INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)

Dundigal, Hyderabad -500 043

ELECTRICAL AND ELECTRONICS ENGINEERING

COURSE DESCRIPTOR

Course Title	CONTROL SYSTEMS					
Course Code	AEEB16					
Programme	B.Tech					
Semester	IV	EEE				
Course Type	CORE					
Regulation	IARE - R18					
Course Structure	**Theory**			**Practical**		
	Lectures	**Tutorials**	**Credits**	**Laboratory**	**Credits**	
	3	1	4	2	1	
Chief Coordinator	Dr. M Pala Prasad Reddy, Associate Professor					
Course Faculty	Dr. P Sridhar, Professor Dr. M Pala Prasad Reddy, Associate Professor					

I. COURSE OVERVIEW:

This course is aimed to introduce the students the principles and applications of control systems in everyday life. The basic concepts of block diagram reduction technique, time response analysis of second order system and solutions to time invariant systems. It deals with various time domain techniques such as root locus and RH criterion and frequency domain techniques which includes bode plot, and Nyquist plots. It explains the concept of state space analysis both in linear and continuous time systems.

II. COURSE PRE-REQUISITES:

Level	Course Code	Semester	Prerequisites
UG	AHSB11	II	Mathematical Transform Techniques
UG	AEEB11	III	Electrical Machines - I

III. MARKS DISTRIBUTION:

Subject	SEE Examination	CIA Examination	Total Marks
Control Systems	70 Marks	30 Marks	100

IV. DELIVERY / INSTRUCTIONAL METHODOLOGIES:

✘	Chalk & Talk	✔	Quiz	✔	Assignments	✘	MOOCs
✔	LCD / PPT	✔	Seminars	✘	Mini Project	✔	Videos
✔	Open Ended Experiments						

V. EVALUATION METHODOLOGY:

The course will be evaluated for a total of 100 marks, with 30 marks for Continuous Internal Assessment (CIA) and 70 marks for Semester End Examination (SEE). Out of 30 marks allotted for CIA during the semester, marks are awarded by taking average of two CIA examinations or the marks scored in the make-up examination.

Semester End Examination (SEE): The SEE is conducted for 70 marks of 3 hours duration. The syllabus for the theory courses is divided into five modules and each module carries equal weightage in terms of marks distribution. The question paper pattern is as follows. Two full questions with "either" or "choice" will be drawn from each module. Each question carries 14 marks. There could be a maximum of two sub divisions in a question.

The emphasis on the questions is broadly based on the following criteria:

50 %	To test the objectiveness of the concept.
50 %	To test the analytical skill of the concept OR to test the application skill of the concept.

Continuous Internal Assessment (CIA):

CIA is conducted for a total of 30 marks (Table 1), with 20 marks for Continuous Internal Examination (CIE), 05 marks for Quiz and 05 marks for Alternative Assessment Tool (AAT).

Table 1: Assessment pattern for CIA

Component	Theory			Total Marks
Type of Assessment	CIE Exam	Quiz	AAT	
CIA Marks	20	05	05	30

Continuous Internal Examination (CIE):

Two CIE exams shall be conducted at the end of the 8th and 16th week of the semester respectively. The CIE exam is conducted for 20 marks of 2 hours duration consisting of five descriptive type questions out of which four questions have to be answered where, each question carries 5 marks. Marks are awarded by taking average of marks scored in two CIE exams.

Quiz - Online Examination

Two Quiz exams shall be online examination consisting of 25 multiple choice questions and are to be answered by choosing the correct answer from a given set of choices (commonly four). Such a question paper shall be useful in testing of knowledge, skills, application, analysis, evaluation and understanding of the students. Marks shall be awarded considering the average of two quiz examinations for every course.

Alternative Assessment Tool (AAT)

This AAT enables faculty to design own assessment patterns during the CIA. The AAT converts the classroom into an effective learning centre. The AAT may include tutorial hours/classes, seminars, assignments, term paper, open ended experiments, METE (Modeling and Experimental Tools in Engineering), five minutes video, MOOCs etc.

