भारतीय प्रौद्योगिकी संस्थान तिरुपति

TIRUPATI

ADVANCED SIGNAL ANALYSIS AND PROCESSING LAB

Lab sheet. No: 06

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Q1. (a) Consider the following difference equation

$y[n] - 0.4y[n-1] + 0.75y[n-2] = 2.2403x[n] + 2.4908x[n-1] + 2.2403x[n-2]$

write a program to find the impulse response of the above equation using impz function.

(b) Modify the program to generate 0 to 40 samples of the impulse response of the following causal LTI system

$y[n] + 0.71y[n-1] - 0.46y[n-1] - 0.62y[n-3] = 0.9x[n] - 0.45x[n-1] + 0.35x[n-2] + 0.002x[n-3]$

(c) Write a Matlab program to generate the impulse response of the system using filter function for 0 to 40 samples and compare the response with question 1b.

(d) Write a Matlab program to generate the step response for first 40 samples.

AIM: To find the impulse response of the differential equation using impz function. And also finding the step response to the differential equation.

Short Theory:

Difference equations arise naturally in all situations in which sequential relation exists at various discrete values of the independent variables.

Let {fn} be a sequence defined for n = 0,1,2,…….,then its Z-transform F(z) is defined as

$$F(z) = Z\{f_n\} = \sum_{n=0}^{\infty} f_n z^{-n},$$

whenever the series converges and it depends on the sequence {fn}.

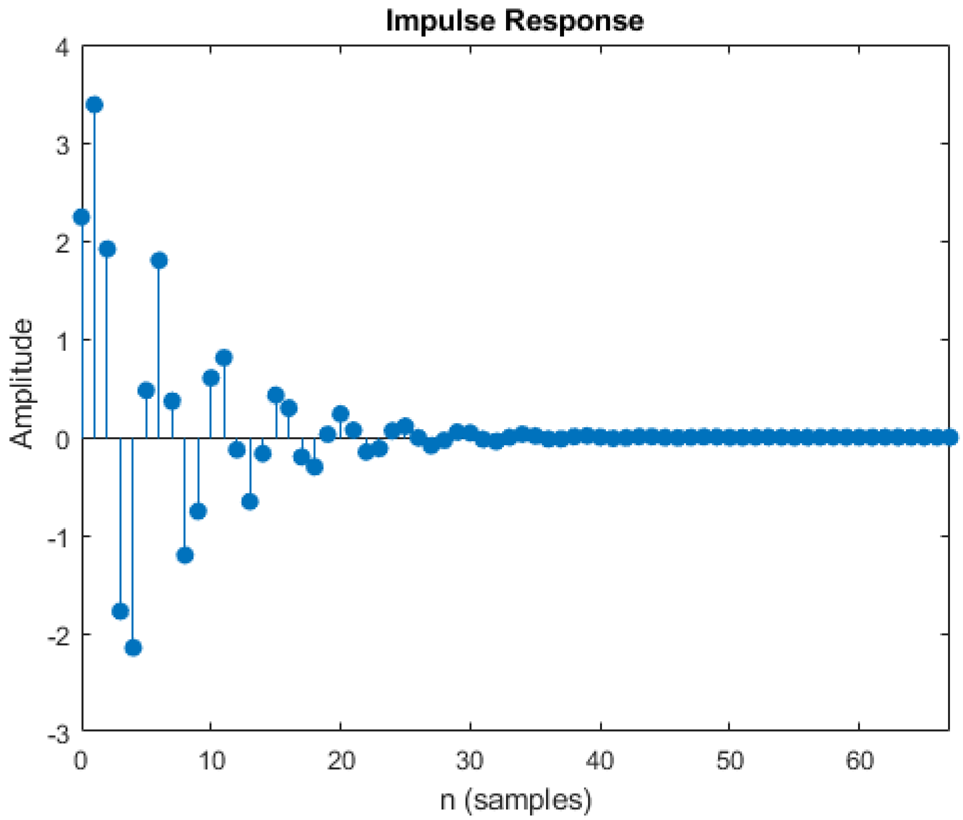
The inverse Z-transform of F(z) is given by Z-1{F(z)} = {fn}.

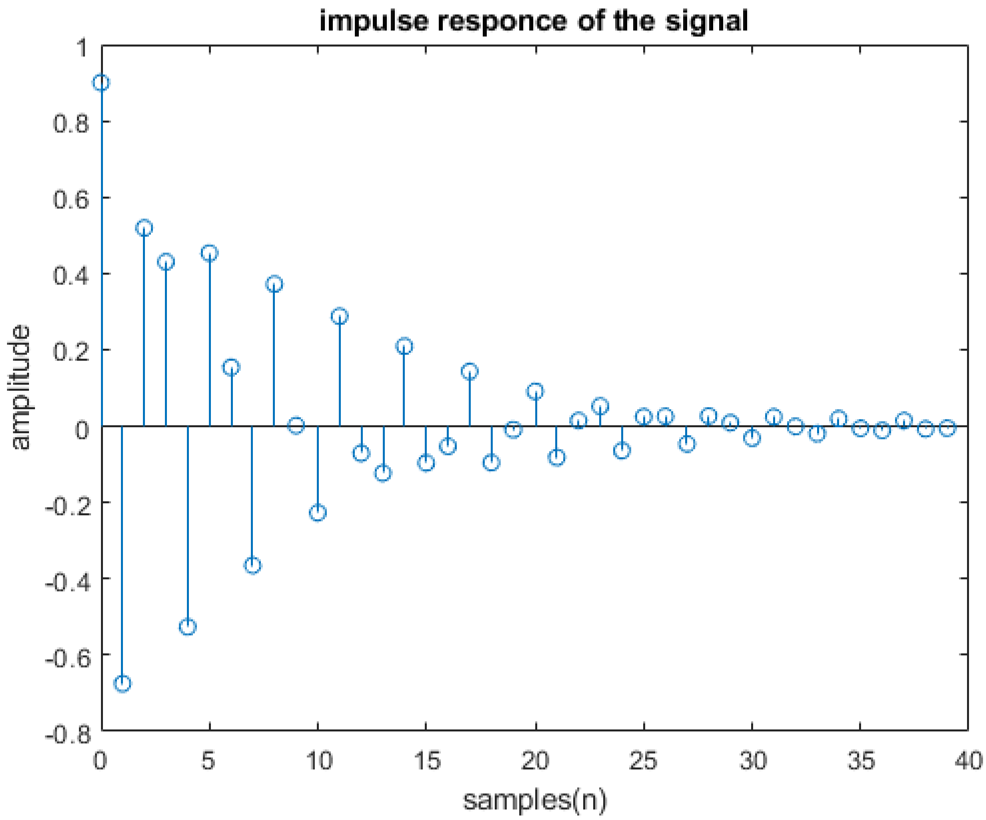
Key Commands:

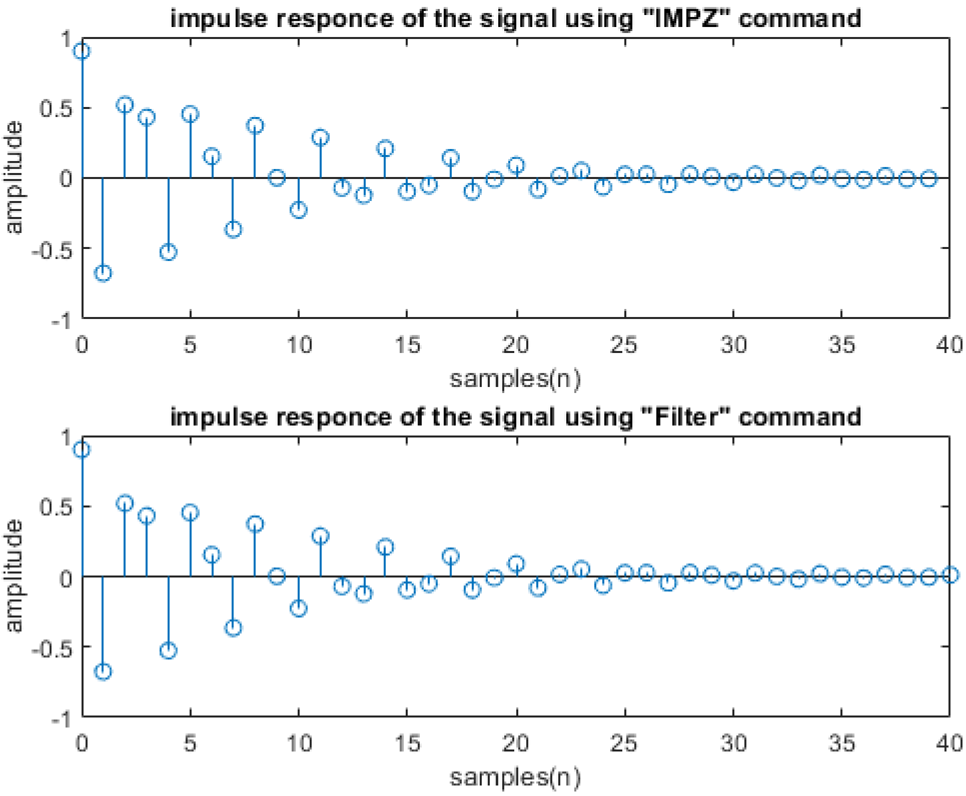
Impz % impz(b,a) returns the impulse response of the digital filter with numerator coefficients b and denominator coefficients a.

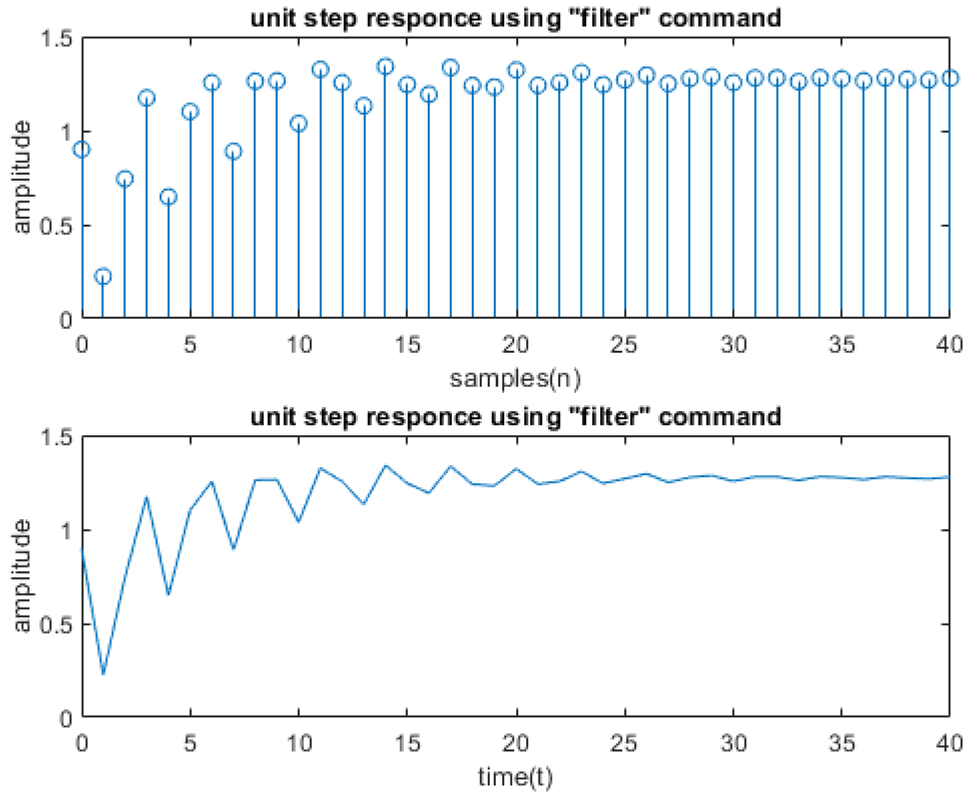
Filter % filter(b,a,x) filters the input data x using a rational transfer function defined by the numerator and denominator coefficients b and a.

