MUZAFFARPUR INSTITUTE OF TECHNOLOGY, Muzaffarpur

COURSE FILE

OF

LINEAR CONTROL THEORY

(031712)

Faculty Name:

MR. HARI CHARAN VERMA

ASSISTANT PROFESSOR, DEPARTMENT OF ELECTRICAL ENGINEERING

Content

Govt. of Bihar

MUZAFFARPUR INSTITUTE OF TECHNOLOGY,
MUZAFFARPUR-842003

(Under the Department of Science & Technology Govt. of Bihar, Patna)

VISION STATEMENT OF ELECTRICAL ENGINEERING DEPARTMENT

To produce cutting edge Electrical Engineers, innovators, researchers, and entrepreneurs with high human values to serve society, industry, nation and the world.

MISSION STATEMENT OF ELECTRICAL ENGINEERING DEPARTMENT

M1. To create state-of-the-art facilities for under-graduate, post- graduate and R&D work.

M2. To cater the needs of society with recent technologies, innovative ideas and inculcate ethical responsibilities.

M3. To develop strong collaborative links with premier industries, institutions and the government agencies.

Program Educational Objectives (PEOs) of Electrical Engineering Department:

PEO 1. Students will be able to engage in life-long learning and research including supportive and responsible roles on multi-disciplinary tasks.

PEO 2. Students will acquire, use and develop skills as required for effective professional and societal practices and leadership quality.

PEO 3. Students will be able to create a new dimension of innovation and entrepreneurship.

Program Outcomes (POs) based on Program Educational Objectives (PEOs) of Electrical Engineering Department:

PO 1. Students will be able to apply knowledge of applied mathematics & science in electrical engineering problems.

PO 2. Students will be able to identify, formulate and solve society and industries related problems.

PO 3. Students will be able to apply knowledge to design a system, component or process to meet desired needs within realistic constraints.

PO 4. Students will be able to conduct laboratory experiments and to critically analyze and interpret experimental data.

PO 5. Students will be able to use the recent techniques, skills, and modern tools necessary for engineering practices.

PO 6. Students will be able to understand the impact of engineering problems, solutions in a global and societal context.

PO 7. Students will be able to demonstrate professional and ethical responsibilities.

PO 8. Students will be able to apply leadership quality to work with team in the area of electrical engineering towards the solution of multi-disciplinary tasks.

PO 9. Students will be able to communicate effectively through verbally, technical writing, reports and presentation.

PO 10. Students will be able to develop confidence for self-education and ability to engage in life-long learning.

COURSE OBJECTIVE AND COURSE OUTCOMES:

Institute/college Name	Muzaffarpur Institute of Technology, Muzaffarpur
Program Name	B.E. Electrical (VII semester)
Course Code/course credits	031712(5)
Course Name	**Linear control theory**
Lecture/ Sessional (per week)	3/2
SEE duration	9 hours
Course Coordinator Name	Mr. Hari Charan Verma

Course objective:

This course shall introduce the fundamentals of modelling and control of linear time invariant systems; primarily from the classical viewpoint of Laplace transforms. The course will be useful for students from major streams of engineering to build foundations of time/frequency analysis of systems as well as the feedback control of such systems.

Course outcomes (CO):

CO1: Students will be able to express the basic elements and structures of feedback control systems.

CO2: Students will be able to correlate the pole-zero configurations of transfer functions and their time-domain response to known test inputs.

CO3: Students will be able to apply Routh-Hurwitz criterion, Root Locus, Bode Plot and Nyquist Plot to determine the domain of stability of linear time-invariant systems.

CO4: Students will be able to Determine the steady-state response, errors of stable control systems and design compensators to achieve the desired performance.

MAPPING OF COs AND POs

Sr. No.	Course Outcome	PO
1.	CO1: Students will be able to express the basic elements and structures of feedback control systems.	PO1, PO2, PO3, PO5, PO6, PO9, PO10
2.	CO2: Students will be able to correlate the pole-zero configurations of transfer functions and their time-domain response to known test inputs.	PO3, PO4, PO6, PO9, PO10
3.	CO3: Students will be able to apply Routh-Hurwitz criterion, Root Locus, Bode Plot and Nyquist Plot to determine the domain of stability of linear time-invariant systems.	PO1, PO3, PO6, PO7, PO8, PO10
4.	CO4: Students will be able to Determine the steady-state response, errors of stable control systems and design compensators to achieve the desired performance.	PO1, PO2, PO4, PO10

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	√	√	√	-	√	√	-	-	√	√
CO2	-	-	√	√	-	√	-	-	√	√
CO3	√	-	√	-	-	√	√	√	-	√
CO4	√	√	-	√	-	-	-	-	-	√

Course Syllabus:

UNIT-I

Introduction: The control system, servomechanism, servomotors, standard test signal.

