method would be needed instead of Gaussian in this implementation.