CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
EET302	LINEAR CONTROL SYSTEMS	PCC	2	2	0	4

Preamble: This course aims to provide a strong foundation on classical control theory. Modelling, time domain analysis, frequency domain analysis and stability analysis of linear systems based on transfer function approach will be discussed. The compensator design of linear systems is also introduced.

Prerequisite : Basics of Circuits and Networks, Signals and 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 feedback systems.
CO 2	Analyse the time domain responses of the linear systems.
CO 3	Apply Root locus technique to assess the performance of linear systems.
CO 4	Analyse the stability of the given LTI systems.
CO 5	Analyse the frequency domain response of the given LTI systems.
CO 6	Design compensators using time domain and frequency domain techniques.

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	3	-	-	-	-	-	-	-	-	2
CO 3	3	3	3	-	2	-	-	-	-	-	-	2
CO 4	3	3	3	-	-	-	-	-	-	-	-	3
CO 5	3	3	3	-	2	-	-	-	-	-	-	3
CO 6	3	3	3	2	-	-	-	-	-	-	-	3

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)	10	10	20
Apply (K3)	30	30	60
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 and explain the transfer function of AC servo motor.
2. With the help of suitable sketches explain the need for a lead compensator.
3. Explain how does the feedback element affect the performance of the closed loop system.

Course Outcome 2 (CO2):

1. Obtain the different time domain specifications for a given second order system with impulse input.
2. Determine the value of the natural frequency of oscillation ω_n for the unity feedback system with forward transfer function $G_p(s) = \frac{K}{s(s+10)}$, which results in a critically damped response. Also analyse the effect of K on damping factor.
3. Problems related to static error constant and steady state error for a given input.

Course Outcome 3(CO3):

1. Determine the value of K such that the closed loop system with $G(s)H(s) = \frac{K}{s\,(s+1)\,(s+4)}$ is oscillatory, using Root locus.
2. Construct the Root locus for the closed loop system with $G(s)H(s) = \frac{K}{s\,(s^2+2\,s+2)}$? Determine the value of K to achieve a damping factor of 0.5?
3. Problems on root locus for systems with positive feedback.

Course Outcome 4 (CO4):

1. Problems related to application of Routh's stability criterion for analysing the stability of a given system.
2. Problems related to assess the stability of the given system using Bode plot.
3. Problem related to the analysis of given system using Nyquist stability criterion.

Course Outcome 5 (CO5):

1. Determine the value of K such that the gain margin for the system with $G(s)H(s) = \frac{K}{s\,(s+1)\,(s+5)}$ equals to 2.

2. Determine the phase margin to assess the stability of the system with $G(s)H(s) = \frac{2}{s\,(s+1)\,(s+4)}$
3. Derive and explain the dependence of resonant peak on damping factor.

Course Outcome 6 (CO6):

1. Problems related to the design of lead compensator using Bode plot.
2. Problems related to the design of lag compensator using Root locus technique.
3. Design the parameters of an electrical lag circuit with f_1= 200 Hz and f_2= 1kHz

Model Question Paper

PAGES: 2

QPCODE:

Reg. No:____________

Name:______________

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

SIXTH SEMESTER B.TECH DEGREE EXAMINATION

MONTH & YEAR

Course Code**: EET302**

Course Name: **LINEAR CONTROL SYSTEMS**

Max. Marks: 100 **Duration: 3 Hours**

PART A

Answer all Questions. Each question carries 3 Marks

1 Give a comparison between open loop and closed loop control systems with suitable examples.

2 Derive the dependence of φ_m and α of a lead compensator and hence explain the restrictions on the selection of α?

3 For a closed loop system with $G(s) = \frac{1}{s\,(s+5)}$; and H(s) = 0.05, calculate the steady state error constants.

4 Check the stability of the system given by the characteristic equation, $G(s) = s^5 + 2s^4 + 4s^3 + 8s^2 + 16s + 32$; using Routh criterion.

5 With suitable sketches explain how the addition of poles to the open-loop transfer function affect the root locus plots.

