DIGITAL SIGNAL PROCESSING LAB

(EL-302)

LABORATORY MANUAL

ENGR. MUHAMMAD IBRAR KHAN

Discrete Time Systems in the Transform (Z)-Domain

(LAB # 09)

Student Name: ______________________________

Roll No: ____________ Section: ___

Date performed: __________, 2019

Prepared by: Engr. Muhammad Asim
Last Edited by: Engr. Muhammad Asim, Mar 07, 2016
Verified by: Dr. Shahzad Saleem
Updated: Spring 2016

Lab # 09: Discrete Time Systems in the Transform (Z)-Domain

Learning Objectives

The aim of this experiment is to illustrate the simulation of some simple Discrete Time Systems using MATLAB and investigate their properties in transform(Z)- domain.

Equipment Required

1. PC
2. Matlab

1. Introduction:

A linear, time-invariant (LTI) discrete-time system is completely characterized in the time-domain by its impulse response sequence, and the output sequence of the LTI system can be computed for any input sequence by convolving the input sequence with its impulse response sequence. Certain classes of LTI discrete-time systems are characterized also by a linear, constant-coefficient difference equation. For such systems, the output sequence can be computed recursively for any input sequence. By applying the DTFT or the z-transform to either the convolution sum description or to the difference equation representation, the LTI discrete-time system can also be characterized in the frequency domain. Such transform domain representations provide additional insight into the behavior of such systems, in addition to making it simpler to design and implement them for specific applications.
Just as the Fourier transform forms the basis of signal analysis, the z-transform forms the basis of system analysis. If x[n] is a discrete signal, its z-transform $X(z)$ is given by:

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

Since the response y[n] of an LTI system to input x[n] is given by the convolution $y[n] = x[n] \, * h[n]$
Where h[n] is the impulse response, we have

$$y[n] = x[n] * h[n] \rightarrow Y(z) = X(z)H(z$$

The ratio $H(z) \; = \; Y\,(z)/X(z)$ defines the impulse response (and so the system response), and is called the transfer function of the system. The inverse z-transform of the transfer function H(z) yields the impulse response h[n].

2. Zeros and Poles Analysis of a DT-System in Matlab

To find zeros and poles matlab function “tf2zp” can be used

```
[z p k]=tf2zpk(num,den);
```

The vectors num and den specify the coefficients of the numerator and denominator polynomials in descending powers of *z*.

z, p are vectors of zeros and poles at the output.

And then we can use

zplane(z,p) to plot these zeros and poles. OR
zplane(num,den) can be directly used to plot zeros and poles of a transfer function.

We can also find the numerator and denominator of transfer function from the zero and poles by using matlab function "zp2tf"

```
[Num,Den]=zp2tf(z,p,k)    %(z,p,k) are same as the output of tf2zpk
```

We can also use "pzmap" function to plot poles and zeros of a transfer function

`pzmap(num, den)` OR `pzmap(p,z)`

3. Rational Z-transform to partial fraction form

When taking inverse z-transform it is most convenient that the transfer function be in partial fraction form. To convert from rational z-transform to partial fraction form MATLAB "residuez" function can be used.

Example,

$$X(z) = \frac{z}{3z^2 - 4z + 1}$$

num = [0 1 0]; den = [3 -4 1];

$$X(z) = \frac{\frac{1}{2}}{1 - z^{-1}} - \frac{\frac{1}{2}}{1 - \frac{1}{3}z^{-1}}$$

```
[r,p,k] = residuez(num,den)
```

r1 =0.5000; r2=-0.5000 ; p1 =1.0000; p2=0.3333; k=0;

We can also use "residuez" function to compute numerator and denominator of transfer function given the zeros, poles and gain.

```
[num,den]=residuez(r,p,k)
```

Task#1:

Express the following z-transform in factored form by finding its zeros and poles , plot its poles and zeros,and then determine its ROCs. If it is unstable then find its impulse response using "impz" function.

$$G(z) = \frac{2z^4+16z^3+44z^2+56z+32}{3z^4+3z^3-15z^2+18z-12}$$

Task#2:

Determine the rational z-transform from its zero and pole locations. The zeros are at z1=0.21, z2=3.14, z3=-0.3+j0.5, z4=-0.3-j0.5; the poles are at p1=-0.45, p2=0.67, p3=0.81+j0.72, p4=0.81-j0.72; and the gain constant k is2.2.

