GUJARAT TECHNOLOGICAL UNIVERSITY

INSTRUMENTATION & CONTROL ENGINEERING (17)

CONTROL SYSTEM DESIGN

SUBJECT CODE: 2161707

B.E. 6th SEMESTER

Type of course: Core Engineering

Prerequisite: Knowledge of engineering mathematics, basics of control theory, simulation know- how on Matlab/ Scilab or other equivalent software

Rationale: The course is useful for the students to get idea of ideal practices in the field of control systems design. This makes students capable for further studies and/ or conducting research work in the field. Students get in touch with recent trends in the field of modern control engineering. Importance of designing the control systems is emphasized.

Teaching and Examination Scheme:

TeachingScheme			Credits	Examination Marks						Total Marks
L	T	P	C	TheoryMarks			PracticalMarks			
				ESE (E)	PA(M)		ESE (V)		PA (I)	
					PA	ALA	ESE	OEP		
4	0	2	6	70	20	10	20	10	20	150

Content:

Sr. No.	Content	Total Hrs	% Weightage
1	Design of Feedback Control Systems : Introduction; Approaches to System Design; Cascade Compensation Networks; Phase-Lead Design Using the Bode Diagram; Phase-Lead Design Using the Root Locus; System Design Using Integration Networks; Phase-Lag Design Using the Root Locus; Phase-Lag , phase lead Design Using the Bode Diagram; Design on the Bode Diagram Using Analytical Methods; Systems with a Pre-filter; Design for Deadbeat Response; Design Examples.	**16**	30
2	Design of State Variable Feedback Systems Introduction, State space representation of physical systems, State space models of some common systems like R-L-C networks, DC motor, inverted pendulum etc., Controllable Canonical Form, Observable Canonical Form, Diagonal Canonical Form, State transition matrix, Solution of state equations, Controllability and Observability, Full-State Feedback Control Design; Observer Design; Integrated Full-State Feedback and Observer; Tracking Reference Inputs; Internal Model Design; Design Examples.	**16**	30
3	**Introduction to Robust Control and optimal control** Robust control system and system sensitivities to parameter perturbations, analysis of robustness, systems with uncertain parameters, considerations in design of robust control system, robust PID controller.	**12**	21

4	**Lyapunov's stability and optimal control** Positive/negative definite, positive/negative semi-definite functions, Lyapunav stability criteria, introduction to optimal control, Riccatti Equation, Linear Quadratic Regulator, Design Examples.	**11**	19

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
14	**14**	**14**	**14**	**14**	**0**

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Note: This specification table shall be treated as a general guideline for students and teachers. The actual distribution of marks in the question paper may vary slightly from above table.

Reference Books:

1. Modern Control Engineering by K. Ogata, PHI.
2. Discrete Time Control Systems by K. Ogata, PHI.
3. Automatic Control Systems by B C Kuo, PHI.
4. Control Systems, Principles and Design by M. Gopal, MC Graw Hill, 2012.

Course Outcome:

After learning the course the students should be able to:

1. CO1 define fundamental control system design specifications and basic principles of controller design.
2. CO2 recognize the importance of observability and controllability for system design.
3. CO3 design modern controllers based on the state space techniques, optimal control and robust control techniques.
4. CO4 design cascade compensators based on time Domain and frequency domain analysis techniques; synthesize the controller using analog circuits.
5. CO5 design state feedback and optimal control.

List of Experiments:

*(followingpracticals are recommended but they are not limited for modifications and or alterations by the faculty member/s teaching the particular subject. The use of MATLAB or SCILAB or equivalent software is suggested.***)**

1	Design a lead compensator for second order plant type 1 system to meet required specification of overshoot and settling time. Design a pre-filter also.
2	Design a state feedback controller $\dot{x}= Ax+Bu$, $y=Cx$,

	where, $A=\begin{pmatrix}0 & 1 & 0\\ 0 & 0 & 1\\ -6 & -11 & -6\end{pmatrix}$, $B=\begin{pmatrix}0\\0\\1\end{pmatrix}$, $C=\begin{pmatrix}1 & 0 & 0\end{pmatrix}$ and u is the unit step input.
3	Design a lag compensator to meet the specification settling time $t_s \leq 10$ s, velocity error constant $K_v = 5$ s^{-1} and damping ratio $\xi = 0.5$ for the system G(s) = $\frac{K}{s(s+1)(s+4)}$
4	Design a state feedback controller $\dot{x} = Ax + Bu$ $y = Cx$, where, $A=\begin{pmatrix}0 & 20.6\\ 1 & 0\end{pmatrix}$, $C=\begin{pmatrix}0 & 1\end{pmatrix}$ $B=$, $\begin{pmatrix}0\\1\end{pmatrix}$ and u is the unit step input. Obtain the observer gain and controller gain where dominant poles are P= [-1.8 $\pm$ 2.4j] and Q=[-8,-8] using Ackermann formula.
5	To implement and Run the closed loop circuit of second order RC network with compensator on proteus.
6	Design a lead compensator for system G(s)= $\frac{K}{S(S+2)}$, Using the frequency response analysis tool Phase margin $\geq 60^\circ$ and $K_v \geq 10$ sec^{-1}.
7	Design a control system which is tracking the step input by the state feedback technique System transfer function G(s)= $\frac{1}{S(S+2)(S+1)}$ Desired poles are p=[-10 , -2+3.464j , -2-3.464j]
8	Design a lag compensator for system G(s)= $\frac{K}{S(0.1S+1)(0.2s+1)}$. Using the frequency response analysis Phase margin $\geq 40^\circ$ and $K_v \geq 30$ sec^{-1}.Bandwidth 5 rad/sec
9	Design optimal controller using Riccatti equation.
10	Analysis of frequency response of lead compensating network.
11	Analysis of frequency response of lag compensating network.
12	Design a control system which is tracking the step input by the state feedback technique System transfer function G(s)= $\frac{1}{S(S+2)(S+1)}$ Desired poles are p=[-10 , -2+3.464j , -2-3.464j]
13	Find stability of any state space model using eigen value analysis and plot it state response.
14	Studying any prototype closed loop system.

All practical can be designed in MATLAB or SCILAB ,/Proteus /Keil.

Design based Problems (DP)/Open Ended Problem: Obtain the state space model of RLC circuit and implement the circuit and obtain its states response for step input (1-5 v DC). Further try to control the output voltage (capacitor voltage) with state feedback controller so that the voltage reference (1-5 v DC) is tracked satisfactorily.

Major Equipment:

Educational prototype models, Computers, simulation software, microcontrollers etc.

List of Open Source Software/learning website:

http://nptel.ac.in/courses/108103007/16

https://en.wikipedia.org/wiki/State-space_representation

http://ctms.engin.umich.edu/CTMS/index.php?example=Introduction&section=ControlStateSpace

ACTIVE LEARNING ASSIGNMENTS: Preparation of power-point slides, which include videos, animations, pictures, graphics for better understanding theory and practical work – The faculty will allocate chapters/ parts of chapters to groups of students so that the entire syllabus to be covered. The power-point slides should be put up on the web-site of the College/ Institute, along with the names of the students of the group, the name of the faculty, Department and College on the first slide. The best three works should submit to GTU.