

# COMPENG 4TL4 – Lab 3 Report

## Discrete Time Fourier Analysis and Filtering

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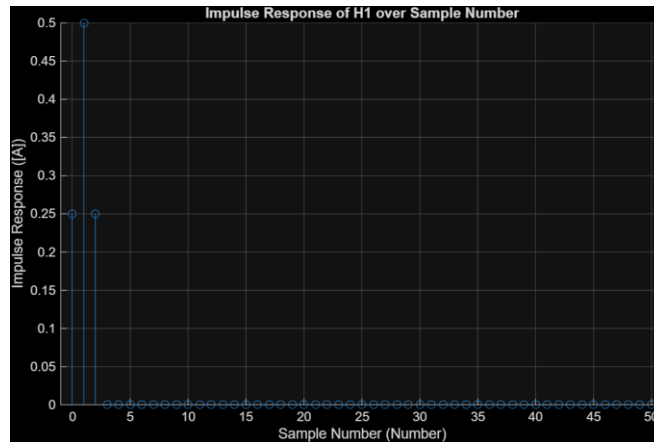
**Section:** L03

**Date Performed:** October 27, 2025

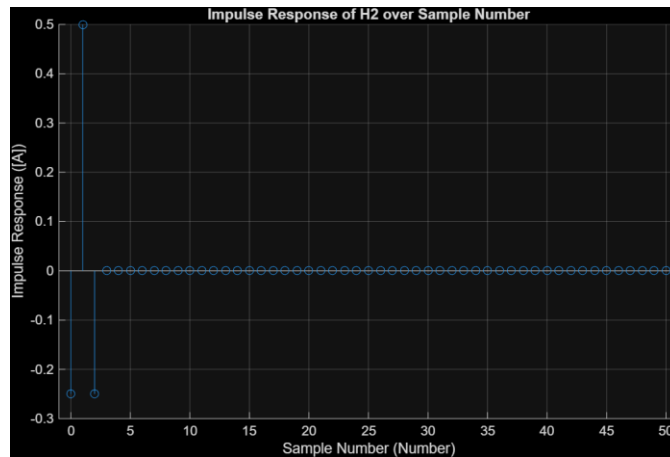
**Report Due:** November 7, 2025

### Introduction to Filtering

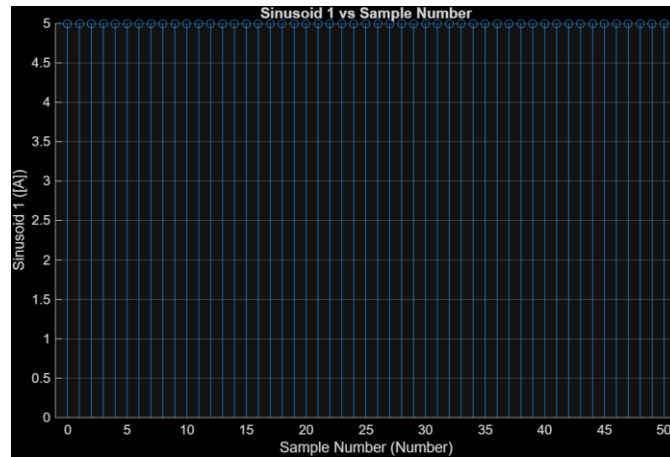
1 a) Consider two impulse responses and six discrete time sinusoidal signals:



