KKR & KSR INSTITUTE OF TECHNOLOGY & SCIENCES

(Approved by AICTE, Delhi, Affiliated to JNTU, Kakinada)

Accredited with "A" Grade by NAAC

Department of Electrical and Electronics Engineering

IV B.Tech II SEM (R13) :: A/Y(2017-2018)

DIGITAL CONTROL SYSTEMS

Hand Out

Preamble:

In recent years digital controllers have become popular due to their capability of accurately performing complex computations at high speeds and versatility in leading non linear control systems. In this context, this course focuses on the analysis and design of digital control systems.

Learning objectives:

- To understand the concepts of digital control systems and assemble various components associated with it. Advantages compared to the analog type.
- The theory of z–transformations and application for the mathematical analysis of digital control systems.
- To represent the discrete–time systems in state–space model and evaluation of state transition matrix.
- To examine the stability of the system using different tests.
- To study the conventional method of analyzing digital control systems in the w–plane.
- To study the design of state feedback control by "the pole placement method."

Syllabus:

UNIT – I:

Introduction and signal processing

Introduction to analog and digital control systems – Advantages of digital systems – Typical examples – Signals and processing – Sample and hold devices – Sampling theorem and data reconstruction – Frequency domain characteristics of zero order hold.

UNIT–II:

Z–transformations

Z–Transforms – Theorems – Finding inverse z–transforms – Formulation of difference equations and solving – Block diagram representation – Pulse transfer functions and finding open loop and closed loop responses.

UNIT–III:

State space analysis and the concepts of Controllability and observability

State Space Representation of discrete time systems – State transition matrix and methods of evaluation – Discretization of continuous – Time state equations – Concepts of controllability and observability – Tests (without proof).

UNIT – IV:

Stability analysis

Mapping between the S–Plane and the Z–Plane – Primary strips and Complementary Strips – Stability criterion – Modified routh's stability criterion and jury's stability test.

UNIT – V:
Design of discrete–time control systems by conventional methods
Transient and steady state specifications – Design using frequency response in the w–plane for lag and led compensators – Root locus technique in the z–plane.
UNIT – VI:
State feedback controllers:
Design of state feedback controller through pole placement – Necessary and sufficient conditions – Ackerman’s formula.

Prerequisite Courses:

S.no	Name of the course	Year/Semester
1	Control Systems	II/I

Course Outcomes:

C421.1	Define Digital control systems ,A/D and D/A conversion
C421.2	Apply z–transformations to different systems
C421.3	Test controllability and Observability of the system
C421.4	examine the stability for digital control systems
C421.5	Analyze digital control systems using w-plane
C421.6	Design of state feedback controller through pole placement

CO-PO Mapping:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
C421.1	3	2	--	1	--	--	--	--	--	--	--	--
C421.2	3	3	2	--	--	--	--	--	--	--	--	--
C421.3	3	3	--	2	--	--	--	--	--	--	--	--
C421.4	3	2	--	3	--	--	--	--	--	--	--	--
C421.5	2	2	3	--	--	--	--	--	--	--	--	--

Lesson Plan:

L /T No.	Topics covered	Teaching Aid	Text Book / Reference Book / Web	Page Numbers
Unit I: Introduction and signal processing				
L-01	Introduction to analog and digital control systems	GB&PC		
L-02	Advantages of digital systems	GB&PC		
L-03	Typical examples	GB&PC		
L-04	Typical examples	GB&PC		
T-01	General examples	GB&PC		
L-05	Sample and hold devices	GB&PC		
L-06	Sample and hold devices	GB&PC		
L-07	Sampling theorem	GB&PC		
L-08	Sampling theorem	GB&PC		
T-02	Sampling theorem example	GB&PC		
L-09	data reconstruction	GB&PC		
L-10	data reconstruction	GB&PC		
L-11	Frequency domain characteristics of zero order hold.	GB&PC		
L-12	Frequency domain characteristics of zero order hold.	GB&PC		
T-3	zero order hold	GB&PC		
Unit II: Z–transformations				
L-13	Z–Transforms	GB&PC	T1	24-25
L-14	Z–Transforms	GB&PC	T1	24-25
L-15	Theorems	GB&PC	T1	31-37
L-16	Theorems	GB&PC	T1	31-37
T-04	Z-Transform theorem	GB&PC	T1	31-37
L-17	Finding inverse z–transforms	GB&PC	T1	37-52
L-18	Finding inverse z–transforms	GB&PC	T1	37-52
L-19	Finding inverse z–transforms	GB&PC	T1	37-52
L-20	Finding inverse z–transforms	GB&PC	T1	37-52
T-05	Problem on finding inverse z–transforms	GB&PC	T1	37-52

