INSTITUTE OF ENGINNERING , CENTRAL CAMPUS,PULCHOWK

SIGNAL ANALYSIS

ALL IN ONE

Visualization of Signals, Fourier Series & Transform, Convolution and Frequency Response

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Contents

List of Figures

List of MATLAB Codes

1 Signal Visualization

Signal is a function of one or more independent variables, which contain some information.Analog signal is a continuous signal in which one time-varying quantity represents another time-based variable and denoted as $x(t), y(t)$.A digital signal is a signal that is used to represent data as a sequence of separate values at any point in time denoted as $x[n], y[n]$.

1.1 Sinusoidal Signal

Sinusoidal signal is in the form of x(t) = A cos($w_0 \pm \phi$) or A sin($w_0 \pm \phi$). In matlab **sin** and **cos** function are used to calculate sine and cosine values and **plot** function to plot continuous Sinusoidal signal. **hold on** & **hold off** command is used to display both signal in single plot. Similarly **xlabel**, **ylabel** and **title** are used for Labeling purposes.

```
hold on
t=-10:0.01:10
y=sin(t)
plot(t,y,'r')
z=cos(t)
plot(t,z,'k')
xlabel('t')
ylabel('x(t), y(t)')
title('Visualization signal x(t) & y(t)')
hold off
```

MATLAB Code 1: Visualization of signal x(t) & y(t)

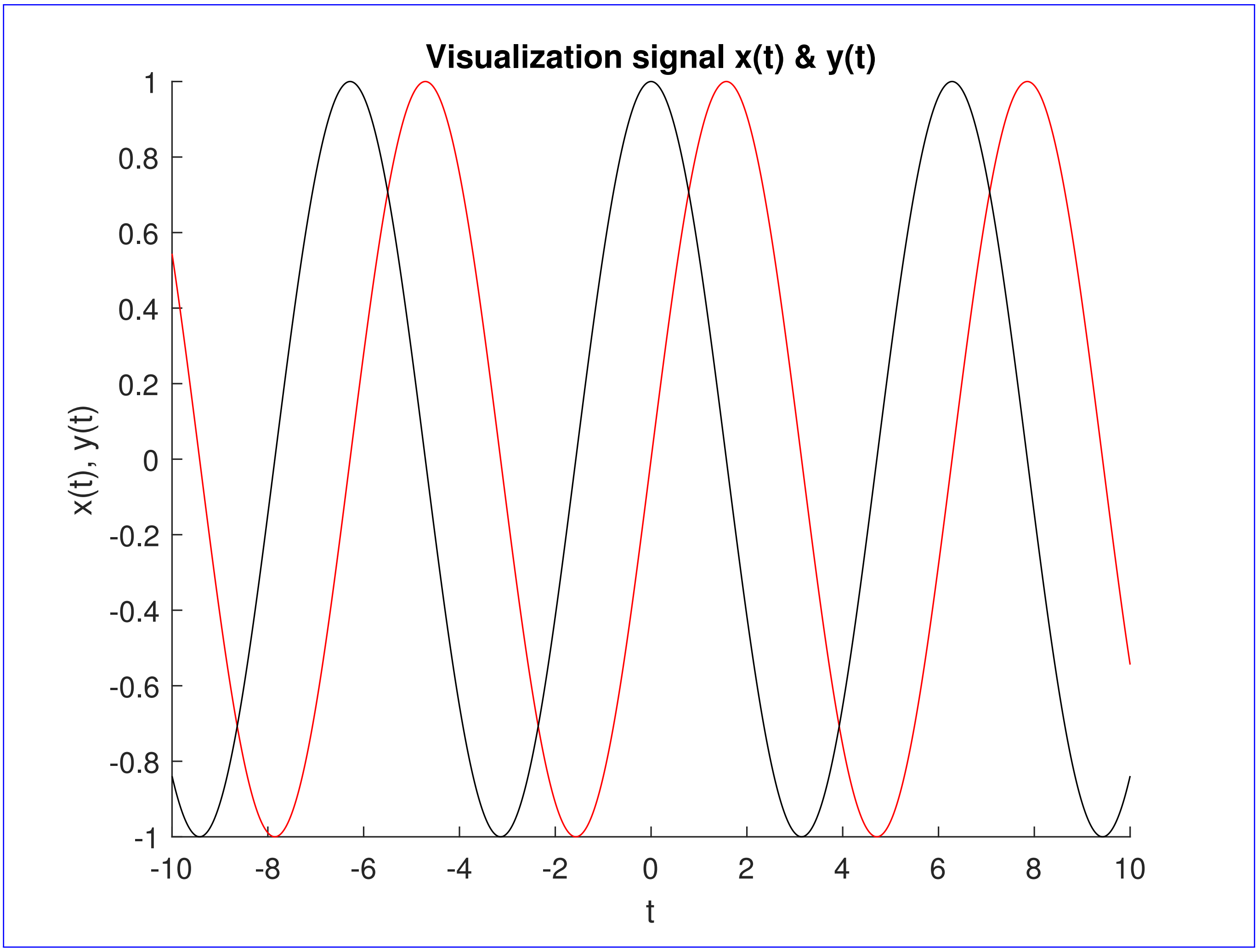

Figure 1: Visualization of Sinusoidal signal

1.2 Ramp Signal

Ramp signal is denoted by $r[n] = an$and $r(t) = at$ for discrete and continuous signal. To plot discrete signal **stem** function is used in MATLAB.

```
t=-10:0.01:10
n=-10:10
a = input('Enter the value of a: ')
y=a*t
z=a*n
subplot(2,1,1)
stem(n,z)
xlabel('n')
ylabel('r[n]')
title('Discrete')
subplot(2,1,2)
plot(t,y)
xlabel('t')
ylabel('r(t)')
title('Continuous')
```