Time response analysis: Time response of second order system, design consideration for higher order system, stability relative stability.

UNIT-II

The root locus technique: Concept, construction of root loci root contours systems with transformation log.

UNIT-III

Frequency response analysis: Correlation between time and frequency response, bode plots, root locus and minimum phase system log magnetic vs phase plots, stability in frequency domain, polar plots.

Mathematics preliminaries: Nyquest stability criteria, Assessment of relation stability using Nyquest criteria.

UNIT-IV

Closed loop frequency response.

Compensation of control system: Introduction, type compensation approach to compensation.

Books:

- Control Systems Engineering by I. J. Nagrath and M. Gopal, New Age International (P) Limited, Publishers, 2nd edition.
- Automatic Control Systems 8th editionby B. C. Kuo 2003 John wiley and sons.
- Modern Control Engineering by Katsuhiko Ogata Prentice Hall of India Pvt. Ltd., 3rd edition, 1998.

GATE Syllabus of Linear Control Theory:

Section: Linear Control Theory

Mathematical modelling and representation of systems, Feedback principle, transfer function, Block diagrams and Signal flow graphs, Transient and SteadyState analysis of linear time invariant systems, Routh-Hurwitz and Nyquist criteria, Bode plots, Root loci, Stability analysis, Lag, Lead and Lead-Lag compensators; P, PI and PID controllers; State space model, State Transition matrix.

ELECTRICAL 7TH SEM TIME TABLE.

ROOM NO.: 50

DAY/TIME	9:00-10:00	10:0-11:00	11:00-12:00	12:00-13:00	13:00-14:00	14:00-15:00	15:00-16:00	16:00-17:00
MONDAY		DCS (RKM)	LCT (HCV)	DCS (T1) (RKM)	LUNCH	WEEKLY TESTS (40 MIN. EACH PAPER)		
						DCS	LCT	PPAS	INT
TUESDAY	INT (SK)	DCS (RKM)	PPAS (HCV)			INT LAB (SK+MK)/LCT (HCV+AKS)		
WEDNESDAY	DCS (RKM)	LCT (HCV)	INT (SK)	DCS (T2) (RKM)		PROJECT-I (FA+MS+HCV)		
THURSDAY		LCT (HCV)	INT (SK)	PPAS (HCV)		INT LAB (SK+MK)/LCT (HCV+RKM)		
FRIDAY	DCS(T3)(RKM)	PROJECT-I (SA+FA+MS+AKS+RKM+HCV)				PPAS (HCV+MS)		
SATURDAY	PPAS (HCV)	PPAS LAB (HCV+MS)				DCS(T4) (RKM)		

ROLL NO. [15E01 -- 15E19 (T1) 15E20 -- 15E37 (T2) 5E38 -- 15E56 (T3) 15E57 – 16E(LE)10 (T4)]

SUBJECT NAME		FACULTY NAME	
LCT	LINEAR CONTROL THEORY	HCV	HARI CHARAN VERMA
DCS	DIGITAL CONTROL SYSTEM	RKM	ROUSHAN KUMAR MISHRA
PPAS	PROTECTION OF POWER APPARTATUS AND SYSTEM	SK	SAKET KUMAR GUPTA
INT	INTELLIGNT INSTRUMENT		

STUDENT LIST:

S.NO.	*Roll No*	*AKU REG. NO.*	*Name*
1	15E56	15103107055	KRISHNA KUMAR
2	15E25	15103107126	SUJEET KUMAR
3	15E35	15103107127	HAPPY KUMAR
4	15E45	15103107128	MAYANK KASHYAP
5	15E01	15103107129	PRASOON BALA
6	15E02	15103107130	SUMI SINGH
7	15E03	15103107131	SURYA NARAYAN SINGH
8	15E07	15103107132	VIVEK KUMAR
9	15E09	15103107133	ANKITA KUMARI SINDURIYA
10	15E10	15103107134	NIRAJ KUMAR
11	15E11	15103107135	SANDEEP KUMAR SITESH
12	15E12	15103107136	NISHANT GUPTA
13	15E13	15103107137	PRAKASH KUMAR
14	15E14	15103107138	PRADEEP KUMAR
15	15E15	15103107139	RAVI RANJAN
16	15E16	15103107140	RAVI SHANKAR SAH
17	15E17	15103107141	ALOK KUMAR
18	15E18	15103107142	RAVI KANT SINGH
19	15E23	15103107143	NAYAN PRIYA
20	15E26	15103107144	ATUL SHAKTI
21	15E27	15103107145	RAHUL KUMAR
22	15E28	15103107146	ABHISHEK KISHORE
23	15E29	15103107147	RUHI KUMARI
24	15E30	15103107148	RAJEEV KUMAR CHOUDHARY