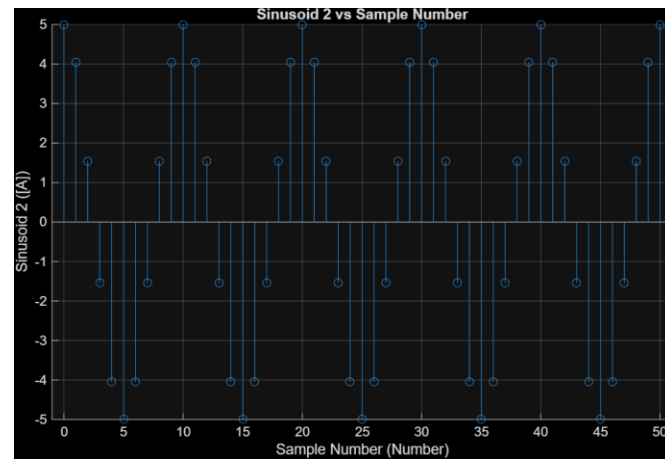
**Figure 1:** Impulse Response of H1



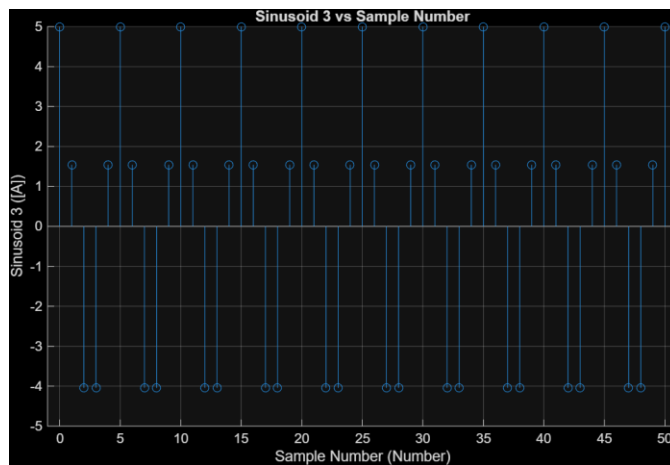
**Figure 2:** Impulse Response of H2



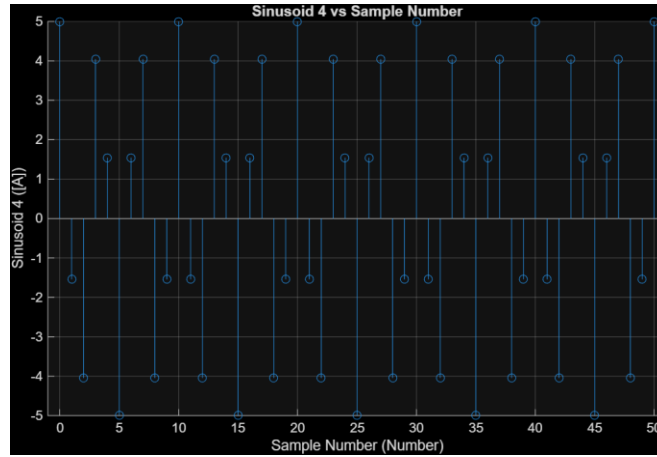
**Figure 3:** Plot of Sinusoid 1



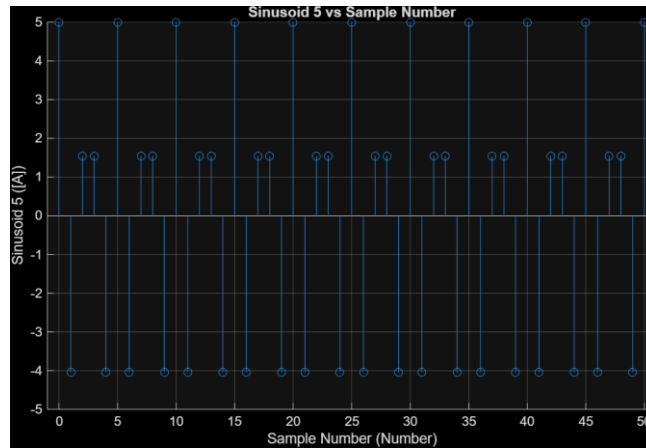
**Figure 4:** Plot of Sinusoid 2



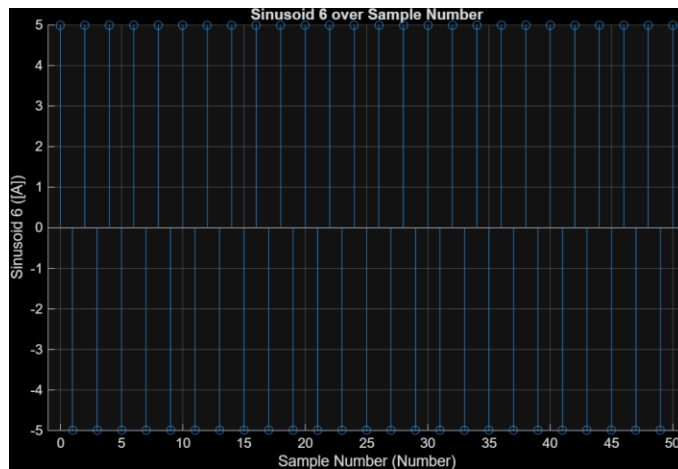
**Figure 5:** Plot of Sinusoid 3



**Figure 6:** Plot of Sinusoid 4



**Figure 7:** Plot of Sinusoid 5



**Figure 8:** Plot of Sinusoid 6

1 b) Calculate the energy in each signal using RMS:

The energy in each signal is:

$X_1 = 5.000000000000000$

$X_2 = 3.570027736477083$

$X_3 = 3.570027736477083$

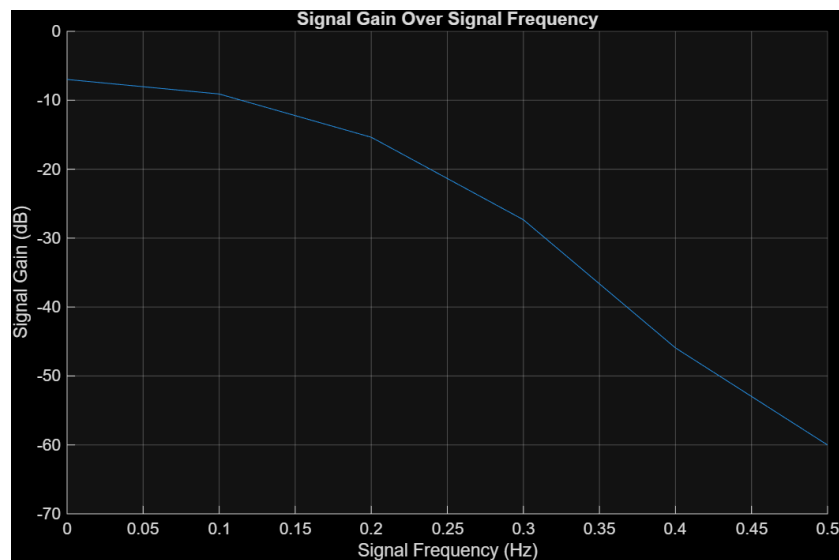
$X_4 = 3.570027736477085$

$X_5 = 3.570027736477083$

$X_6 = 5.000000000000000$

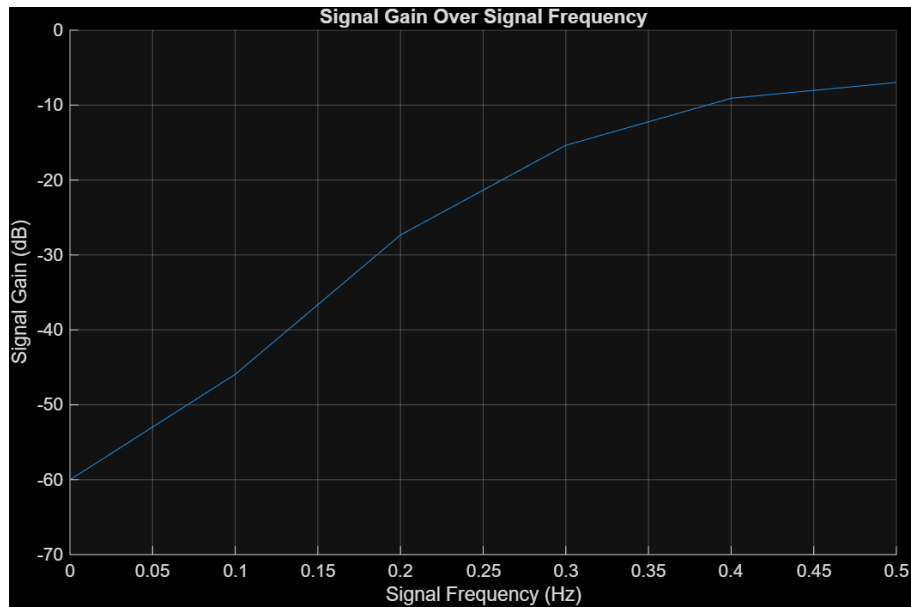
The energy for signal  $X_1$  and  $X_6$  makes sense as the cosine with that frequency results in cosine going to 1 and therefore only the constant participates in the energy of the signal. We still get an RMS value for the other signals as this is a discrete representation, so we don't have all samples such that they perfectly cancel out.