MATLAB Code 2: Discrete and Continuous ramp Signal

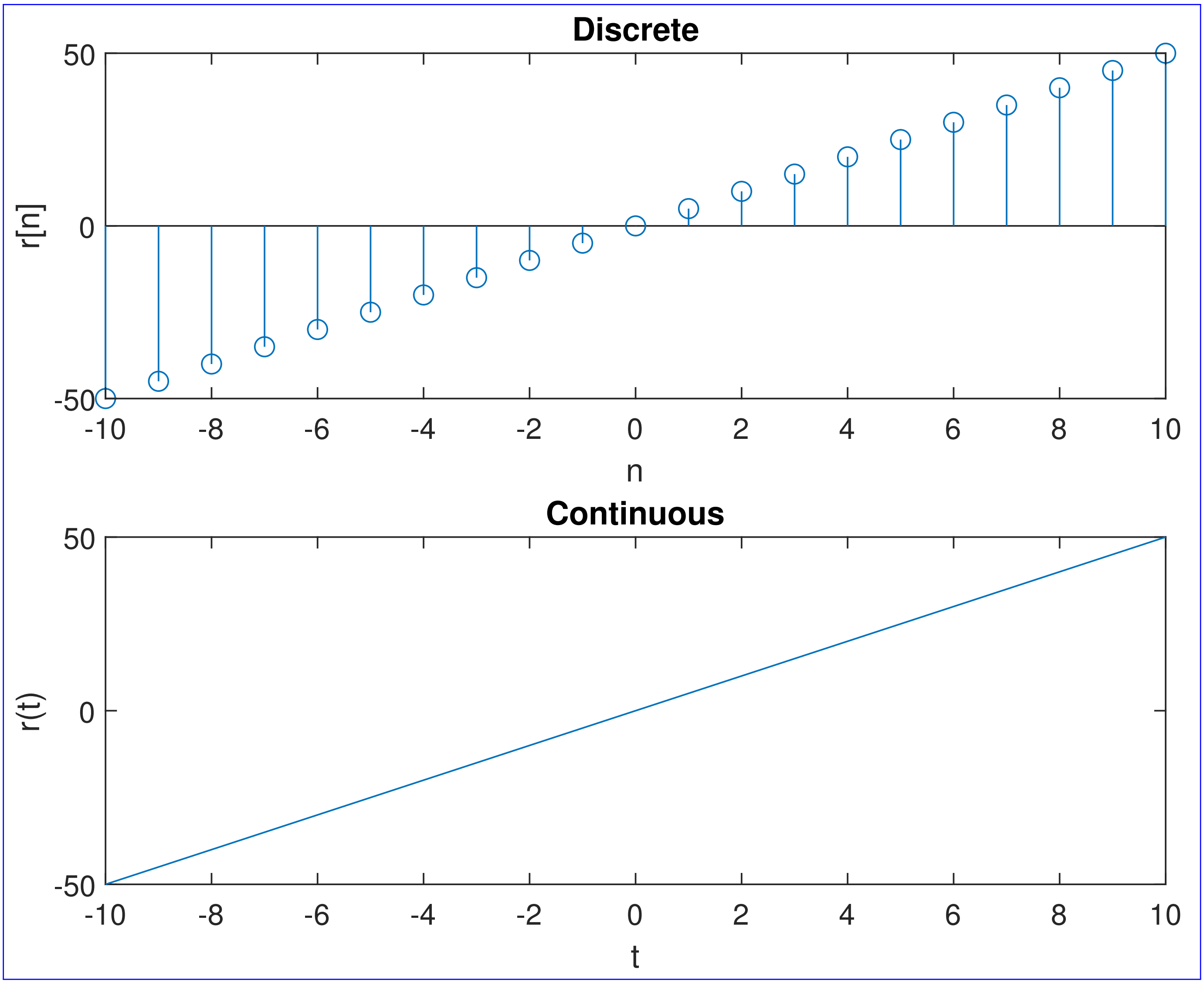

Figure 2: Discrete and Continuous ramp Signal when a=2

1.3 Exponential Signal

Continous time exponential signal $y(t) = ce^{(}at)$ and discrete time exponential signal $y[n] = ce^{(}an)$ were plotted using MATLAB.

```
t=-10:0.01:10
n=-10:10
c = input('Enter the value of c: ')
a= input('Enter the value of a: ')
y=c*exp(a*t)
z=c*exp(a*n)
subplot(2,1,1)
plot(t,y)
xlabel('t')
ylabel('y(t)')
title('Continuous Exponential Signal ')
subplot(2,1,2)
stem(n,z)
xlabel('n')
ylabel('y[n]')
title('Discrete Exponential Signal ')
```