Plots:


Impulse Response
Amplitude
n (samples)
4
3
2
1
0
-1
-2
-3
0
10
20
30
40
50
60


impulse responce of the signal
amplitude
samples(n)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
0
5
10
15
20
25
30
35
40





Inferences/comments:

1) Impulse response of a given h(z) is same if we find the impulse response using Filter command and using Impz command
2) By using impz command we can only find the impulse response but with filter command we can find any system response .

Q2. Use function ztrans to find z transform of a^nu[n]. Find inverse z- transform using iztrans and verify.

AIM: To find the z transform for the a^n u(n) and also find the inverse z transform and verify with the given input signal.

Short Theory:

The bilateral (two sided) z-transform of a discrete time signal x(n) is given as

$$\text{Z.T}[x(n)]=X(Z)=\sum_{n=-\infty}^{\infty} x(n)z^{-n}$$

Let us take $x1(n) = a^{\wedge n}\, u(n)$ The z-transform of $x_1(n) = a^n u(n)$ is given by

$$Z\,[a^n(u)] = \frac{1}{1-az^{-1}} \qquad \text{ROC } |z| > |a|$$

i.e.,

$$X_1[z] = \frac{1}{1-az^{-1}} \qquad \text{ROC } |z| > |a|$$

Key Commands:

ztrans % ztrans(f) finds the Z-Transform of f. By default, the independent variable is n and the transformation variable is z.

iztrans % iztrans(F) returns the Inverse Z-Transform of F. By default, the independent variable is z and the transformation variable is n.

Inferences/comments:

1) We can find the z transform of any signal using the command ztrans(), and the inverse z transform of the signal by using the iztrans()
2) By using the ztrans() command we can not find the left handed signal. But by using the properties of z transform we can find the left-handed signals also. i,e.. x(-n) ⇔ X(1/z)
3) Heaviside function is similar to u(n). with out the u(n) or Heaviside function we can get the z transform for right-handed signal.
4) In this question output of iztrans is exactly same as the input given.

Q3. Let X1(z) = 6z^2 +3z +2+ 3z^−1 +4z^−2 and X2(z) = 4z +7+ 5z^−1 +6z^−2. Determine X3(z)=X1(z)X2(z) using conv function. Verify the result theoretically.

AIM: To find the X3(z)=X1(z)X2(z) using conv function and verify the result with theoretical result.

Short Theory:

Let x[n] be a discrete-time signal which is:

- Causal (x[n] = 0 for n < 0)
- Finite Duration (x[n] = 0 for all n > N for some N)

The z-transform of x[n] is the polynomial (in z −1)

Z{x[n]} = X(z) = x[0] + x[1]z ^−1 + x[2]z ^−2 + . . . + x[N]z ^−N

= (x[0]z ^N + x[1]z^ N−1 + . . . + x[N])/z^N .

Convolution property

If two sequences x1(n) and x2(n) and their corresponding Z Transforms are given by

x1(n)⇔X1(z)

and

x2(n)⇔X2(z),

then the Z Transform of the convolution of the two sequences x1(n) and x2(n) is the product of their corresponding Z transforms. Thus,

y(n)=x1(n)* x2(n) ⇔X1(z)* X2(z)

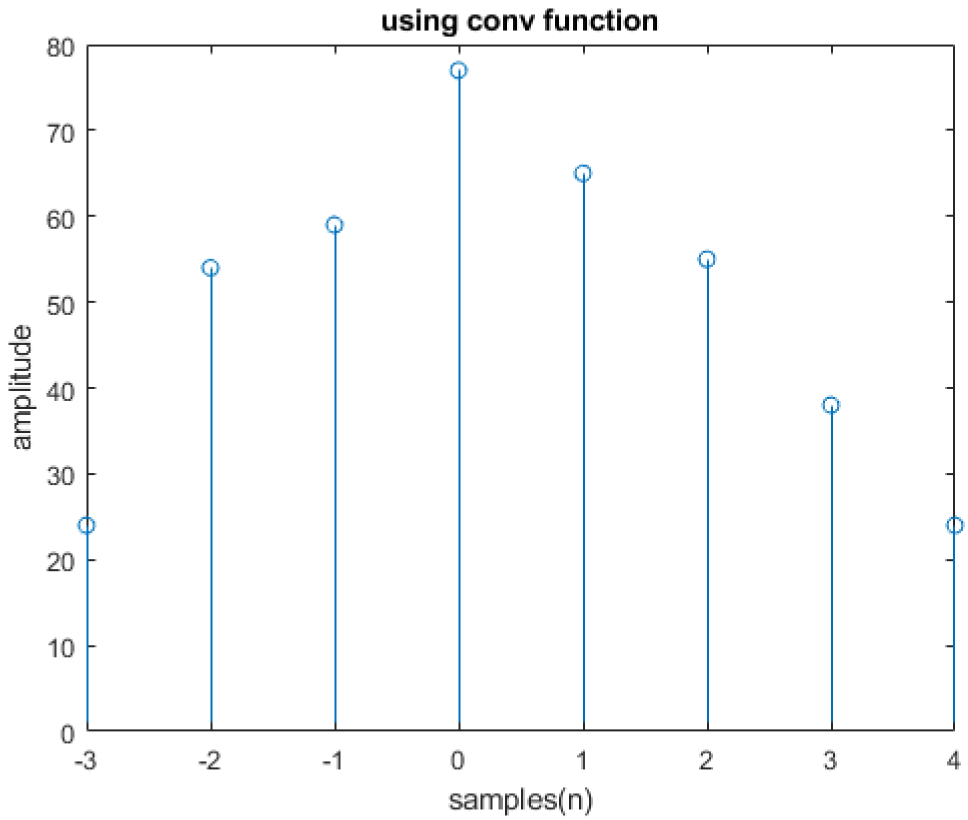
Key Commands:

Conv % conv(u,v) returns the convolution of vectors u and v.

ztrans % ztrans(f) finds the Z-Transform of f. By default, the independent variable is n and the transformation variable is z.

