

APJ ABDUL KALAM
TECHNOLOGICAL
UNIVERSITY

SEMESTER VI

MINOR



CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
EET 382	POWER SEMICONDUCTOR DRIVES	VAC	3	1	0	4

Preamble: This course is intended to provide fundamental knowledge in dynamics and control of Electric Drives, to justify the selection of Drives for various applications and to familiarize the various semiconductor controlled drives employing various motors

Prerequisite: Basic knowledge of mathematics, basic electronics and analog electronics.

Course Outcomes: After the completion of the course the student will be able to

CO 1	Explain dynamics and control of electric drives.
CO 2	Explain the performance of DC motor drives used in various applications.
CO 3	Explain control strategies for three phase induction motor drives.
CO 4	Explain variable speed synchronous motor drives.
CO5	Choose an appropriate drive system for a specific application.

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO 1	3	1	-	-	-	-	-	-	-	-	-	1
CO 2	3	2	1	-	-	-	-	-	-	-	-	1
CO 3	3	3	-	-	-	-	-	-	-	-	-	1
CO 4	3	3	-	-	-	-	-	-	-	-	-	1
CO 5	3	2	1	2	2	-	-	-	-	-	-	1

Assessment Pattern

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember	10	10	20
Understand	20	20	40
Apply	20	20	40
Analyse			
Evaluate			
Create			

End Semester Examination Pattern : There will be two parts; Part A and Part B. **Part A** contain 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions. **Part B** contains 2 questions from each module of which student should answer any one. Each question can have maximum 2 sub-divisions and carry 14 marks.

Course Level Assessment Questions**Course Outcome 1 (CO1):**

1. Draw and explain the typical torque speed characteristics of different types of mechanical loads pump, hoist, fan and traction loads. Write the various factors that influence the choice of electric drives?
2. Explain clearly, the four quadrant operation of a motor driving a hoist load.
3. Differentiate between passive and active load torques with example.

Course Outcome 2 (CO2)

1. Explain using suitable diagrams and wave forms, two quadrant operation of single phase full converter fed separately excited dc motor drive for continuous and discontinuous mode of operation and obtain the boundary between two modes. Derive the output voltage equation for both modes.
2. Draw the circuit diagram of a class-C chopper fed DC motor drive. Draw its V/I characteristics.
3. Explain the four quadrant operation of a chopper fed dc motor drive with the help of necessary circuit diagram and waveform

Course Outcome 3 (CO3):

1. Draw and explain the speed torque characteristics of a stator voltage controlled induction motor. Why stator voltage control is not suitable for speed control of induction motor with constant load torque.
2. Explain the static Kramer scheme for the speed control of a slip ring IM. How the slip power is effectively utilised in this drive?
3. Explain v/f control of induction motor. Draw the speed torque characteristics. How the speed of induction motor is controlled using Voltage source inverter?

Course Outcome 4 (CO4):

1. Explain power and torque capability curves of a synchronous motor drive. In variable frequency control of synchronous motor drive, why V/f ratio is maintained constant upto base speed and voltage constant above base speed.
2. Explain the true synchronous mode of operation of synchronous motor drive.
3. How can we control the speed of an ac motor drive using field oriented control? Explain with the help of a block diagram
4. With a suitable block diagram explain variable frequency control of synchronous motor drive in self control mode

Course Outcome 5 (CO5):

1. Differentiate trapezoidal type BLDC motor and sinusoidal type PMSM motor
2. With neat sketches explain the operation of a switched reluctance motor drive.
3. Explain the principle of operation of PMSM motor for 120° commutation with neat circuit diagram.
4. With a block diagram explain the micro controller based PMSM drive

Model Question Paper

QP Code:

Pages: 2

Reg No: _____

Name: _____

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY
SIXTH SEMESTER B.TECH DEGREE EXAMINATION,
MONTH & YEAR
Course Code: EET382

Course Name: POWER SEMICONDUCTOR DRIVES

Max. Marks: 100

Duration: 3 Hours

PART A

Answer all Questions. Each question carries 3 Marks

1. What are the different components of a load torque? Explain each components of load torque.
2. Derive the mathematical condition to obtain the steady state stability of an electric drive.
3. Which are the method of speed control suitable for getting speeds higher than base speed and lower than base speed in a dc motor?
4. Explain the regenerative braking operation of a chopper fed dc motor drive with the help of necessary circuit diagram.
5. Explain the speed control of three phase induction motor by varying stator voltage.
6. Explain v/f control of induction motor. Draw the speed torque characteristics.
7. How to control the speed of synchronous motor by using voltage source inverter?
8. Why the field oriented control of ac motor is superior to other types of speed control?
9. Explain about the classification of PM synchronous motor.
10. Compare the construction and performance of BLDC motor and PMAC motor.