MATLAB Code 3: Discrete and Continuous Exponential Signal

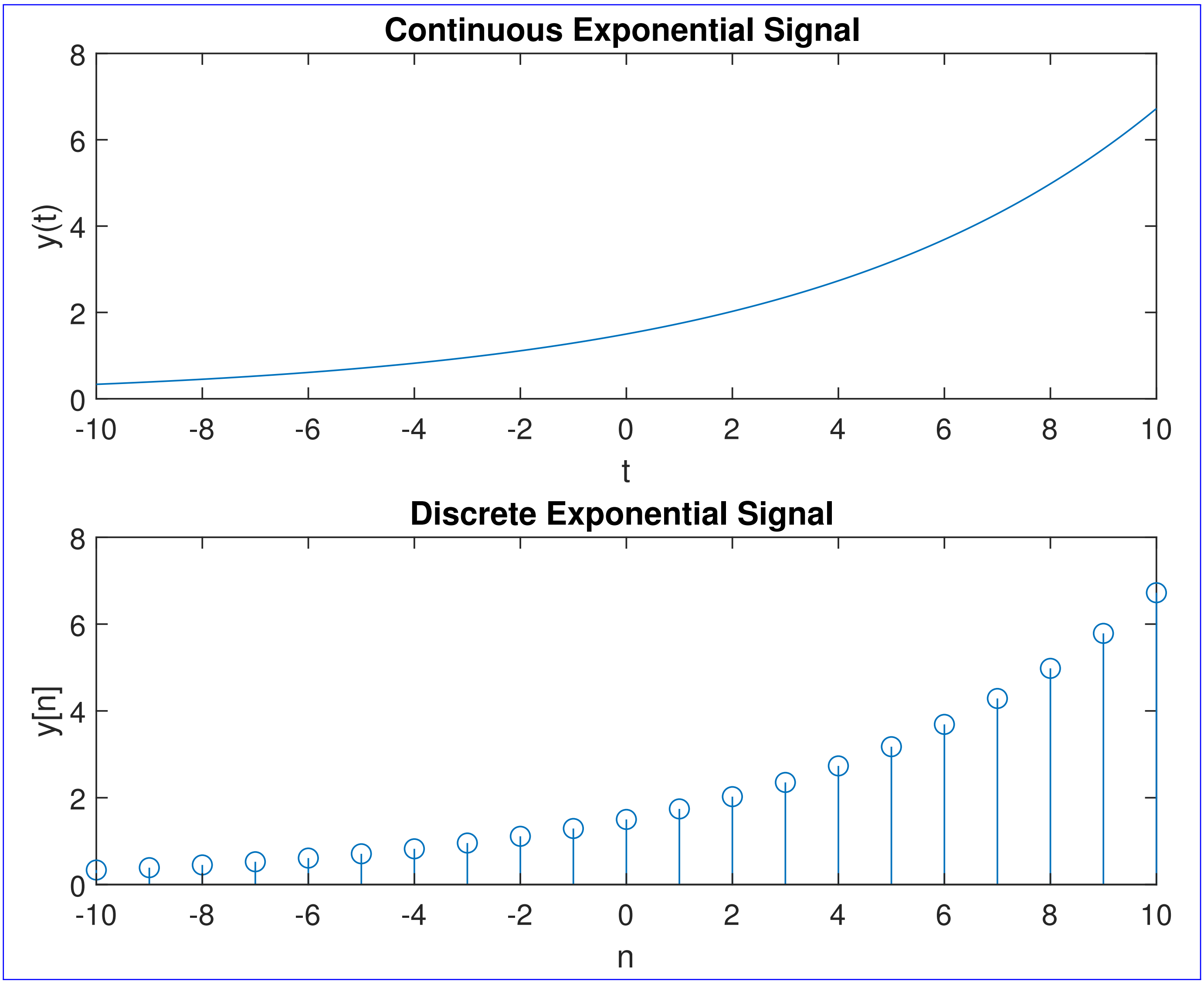

Figure 3: Discrete and Continuous Exponential Signal when c=1.5 & a=0.15

1.4 Unit Step Signal

u(t) & **u[n]** are continuous and discrete Unit step function which has value 1 for variable(t or n) $\geqq 0$

```
t=-10:0.01:10
y=zeros(size(t))
y(t>=0)=1
subplot(2,1,1)
plot(t,y)
xlabel('t')
ylabel('y(t)')
title('Continuous Unit Step Function')
subplot(2,1,2)
hold on
for n=-10:10
    if(n<0)
        stem(n,0)
    else
        stem(n,1)
    end
end
xlabel('n')
ylabel('y[n]')
title('Discrete Unit Step Function')
hold off
```