25	15E32	15103107149	KISHAN KUMAR
26	15E33	15103107150	MANISH KUMAR
27	15E34	15103107151	AMIT KUMAR
28	15E36	15103107152	RAVI RANJAN
29	15E37	15103107153	SHASHANK SUDHANSHU
30	15E38	15103107154	NEHA GUPTA
31	15E39	15103107155	SWETA JAMUAR
32	15E40	15103107156	SURUCHI KUMARI
33	15E42	15103107157	TAHA ALAM
34	15E44	15103107159	NIKET NIRAJ
35	15E47	15103107160	ASHUTOSH SHIVAM JHA
36	15E49	15103107161	MEDHA CHAUDHARY
37	15E41	15103107162	SOURAV SRIKANT
38	15E51	15103107163	PRIYANKA SUMAN
39	15E52	15103107164	PALLAVI KUMARI
40	15E54	15103107165	SHASHI RANJAN
41	15E57	15103107166	RAJLAXMI KUMARI
42	15E59	15103107168	AJIT KUMAR
43	15E61	15103107170	NAYAN KUMAR NAYAN
44	15E63	15103107171	RAJU KUMAR
45	15E64	15103107172	PREM NARAYAN CHAUDHARY
46	15E31	15103107173	SAURAV KUMAR
47	15E04	15103107174	BINDIA RANI
48	15E06	15103107176	MADHU KUMARI
49	15E08	15103107177	KAJAL RAJ

50	15E19	15103107178	OM PRAKASH CHAUDHARY
51	15E20	15103107179	AMAN KUMAR
52	15E24	15103107180	JYOTI KUMARI
53	15E21	15103107181	MD SARFARAJ AHMAD
54	15E46	15103107182	SATISH KUMAR
55	15E48	15103107183	PAVAN KUMAR
56	15E55	15103107184	DEO
57	15E62	15103107185	SUDEEP KUMAR
58	15E50	15103107186	NAGESHWAR SHARMA
59	15E22	15103107278	AZIM ANSARI
60	15E65	15104107203	PRIYANKA KUMARI
62	15E66	15106107258	DEEPAK KUMAR SINGH
63	16(LE)E10	16103107901	GAUTAM BHARTI
64	16(LE)E06	16103107902	SHEKHAR KUMAR
65	16(LE)E01	16103107903	SHAFAQUE NAZREEN
66	16(LE)E07	16103107904	MD MOIN
67	16(LE)E03	16103107905	PRIYANKA KUMARI
68	16(LE)E02	16103107906	PAVAN KUMAR
69	16(LE)E04	16103107908	ROHAN RAJ
70	16(LE)E09	16103107909	PINTU KUMAR

Course Plan:

Text Books:

TB1: Control Systems Engineering by I. J. Nagrath and M. Gopal, New Age International (P) Limited, Publishers, 2nd edition.

Reference Books:

RB1: Automatic Control Systems 8th editionby B. C. Kuo 2003 John wiley and sons.

RB2: Modern Control Engineering by Katsuhiko Ogata Prentice Hall of India Pvt. Ltd., 3rd edition, 1998.

Other readings and relevant websites

S.No.	**Link of Journals, Magazines, websites and Research Papers**
1.	http://nptel.ac.in/courses/108101037/
2.	https://nptel.ac.in/courses/108103007/
3.	https://nptel.ac.in/courses/108102043/
4.	https://www.springer.com/in/book/9781852333164
5.	https://pdfs.semanticscholar.org/3b01/057aa12a63fddd69b2f265445828f8df4d41.pdf