(10 x 3 =30)

PART B

Answer any one full question from each module. Each question carries 14 Marks

Module 1

11. (a) A motor load system has the following details: Quadrants I and II, $T = 400 - 0.4N$, N-m, where N is the speed in rpm. Motor is coupled to a active load torque, $T_l = \pm 200$, N-m. Calculate motor speeds for motoring and braking in forward direction. When operating in quadrants III and IV, $T = -400 - 0.4N$, N-m. Calculate the equilibrium speed in quadrant III. **(8)**
- (b) What are the speed- torque characteristics of pump, fan and traction loads? **(6)**

12. (a) With the help of a neat sketch explain the multi quadrant operation of a motor driving hoist load (8)
- (b) Explain the operation of closed loop control scheme? What are the importance of current control and speed control loops (6)

Module 2

13. (a) A 220 V, 1500 rpm, 11.6 A separately excited motor is controlled by a 1-phase fully controlled rectifier with an ac source voltage of 230 V, 50 Hz. Filter inductance is added to ensure continuous conduction for any torque greater than 25 percent of rated torque, $R_a = 2 \text{ ohm}$. What should be the value of the firing angle to get the rated torque at 1000 rpm? Calculate the firing angle for the rated braking torque and - 1500 rpm. Also calculate the motor speed at the rated torque and $\alpha = 160^\circ$ for the regenerative braking in the second quadrant. (7)
- (b) Explain the operation of four quadrant chopper fed separately excited DC motor drive with necessary diagrams. (7)
14. (a) A 220 V, 1000 rpm and 200 A separately excited dc motor has an armature resistance of 0.02Ω . The motor is fed from chopper which provides both motoring and braking operations. The source has a voltage of 230V. Assume CCM. (i) Calculate duty ratio of chopper for motoring operation at rated torque and 400 rpm. (ii) Calculate duty ratio of chopper for braking operation at rated torque and 400 rpm. (8)
- (b) Draw the circuit diagram and waveforms of a class-C chopper fed DC motor. Explain. Draw its V/I characteristics. (6)

Module 3

15. (a) Explain the static Kramer scheme for the speed control of a slip ring IM. Explain the firing angle control of thyristor bridge with constant motor field. (8)
- (b) Explain the closed loop static rotor resistance control method for the speed control of a slip ring induction motor. What are the disadvantages of this method? (6)
16. (a) What is slip power recovery scheme? Describe static Scherbius drive and show that the slip at which it operates is given by $S = - (aT / a) \cos\alpha$, where a and aT pertain to per phase turns ratio for induction motor and transformer respectively. Why it is always suggested to use a transformer in line side converter for static Scherbius drive? (10)
- (b) Compare speed control of induction motor using VSI and CSI (4)

Module 4

17. (a) Explain the different mode of operation of synchronous motor drive by variable frequency control method. (10)
- (b) Briefly explain the concept of space vector (4)

18. (a) With the help of block diagram explain the closed loop speed control of load commutated inverter fed synchronous motor. (8)
- (b) Explain the frame transformation from three phase to synchronous reference frame. What is its significance in speed control? (6)

Module 5

19. (a) With the help of schematic diagram explain microcontroller based permanent magnet synchronous motor drives (7)
- (b) With suitable converter circuit diagram discuss the modes of operation of Switched Reluctance motor drive. (7)
20. Explain the principle of operation and control circuit of PMBLDC motor for 120° commutation with neat circuit diagram. (14)

Syllabus

Module 1

Introduction to electric drives – Block diagram – advantages of electric drives – Dynamics of motor load system, fundamental equations, and types of load – classification of load torque, four quadrant operation of drives. Steady state stability. Introduction to closed loop control of drives.

Module 2

DC motor drives- constant torque and constant power operation, separately excited dc motor drives using controlled rectifiers, single phase semi converter and single phase fully controlled converter drives. Three phase semi converter and fully controlled converter drives.

Chopper controlled DC drives. Analysis of single quadrant chopper drives. Regenerative braking control. Two quadrant chopper drives. Four quadrant chopper drives.

Module 3

Induction Motor Drives-Three phase induction motor speed control using semiconductor devices. Stator voltage control – stator frequency control – Stator voltage and frequency control (v/f) - Voltage source inverter control - Current source inverter control. Rotor chopper speed control – slip power recovery control schemes – sub synchronous and super synchronous speed variations.