MATLAB Code 4: Discrete and Continuous Unit Step Signal

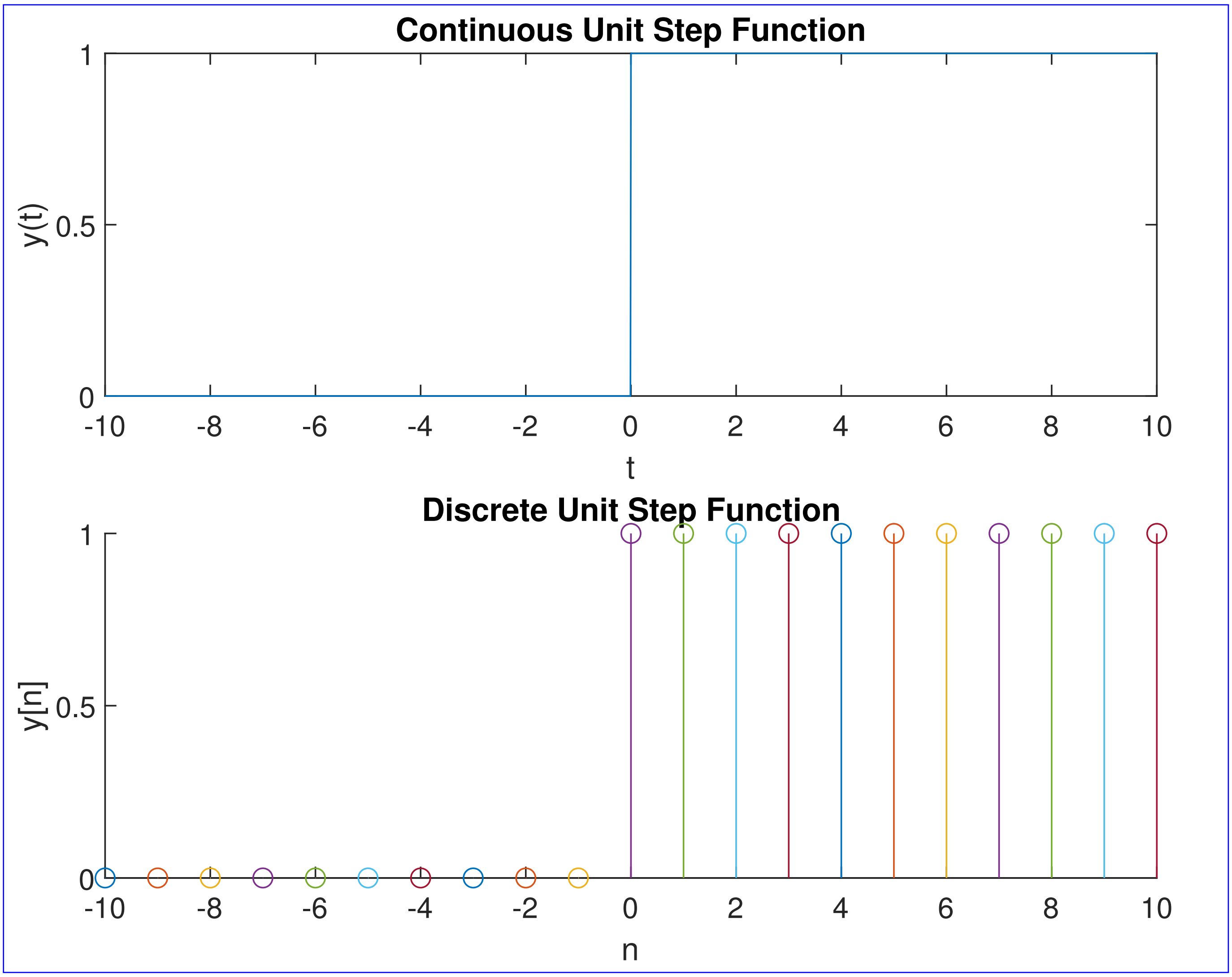

Figure 4: Discrete and Continuous Unit Step Signal

2 Fourier Series

A continuous time signal $x(t)$ with period T is represented by Fourier series as

$$x(t) = \sum_{k=-\infty}^{\infty} a_k e^{jkw_o t}$$

$$here, w_o = 2\pi/T$$

$$a_k = \int_T x(t) e^{-jw_o t}\, dx$$

The Fourier series representation of a square wave with period T and amplitude a is given by:

$$x(t) = \frac{4a}{\pi} \sum_{k=1}^{\infty} \frac{sin((2k-1)w_o t)}{2k-1}$$

The sum of all the odd harmonics of the sinusoidal signal forms a square wave approximation.So, we varies the no of terms in summation.

```
x=0
t=-10:0.01:10
a=40
w=5
n=input('Enter the value of n: ')
for i=1:2:n
```

```
x=x+(4*(a/pi))*(sin(i*w*t)*1/i)
end
plot(t,x)
xlabel('t')
ylabel('x(t)')
title('Fourier Series Representation of a Square Wave')
```