L-21	Formulation of difference equations and solving	GB&PC	T1	52-54
L-22	Formulation of difference equations and solving	GB&PC	T1	52-54
L-23	Block diagram representation	GB&PC	T1	75-78
L-24	Block diagram representation	GB&PC	T1	75-78
T-06	Problem of difference equations and solving	GB&PC	T1	52-54
L-25	Pulse transfer functions	GB&PC	T1	98-110
L-26	Pulse transfer functions	GB&PC	T1	98-110
L-27	finding open loop and closed loop responses	GB&PC	T1	110-114
L-28	finding open loop and closed loop responses	GB&PC	T1	110-114
T-07	Problem of difference equations and solving	GB&PC		
Unit III: State space analysis and the concepts of Controllability and observability				
L-29	State Space Representation of discrete time systems	GB&PC	T1	297-302
L-30	State transition matrix	GB&PC	T1	302-312
L-31	methods of evaluation	GB&PC	T1	302-312
L-32	Discretization of continuous Time state equations	GB&PC	T1	312-317
T-08	Problem on state transition matrix	GB&PC	T1	302-312
L-33	Concepts of controllability and observability	GB&PC	T1	377-396
L-34	controllability Tests	GB&PC	T1	377-396
L-35	observability Tests	GB&PC	T1	377-396
L-36	observability Tests	GB&PC	T1	377-396
T-09	Problem on controllability and observability test	GB&PC	T1	377-396
Unit IV: Symmetrical Fault Analysis				
L-37	Mapping between the S–Plane and the Z–Plane	GB&PC	T1	174-182
L-38	Mapping between the S–Plane and the Z–Plane	GB&PC	T1	174-182
L-39	Primary strips and Complementary Strips	GB&PC	T1	182-193
L-40	Primary strips and Complementary Strips	GB&PC	T1	191-192
T-10	Mapping between S–Plane and the Z–Plane	GB&PC	T1	185-191
L-41	Stability criterion	GB&PC	T1	193-204
L-42	Stability criterion	GB&PC	T1	193-204
L-43	Modified routh's stability criterion	GB&PC	T1	225-242
L-44	Modified routh's stability criterion	GB&PC	T1	225-242
T-11	Problem on Stability	GB&PC	T1	225-242
L-45	Jury's stability test.	GB&PC	T1	204-225
L-46	Jury's stability test.	GB&PC	T1	193-204

Unit V: Design of discrete–time control systems by conventional methods				
L-47	Transient and steady state specifications	GB&PC	T1	193-204
L-48	Transient and steady state specifications	GB&PC	T1	193-204
T-12	Problem on Jury's stability test.	GB&PC	T1	193-204
L-49	Design using frequency response in the w–plane for lag and led compensators	GB&PC	T1	225-242
L-50	Design using frequency response in the w–plane for lag and led compensators	GB&PC	T1	225-242
L-51	Design using frequency response in the w–plane for lag and led compensators	GB&PC	T1	225-242
L-52	Design using frequency response in the w–plane for lag and led compensators	GB&PC	T1	225-242
T-13	Problem on Jury's stability test.	GB&PC	T1	193-204
L-53	Root locus technique in the z– plane.	GB&PC	T1	204-225
L-54	Root locus technique in the z– plane.	GB&PC	T1	204-225
L-55	Root locus technique in the z– plane.	GB&PC	T1	204-225
L-56	Root locus technique in the z– plane.	GB&PC	T1	204-225
T-14	Root locus technique	GB&PC	T1	204-225
Unit VI: State feedback controllers				
L-57	Design of state feedback controller through pole placement	GB&PC	T1	402-421
L-58	Design of state feedback controller through pole placement	GB&PC	T1	402-421
L-59	Necessary and sufficient conditions	GB&PC	T1	402-421
L-60	Necessary and sufficient conditions	GB&PC, PPT	T1	402-421
T-15	state feedback controller	GB&PC	T1	402-421
L-61	Ackerman's formula	GB&PC	T1	402-421
L-62	Ackerman's formula	GB&PC	T1	402-421
L-63	Ackerman's formula	GB&PC	T1	402-421
L-64	Ackerman's formula	GB&PC	T1	402-421
T-16	Ackerman's formula derivation	GB&PC	T1	402-421