Module 4

Synchronous motor drives – Synchronous motor variable speed drives- variable frequency control- modes of variable frequency control. Closed loop speed control of load commutated inverter fed synchronous motor drive .Concept of space vector – Basic transformation in reference frame theory – field orientation principle.

Module 5

Permanent Magnet and variable reluctance motor drives – different types –Sinusoidal PMAC drives-Brushless DC motor drives- control requirements, converter circuits, modes of operation . Microcontroller based permanent magnet synchronous motor drives (schematic only). Switched Reluctance motor drive- converter circuits- modes of operation.

Text Books

1. Bimal K. Bose “Modern power electronics and AC drives” Pearson Education, Asia 2003
2. Gopal K. Dubey. “Fundamentals of Electric Drives” , second edition, Narosa Publishing house

Reference Books

1. Dewan S.B. , G. R. Slemon, A. Strauvhen, “Power semiconductor drives”, John Wiley and sons.
2. Dr. P. S. Bimbra “Power electronics”, Khanna publishers.
3. Dubey G. K. “Power semiconductor control drives” Prentice Hall, Englewood Cliffs, New Jersey, 1989.
4. N. K. De, P. K. Sen “Electric drives” Prentice Hall of India 2002.
5. Ned Mohan, Tore m Undeland, William P Robbins, “Power electronics converters applications and design”, John Wiley and Sons.
6. Pillai S. K. “A first course on electric drives”, Wielely Eastern Ltd, New Delhi.
7. Vedam Subrahmanyam, “Electric Drives”, MC Graw Hill Education, New Delhi.
8. 8.R. Krishnan , “Electric Motor Drives Modeling, Analysis and Control”, Prentice Hall of India 2007.

Course Contents and Lecture Schedule

No	Topic	No. of Lectures
1	Introduction to electric drives (9 hours)	
1.1	Block diagram – Parts of Electric Drives. advantages of electric drives	2
1.2	Dynamics of motor load system, fundamental torque equations, equivalent value of drive parameters (both rotational and translational motion)	2
1.3	components of load torque ,types of load and classification of load torque	2
1.4	four quadrant operation of drives	1
1.5	Steady state stability- condition for stability of equilibrium point	1
1.6	Introduction to closed loop control of drives- speed, current, torque and position control	1
2	DC motor drives (10 hours)	

2.1	Speed control-constant torque and constant power operation	2
2.2	Separately excited dc motor drives using controlled rectifiers- single phase semi converter and single phase fully controlled converter drives.	3
2.3	Three phase semi converter and fully controlled converter drives.	2
2.4	Chopper controlled DC drives- Analysis of single quadrant chopper drives. Regenerative braking control.	1
2.5	Two quadrant chopper drives. Four quadrant chopper drives	2
3	Induction Motor Drives (8 hours)	
3.1	Three phase induction motor speed control using semiconductor devices. Stator voltage control – stator frequency control	2
3.2	Stator voltage and frequency control (v/f)	1
3.3	Voltage source inverter control - Current source inverter control.	2
3.4	Static Rotor resistance speed control using chopper	1
3.5	Slip power recovery control schemes – sub synchronous and super synchronous speed variations.	2
4	Synchronous motor drives (9 hours)	
4.1	Synchronous motor variable speed drives- variable frequency control- modes of variable frequency control- true synchronous mode and self control mode	3
4.2	Closed loop speed control of load commutated inverter fed synchronous motor drive	2
4.3	Concept of space vector –Basic transformation in reference frame theory.	2
4.4	Principle of vector control- introduction to field oriented control of ac motor drives	2
5	Permanent Magnet and variable reluctance motor drives (8 hours)	
5.1	Different types –Sinusoidal PMAC drives-	2
5.2	Brushless DC motor drives- control requirements, converter circuits, modes of operation.	3
5.3	Microcontroller based permanent magnet synchronous motor drives (schematic only).	1
5.4	Switched Reluctance motor drive- converter circuits- modes of operation.	2

CODE	COURSE NAME	CATEGORY	L	T	P	CREDITS
EET384	INSTRUMENTATION AND AUTOMATION OF POWER PLANTS	VAC	3	1	0	4

Preamble: This course introduces measurements and instruments used in power plants. Automation of power plants and Supervisory control and data acquisition are also discussed.

Prerequisite: Introduction to Power Engineering/ Energy Systems

Course Outcomes : After the completion of the course the student will be able to:

CO 1	Analyse different instruments used for measuring parameters in a power plant.
CO 2	Explain various control systems in power plants.
CO 3	Identify different components of SCADA for applications in power plants.