MATLAB Code 5: Fourier Series Representation of a Square Wave

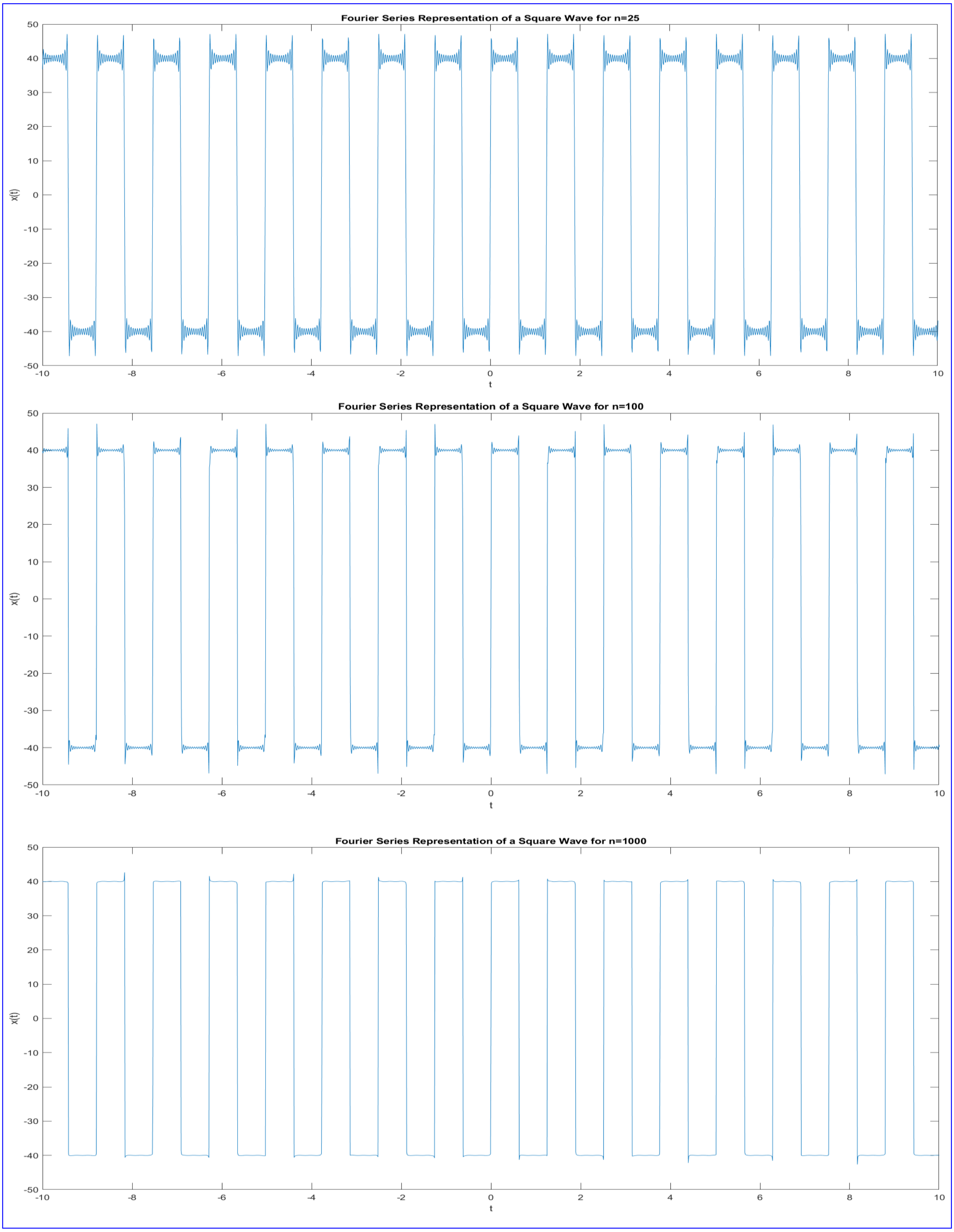

Figure 5: Fourier Series Representation of a Square Wave

3 Fourier Transform

The fourier transform of a continuous time signal $x(t)$ is mathematically given as,

$$X(j\omega) = \int_{-\infty}^{\infty} x(t)e^{-j\omega t}dt$$

Likewise, the fourier transform of a discrete time signal $x[n]$ is mathematically given as,

$$X(e^{j\omega}) = \sum_{n=-\infty}^{\infty} x[n]e^{-j\omega n}$$

The **fft** function in MATLAB returns the real and imaginary parts of the fast fourier transform for the input argument. The real and imaginary parts are plotted separately.

```
x=[0,1,2,3]
y=fft(x,4)
subplot(3,1,1)
stem(x)
xlabel('n')
ylabel('x[n]')
title('Discrete Signal x[n]')
subplot(3,1,2)
stem(real(y))
xlabel('n')
ylabel('Re(X(\omega))')
title('Real part of DTFT for x[n]')
subplot(3,1,3)
stem(imag(y))
xlabel('n')
ylabel('Im(X(\omega))')
title('Imaginary part of DTFT for x[n]')
```

MATLAB Code 6: Fourier transform of x[n] = [0,1,2,3]

