

Department of Electrical and Computer Engineering

ECED4601 Digital Control System

Lab3 Digital State Space -Model

- **Objectives**

1. To learn some MATLAB commands that deals with the discrete time systems.
2. To give the students the ability to program using MATLAB.
3. To transform between transfer function and state space model of the system.

- **Introduction**

There are several different ways to describe a system of linear differential equations. The **state-space representation** is given by the equations:

$$\dot{x} = Ax + Bu$$

$$y = Cx + Du$$

The state-space approach to the analysis of dynamic systems can be extended to the **discrete-time case**. The general state-space representation of linear discrete-time system is:

$$x(k + 1) = G(k)x(k) + H(k)u(k)$$

$$y(k) = C(k)x(k) + D(k)u(k)$$

Where $x(k)$ is the state vector, $u(k)$ is the input vector, and $y(k)$ is the output vector.

Hints:

ss2tf: State-space to transfer function conversion.

`[NUM,DEN] = ss2tf (A,B,C,D)`

tf2ss: Transfer function to state-space conversion.

`[A,B,C,D] = tf2ss(num,den)`

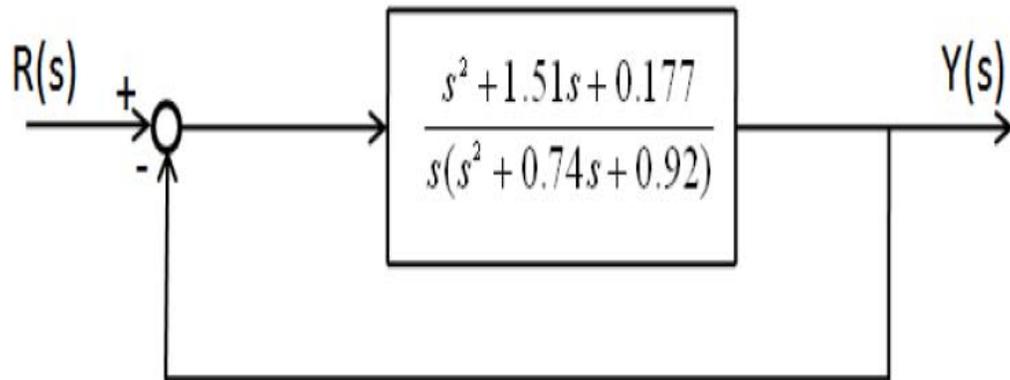
c2dm: Conversion of continuous LTI systems to discrete-time.

`[Ad,Bd,Cd,Dd] = c2dm(A,B,C,D,Ts,'method')`

Converts the continuous-time state-space system (A,B,C,D) to discrete time system using ('zoh' , 'foh' , 'tustin' , 'matched') methods.

String specifying a discretization method:

1) For the following continuous SISO control system shown in Figure below:



Using MATLAB code and SIMULINK to:

- Draw the step response of the closed loop system using SIMULINK.
- Obtain the state space representation of the open loop system.
- Convert the continuous SISO system to digital state space model using "zoh" method and $T_s=0.5$ Sec.
- Repeat steps (c) using the methods of conversion: 'foh', 'tustin', 'matched'.

2) Consider the transfer function of SISO control system

$$G(s) = \frac{1}{s(s^2 + 2s + 2)}$$

Use MATLAB AND state variable equation to carry out discretization.

- Assume the sampling time is ($T_s= 0.5$) computer the discrete function $G(z)$.
- Express $G(z)$ in zero and pole form
- Plot a pole-zero diagram

3) A system is given by the following state space model:

$$A = \begin{bmatrix} -14 & -56 & -64 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix}; B = \begin{bmatrix} 1 \\ 0 \\ 0 \\ 0 \end{bmatrix}; C = [0 \ 1 \ 10 \ 24]; D = 0$$

- a) Is the system state controllable?
- b) Is the system state observable?
- c) Determine the transfer function of the system.

4) In a continuous control system the state space representation of the plant is characterized by the following state matrices:

$$A = \begin{bmatrix} -2 & 0 & 2 \\ 0 & -2 & 0 \\ 2 & 0 & -2 \end{bmatrix}; B = \begin{bmatrix} 2 \\ 2 \\ 2 \end{bmatrix}; C = [2 \ 2 \ 2]; D = 0$$

- a) Give the transfer function of the state space system
- b) Give the $G(z)$ discrete transfer function of the process in zero-pole form if zero order hold is applied and sampling rate $T_s = 0.25$
- c) Plot a pole-zero diagram from vectors of poles and zeros
- d) Give the poles of the system. Is the system stable?
- e) Is the system state controllable? Is the system state observable?

- **Guidelines for writing the Lab Report**

The report has to include:

- ❖ Title page - Including: course number, lab title, student names, student IDs, Date the report was submitted.
 - ❖ Abstract - A summary of the contents of the lab report.
 - ❖ Procedure of methods or approach to the design or/and conduct of the experiments
 - ❖ Diagrams - Include all SIMULINK blocks used in the lab if any.
 - ❖ Plots - All plots of system response should be included in your report, including title, labels with unit, legends, etc. Note that Diagrams and Plots must be computer generated. Hand-drawn plots will not be accepted. All diagrams and plots must be labeled. The labels and annotations can be done by hand if appropriate but have to be clear.
 - ❖ Code - Include any code used in the lab. The code must be commented properly. It is good practice to put your code in separate m-files.
 - ❖ Discussion and answer to questions if any.
 - ❖ Conclusion or any other relevant ideas.
-