COURSE PLAN

Lecture Number	Topics	Web Links for video lectures	Text Book / Reference Book	Page numbers o Text Book(s)
1-4	**Introduction**		TB1, RB2	1-90
	The control system, servomechanism, servomotors, standard test signal.	http://nptel.ac.in/courses/108101037/		
5-10	**Time response analysis**		TB1, RB1	193-268
	Time response of second order system, design consideration for higher order system, stability relative stability.	http://nptel.ac.in/courses/108101037/4		
11-18	**The root locus technique**		TB1, RB1	297-343
	Concept, construction of root loci root contours systems with transformation log.	https://www.youtube.com/watch?v=3iSAKkORVuk		
19-26	**Frequency response analysis**		TB1	345-376
	Correlation between time and frequency response, bode plots, root locus and minimum phase system log magnetic vs phase plots, stability in frequency domain, polar plots.	https://nptel.ac.in/courses/108103007/		
26-30	**Mathematics preliminaries**		TB1	377-423
	Nyquest stability criteria, Assessment of relation stability using Nyquest criteria.	https://www.youtube.com/watch?v=m-DkjNEZ1EM		
31-33	**Introduction**		TB1, RB2	269-295
	Closed loop frequency response.	https://www.youtube.com/watch?v=psx3gsKbY2U		
34-41	**Compensation of control system**		TB1, RB2	569-640
	Introduction, type compensation approach to compensation.	http://nptel.ac.in/courses/108101037/12		

LECTURE PLAN

Topics	Lecture Number	Date on which the Lecture was taken
Introduction		
Block diagram	**1**	
Signal flow graph	**2**	
The control system, servomechanism.	**3**	
Servomotors	**4**	
standard test signal	**5**	
Time response analysis		
Time response of second order system.	**6**	
Transient Analysis	**7**	
Design consideration for higher order system.	**8**	
Relative stability	**9**	
The root locus technique		
Basic concept	**10**	
Root locus plot	**11**	
construction of root loci root contours systems with transformation log.	**12**	

Frequency response analysis		
Correlation between time and frequency response	**13**	
Bode plots	**14**	
Root locus and minimum phase system log magnetic vs phase plots	**15**	
Stability in frequency domain	**16**	
Polar plots	**17**	
Mathematics preliminaries		
Nyquest stability criteria	**18**	
Gain Margin	**19**	
Phase Margin	**20**	
Assessment of relation stability using Nyquest criteria.	**21**	
Closed loop frequency response.	**22**	
Compensation of control system		
Introduction	**23**	
Type compensation approach to compensation.	**24**	

Question Bank:

(c) Closed Loop stability

$$G(s)H(s) = \frac{2(S+0{\cdot}25)}{S^2(S+1)(S+0{\cdot}5)}$$ 14

7. Sketch the root locus for the open loop transfer function of a unity feedback control system given below and determine.
   (i) Value of K for S=0·5 14
   (ii) Value of K for marginal stability
   (iii) Value of K at S=–4

$$G(s) = \frac{K}{S(S+1)(S+3)}$$

8. Open loop transfer function for an unity feedback control system is $G(s) = \frac{K}{S(1+0{\cdot}25)}$

   Design suitable compensator such that system will have Kv=10. PM=50°.

9. Write short notes on any two: 7×2
   (a) Phase log compensation
   (b) Two phase a.c. servomotor

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Code : 031712

B.Tech.7th Semester Special Examination,2016

Linear Control Theory

Time : 3 hours *Full Marks : 70*

Instructions :

*(i) There are **Nine** questions in this paper.*

*(ii) Attempt **Five** questions in all.*

*(iii) **Questions No.1 is Compulsory.***

(iv) The marks are indicated in the right hand margin.

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1. Answer any seven questions fill in the blanks. 2×7=14
   (a) Laplace transform of t^{ne-at} is.....
   (b) Impulse response of a system having transfer function $\frac{1}{ST+1}$ is.....
   (c) Characteristic equation for a second order system is $S^2+1{\cdot}6S+16=0$. Rise time is .....
   (d) For an undamped system roots of the characteristic equation should lie on the ..... S plane.
   (e) Closed Loop control system having characteristic equation $S^3+4{\cdot}55^2+3.55+1{\cdot}5=0$ is .....
   Options ; (i) stable (ii) unstable

(f) No. of branches of root locus plot for an open loop transfer function for a closed loop system

$$G(s)H(s) = \frac{K}{S(S+1)(S+3)} \text{ .....}$$

(g) Steady state accuracy of a system in improved by ..... compensator.

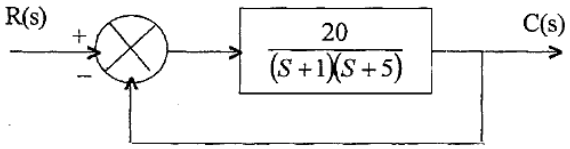
(h) 3 corner frequencies for the open loop transfer function

$$G(s)H(s) = \frac{2ls + 0.25}{S^2(S+1)(S+0.5)} \text{ are .....}$$

(i) Steady state error of system represented by $\frac{1}{ST+1}$ subjected to ramp input is.....