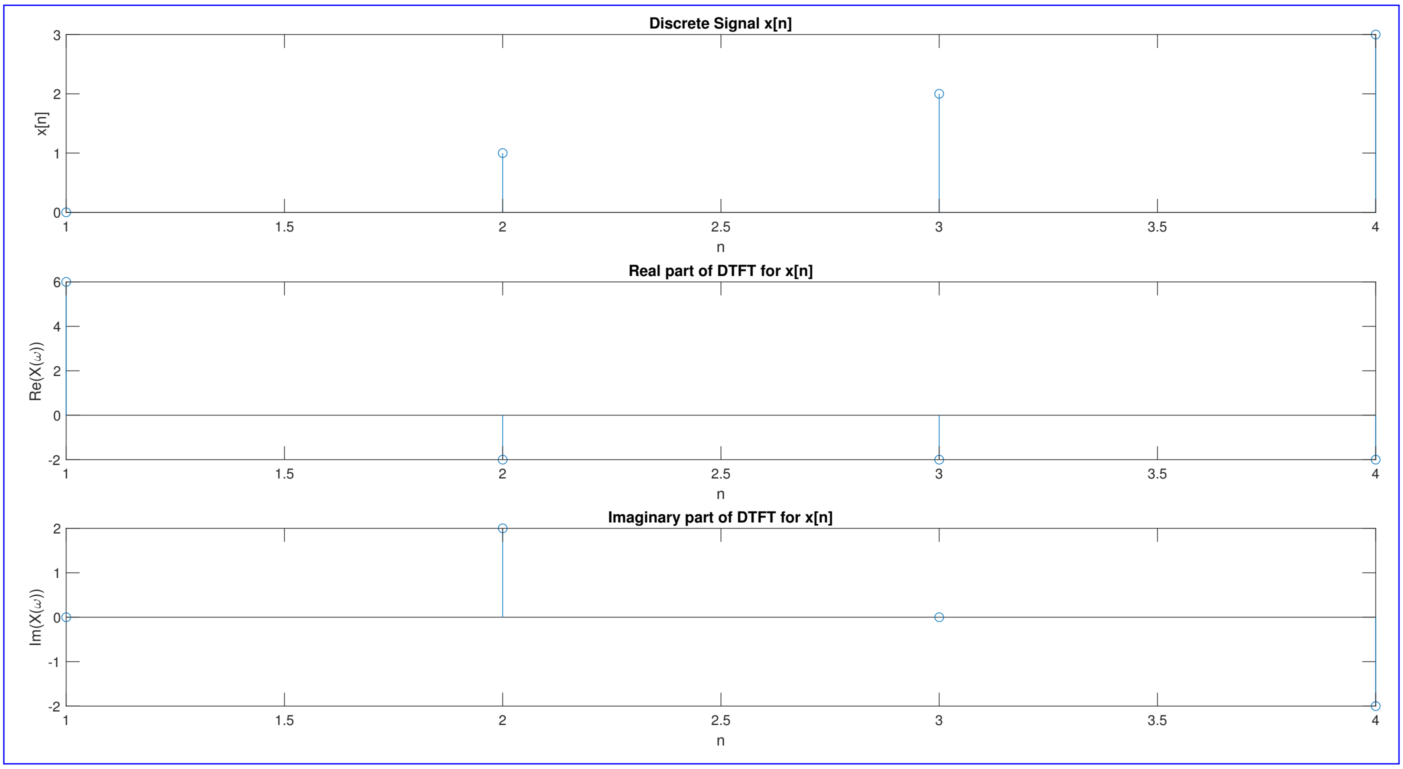

Figure 6: Fourier transform of x[n] = [0,1,2,3]

4 Convolution

The convolution of two continuous time signals $x(t)$ and $h(t)$, called the convolution integral, is mathematically given as,

$$y(t) = x(t) * h(t) = \int_{-\infty}^{\infty} x(u)h(t-u)du$$

Likewise, the convolution of two discrete time signals $x[n]$ and $h[n]$, called the convolution sum, is mathematically given as,

$$y[n] = x[n] * h[n] = \sum_{k=-\infty}^{\infty} x[n]h[n-k]$$

The **conv** function returns the convolution for two discrete sequences in MATLAB.

```
x=[1,3,2,1,1]
h=[1,2,-1,1]
y=conv(x,h)
subplot(3,1,1)
stem(x)
xlabel('n')
ylabel('x[n]')
title('Input Signal x[n]')
subplot(3,1,2)
stem(h)
xlabel('n')
ylabel('h[n]')
title('Impulse Response Signal h[n]')
subplot(3,1,3)
stem(y)
xlabel('n')
ylabel('y[n]')
title('Output Signal y[n]')
```

MATLAB Code 7: Convolution for two discrete sequences $x[n]$ = [1,3,2,1,1] and $h[n]$ = [1,2,-1,1]