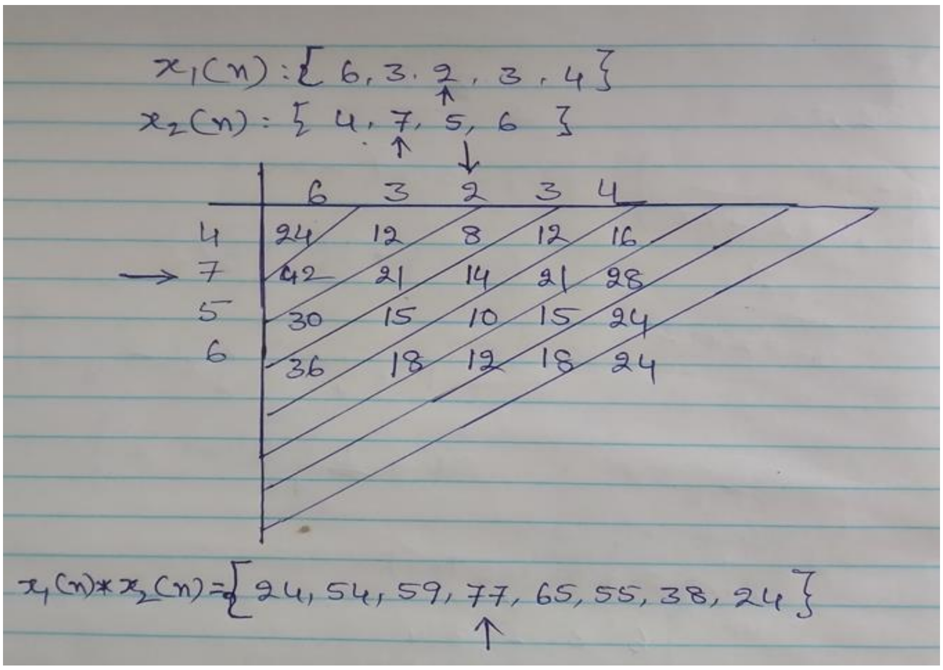
iztrans % iztrans(F) returns the Inverse Z-Transform of F. By default, the independent variable is z and the transformation variable is n.

Plots:



Inferences/comments:

1) In any transform convolution in one domain is multiplication of same corresponding signals in other domain
2) From the theoretical calculations, x1(n)*x2(n)=[24,54,59,77,65,55,38,24] , the zero position is at 77.



Q4. Determine the output response of an LTI system. Suppose a causal LTI system has a transfer function

H(z) = (z^−1 + 3)/(1 − 0.5z^−1)(1 + 0.25z^−1)

Assume the z-transform of the signal is X(z) = (1−z^−1)/(1−0.6z^−1)

(a) Plot the pole zero maps for H(z), X(z), Y (z).

(b) Plot the impulse response h[n].

(c) Plot the output signal y[n].

AIM: To find the output response of a given system, and plot the pole zero plot for the h(z), x(z), and y(z).

Short Theory:

The bilateral (two sided) z-transform of a discrete time signal x(n) is given as

$$Z.T[x(n)]=X(Z)=\sum_{n=-\infty}^{\infty} x(n)z^{-n}$$

The poles of a z-transform are the values of z for which if X(z)=∞

The zeros of a z-transform are the values of z for which if X(z)=0

$$\boxed{X(z)=\frac{N(z)}{D(z)}=\frac{b_0+b_1z^{-1}+\ldots+b_Mz^{-M}}{a_0+a_1z^{-1}+\ldots+a_Nz^{-N}}=\frac{\sum_{k=0}^{M}b_kz^{-k}}{\sum_{k=0}^{M}a_kz^{-k}}}$$

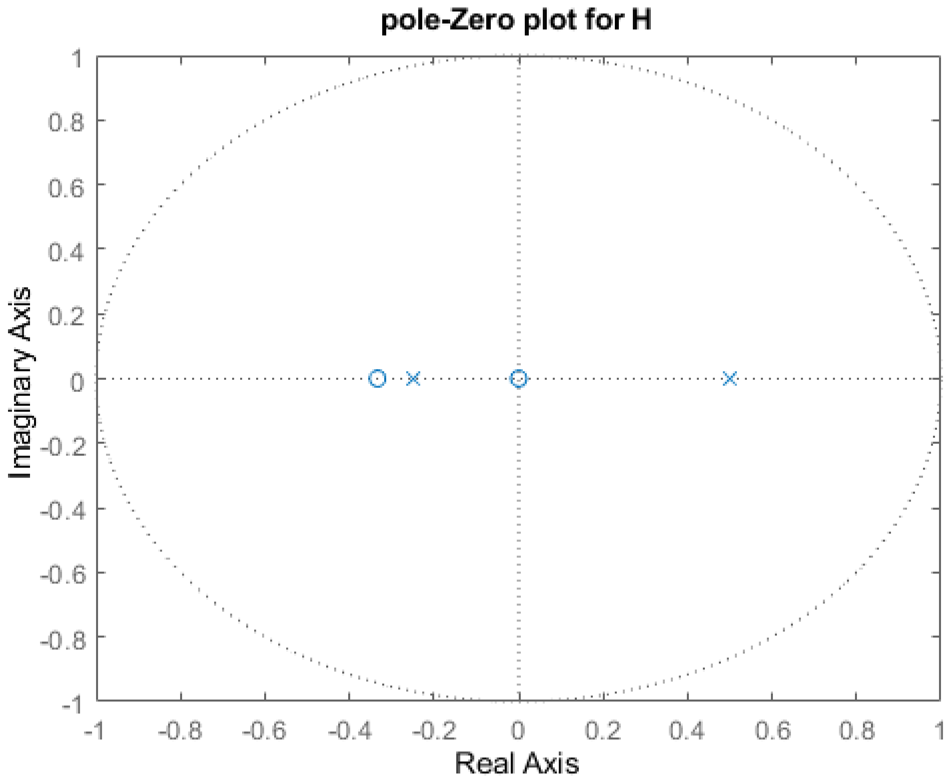
Key Commands:

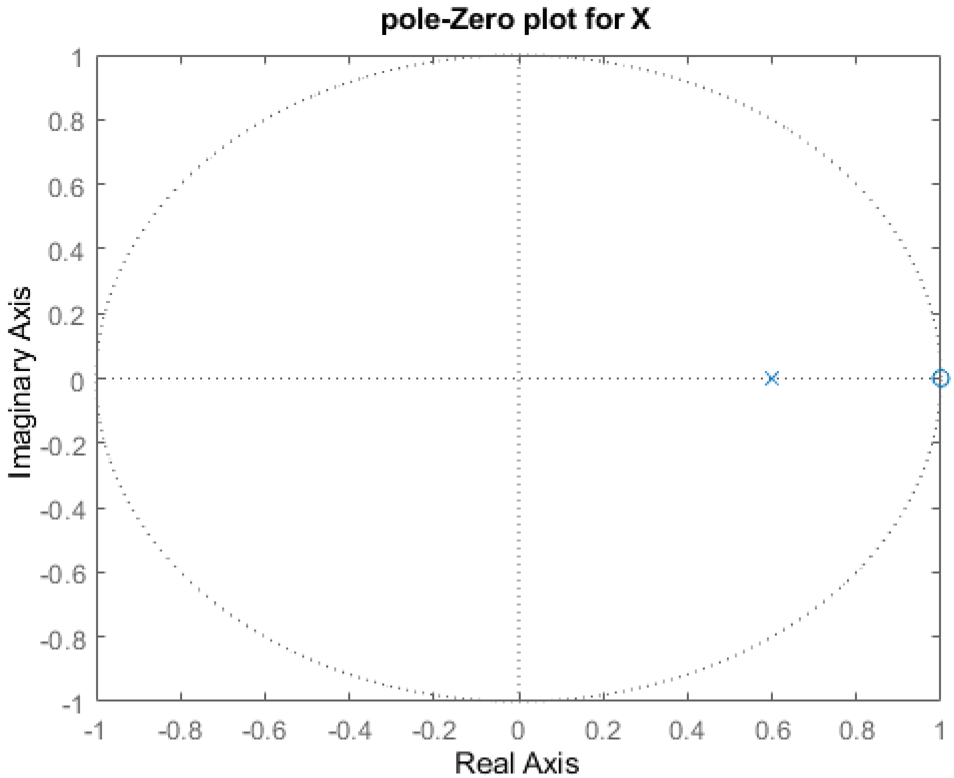
ztrans % ztrans(f) finds the Z-Transform of f. By default, the independent variable is n and the transformation variable is z.

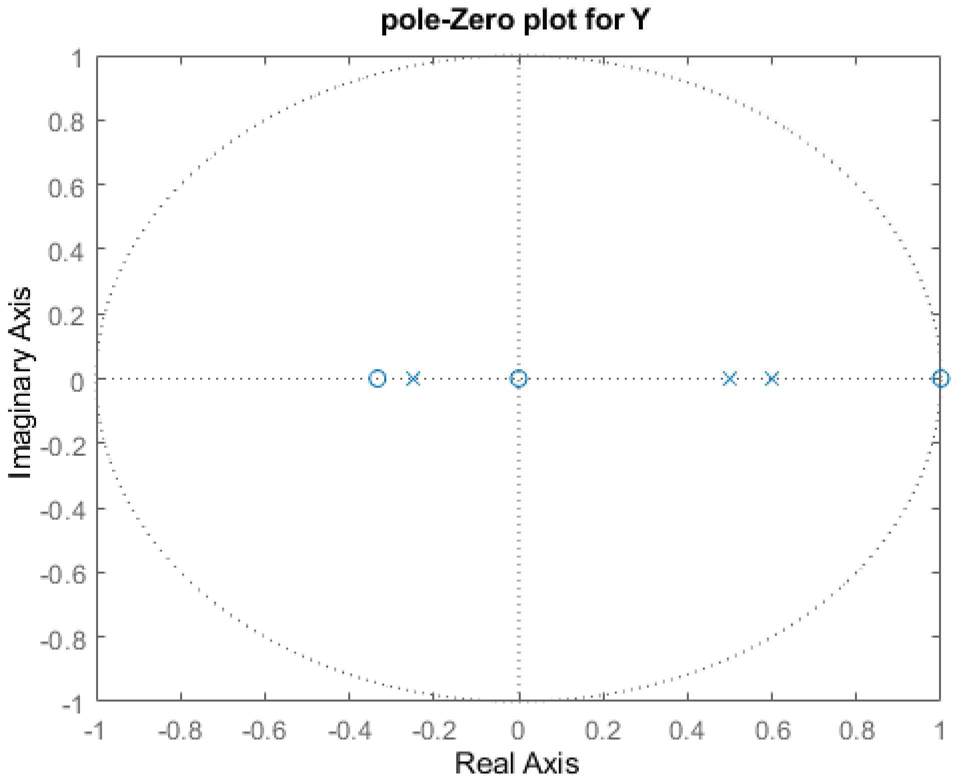
iztrans % iztrans(F) returns the Inverse Z-Transform of F. By default, the independent variable is z and the transformation variable is n.