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO 1	3	3										1
CO 2	3	3										1
CO 3	3	3										1

Assessment Pattern

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember (K1)	10	10	10
Understand (K2)	20	20	40
Apply (K3)	20	20	50
Analyse (K4)	-	-	-
Evaluate (K5)	-	-	-
Create (K6)	-	-	-

End Semester Examination Pattern: There will be two parts; Part A and Part B. Part A contain 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions. Part B contains 2 questions from each module of which student should answer any one. Each question can have maximum 2 sub-divisions and carry 14 marks.

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Explain the working of a digital frequency meter (K2)
2. Explain the working of a radiation detector (K2)

Course Outcome 2 (CO2):

1. Compare the performance of boiler following mode and turbine following mode of operation in power plants. (K4).
2. Explain interlocks in boiler operation (K2).

Course Outcome 3 (CO3):

1. Discuss about the various SCADA architectures. Compare them.(K2, K3)
2. Explain the ladder logic approach of programming in a PLC(K2,).

Model Question paper

QP CODE:

PAGES:2

Reg. No: _____

Name: _____

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY
SIXTH SEMESTER B.TECH DEGREE EXAMINATION,
MONTH & YEAR
Course Code: EET384

Course Name: INSTRUMENTATION AND AUTOMATION OF POWER PLANTS

Max. Marks: 100

Duration: 3 Hours

PART A (3 x 10 = 30 Marks)

Answer all Questions. Each question carries 3 Marks

1. Explain briefly the working principle of an induction type wattmeter.
2. Discuss the role of dust monitor in power plants.
3. Write notes on temperature measurement techniques used in boilers?
4. Discuss how pedestal vibration is measured in boilers?
5. Explain what do you mean by co-ordinated control in boilers.
6. Discuss the role of distributed control system in a power plant.
7. List out the differences between RTUs and IEDs.

8. State the advantages and disadvantages of PLC.
9. Discuss the operating states of a power system.
10. Explain briefly what do you mean by Energy Management System.

PART B (14 x 5 = 70 Marks)

Answer any one full question from each module. Each question carries 14 Marks

Module 1

11. a. With the help of a neat diagram, explain the working of a digital frequency meter. (7)
 b. Explain how the flow of feed water is measured in power plants. (7)
12. a. With the help of a neat sketch, explain the working of a power factor meter. (10)
 b. Explain the working of a radiation detector. (4)

Module 2

13. a. Explain how flame monitoring is done in boilers. (6)
 b. Discuss the pressure measuring devices in boilers. (7)
14. a. Describe with a neat schematic, how shaft vibration can be detected. (7)
 b. Explain the working of a non contact type speed measuring device. (7)

Module 3

15. a. Explain the control of boiler drum level in power plant operation. (7)
 b. Explain how steam temperature can be controlled in boilers. (7)
16. a. Compare the performance of boiler following mode and turbine following mode of operation in power plants. (7)
 b. Explain interlocks in boiler operation. (7)

Module 4

17. a. Describe the basic components of a SCADA system. (4)
 b. Describe the components of an IED. (4)
 c. Explain the ladder logic approach of programming in a PLC (6)
18. a. Explain the objectives of SCADA. (4)
 b. Discuss about the various SCADA architectures. Compare them. (10)

Module 5

19. a. Discuss the main requirements of an Energy Management System. (4)
 b. With the help of a diagram, explain what do you understand by an EMS framework. (10)
20. Explain the applications of SCADA in generation operation and management. (14)

Syllabus**Module 1**

Measurements in power plants: Electrical measurements – current, voltage, power, frequency, power factor etc. – non electrical parameters – flow of feed water, fuel, air and steam with correction factor for temperature – steam pressure and steam temperature – drum level measurement – radiation detector – smoke density measurement – dust monitor.

Module 2

Measurement in boiler and turbine: Metal temperature measurement in boilers, piping. System for pressure measuring devices - smoke and dust monitor - flame monitoring. Introduction to turbine supervising system - pedestal vibration - shaft vibration - eccentricity measurement. Installation of non-contracting transducers for speed measurement.

Module 3

Controls in boilers: Boiler drum level measurement methods - feed water control - soot blowing operation - steam temperature control - Coordinated control - boiler following mode operation - turbine following mode operation - selection between boiler and turbine following modes. Distributed control system in power plants interlocks in boiler operation - Cooling system - Automatic turbine runs up systems.