GB&CP: Green Glass Board & Piece of chalk, L: lecture, T: Tutorial, W: Web reference

TEXTBOOK:

T1. Discrete–Time Control systems – K. Ogata, Pearson Education/PHI,2nd Edition

REFERENCES:

R1. Digital Control Systems, Kuo, Oxford University Press, 2nd Edition,2003.
R2. Digital Control and State Variable Methods by M.Gopal, TMH

WEB REFERENCES:

W1:nptel.ac.in/downloads/108103008/

W2: https://ocw.mit.edu/courses/mechanical-engineering/2-171-analysis-and-design-of-digital-control-systems-fall-2006/index.htm

Experiments Related to Course:

--NIL—

Unit wise Important Questions:

Unit I: Introduction and signal processing

	QUESTIONS	Marks	Related to CO	Level of Learning
1	A. Explain digital control System with the help of block diagram? Give the advantages of DCS?	5	CO-4	Knowledge
	B. Explain Digital control system with any one Example?	5	CO-4	Knowledge
2	A. Explain Analog to digital data conversion in detail?	5	CO-4	Comprehension
	B. Explain in detail about sample and hold devices	5		
3	A. Define Acquisition time, Aperture time, settling time of sample and hold device	5	CO-4	Knowledge
	B. Give block diagram of Sample/Hold device	5	CO-4	Application
4	A. Define Sampling Theorem	5	CO-4	Knowledge
	B. Explain simplified block diagram representation of A/D and D/A converters	5	CO-4	Comprehension
5	A. Expalin successive approximation method of A/D converter?	5	CO-4	Comprehension
	B. Expalin Integration type A/D converter	5		
6	A. Define Zero order hold?	5	CO-4	Comprehension
	B. Expalin frequency domain characteristics of Zero order hold?	5	CO-4	Comprehension

Unit II: Z–transformations

	QUESTIONS	Marks	Related to CO	Level of Learning
1	A. Define Z-Transform and Inverse Z-Transform	5	CO-4	Knowledge
	B. Find Z-Transform of Unit step function and Unit ramp function	5	CO-4	Knowledge
2	State and prove different properties of Z-Transform	10	CO-4	Comprehension
3	A. Find inverse Z-Transform of following function using Direct Division method $X(z) = \frac{1\ z+5}{(z-1)(z-0.2)}$	5	CO-4	Knowledge
	B. Find inverse Z-Transform of following function using Partial fraction method $X(z) = \frac{(1 - e^{-a})z}{(z-1)(z-e^{-a})}$	5	CO-4	Application
4	A. Find inverse Z-Transform of following function using inversion integral method $X(z) = \frac{(1 - e^{-a})z}{(z-1)(z-e^{-a})}$	5	CO-4	Knowledge
	B. Solve the following difference equation x(k+2)+3x(k+1)+2x(k)=0 where x(0)=0,x(1)=1.	5	CO-4	Comprehension
5	A. Define Pulse transfer function with a block diagram	5	CO-4	Comprehension
	B. Obtain Pulse transfer function of following function $G(s) = \frac{1}{(s+a)}$	5		
6	A. Explain Pulse transfer function of cascaded elements?	5	CO-4	Comprehension
	B. Explain Pulse transfer function of closed loop system?	5	CO-4	Comprehension

Unit III: State space analysis and the concepts of Controllability and observability

	QUESTIONS	Marks	Related to CO	Level of Learning
1	A. What is state space? Discuss the significance of State space	5	CO-4	Knowledge