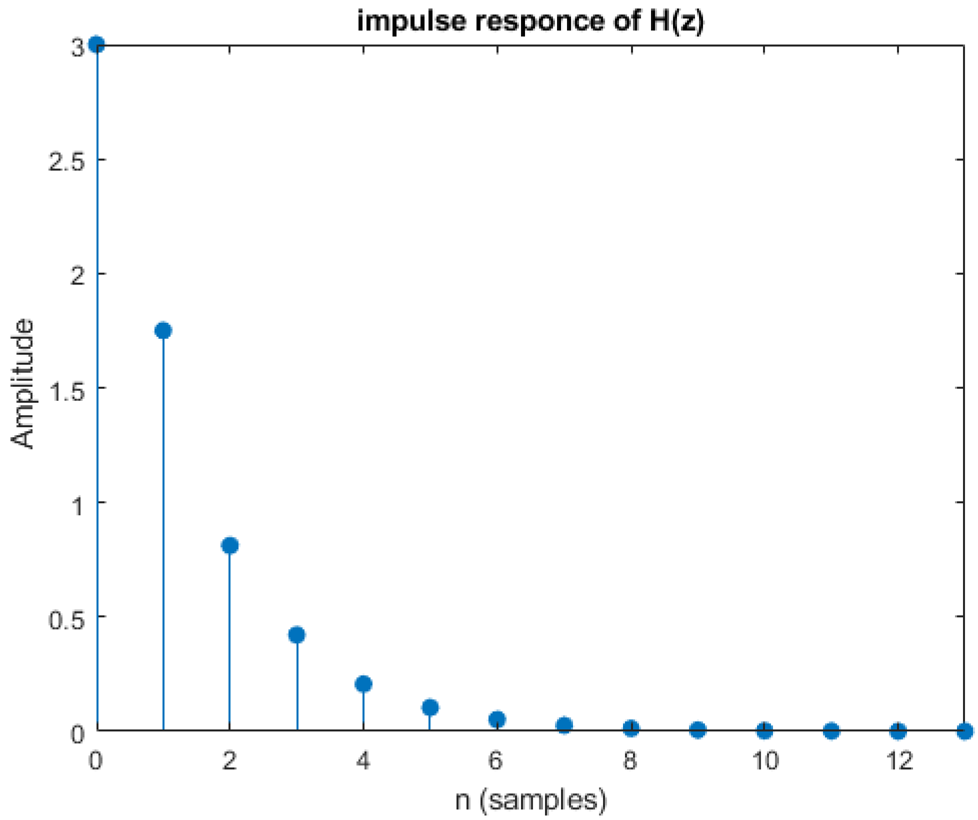
pzmap % pzmap(H) creates a pole-zero plot of the continuous or discrete-time dynamic system model H.

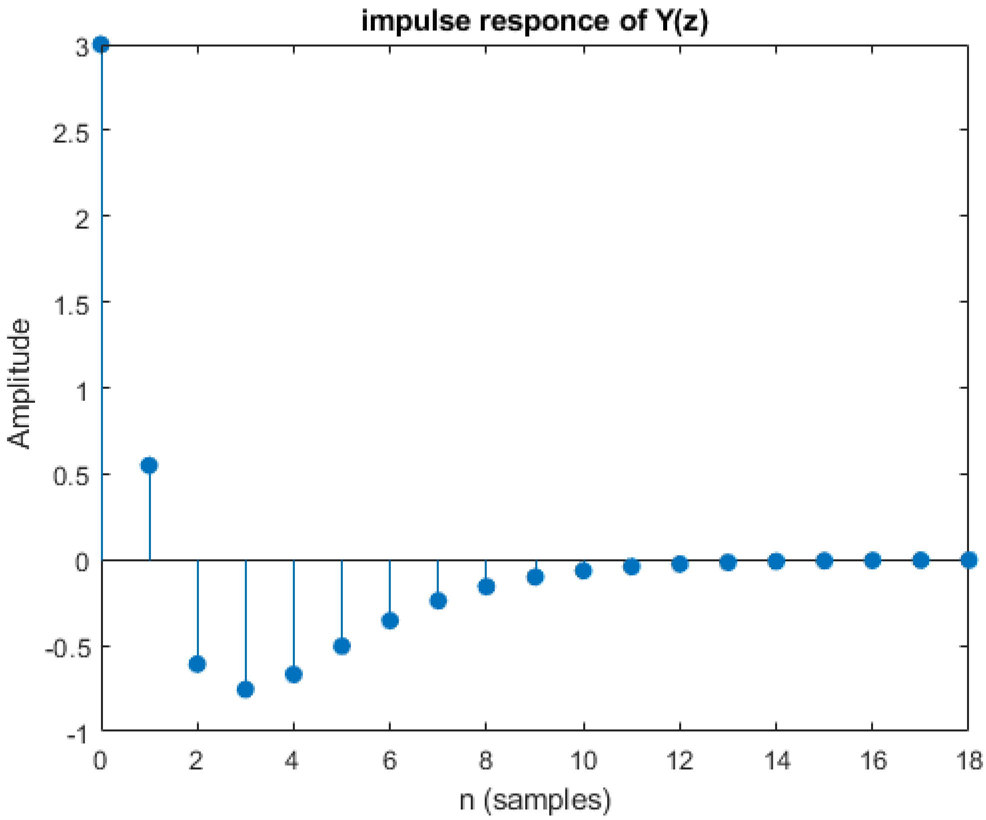
Plots:


pole-Zero plot for H
Imaginary Axis
Real Axis
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1


pole-Zero plot for X
Imaginary Axis
Real Axis
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1


pole-Zero plot for Y
Imaginary Axis
Real Axis
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1


impulse responce of H(z)
Amplitude
n (samples)
3
2.5
2
1.5
1
0.5
0
0
2
4
6
8
10
12



Inferences/comments:

1) Form the pole zero plot of
   a) H(z) is a having a 2 poles and 2 zeros and all poles and zeros are inside the unit circle.
   b) X(z) is having a 1 pole and 1 zero and pole is inside the unit circle.
   c) Y(z) is having a 3 poles and 3 zeros and all poles and zeros are inside the unit circle.
2) From the Impulse response of a H(z) is we can clearly observe that, it is a decaying exponential signal. And from the pole zero plot all poles and zeros are in side the unit signal, system is a stable system.
3) And y(n) is a finite impulse response.

Q5. Plot the pole-zero map of the transfer function H(z) of the system discussed in prelab question 2. i,e.. When the input to an LTI system is x[n] = (1/3)^n u[n] + 2^n u[−n − 1] . the corresponding output is y[n] = 5 (1/3)^n u[n] – 5(2/3)^n u[n]
Also plot the impulse response h[n], input signal x[n] and the output signal y[n].

AIM: Plot the pole-zero map of the given H(z) and plot the impulse response for the h[n], x[n] and y[n].