6 Explain Ziegler – Nichol's PID tuning rules.

7 Explain the features of non-minimum phase systems with a suitable example.

8 How do you determine the gain margin of a system, with the help of Bode plot?

9 State and explain Nyquist stability criterion.

10 Discuss the procedure for Lag compensator design using Root locus technique.

PART B

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

Module 1

11 a) Derive the transfer function of an Armature controlled dc servo motor. Assess the effect of time constants on the system performance. **(9)**

b) Compare the effect of H(s) on the pole-zero plot of the closed loop system with $G(s) = \frac{s+3}{(s^2+3s+2)}$ with: i) derivative feed back H(s)= s; ii) integral feedback H(s)=1/s. **(5)**

12 a) Why compensation is necessary in feedback control system? What are the factors to be considered for choosing the feedback compensation? **(6)**

b) With relevant characteristics explain the operation of the following control devices. i) Synchro error detector, ii) Tachogenerator. **(8)**

Module 2

13 a) Derive an expression for the step response of a critically damped second order system? Explain the dependency of Mp on damping factor. **(9)**

b) Determine the value of K and the natural frequency of oscillation ω_n for the unity feedback system with forward transfer function $G(s) = \frac{K}{s(s+10)}$, which results in a critically damped response when subjected to a unit step input.
Also determine the steady state error for unit velocity input. **(5)**

14 a) A unity feedback system is characterized by an open loop transfer function $G(s) = \frac{20}{(s^2+5s+5)}$. Determine the transient response when subjected to a unit step input and sketch the response. Evaluate the maximum overshoot and the corresponding peak time of the system. . **(9)**

b) Using Routh criterion determine the value of K for which the unity feedback closed loop system with $G(s) = \frac{K}{s(s^2+20s+8)}$ is stable. . **(5)**

Module 3

15 a) Design a lag lead compensator with open loop transfer function $G(s) = \frac{K}{s(s+0.5)}$ to satisfy the following specifications (i) damping ratio of the dominant closed loop poles is 0.5 (ii) Undamped natural frequency of the dominant closed loop poles ω_n = 5 rad/sec iii) Velocity error constant K_v = 80. **(10)**

b) Compare between PI and PD controllers. **(4)**

16 a) Sketch root locus for a system with $G(s)H(s) = \frac{K(s+1)}{s(s+4)}$. Hence determine the range of K for the system stability. . **(9)**

b) With help of suitable sketches, explain how does Angle and Magnitude criteria of Root locus method help in control system design. **(5)**

Module 4

17 a) The open-loop transfer function of a unity feedback system is $G(s)=\frac{K}{s(0.5s+1)(0.04s+1)}$.Use asymptotic approach to plot the Bode diagram and determine the value of K for a gain margin of 10 dB. **(8)**

b) Compare between the polar plots for $G(s)H(s)=\frac{K}{(s+4)}$ and $G(s)H(s)=\frac{K(s-4)}{(s+4)}$. **(6)**

18 a) Draw the polar plot of an open loop transfer function G(s)= $\frac{6}{(s+1)(s+2)}$ and comment on the phase margin and gain margin. **(8)**

b) Explain the detrimental effects of transportation lag, using Bode plot. **(6)**

Module 5

19 a) Draw Nyquist plot for the system whose open loop transfer function is $G(s)H(s)=\frac{K}{s(s+2)(s+10)}$. Determine the range of K for which the closed loop system is stable. **(9)**

b) Write a short note on Nichols chart. . **(5)**

20 a) Design a phase lead compensator for a unity feedback system given by the open loop transfer function $G(s)=\frac{K}{s(S+1)}$ to meet the following specifications (i) phase margin of the system > 45 deg (ii) ess for unit ramp <1/15 (iii) gain crossover frequency must be 7.5 rad/sec. **(11)**

b) Explain the design constrains on the selection of corner frequencies of lag compensator. **(3)**

Syllabus

Module 1

Feedback Control Systems (9 hours)

Open loop and closed loop control systems- Examples of automatic control systems - Transfer function approach to feed back control systems – Effect of feedback

Control system components – Control applications of DC and AC servo motors, Tacho generator, Synchro, Gyroscope and Stepper motor

Controllers- Types of controllers & Compensators - Transfer function and basic characteristics of lag, lead and lag-lead phase compensators.

Module 2

Performance Analysis of Control Systems (9 hours)

Time domain analysis of control systems: Time domain specifications of transient and steady state responses- Impulse and Step responses of first and second order systems- Pole dominance for higher order systems.

Error analysis: Steady state error analysis and error constants -Dynamic error coefficients.

Stability Analysis: Concept of BIBO stability and Asymptotic stability- Time response for various pole locations- stability of feedback systems - Routh's stability criterion- Relative stability

Module 3

Root Locus Analysis and Compensator Design (11 hours)

Root locus technique: Construction of Root locus- stability analysis- effect of addition of poles and zeroes- Effect of positive feedback systems on Root locus

Design of Compensators: Design of lag, lead and lag-lead compensators using Root locus technique.

PID controllers: PID tuning using Ziegler-Nichols methods.