VI. HOW PROGRAM OUTCOMES ARE ASSESSED:

Program Outcomes (POs)		Strength	Proficiency Assessed by
PO 1	**Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.	3	Assignments
PO 2	**Problem analysis**: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.	2	Assignments
PO 3	**Design / development of solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.	2	Assignments and Seminars
PO4	**Conduct Investigations of Complex Problems:** Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions	2	Assignments and Seminars
PO7	**Environment and Sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development	2	Seminars

3 = High; 2 = Medium; 1 = Low

VII. HOW PROGRAM SPECIFIC OUTCOMES ARE ASSESSED:

Program Specific Outcomes (PSOs)		Strength	Proficiency Assessed by
PSO 1	**Professional Skills**: Able to utilize the knowledge of high voltage engineering in collaboration with power systems in innovative, dynamic and challenging environment, for the research based team work.	2	Assignments and Seminars
PSO 2	**Problem Solving:** To explore the scientific theories, ideas, methodologies and the new cutting edge technologies in renewable energy engineering, and use this erudition in their professional development and gain sufficient competence to solve the current and future energy problems universally.	-	-
PSO 3	**Modern Tools in Electrical Engineering:** To be able to utilize of technologies like PLC, PMC, process controllers, transducers and HMI and design, install, test , maintain power systems and industrial applications.	-	-

3 = High; 2 = Medium; 1 = Low

VIII. COURSE OBJECTIVES :

The course should enable the students to:	
I	Organize modeling and analysis of electrical and mechanical systems.
II	Analyze control systems by block diagrams and signal flow graph technique.
III	Demonstrate the analytical and graphical techniques to study the stability.
IV	Illustrate the frequency domain and state space analysis.

IX. COURSE OUTCOMES (COs):

COs	Course Outcomes	CLO's	Course Learning Outcomes
CO1	Classify the types and configurations of control systems and describe the mathematical models of dynamic systems.	CLO 1	Differentiate between open loop, closed loop system and their importance in real time applications.
		CLO 2	Predict the transfer function of translational and rotational mechanical, electrical system using differential equation method.
		CLO 3	Analyze the analogy between electrical, translation and rotational mechanical systems.
CO2	Apply various techniques to obtain transfer functions and examine the time response of control systems using standard test signals.	CLO 4	Apply the block diagram and signal flow graph technique to determine transfer function of an control systems.
		CLO 5	Demonstrate the response of first order and second order systems with various standard test signals.
		CLO 6	Estimate the steady state error and its effect on the performance of control systems and gives the importance of PID controllers.

COs	Course Outcomes	CLO's	Course Learning Outcomes
CO3	Analyze the system response and stability in time domain	CLO 7	Summarize the procedure of Routh – Hurwirtz criteria to study the stability of physical systems
		CLO 8	List the steps required to draw the root – locus of any control system and predict the stability.
		CLO 9	Explain the effect on stability by adding zeros and poles to the transfer function of control system.
CO4	Examine the characteristics and stability of control systems in frequency domain.	CLO 10	Discuss the method of Bode plot and Polar plot to calculate gain margin and phase margin of control system.
		CLO 11	Describe the characteristics of control system and its stability by plotting Nyquist plot**.**
		CLO 12	Compare the behavior of control system in terms of time domain and frequency domain response.
CO5	Obtain the models of control systems in state space form and design compensators to meet the desired specifications.	CLO 13	Define the state model of control system using its block diagram and give the role of diagonalization in state space analysis.
		CLO 14	Formulate the state transmission matrix and explain the concept of controllability and observability.
		CLO 15	Design of lag, lead, lag – lead compensator to improve stability of control system.
		CLO 16	Apply the concept of different stability criterions and time, frequency response solution to solve real time world applications.
		CLO 17	Explore the knowledge and skills of employability to succeed in national and international level competitive examinations.