Short Theory:

The bilateral (two sided) z-transform of a discrete time signal x(n) is given as

$$\text{Z.T}[x(n)]=X(Z)=\sum_{n=-\infty}^{\infty} x(n)z^{-n}$$

The poles of a z-transform are the values of z for which if X(z)=∞

The zeros of a z-transform are the values of z for which if X(z)=0

$$X(z)=\frac{N(z)}{D(z)}=\frac{b_0+b_1z^{-1}+\ldots+b_Mz^{-M}}{a_0+a_1z^{-1}+\ldots+a_Nz^{-N}}=\frac{\sum_{k=0}^{M} b_kz^{-k}}{\sum_{k=0}^{M} a_kz^{-k}}$$

Key Commands:

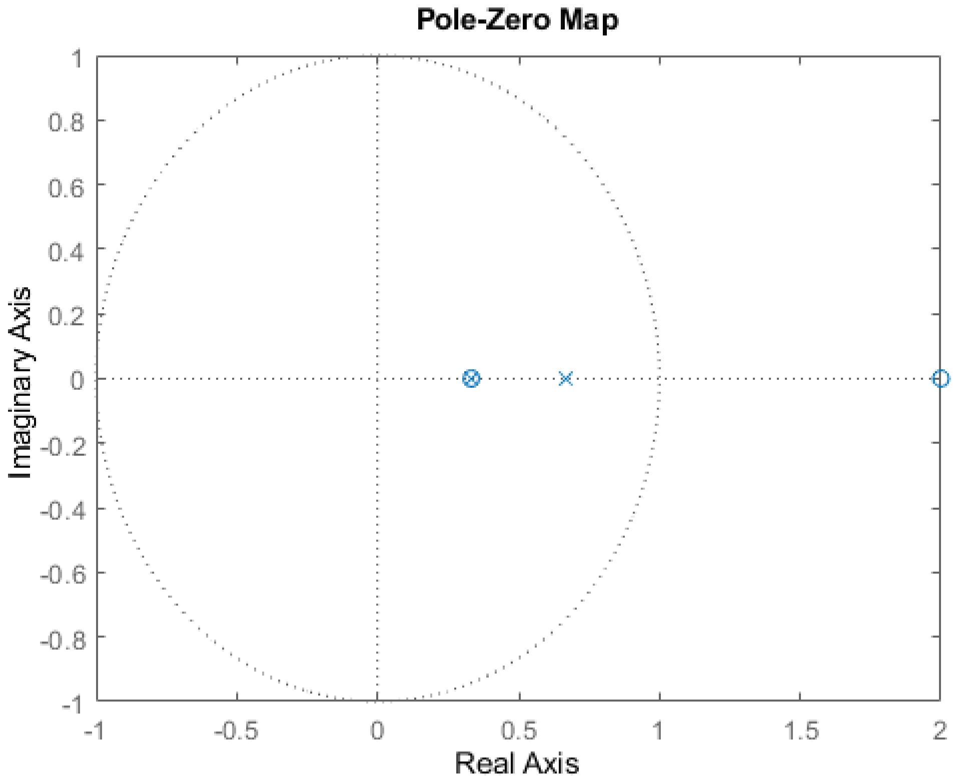
pzmap % pzmap(H) creates a pole-zero plot of the continuous or discrete-time dynamic system model H.

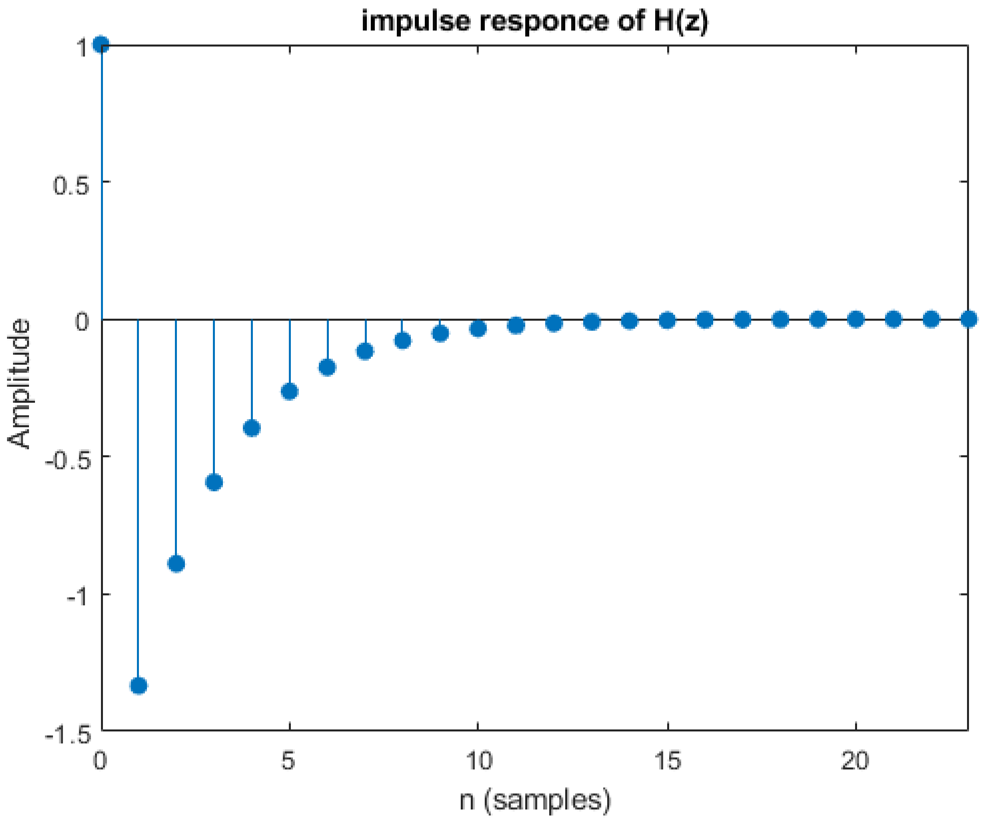
ztrans % ztrans(f) finds the Z-Transform of f. By default, the independent variable is n and the transformation variable is z.