Simulation based analysis: Introduction to simulation tools like MATLAB/ SCILAB or equivalent for Root locus based analysis (Demo/Assignment only)

Module 4

Frequency domain analysis (9 hours)

Frequency domain specifications- correlation between time domain and frequency domain responses

Polar plot: Concepts of gain margin and phase margin- stability analysis

Bode Plot: Construction- Concepts of gain margin and phase margin- stability analysis, Effect of Transportation lag and Non-minimum phase systems.

Module 5

Nyquist stability criterion and Compensator Design using Bode Plot (9 hours)

Nyquist criterion: Nyquist plot- Stability criterion- Analysis

Introduction to Log magnitude vs. phase plot and Nichols chart (concepts only) - Compensator design using Bode plot: Design of lag, lead and lag-lead compensator using Bode plot.

Simulation based analysis: Introduction to simulation tools like MATLAB/ SCILAB or equivalent for various frequency domain plots and analysis (Demo/Assignment only).

Textbooks

1. Nagarath I. J. and Gopal M., Control System Engineering, 5/e, New Age Publishers
2. Ogata K, Modern Control Engineering, 5/e, Prentice Hall of India.
3. Nise N. S, Control Systems Engineering, 6/e, Wiley Eastern
4. Dorf R. C. and Bishop R. H, Modern Control Systems, 12/e, Pearson Education

Reference Books

1. Kuo B. C, Automatic Control Systems, 7/e, Prentice Hall of India
2. Desai M. D., Control System Components, Prentice Hall of India, 2008
3. Gopal M., Control Systems Principles and Design, 4/e, Tata McGraw Hill.
4. Imthias Ahamed T. P, Control Systems, Phasor Books, 2016

Course Contents and Lecture Schedule:

Module	Topic coverage	No. of Lectures
1	**Feedback Control Systems (9 hours)**	
1.1	Terminology and basic structure of Open loop and Closed loop control systems- Examples of Automatic control systems (block diagram representations only)	2
1.2	Transfer function approach to feed back control systems- Effect of feedback- Characteristic equation- poles and zeroes- type and order.	2
1.3	Control system components: Transfer functions of DC and AC servo motors –Control applications of Tacho generator, Synchro, Gyroscope and Stepper motor	3
1.4	Need for controllers: Types of controllers – Feedback, Cascade and Feed forward controllers Compensators: Transfer function and basics characteristics of lag, lead, and lag-lead phase compensators	2
2	**Performance Analysis of Control Systems (9 hours)**	
2.1	Time domain analysis of control systems: Time domain specifications of transient and steady state responses- Impulse and Step responses of First order systems- Impulse and Step responses of Second order systems- Pole dominance for higher order systems	3

2.2	Error analysis: Steady state error analysis - static error coefficient of Type 0, 1, 2 systems. Dynamic error coefficients	2
2.3	Stability Analysis: Concept of stability-BIBO stability and Asymptotic stability- Time response for various pole locations- stability of feedback systems	2
2.4	Application of Routh's stability criterion to control system analysis- Relative stability	2
3	**Root Locus Analysis and Compensator Design (11 hours)**	
3.1	Root locus technique: General rules for constructing Root loci – stability from root loci -	3
3.2	Effect of addition of poles and zeros on Root locus	1
3.3	Effect of positive feedback systems on Root locus	1
3.4	Design using Root locus: Design of lead compensator using root locus.	2
3.5	Design of lag compensator using root locus.	1
3.6	Design of lag-lead compensator using root locus	1
3.7	PID Controllers: Need for P, PI and PID controllers	1
3.8	Design of P, PI and PID controller using Ziegler-Nichols tuning method.	1
3.9	Simulation based analysis: Introduction to simulation tools like MATLAB/ SCILAB or equivalent simulation software and tool boxes for Root locus based analysis (Demo/Assignment only)	
4	**Frequency domain analysis (9 hours)**	
4.1	Frequency domain specifications- correlation between time domain and frequency domain responses	2
4.2	Polar plot: Concepts of gain margin and phase margin- stability analysis	2
4.3	Bode Plot: Construction of Bode plots- gain margin and phase margin- Stability analysis based on Bode plot	4
4.4	Effect of Transportation lag and Non-minimum phase systems	1
5	**Nyquist stability criterion and Compensator Design using Bode Plot (9 hours)**	
5.1	Nyquist stability criterion: Nyquist plot- Stability criterion- Analysis	3
5.2	Introduction to Log magnitude vs. phase plot and Nichols chart	1
5.3	Design using Bode plot: Design of lead compensator using Bode plot.	2
5.4	Design of Lag compensator using Bode plot.	2
5.5	Design of Lag- lead compensator using Bode plot	1
5.6	Simulation based analysis: Introduction to simulation tools like MATLAB/ SCILAB or equivalent simulation software and tool boxes for various frequency domain plots and analysis (Demo/Assignment only).	