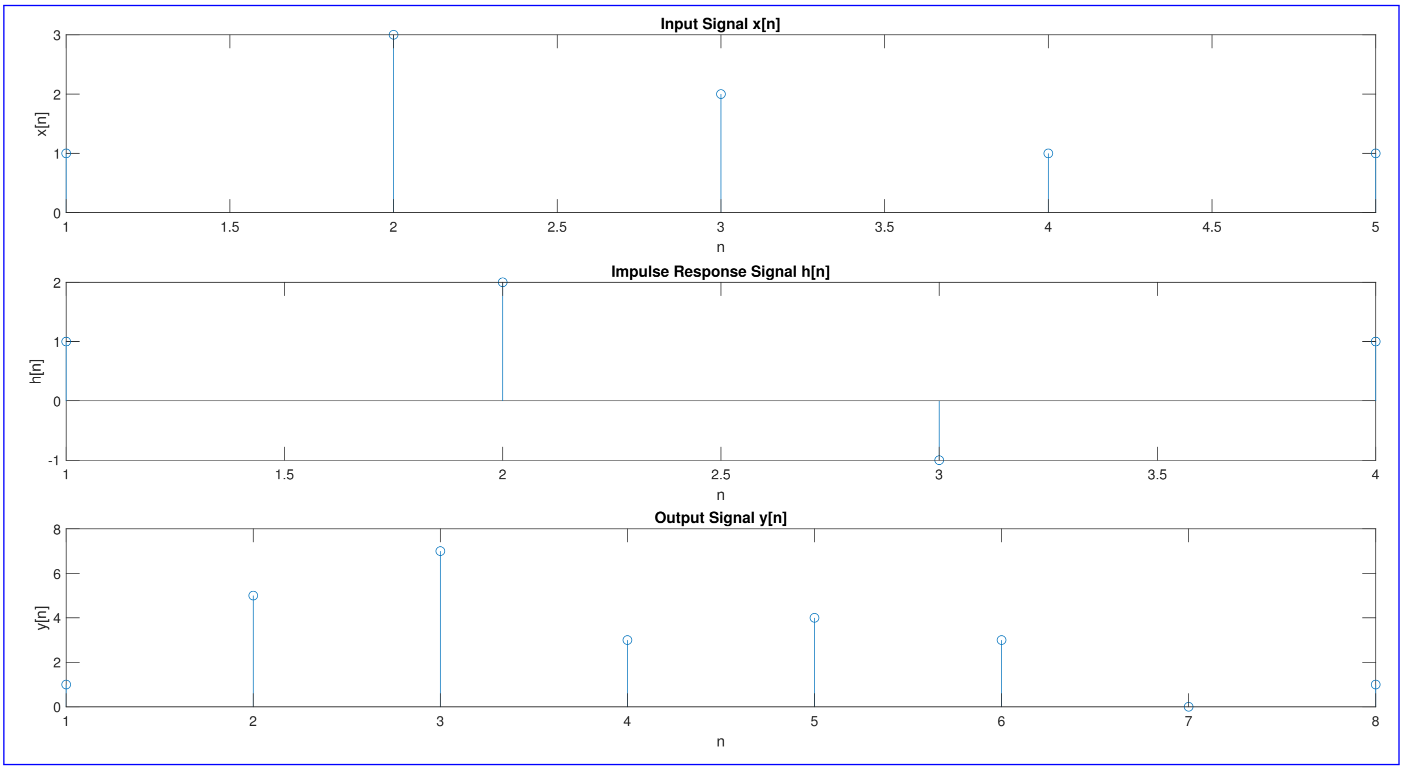

Figure 7: Convolution for two discrete sequences $x[n]$ = [1,3,2,1,1] and $h[n]$ = [1,2,-1,1]

Convolution for two discrete sequences $x[n]$ = 0.5 n and $h[n] = u[n]$

```
n=0:10
h=ones(1,11)
x= power(0.5,n)
y=conv(x,h)
subplot(3,1,1)
stem(x)
xlabel('n')
ylabel('x[n]')
title('Input Signal x[n]')
subplot(3,1,2)
stem(h)
xlabel('n')
ylabel('h[n]')
title('Impulse Response Signal h[n]')
subplot(3,1,3)
stem(y)
xlabel('n')
ylabel('y[n]')
title('Output Signal y[n]')
```

MATLAB Code 8: Convolution for two discrete sequences $x[n]$ = 0.5 n and $h[n] = u[n]$

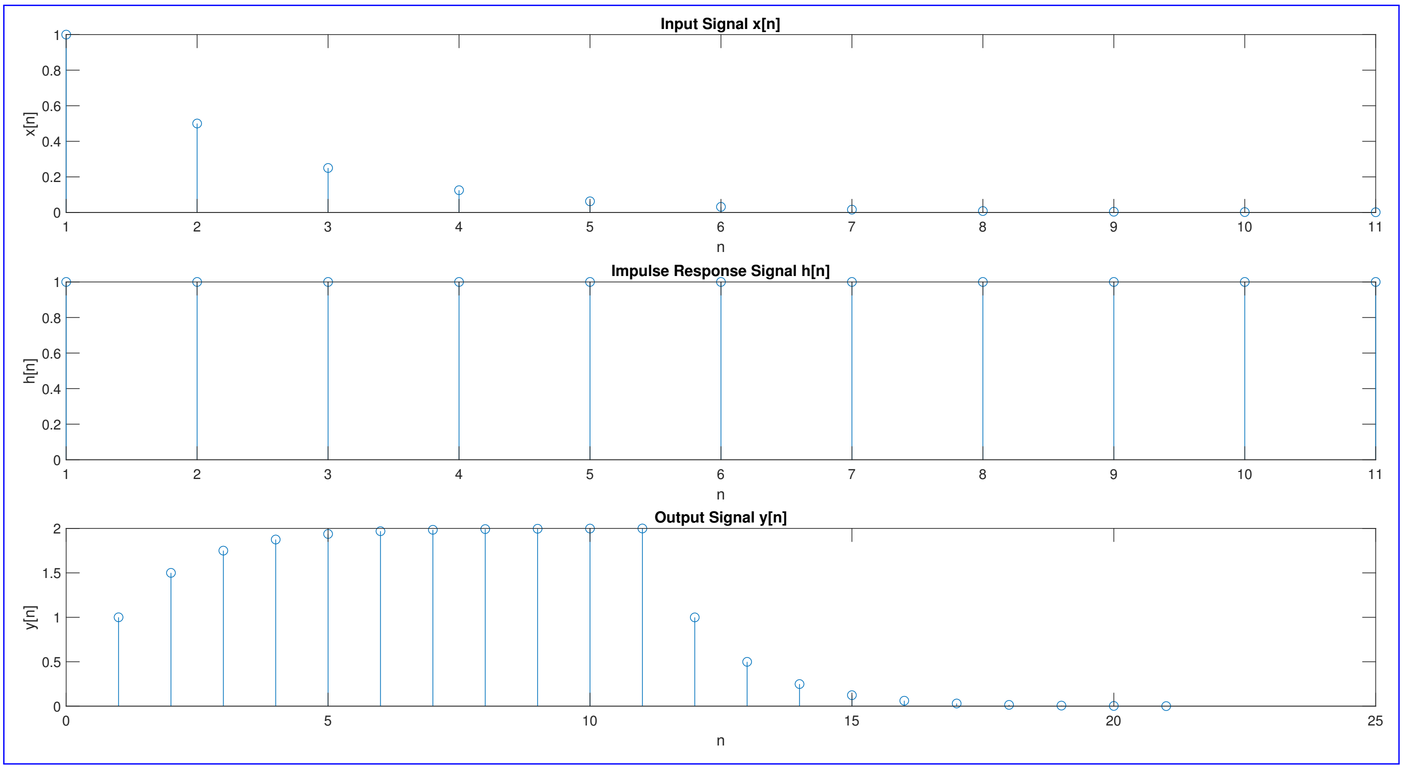

Figure 8: Convolution for two discrete sequences $x[n]$ = 0.5 n and $h[n] = u[n]$