1 c) Convolve the first impulse response with each signal and calculate RMS of each output signal. Calculate difference between output and input RMS values for each of the signals in terms of system gain measured in decibels:



**Figure 9:** Gain of first impulse response system

1 d) Repeat part c with the impulse response H2:



**Figure 10:** Gain of second impulse response system

1 e) What are the differences between the two plots? What are the differences between the impulse response signals in terms of the frequencies of the input signals they pass?

The difference between the two plots is that the first plot attenuates high frequencies while the second impulse response shows that the system attenuates low frequencies. You can see that by convolving the input signals it will result in the low frequencies being passed using H1 and the high frequencies being passed using H2.

### The Discrete-Time Fourier Transform (DTFT)

2 a) We created the function `output_dtft(x,w)` in a separate MATLAB file, which returns the DTFT, where  $x$  is the input signal and  $w$  is the vector of angular frequencies at which the DTFT should be evaluated. The function creates a column vector for the  $n$  values, which ranges from 0 to length of input vector  $x - 1$ . Given  $n$ ,  $x$  and  $w$ , the function calculates the DTFT by performing element-wise multiplication between  $x'$  and  $e^{-j\omega n}$ , and summing all rows of each column.

2 b) Using the function from part (a), we calculate the DTFT of the impulse responses  $h_1[n]$  and  $h_2[n]$  for frequencies in range  $[-3\pi, 3\pi]$ . We used 100 samples for a smooth plot.

The resulting DTFT values are complex numbers. This is correct because in our DTFT computations, we multiply our input signal with  $e^{-j\omega n}$ , which makes our resulting signal complex since  $e^{jm}$  adds a phase shift of  $m$  radians to whatever it multiplies. This also aligns with our knowledge of DTFT, since we know the DTFT of a signal will have a magnitude component and a phase component, which are the components of complex numbers. The below MATLAB output of  $H_1(w)$  verifies our understanding.

H\_1 =

Columns 1 through 4

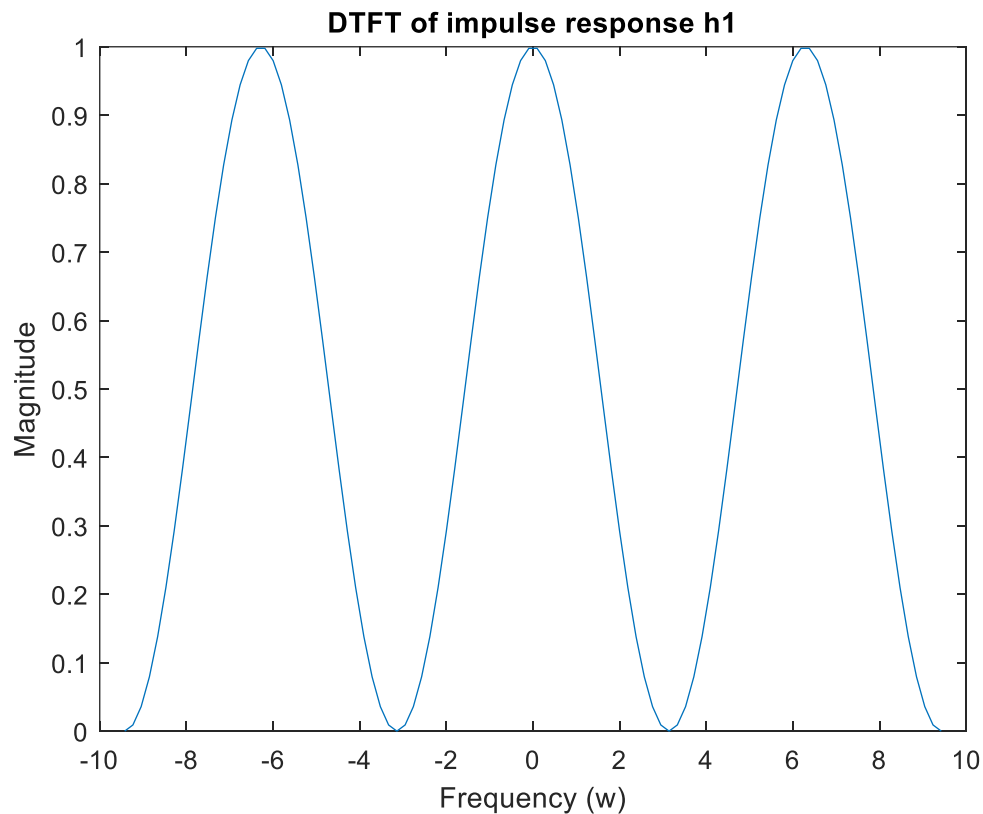
0.0000 + 0.0000i -0.0089 + 0.0017i -0.0333 + 0.0133i -0.0668 + 0.0429i