Module 4

Introduction to SCADA systems: - Elements of a SCADA system - benefits of SCADA system - SCADA Architecture: Various SCADA architectures, advantages and disadvantages of each system

SCADA System Components: - Remote Terminal Unit-(RTU), Intelligent Electronic Devices (IED) - PLC: Block diagram, Ladder diagram, Functional block diagram, Applications, Interfacing of PLC with SCADA.

Module 5

SCADA Applications: □ Operating states of a power system - Energy management System (EMS) – EMS framework – Generation operation and management – Load forecasting – unit commitment – hydrothermal co-ordination – Real time economic dispatch and reserve monitoring – real time automatic generation control

Text books:

1. P. K. Nag, "Power Plant Engineering" 2nd Edition, Tata McGraw-Hill Education, 2002.
2. R.K.Jain, "Mechanical and Industrial Measurements", 10th Edition, Khanna Publishers, New Delhi, 1995.
3. Sam. G.Dukelow, "The Control of Boilers", 2nd Edition, ISA Press, New York, 1991.
4. Stuart A. Boyer, 'SCADA-Supervisory Control and Data Acquisition', Instrument Society of America Publications, USA, 2004.

Reference Books:

1. David Lindsley, "Boiler Control Systems", McGraw Hill, New York, 1991.
2. Jervis M.J, "Power Station Instrumentation", Butterworth Heinemann, Oxford, 1993.

Course Contents and Lecture Schedule:

Sl. No	Topic	No. of Lectures
1	Measurements in a power plant (8 hours)	
1.1	Electrical measurements – Current, voltage, power, frequency, power factor etc.	2
1.2	Non electrical parameters – Flow of feed water, fuel, air and steam with correction factor for temperature – Steam pressure and steam temperature	2
1.3	Drum level measurement – Radiation detector	2
1.4	Smoke density measurement – Dust monitor.	2
2	Monitoring (9 hours)	
2.1	Measurement in boiler and turbine: Metal temperature measurement in boilers, piping.	2
2.2	System for pressure measuring devices, smoke and dust monitor, flame monitoring.	2
2.3	Introduction to turbine supervising system, pedestal vibration	1
2.4	Shaft vibration, eccentricity measurement.	2
2.5	Installation of non-contracting transducers for speed measurement.	2
3	Control systems (9 Hours)	
3.1	Controls in boiler: Boiler drum level measurement methods, feed water control, soot blowing operation, steam temperature control	2
3.2	Coordinated control, boiler following mode operation, turbine following mode operation	1
3.3	Selection between boiler and turbine following modes.	1
3.4	Distributed control system in power plants interlocks in boiler operation.	1
3.5	Cooling system, Automatic turbine runs up systems.	2

4	SCADA systems (10 Hours)	
4.1	Introduction to SCADA systems: - Elements of a SCADA system - benefits of SCADA system	1
4.2	SCADA Architecture: □ Various SCADA architectures, advantages and disadvantages of each system	2
4.3	SCADA System Components: - Remote Terminal Unit-(RTU),	3
4.4	Intelligent Electronic Devices (IED) - PLC: Block diagram, Ladder diagram, Functional block diagram	3
4.5	Applications, Interfacing of PLC with SCADA.	1
5	SCADA applications (9 Hours)	
5.1	SCADA Applications: □ Operating states of a power system	2
5.2	Energy management System (EMS) – EMS framework	3
5.3	Generation operation and management – Load forecasting – unit commitment	2
5.4	Hydrothermal co-ordination – Real time economic dispatch and reserve monitoring – real time automatic generation control	2



CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
EET386	DIGITAL CONTROL	VAC	3	1	0	4

Preamble: This course aims to provide a strong foundation in digital control systems. Modelling, time domain analysis, frequency domain analysis and stability analysis of sampled data control systems based on Pulse Transfer function (conventional) approach and State variable concept are discussed. The design of digital control is also introduced.

Prerequisite: Basics of Circuits, Networks and Control Systems

Course Outcomes: After the completion of the course the student will be able to:

CO 1	Describe the role of various control blocks and components in digital control systems.
CO 2	Analyse the time domain responses of the sampled data systems using Z Transform.
CO 3	Analyse the stability of the given discrete time system.
CO 4	Apply state variable concepts to assess the performance of linear systems
CO 5	Apply Liapunov methods to assess the stability of linear systems
CO 6	Explain control system design strategies in discrete time domain.