X. COURSE LEARNING OUTCOMES (CLOs):

CLO Code	CLO's	At the end of the course, the student will have the ability to:	PO's Mapped	Strength of Mapping
AEEB16.01	CLO 1	Differentiate between open loop, closed loop system and their importance in real time applications.	PO1 PO3	3
AEEB16.02	CLO 2	Predict the transfer function of translational and rotational mechanical, electrical system using differential equation method.	PO2 PO3	3
AEEB16.03	CLO 3	Analyze the analogy between electrical, translation and rotational mechanical systems.	PO4 PO7	3
AEEB16.04	CLO 4	Apply the block diagram and signal flow graph technique to determine transfer function of an control systems.	PO3, PO4	3

CLO Code	CLO's	At the end of the course, the student will have the ability to:	PO's Mapped	Strength of Mapping
AEEB16.05	CLO 5	Demonstrate the response of first order and second order systems with various standard test signals.	PO1, PO3	2
AEEB16.06	CLO 6	Estimate the steady state error and its effect on the performance of control systems and gives the importance of PID controllers.	PO2, PO4	2
AEEB16.07	CLO 7	Summarize the procedure of Routh – Hurwirtz criteria to study the stability of physical systems	PO1, PO3	2
AEEB16.08	CLO 8	List the steps required to draw the root – locus of any control system and predict the stability.	PO1, PO2	3
AEEB16.09	CLO 9	Explain the effect on stability by adding zeros and poles to the transfer function of control system.	PO2, PO3	2
AEEB16.10	CLO 10	Discuss the method of Bode plot and Polar plot to calculate gain margin and phase margin of control system.	PO1, PO2	3
AEEB16.11	CLO 11	Describe the characteristics of control system and its stability by plotting Nyquist plot.	PO2, PO3	2
AEEB16.12	CLO 12	Compare the behavior of control system in terms of time domain and frequency domain response.	PO1, PO2	3
AEEB16.13	CLO 13	Define the state model of control system using its block diagram and give the role of diagonalization in state space analysis.	PO1, PO2	2
AEEB16.14	CLO 14	Formulate the state transmission matrix and explain the concept of controllability and observability.	PO2, PO3	3
AEEB16.15	CLO 15	Design of lag, lead, lag – lead compensator to improve stability of control system.	PO1, PO2	2
AEEB16.16	CLO 16	Apply the concept of different stability criterions and time, frequency response solution to solve real time world applications.	PO2, PO3	2
AEEB16.17	CLO 17	Explore the knowledge and skills of employability to succeed in national and international level competitive examinations.	PO1, PO2	2

3= High; 2 = Medium; 1 = Low

XI. MAPPING COURSE OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES

COs	Program Outcomes (POs)					
	PO1	PO2	PO3	PO4	PO7	PSO1
CO 1	1	1	2	2	1	2
CO 2	2	1	2	2		1
CO 3	2	2	2			
CO 4	2	3	1			2
CO 5	2	2	1			

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XII. MAPPING COURSE LEARNING OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES:

(CLOs)	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CLO 1	2		3										2		
CLO 2		2	3										2		
CLO 3				3			3								
CLO 4			3	3									2		
CLO 5	2		2										2		
CLO 6		2		2											
CLO 7	2		2												
CLO 8	3	3													
CLO 9		2	2												
CLO 10	3	3													
CLO 11		2	2										2		
CLO 12	3	3											2		
CLO 13	2	2													
CLO 14		2	2												
CLO 15	2	2											2		
CLO 16		2	2										2		

(CLOs)	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CLO 17	2	2											2		

3 = High; 2 = Medium; 1 = Low

XIII. ASSESSMENT METHODOLOGIES – DIRECT

CIE Exams	PO1, PO2, PO3, PO 4, PO7,PSO1	SEE Exams	PO1, PO2, PO3, PO 4, PO7,PSO1	Assignments	PO1, PO2, PO3, PO 4, PO7,PSO1	Seminars	PO1, PO2, PO3, PO 4, PO7,PSO1
Laboratory Practices	PO1, PO2, PO3, PO 4, PO7,PSO1	Student Viva	-	Mini Project	PO1, PO2, PO3, PO 4, PO7,PSO1	Certification	-
Term Paper	-						

XIV. ASSESSMENT METHODOLOGIES – INDIRECT

✔	Early Semester Feedback	✔	End Semester OBE Feedback
✘	Assessment of Mini Projects by Experts		