Columns 5 through 8

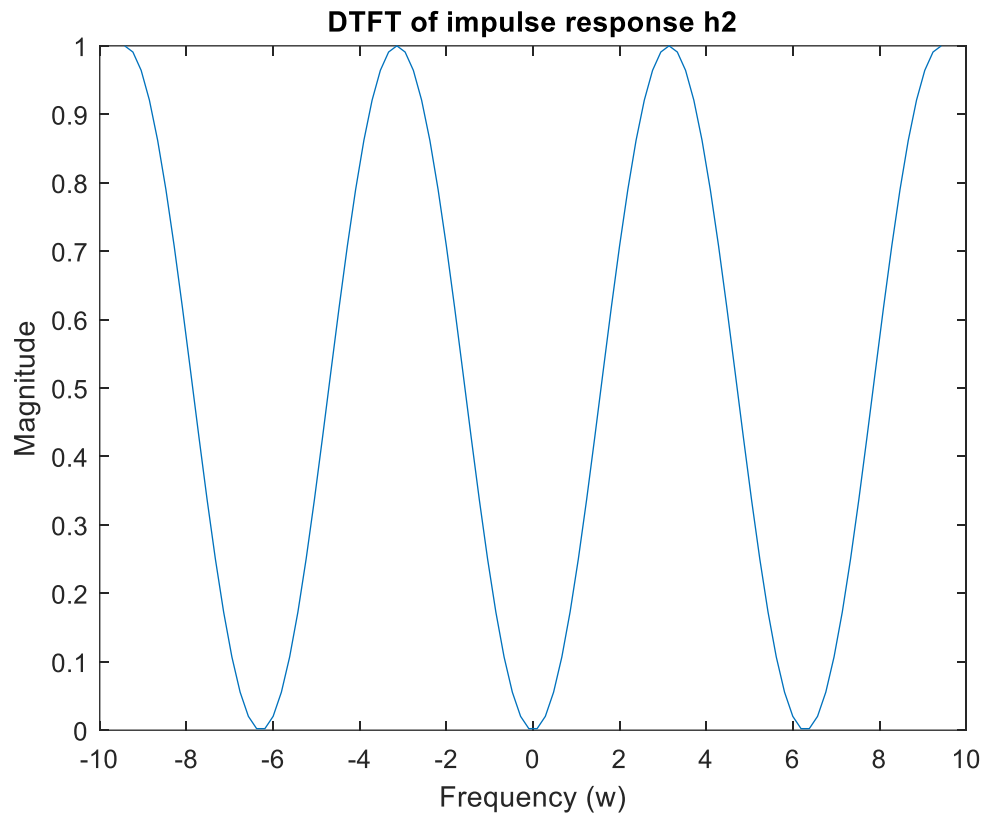
-0.1000 + 0.0953i -0.1218 + 0.1710i -0.1214 + 0.2659i -0.0901 + 0.3713i

**Figure 11:** First 8 elements of  $H_1(w)$ , the DTFT of impulse response  $h_1[n]$

2 c) With the DTFT of the impulse responses  $h_1[n]$  and  $h_2[n]$  evaluated at the frequencies  $w$ , we plot the magnitude of  $h_1[n]$  and  $h_2[n]$  vs.  $w$ . For both the plots of  $H_1(w)$  and  $H_2(w)$ , we observe periodicity with a period of  $2\pi$ . This is because in the complex plane, for any angle  $w$ ,  $w = w + 2\pi$ . This can be observed in the plots below.