5 Frequency Response of a System

For a system with $h(t)$ as the impulse response, and $x(t)$ as the input signal, the output $y(t)$ is related to the input as the convolution,

$$y(t) = x(t) * h(t) = \int_{-\infty}^{\infty} x(u)h(t-u)du$$

According to the convolution property of fourier transforms, the fourier transforms of the signals are related as,

$$Y(j\omega) = H(j\omega)X(j\omega)$$

where $H(j\omega)$, the fourier transform of the impulse response of the system is the frequency response of the system. Likewise, for discrete time input signal $x[n]$ to a system with the impulse response $h[n]$, the output in frequency domain is mathematically given as,

$$Y(e^{j\omega}) = H(e^{j\omega})X(e^{j\omega})$$

where $H(e^{j\omega})$, the fourier transform of the impulse response of the system is the frequency response of the system. During the lab experiment, we plotted the frequency response given as,

$$H(z) = \frac{0.008 - 0.033z + 0.05z^2 - 0.033z^3 + 0.008z^4}{1 + 2.37z + 2.7z^2 + 1.6z^3 + 0.5z^4}$$

The **freqz** function returns the frequency response of a system whose amplitude and phase were plotted separately in MATLAB.

```
num=[0.008,-0.033,0.05,-0.033,0.008]
den=[1,2.37,2.7,1.6,0.4]
w=200
x=freqz(num,den,w)
subplot(2,1,1)
plot(abs(x))
xlabel('\omega')
ylabel('|H(\omega)|')
title('Magnitude Plot of Frequency Response')
subplot(2,1,2)
plot(angle(x))
xlabel('\omega')
ylabel('\angle H(\omega)')
title('Phase Plot of Frequency Response')
```

MATLAB Code 9: Frequency response of $H(z)$

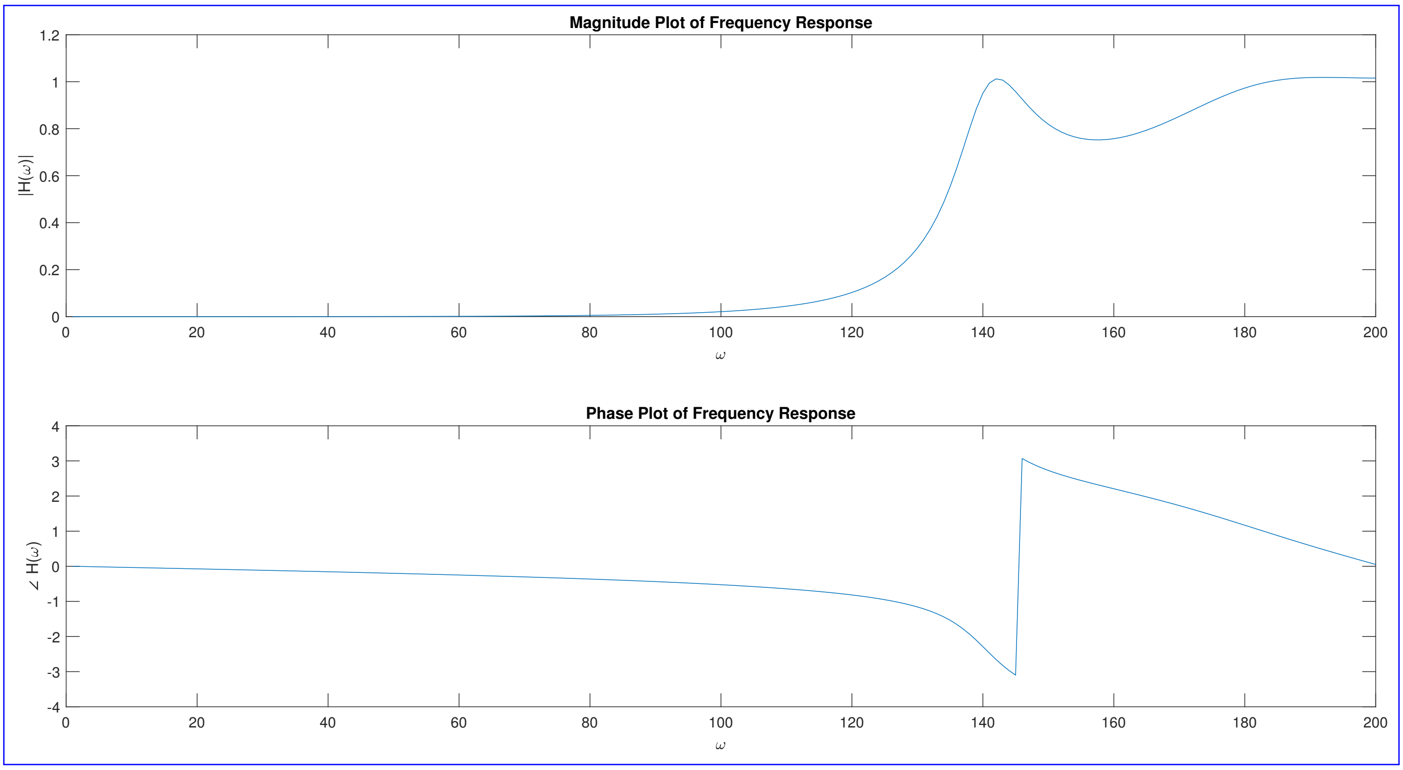

Figure 9: Frequency response of $H(z)$

6 Conclusion

In this Lab we got familiarize to various MATLAB function. We were able to Plot some basic function like unit, exponential, Sinusoidal, Ramp etc. We also find and plot Fourier Series and Transform and additionally performed Convolution with **conv** function and view frequency response of the system. Thus all the LAB exercises were completed.