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO 1	3		-	-	-	-	-	-	-	-	-	1
CO 2	3	2	-	-	2	-	-	-	-	-	-	1
CO 3	3	2	-	-	-	-	-	-	-	-	-	1
CO 4	3	2	-	-	2	-	-	-	-	-	-	1
CO 5	3	2	-	-	-	-	-	-	-	-	-	1
CO 6	3	2	-	-	-	-	-	-	-	-	-	1

Assessment Pattern:

Total Marks	CIE marks	ESE marks	ESE Duration
150	50	100	03 Hrs

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember (K1)	10	10	20
Understand (K2)	15	15	40
Apply (K3)	25	25	40
Analyse (K4)			
Evaluate (K5)			
Create (K6)			

End Semester Examination Pattern : There will be two parts; Part A and Part B. **Part A** contains 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions.

Part B contains 2 questions from each module of which student should answer any one. Each question carries 14 marks and can have maximum 2 sub-divisions.

Course Level Assessment Questions:

Course Outcome 1 (CO1)

1. Derive the transfer function and obtain the frequency response characteristics of zero order hold circuit.
2. Explain how reconstruction of original signal is achieved from discrete time signals.
3. Explain any three factors to be considered for the choice of sampling frequency for a system.

Course Outcome 2 (CO2):

1. Derive the transfer function and obtain the frequency response characteristics of first order hold.
2. Problems related to steady state error.
3. Problems related to ZTF from difference equation form.

Course Outcome 3(CO3):

1. Problems related to the stability analysis using Jury's test
2. Problems related to the stability analysis using Bilinear Transformation
3. Problems to determine range of K or other TF parameter for stability/ oscillation.

Course Outcome 4 (CO4):

1. Problems related to canonical form representations
2. Problems based on state transition matrix
3. Problems to determine the solution of state equations.

Course Outcome 5 (CO5):

1. Check the stability of the given LTI system using Liapunov method.
2. Explain the physical relevance of Liapunov function.
3. Test the stability of the given nonlinear state model.

Course Outcome 6 (CO6):

1. Design a digital controller using root locus approach to meet the required specifications.
2. Problems on PID tuning and selection.
3. Pole placement problems for LTI systems.

Model Question Paper

PAGES: 3

QP CODE:

Reg.No: _____

Name: _____

**APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY
SIXTH SEMESTER B.TECH DEGREE EXAMINATION
MONTH & YEAR**

Course Code: EET386

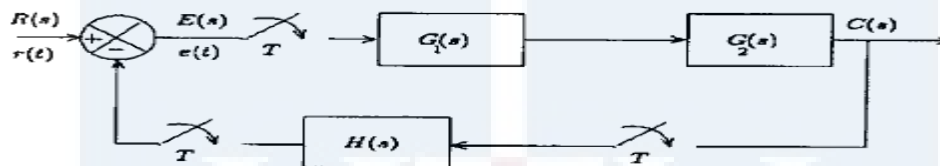
Course Name: **DIGITAL CONTROL**

Max. Marks: 100

Duration: 3 Hours

PART A**Answer all Questions. Each question carries 3 Marks**

- 1 Explain any four advantages of sampled data control systems.
- 2 Determine the z-transform of $x(n) = (1/2)^n u(-n)$.
- 3 Obtain the pulse transfer function for the given system.



- 4 Obtain the poles and zeroes of the system governed by the difference equation:

$$y(n) + \frac{5}{4}y(n-1) + \frac{3}{8}y(n-2) = 2x(n) - x(n-1)$$
- 5 Draw and explain the mapping between s-plane to z-plane for the constant frequency loci.
- 6 Explain how does the P- controller affect the performance of a DT system.
- 7 Obtain the diagonal canonical form of the system with $G(z) = \frac{z+0.5}{(z^2+1.4z+0.4)}$
- 8 Determine the state transition matrix for the DT system with state matrix

$$A = \begin{bmatrix} 0 & 1 \\ -0.15 & -1 \end{bmatrix}$$
- 9 State and explain the Liapunov stability theorem for LTI discrete time systems.
- 10 Determine the observability of the system with: $A = \begin{bmatrix} -5 & 0 \\ -2 & -3 \end{bmatrix}; C = [1 \quad -1]$

PART B**Answer any one full question from each module. Each question carries 14 Marks****Module 1**

- 11 a) Derive the transfer function of a ZoH circuit. (5)
 b) Determine the inverse z-transform of the following functions:

$$i) X(z) = \frac{2z^{-1}}{(1-0.25z^{-1})^2}; ROC: |z| > \frac{1}{4}, \text{ and, } ii) F(z) = \frac{3z^{-1}}{(1-z^{-1})(1-2z^{-1})}; ROC: |z| > 2$$
 (9)
- 12 a) Determine the Z transform of $H(s) = \frac{3}{s(s+2)^2}$ (4)

b) Write short notes on:

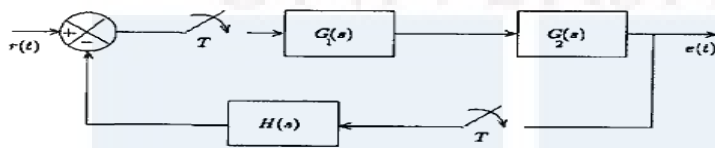
- i) Aliasing effect
- ii) Importance of First order hold circuit
- iii) Region of convergence for ZT

(10)

Module 2

- 13 a) i) Obtain the direct form realization for the system described by the difference equation: $y(n) - \frac{5}{6}y(n-1] + \frac{1}{6}y(n-2) = 2x(n)$
- ii) Also determine the impulse response $h(n)$ for the above system. (3+5)

- b) Obtain the pulse transfer function for the unity feedback system with $G_1(s) = \frac{1}{s}$, $G_2(s) = \frac{1}{(s+2)}$ and assume $T=1$ second



(6)

- 14 a) Obtain the unit impulse response $C(n)$ of the following feedback DT system with

$$G(s) = \frac{1}{(s+3)}, H(s) = \frac{1}{s}$$

Assume ideal sampling and $T=1$ ms.



(9)

- b) Explain the factors on which the steady state error constants depend on? (5)

Module 3

- 15 a) Check stability of the system described by the following characteristic equation, using Bilinear transformation: $z^3 - 0.2z^2 - 0.25z + 0.05 = 0$ (7)
- b) With suitable characteristics compare between PI and PD controllers. (7)
- 16 a) For a unity feedback system with $G(z) = \frac{K}{z(z^2 - 0.2z - 0.25)}$ determine the range for K for ensuring stability, using Jury's test. (5)
- b) With help of suitable sketches, explain how can you use root locus technique to design a digital controller. (9)

Module 4

- 17 a) Obtain the phase variable representation for the system with $G(z) = \frac{z+0.5}{(z^3+1.4z^2+0.5z+0.2)}$ (5)
- b) Determine the solution for the homogeneous system $x(k+1) = G x(k)$, where: $G = \begin{bmatrix} 0 & 1 \\ -0.16 & -1 \end{bmatrix}$ and $x(0) = \begin{bmatrix} 1 \\ -1 \end{bmatrix}$ (9)
- 18 a) Determine the pulse transfer function $Y(z)/U(z)$ for the system with: $x(k+1) = G x(k) + H u(k)$ and $y(k) = C x(k) + D u(k)$, where $G = \begin{bmatrix} 0 & 1 \\ -0.16 & -1 \end{bmatrix}$, $H = \begin{bmatrix} 1 \\ 1 \end{bmatrix}$, $C = [1 \ 0]$ and $D=0$ (9)

- b) Show that for a given pulse transfer function, the states space representation is not unique. (5)

- a) Determine the stability of the LTI system with state model using Liapunov method:

$$\dot{X} = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -1 & -2 & -5 \end{bmatrix} X \quad (9)$$

- b) Determine the controllability of the state model: $\dot{x} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 2 \\ 0 & -1 & -7 \end{bmatrix} x + \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} u$ (5)

- 19 a) Test stability of the nonlinear system given below, using Liapunov method.

$$\dot{X} = \begin{bmatrix} -4 & 0 \\ 3x_2^2 & -2 \end{bmatrix} X$$

(4)

- b) Design a state feedback controller for the following system such that the closed loop poles are placed at: $-1 \pm j2$ and -10 .

$$\dot{x} = \begin{bmatrix} 0 & 1 & 0 \\ 0 & -1 & 2 \\ 0 & -1 & -5 \end{bmatrix} x + \begin{bmatrix} 0 \\ 0 \\ 2 \end{bmatrix} u \quad (10)$$

Syllabus

Module 1

Digital control system (10 hours)

Basic block diagram of digital control system- Typical examples- Advantages of digital control systems.

Mathematical modelling of sampling process- sampling theorem- Aliasing effect- Impulse train sampling- Zero order and First order hold circuits- Signal reconstruction.

Discrete form of special functions- Discrete convolution and its properties.

Z Transform: Region of convergence- Properties of Z transform — Inverse ZT- methods.