XV. SYLLABUS

MODULE-I	INTRODUCTION AND MODELING OF PHYSICAL SYSTEMS
Control systems: Introduction, open loop and closed loop systems, examples, comparison, mathematical modeling and differential equations of physical systems, concept of transfer function, translational and rotational mechanical systems, electrical systems, force, voltage and force, current analogy.	
MODULE-II	**BLOCK DIAGRAM REDUCTION AND TIME RESPONSE ANALYSIS**
Block Diagrams: Block diagram representation of various systems, block diagram algebra, characteristics of feedback systems, AC servomotor, signal flow graph, Mason‟s gain formula; Time response analysis: Standard test signals, shifted unit step, shifting theorem, convolution integral, impulse response, unit step response of first and second order systems, time response specifications, steady state errors and error constants, dynamic error coefficients method, effects of proportional, derivative and proportional derivative, proportional integral and PID controllers.	
MODULE-III	**CONCEPT OF STABILITY AND ROOT LOCUS TECHNIQUE**
Concept of stability: Necessary and sufficient conditions for stability, Routh‟s and Routh Hurwitz stability criterions and limitations. Root locus technique: Introduction, root locus concept, construction of root loci, graphical	

determination of „k" for specified damping ratio, relative stability, effect of adding zeros and poles on stability.

MODULE-IV	FREQUENCY DOMAIN ANALYSIS
Frequency domain analysis: Introduction, frequency domain specifications, stability analysis from Bode plot, Nyquist plot, calculation of gain margin and phase margin, determination of transfer function, correlation between time and frequency responses.	
MODULE-V	**STATE SPACE ANALYSIS AND COMPENSATORS**
State Space Analysis: Concept of state, state variables and state model, derivation of state models from block diagrams, diagonalization, solving the time invariant state equations, state transition matrix and properties, concept of controllability and observability; Compensators: Lag, lead, lead - lag networks.	

Text Books:

1. I J Nagrath, M Gopal, "Control Systems Engineering", New Age International Publications, 3rd Edition, 2007.
2. K Ogata, "Modern Control Engineering", Prentice Hall, 4th Edition, 2003.
3. N C Jagan, "Control Systems", BS Publications, 1st Edition, 2007.

Reference Books:

1. Anand Kumar, "Control Systems", PHI Learning, 1st Edition, 2007.
2. S Palani, "Control Systems Engineering", Tata McGraw-Hill Publications, 1st Edition, 2001.
3. N K Sinha, "Control Systems", New Age International Publishers, 1st Edition, 2002.

XVI. COURSE PLAN:

The course plan is meant as a guideline. Probably there may be changes.

Lecture No	Topics to be covered	Course Learning Outcomes (CLOs)	Reference
1	Understand basic concept of the control system	CLO 1	T1:1.1
2	Summarize various types of control systems.	CLO 1	T1:1.2
3	Understand open Loop and closed loop control systems	CLO 2	T1:1.3
4	Explain Open Loop and Closed loop control systems and their differences	CLO 2	T1:1.4-1.7
5	Explain the Differences of open and closed control system	CLO 2	T1:1.4-1.7
6	Analyze the examples of closed control system	CLO 2	T1:1.4-1.7
7	Analyze the various examples of closed control system	CLO 2	T1:1.4-1.7
8	Summarize the classification of control systems	CLO 3	T1:1.1
9	Understand feed –back characteristics, Effects of feedback.	CLO 3	T1:1.3

Lecture No	Topics to be covered	Course Learning Outcomes (CLOs)	Reference
10	Understand the Differential equations, Impulse Response and transfer function of a Control Systems.	CLO 6	T1:1.4
11	Analyze Impulse Response and transfer function of a Control Systems.	CLO 6	T1:1.4
12	Analyze the concept of translational and rotational mechanical system.	CLO 7	T1:1.10
13	Analyze the translational and rotational mechanical system with examples.	CLO 6	T1:1.10
14	Understand the Block diagram representation of systems considering electrical systems.	CLO 7	T1:1.11
15	Understand the Block diagram representation of systems considering electrical systems as examples.	CLO 4	T1:1.11
16	Analyze problems on Block diagram reduction technique.	CLO 4	T1:1.11
17	Understand the Problems on Block diagram algebra.	CLO 5	T1:1.11
18	Analyze the Problems on Block diagram algebra.	CLO 5	T1:1.11
19	Understand the concept of Signal flow graph - Reduction using Mason’s gain formula.	CLO 5	T1:1.12
20	Analyze the Signal flow graph - Reduction using Mason’s gain formula.	CLO 5	T1:1.12
21	Understand the Time response analysis of system.	CLO 5	T1:3.1
22	Understand the concept Time response of first order systems.	CLO 8	T1:3.5
23	Understand and analyze the concept time response of first order systems.	CLO 8	T1:3.5
24	Understand the characteristic equation of feedback control systems.	CLO 9	T1:3.6
25	Understand the concept of characteristic equation of feedback control systems	CLO 9	T1:3.6
26	Understand the concept of transient response of second order systems - Time domain specifications	CLO 9	T1:3.7
27	Analyze Transient response of second order systems - Time domain specifications	CLO 8	T1:3.7
28	Understand the concept of steady state response - Steady state errors	CLO 8	T1:3.10,3.11
29	Understand the concept of steady state errors and error constants	CLO 8	T1:3.10,3.11