Task#3:

Determine the partial fraction expansion of the z-transform *G(z)* using Matlab and write it in expanded form Y(z)

$$G(z) = \frac{18z^3}{18z^3+3z^2-4z-1}$$

Task#4:

Determine the rational form of z-transform from its partial-fraction expansion representation Y(z) it is the inverse of above question.

4. Transfer Function and Frequency Response

The z-transform of the impulse response sequence {h[n]} of an LTI discrete-time system is its transfer function H(z) . If the ROC of H(z) includes the unit circle, as it does in the case of a stable system, then H(z) evaluated on the unit circle, that is, for $z = e^{j\omega}$, is the frequency response H($e^{j\omega}$) of the system.
An LTI system is only stable if its ROC includes the unit circle.

Task#05:

a) Find the transfer function H(z) of following causal(right-sided)IIR system using "tf" function.

$$y[n] - 0.5y[n-1] + 0.7y[n-2] = 0.15x[n] - 0.15x[n-2]$$

b) Find poles and zeros of above computed transfer function and plot these using "zplane" command.
c) Find ROC of above systems and tell wheteher it is stable or not?
d) If it is stable then find its frequency response using "freqz" function and plot it its magnitude and phase response.

Task#06:

a) Find the transfer function H(z) of following non causal(left-sided) IIR system using "tf" function.

$$y[n] - 3y[n+1] + 0.7y[n+3] = 0.15x[n] - x[n+2]$$

b) Find poles and zeros of above computed transfer function and plot these using "zplane" command.
c) Find ROC of above systems and tell wheteher it is stable or not?
d) If it is stable then find its frequency response using "freqz" function and plot its magnitude and phase response.
e) Find the impulse response of above system.

Task#07:

a) Find the transfer function H(z) of following non causal(double-sided) IIR system using "tf" function.

$$y[n] - 3y[n+1] + 0.7y[n-3] = 0.15x[n] - x[n-2] + 3x[n+3]$$

b) Find poles and zeros of above computed transfer function and plot these using "zplane" command.
c) Find ROC of above systems and tell wheteher it is stable or not?
d) If it is stable then find its frequency response using "freqz" function and plot it its magnitude and phase response.
e) Find the impulse response of above system.

Task#8(a):

Determine the first 11 coefficients of the inverse z-transform of the given equation H(z) using **impz** function,

$$H(z)=\frac{1+2.0z^{-1}}{1+0.4z^{-1}-0.12z^{-2}}$$

Task#8(b):

Determine the first 11 coefficients of the inverse z-transform of the given equation H(z) using **filter()** function,

$$H(z)=\frac{1+2.0z^{-1}}{1+0.4z^{-1}-0.12z^{-2}}$$

Task#9:

Using MATLAB compute and plot the group delay of the causal LTI discrete-time system with a transfer function given by

$$H(z)=\frac{z^{-1}-1.2z^{-2}+z^{-3}}{1-1.3z^{-1}+1.04z^{-2}-0.222z^{-3}}$$

HINT: Use the “grpdelay” function.

Student's feedback: Purpose of feedback is to know the strengths and weaknesses of the system for future improvements. This feedback is for the 'current lab session'. Circle your choice:

[-3 = Extremely Poor, -2 = Very Poor, -1 = Poor, 0 = Average, 1 = Good, 2 = Very Good, 3 = Excellent]:

The following table should describe your experience with:

S#	**Field**	**Rating**	**Describe in words if required**
1	Overall Session	-3 -2 -1 0 1 2 3	
2	Lab Instructor	-3 -2 -1 0 1 2 3	
3	Lab Staff	-3 -2 -1 0 1 2 3	
4	Equipment	-3 -2 -1 0 1 2 3	
5	Atmosphere	-3 -2 -1 0 1 2 3	

Any other valuable feedback: ____

____

____

____

Student's Signature: ______________________________

MARKS AWARDED	**Attitude**	**Neatness**	**Correctness of results**	**Initiative**	**Originality**	**Conclusion**	**TOTAL**
TOTAL	**10**	**10**	**10**	**20**	**20**	**30**	**100**
EARNED							

Lab Instructor's Comments:____

____

____

____

Lab Instructor's Signature: ________________________________