Module 2

Analysis of LTI Discrete time systems (8 hours)

Difference equation representations of LTI systems- Block diagram representation in Direct form

Z-Transfer function- Analysis of difference equation of LTI systems using Z transfer function.

Pulse transfer function: Pulse transfer function of closed loop systems.

Time responses of discrete data systems-Steady state performance-

Static error constants

Module 3

Stability analysis and Digital controllers (9 hours)

Stability analysis: Stability analysis of closed loop systems in the z-plane, Jury's stability test- Use of bilinear transformation for stability analysis.

Digital Controllers: Introduction to Digital Controllers- Root locus based design of digital Controllers.

PID controllers: Digital PID controller and design of PID controllers.

Module 4**State space analysis (8 hours)**

State variable model of discrete data systems -Various canonical form representations- controllable, observable forms, Diagonal canonical and Jordan canonical forms

State transition matrix: Properties- Computation of state transition matrix using z-transform method -Solution of homogeneous systems

Determination of transfer function from state space model.

Module 5**Pole placement design and Liapunov stability analysis (10 hours)**

Controllability and observability for continuous time systems

Pole placement design using state feedback for continuous time systems

Controllability and observability for discrete time systems- Digital control design using state feedback discrete time systems

Liapunov stability Analysis: Liapunov function- Liapunov methods to stability of linear and nonlinear systems- Liapunov methods to LTI continuous time systems

Liapunov methods to LTI Discrete time systems (Theorem only).

Text Books:

1. Ogata K., Discrete Time Control Systems, 2/e, Pearson Education.
2. Kuo B. C, Digital Control Systems, 2/e, Saunders College Publishing, Philadelphia, 1992.
3. Gopal M, Digital Control and State Variable Methods, 2/e, Tata McGraw Hill
4. Philips C. L., Nagle H. T. and Chakraborty A., Digital Control Systems, 4/e, Pearson

References:

1. Constantine H. Houpsis and Lamont G. B., Digital Control Systems Theory, Hardware Software, 2/e, McGraw Hill.
2. Isermann R., Digital Control Systems, Fundamentals, Deterministic Control, 2/e, Springer Verlag, 1989.
3. Liegh J. R, Applied Digital Control, 2/e, Dover Publishers.
4. Gopal M, Modern Control System Theory, 2/e, New Age Publishers

Course Contents and Lecture Schedule:

Module	Topic coverage	No. of Lectures
1	Digital control system (10 hours)	
1.1	Basic block diagram of digital control system- Typical examples- Advantages of digital control systems.	1
1.2	Mathematical modelling of sampling process -sampling theorem- Aliasing effect- Impulse train sampling	2
1.3	Zero order and First order hold circuits- Signal reconstruction	2
1.4	Discrete form of special functions- Discrete convolution and its properties	1
1.5	Z Transform: Region of convergence- Properties of the Z transform –	2

1.6	Inverse ZT- methods	2
2	Analysis of LTI Discrete time systems (8 hours)	
2.1	Difference equation representations of LTI systems- Delay operator and block diagram representation in Direct form	1
2.2	Z-Transfer function- Analysis of difference equation of LTI systems using ZTF	2
2.3	Pulse transfer function: Pulse transfer function of closed loop systems	2
2.4	Time responses of discrete data systems-Steady state performance-static error constants	3
3	Stability analysis and Digital controllers (9 hours)	
3.1	Stability analysis: Stability analysis of closed loop systems in the z-plane, Jury's stability test.	2
3.2	Use of bilinear transformation and extension of Routh-Hurwitz criterion for stability.	2
3.3	Digital Controllers: Introduction to Digital controllers- Root locus based design of Digital controllers.	3
3.4	PID controllers: Digital PID controller and design of PID controllers.	2
4	State space analysis (8 hours)	
4.1	State variable model of discrete data systems -Various canonical form representations-controllable and observable forms	2
4.2	Diagonal canonical and Jordan forms	2
4.3	State transition matrix- properties- Computation of state transition matrix using z-transform method	2
4.4	Solution of homogeneous systems	1
4.5	Determination of pulse transfer function from state space model	1
5	Pole placement design and Liapunov Stability Analysis (10 hours)	
5.1	Controllability and observability for continuous time systems	2
5.2	Pole placement design using state feedback for continuous time systems	2
5.3	Controllability and observability for discrete time systems- Digital control design using state feedback discrete time systems	3
5.4	Liapunov stability Analysis: Liapunov function- Liapunov methods to stability of linear and nonlinear systems- Liapunov methods to LTI continuous time systems	2
5.5	Liapunov methods to LTI Discrete Time systems (Theorem only).	1