(j) Natural frequency of oscillation of a unity feedback system having open loop transfer function. $\frac{25}{S(S+5)}$ is.....

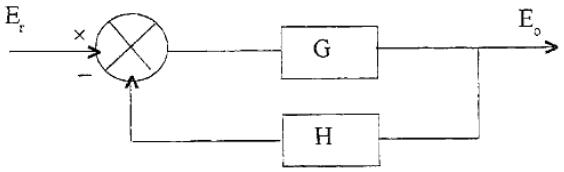
2. The block diagram of a unity feedback control system is



Determine peak time, maximum overshoot, time at which first undershoot occurs, time period of oscillations, and number of cycles completed before reaching steady state. 14

3. (a) Discuss static error coefficients. 7

(b) A closed loop control system shown in figure below. G=200, H=0·1. Determine reference voltage E_r for keeping E_o=250. 7



4. (a) Determine the transfer function of armature controlled dc servomotor. 7

(b) Using Routh-Hurwitz criterion determine the stability of a unity feedback control system whose open loop transfer function is given by $G(s) = \frac{\ell - ST}{S(S+2)}$ 7

5. Examine the closed loop stability of the system whose open loop transfer function is given by $G(s)H(s) = \frac{50}{(s+1)(s+2)}$ using Nyquist criterion. 14

6. Construct Bode Plot for the system whose open loop transfer function is given below determine.

(a) gain margin

(b) phase marginal

7. Design a phase lead compensation network for a system having open loop transfer function given below such that the system will have acceleration error coefficient Ka = 100 sec^{-1} and suitable phase margin for stable operation. 14

$$G(S)H(S) = \frac{K}{S^2(1+0.055)}$$

8. (a) Discuss how frequency response of a closed loop system can be obtained.
   (b) What are the effect of adding pole and zero in forward path for a second order control system.
   (c) What are the advantages of frequency domain analysis. 14

9. Write short notes:
   (a) Lag-Lead compensator. 7
   (b) Procedure for sketch the polar plot. 7

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Code : 031812

B. Tech. 8th Semester Exam., 2017

Linear Control Theory

Time : 3 hours *Full Marks : 70*

Instructions :

(i) The marks are indicated in the right-hand margin.
(ii) There are NINE questions in this paper.
(iii) Attempt FIVE questions in all.
(iv) Questions No. 1 is compulsory.

1. 14
   (a) Laplace transform of an impulse input is ..... (Fill in the gap).
   (b) What is the steady state error of a first order system subjected to ramp input? System is $\frac{1}{ST+1}$.
   (c) What will be the nature of time response. If the value of ξ is zero?
   (d) What will be the value of settling time in terms of ξ 8 ω_n on 5% basis?
   (e) For finding out stability using Nyquist ..... transfer function is considered. (Fill in the blank.)

(f) If gain margin is (+)ve phase margin is negative the system will be .....
(fill in the blank) (Stable/unstable)

(g) Root locus plot is used to determine relative/ absolute (Tick right one) stability.

(h) What will be the starting point of root locus plot?

(i) No if branch of root locus plot depends on what parameters?

(j) Write the expression for maximum overshoot for a 2nd order system.

2. (a) Find the transfer function for armature controlled dc servomotor. 7

(b) What are the different standard test signal used in control system. Discuss them. 7

3. (a) Derive the expression for rise time of a second order control system. 7

(b) Overall transfer function of a control system is given by 7

$$\frac{c(s)}{R(s)} = \frac{16}{S^2 + 1.6S + 16}$$

Determine rise time, peak time, maximum overshoot and steady state error.

4. Sketch the root locus plot for the open loop transfer function of a unity feed back control system is given below determine.

(i) Value of k for $\zeta = 0.5$

(ii) Value of k for marginal stability

(iii) Value of ϑ at $S = -4$

$$G(S) = \frac{K}{S(S+1)(S+3)}$$

5. Sketch the asymptotic Bode plot for the transfer given below. 14

$$G(S)H(S) = \frac{2(S+0.25)}{S^2(S+1)(S+0.5)}$$

Determine

(a) Phase Cross over frequency

(b) Gain cross over frequency

(c) Gain margin

(d) Phase margin

(e) System stability

6. Draw the Nyquist plot for the transfer function given below and comment on closed loop stability. 14

$$G(S)H(S) = \frac{2.2}{S(S+1)(S^2+2S+2)}$$