	B. Explain state transition matrix	5	CO-4	Knowledge
2	Explain different State Space Representation of discrete time systems methods	10	CO-4	Comprehension
3	Derive all different State Space Representations of following system $\frac{Y(z)}{U(z)} = \frac{z+1}{z^2+1.3z+0.4}$	10	CO-4	Knowledge
4	Obtain the state transition matrix of X(k+1)=Gx(k) + Hu(k) Y(k)=C x(k) $G = \begin{bmatrix} 0 & 1 \\ -0.16 & -1 \end{bmatrix}$ H=$\begin{bmatrix} 1 \\ 1 \end{bmatrix}$ C=$[1 \quad 0]$ Also obtain x(k) and y(k)	10	CO-4	Knowledge
5	A. Derive the condition for Controllability	5	CO-4	Comprehension
	B. Check the following is Controllable or not $$\frac{Y(z)}{U(z)} = \frac{z+0.2}{(z+0.8)(z+0.2)}$$ Whose state matrices are $G = \begin{bmatrix} 0 & 1 \\ -0.16 & -1 \end{bmatrix}$ H=$\begin{bmatrix} 1 \\ 1 \end{bmatrix}$ C=$[1 \quad 0]$	5		
6	A. Derive the condition for Observability	5	CO-4	Comprehension
	B. Check the following is Observability or not $$\frac{Y(z)}{U(z)} = \frac{z+0.2}{(z+0.8)(z+0.2)}$$ Whose state matrices are $G = \begin{bmatrix} 0 & 1 \\ -0.16 & -1 \end{bmatrix}$ H=$\begin{bmatrix} 1 \\ 1 \end{bmatrix}$ C=$[1 \quad 0]$	5	CO-4	Comprehension

Unit IV: Stability analysis

	QUESTIONS	Marks	Related to CO	Level of Learning
1	Explain the mapping between Spine and Z plane i) Primary and complementary strips ii) Constant frequency loci iii) Constant damping loci	10	CO-4	Knowledge
2	Explain stability conditions of closed loop systems in Z over in S plane.	10	CO-4	Knowledge
3	a) Discuss the stability analysis of discrete control	5	CO-4	Knowledge

	system using I)Routh Stability criteria ii) Bilinear transformation			
	b)Using jury stability criterion ,determine the stability of the following discrete time Systems. $Z^3+3.3Z^2+4Z+0.8=0$	5		Comprehension
4	B) Using jury stability criterion find range of 'k "which characteristics equation $Z^{3+}KZ^2+1.5KZ-(k+1)=0$ is closed loop stable.	5	CO-4	Knowledge
	A) State and explain jury stable test.	5		Knowledge
5	b) Consider the discrete time unity feedback control system.(T=1sec) whose open loop pulse transfer function is given by G(z)=K(0.3679Z+0.2642)/(Z-0.3679)(Z- Determine range of K for stability .	5	CO-4	Comprehension
	a) Distinguish between the jury stability test and stability analysis using bilinear transformation Coupled with Routh stability criterion.	5		Knowledge
6	Explain the mapping between Spine and Z plane	10	CO-4	Comprehension

Unit V: Design of discrete–time control systems by conventional methods

	QUESTIONS	Marks	Related to CO	Level of Learning
1	a)Write the transient response specifications	5	CO-5	Knowledge
	b)Explain design procedure in plane	5	CO-4	Knowledge
2	a)Discuss about response of linear time invariant discrete time system to a sinusoidal input	5	CO-4	Comprehension
	b)Explain the relation between bilinear transformation and W plane	5	CO-5	Knowledge
3	a)Discuss the review of Phase Lag, Phase Lead and Phase Lead Lag compensation	5	CO-4	Knowledge
	b)Explain about digital PID controllers	5	CO-4	Knowledge
4	a)State some of the Specifications of Transient response	5	CO-4	Knowledge
	b)Explain about the Response of linear time invariant discrete time system to a Sinusoidal input	5	CO-4	Knowledge
5	a)Explain W-plane design procedure	5	CO-4	Comprehension
	b)Discuss relation between bilinear transformation and w-plane	5	CO-4	Knowledge
6	a)Explain phase lag, lead and lag-lead compensator	5	CO-4	Comprehension
	b)What are the PID controllers and explain	5	CO-4	Comprehension

Unit VI: State feedback controllers

	QUESTIONS	Marks	Related to CO	Level of Learning
1	Explain the sufficient condition for design of state feedback controller through pole placement	5	CO-5	Knowledge
2	Derive the Ackerman’s formula	5	CO-4	Comprehension