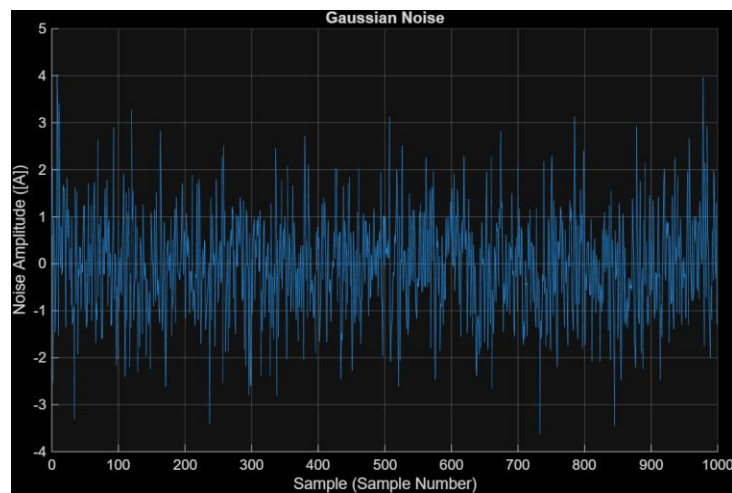
**Figure 12:** Magnitude plot of  $H_1(w)$ , the DTFT of impulse response  $h_1[n]$



**Figure 13:** Magnitude plot of  $H_2(\omega)$ , the DTFT of impulse response  $h_2[n]$

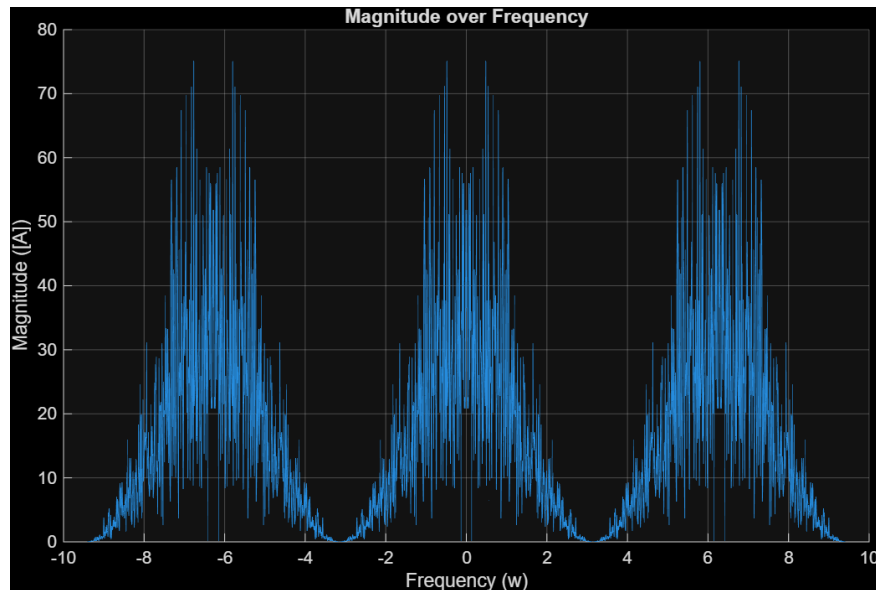
### Filtering White Gaussian Noise

3 a)