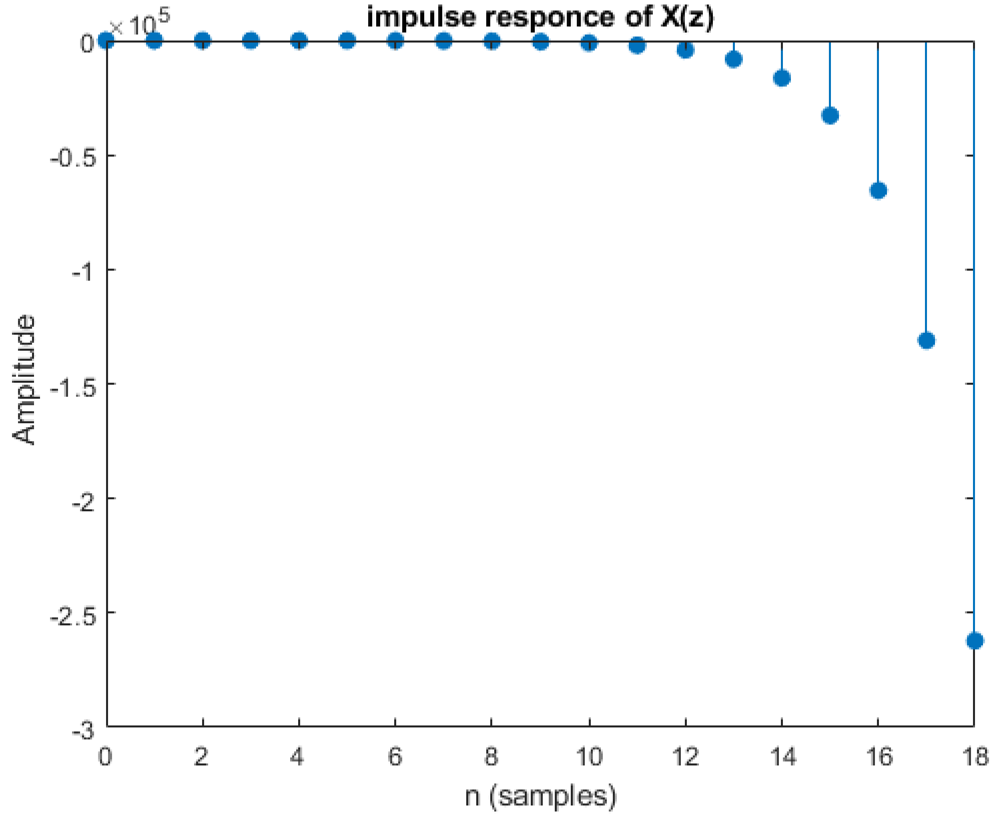
Impz % impz(b,a) returns the impulse response of the digital filter with numerator coefficients b and denominator coefficients a.

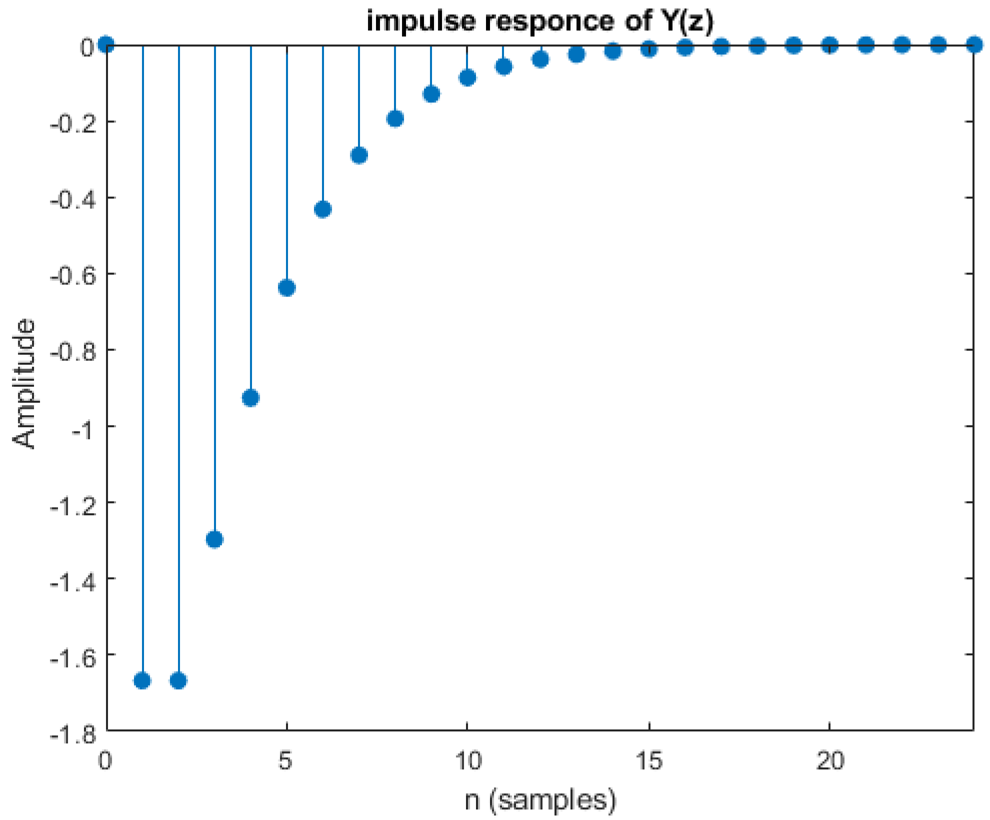
`oldparam=sympref('HeavisideAtOrigin', 1)`--→ this command useful to get the Heaviside function gives the value at the origin is 1.

Plots:


Pole-Zero Map
Imaginary Axis
Real Axis
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1
-0.5
0
0.5
1
1.5
2


impulse responce of H(z)
Amplitude
n (samples)
1
0.5
0
-0.5
-1
-1.5
0
5
10
15
20





Inferences/comments:

1) From the pole zero plot of the H(z) we can obverse that 2 poles are inside the unit circle and 1 pole is out side the unit circle.
2) From the impulse response of the H(z) , it is a decreasing exponential signal. System is stable.