Lecture No	Topics to be covered	Course Learning Outcomes (CLOs)	Reference
30	Understand the Effects of proportional, derivative and integral systems.	CLO 8	T1:3.8
31	Understand the Effects of proportional derivative, proportional integral systems.	CLO 10	T1:3.8
32	Understand the operation of PID controller.	CLO 10	T1:4.1
33	Understand concept of stability.	CLO 10	T1:4.1
34	Necessary and sufficient conditions for stability.	CLO 10	T1:4.1
35	Understand the concept of Routh's stability criterion.	CLO 10	T1:5.3
36	Understand the limitations of Routh's stability.	CLO 10	T1:5.3
37	Explain the concept of root locus.	CLO 10	T1:5.8
38	Analyze Root locus and problems.	CLO 10	T1:5.8
39	Understand graphical determination of 'k' for specified damping ratio, relative stability	CLO 11	T1:4.1
40	Understand the concept of frequency domain response analysis.	CLO 11	T1:4.2
41	Understand the frequency response analysis.	CLO 11	T1:4.3, 4. 4,4.5,4.6
42	Understand the concept of Frequency domain specifications expressions.	CLO 11	T1 :4.7
43	Understand the Frequency domain specifications expressions.	CLO 11	T1:4.3,4. 4,4.5,4.6
44	Understand and analyze transfer function from the Bode Diagram.	CLO 11	T1:4.3,4. 4,4.5,4.6
45	Analyze transfer function from the Bode Diagram-Phase margin and Gain margin.	CLO 11	T1:4.3,4. 4,4.5,4.6
46	Analyze transfer function from the Bode Diagram-Phase margin, Gain margin and phase crossover frequency problems.	CLO 12	T1:4.3,4. 4,4.5,4.6
47	Understand the concept of polar plots with examples.	CLO 12	T1:4.3,4. 4,4.5,4.6
48	Understand the concept of nyquist plots examples.	CLO12	T1:4.8
49	Understand the concept of correlation between time and frequency.	CLO 14	T1:4.9
50	Understand correlation between time and frequency response.	CLO 14	T1:4.3
51	Understand compensation technique.	CLO 14	T1:4.1
52	Analyze compensation technique using pole-zero plot.	CLO 14	T1:4.1
53	Analyze the concept of compensation design.	CLO 15	T1:4.8
54	Analyze the problems compensator design.	CLO 15	T1:4.9

Lecture No	Topics to be covered	Course Learning Outcomes (CLOs)	Reference
55	Understand concept of state, state variables and state model .	CLO 15	R2:10.1 to20
56	Understand the time invariant state equations, state transition matrix.	CLO 15	R2:10.1to 20
57	Understand the concept of diagonalization.	CLO 15	R2:10.1to 20
58	Understand the concept of state transition matrix and its properties.	CLO 16	R2:10.1to20
59	Understand concept of controllability and observability	CLO 16	R2:10.1 to20
60	Analyze the concept of controllability and observability with problems.	CLO 16	R2:10.1to 20

XVII. GAPS IN THE SYLLABUS-TO MEET INDUSTRY / PROFESSION REQUIREMENTS:

S No	Description	Proposed Actions	Relevance With POs	Relevance With PSOs
1	Output derivative controller feedback systems	NPTEL	PO1, PO2	PSO1
2	Design of brushless DC motor	NPTEL	PO1, PO2	PSO1
3	Real time applications of control theory in modern devices	Guest lectures	PO1, PO2, PO3	PSO1

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