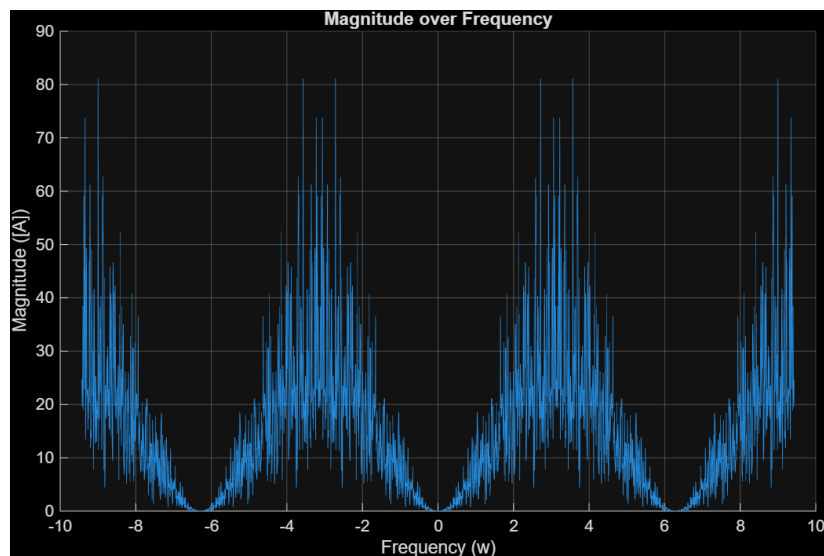


**Figure 14:** White Gaussian Noise

3 b) Looking at the Magnitude over Frequency plot of the first system in Figure 15, we see that it agrees as only the low frequencies get passed through (signal centered around zero has the highest peak at zero). Looking at the Magnitude over Frequency plot of the second system in Figure 16, we see that the high frequencies have been let through as the peak that was at zero has dropped to zero and now there are only peaks at higher frequencies (before repeating).



**Figure 15:** White Gaussian Noise convolved with H1 (Lowpass filter)

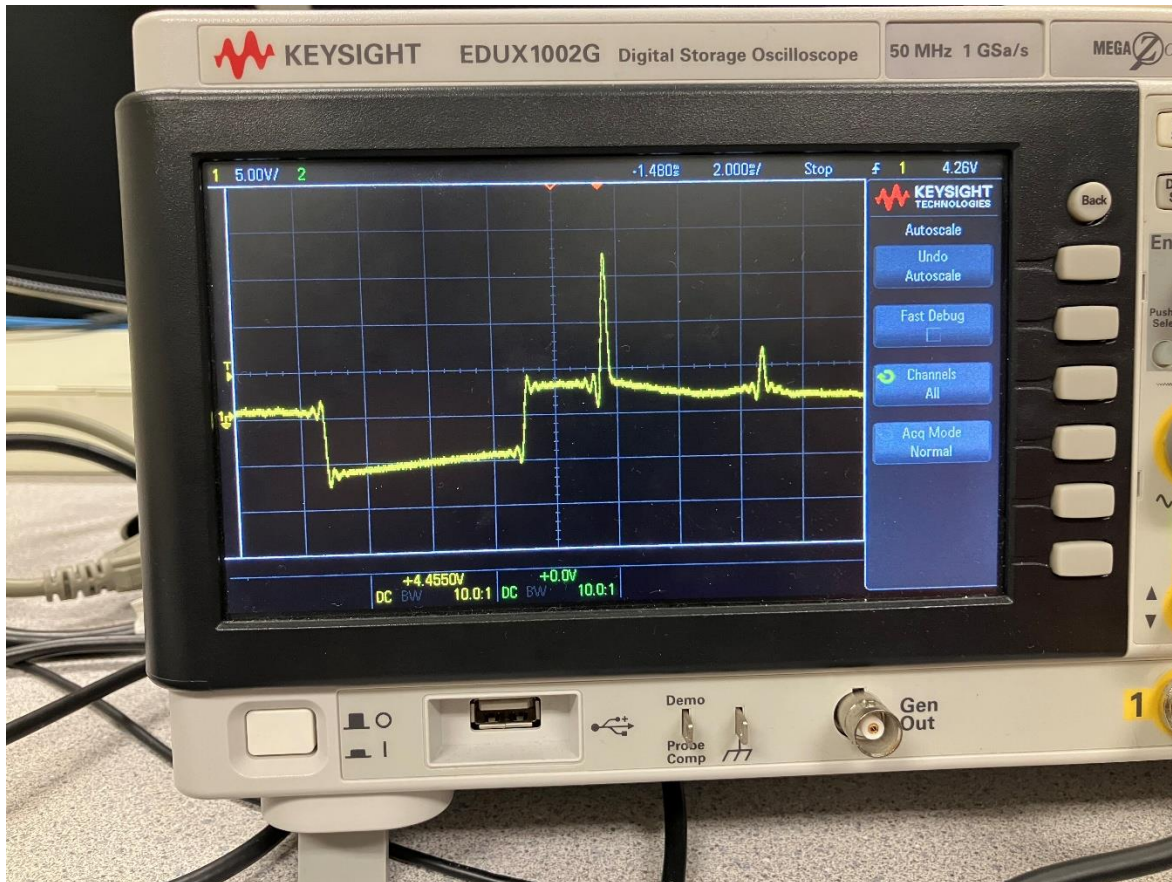


**Figure 16:** White Gaussian Noise convolved with H2 (High Pass Filter)

## Radar Data Target Detection with Convolution on the TMS 320 DSP Processor

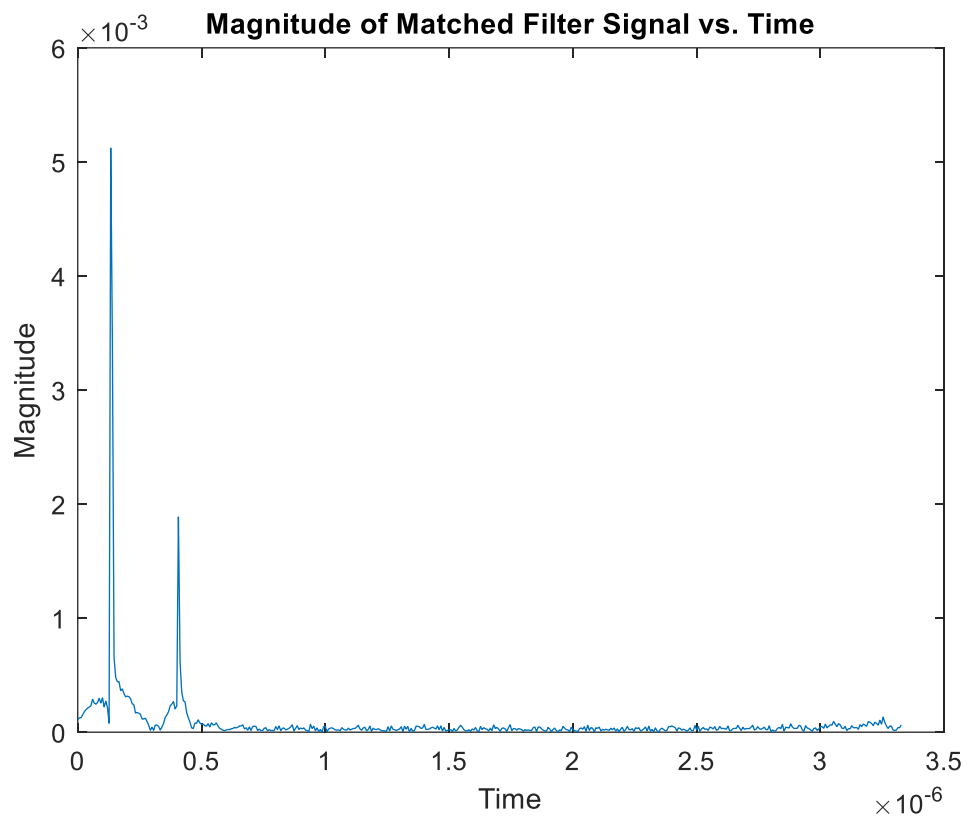
4 a) We read and understood the implementation of the matched filter.

4 b) After compiling and running the C code, we observe the signal below on the oscilloscope. From the observed signal, we see two pulses at different time delays. This tells us that there are two targets at different distances from the radar.



**Figure 17:** Signal obtained after the matched filter

Our C program exports this signal to a csv file, which we import into MATLAB. We plot the magnitude of our matched filter signal vs. time below. We found the sample points at which these peaks occur and estimate the range of the targets with the equation  $r = \frac{n_{peak}c}{2f_s}$ . Also below is the MATLAB output of the final estimated range of the two targets.



**Figure 18:** Magnitude of matched filter signal vs. time

```
range =  
  
    20  
    61
```

**Figure 19:** Estimated range of the two targets computed in MATLAB