INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)

Dundigal, Hyderabad - 500 043

AERONAUTICAL ENGINEERING

COURSE DESCRIPTION FORM

Course Title	**CONTROL THEORY APPLICATION TO FLIGHT CONTROL SYSTEMS**			
Course Code	**A72119**			
Class	**IV B.Tech I Semester**			
Regulation	**R15 - JNTUH**			
Course Structure	**Lectures**	**Tutorials**	**Practicals**	**Credits**
	4	**-**	**-**	**4**
Course Coordinator	**Ms. D. Anitha, Assistant Professor, Dept of AE.**			
Team of Instructors	**Ms. D. Anitha, Assistant Professor, Dept of AE.**			

I. COURSE OVERVIEW

This course introduces the basic concepts of circuit analysis which is the foundation for all subjects of the Control Engineering discipline. The emphasis of this course if laid on the basic analysis of circuits which includes single phase circuits, open loop system, closed loop system, system time response, autopilot control feedback block diagrams.

II. PREREQUISITE(S)

Level	Credits	Periods	Prerequisite
UG	6	5	Mathematics - I
UG	4	5	Mathematics - II
UG	4	5	Electrical And Electronics Engineering

III. MARKS DISTRIBUTION

Sessional Marks	University End Exam Marks	Total Marks
There shall be 2 midterm examinations. Each midterm examination consists of subjective test. The subjective test is for 20 marks, with duration of 2 hours. Subjective test of each semester shall contain 5 one mark compulsory questions in part-A and part-B contains 5 questions, the student has to answer 3 questions, each carrying 5 marks. First midterm examination shall be conducted for the first two and half units of syllabus and second midterm examination shall be conducted for the remaining portion. Five marks are earmarked for assignments. There shall be two assignments in every theory course. Marks shall be awarded considering the average of two assignments in each course.	75	100

IV. EVALUATION SCHEME

S. No	Component	Duration	Marks
1	I Mid examination	80 minutes	20
2	I Assignment	--	05
3	II Mid examination	80 minutes	20
4	II Assignment	--	05
5	External examination	3 hours	75

V. COURSE OBJECTIVES

The objective of the teacher is to impart knowledge and abilities to the students to:

I. Describe the basic concepts and elements of Control Systems.
II. Discuss and Revise certain mathematical operations such as Laplace Transform and Fourier Transform.
III. Knowledge about the basic concepts such as Transfer function, Feedback Controls.
IV. Solve Control problems using Classical as well as Modern Control Theory.
V. Modeling of dynamic system using Modern Control Theory.

VI. COURSE OUTCOMES

At the end of the course the students are able to:

1. Define the basic concepts associated with Classical as well as Modern Control Theory.
2. Review Fourier Transform with mathematical operations.
3. Review Laplace Transform and some other important mathematical operations.
4. Understand about the concepts of Transfer function, its merits and applications.
5. Design of different types of controllers -active, passive -series, feed forward, feedback etc.
6. Analyze an aircraft's performance to controls and related aspects.
7. Design of Autopilots on applying classical control theory.
8. Model dynamic systems using modern control theory -State Space Representation.
9. Evaluate an aircraft's performance from the control point of view as a system.
10. Design of Time Invariant Linear Control Systems.
11. Understand about stability augmentation systems for an aircraft.
12. Relate Classical Control Theory to aircraft's response to control.
13. Understand about the concepts of feedback control its merits and applications
14. Understand about control augmentation systems for an aircraft.
15. Explain the fly by wire systems and autopilot systems

VII. HOW PROGRAM OUTCOMES ARE ASSESSED

Program outcomes		Level	Proficiency assessed by
PO1	**General knowledge:** An ability to apply the knowledge of mathematics, science and Engineering for solving multifaceted issues of Aeronautical Engineering	S	Assignments
PO2	**Problem Analysis**: An ability to communicate effectively and to prepare formal technical plans leading to solutions and detailed reports for Aeronautical systems	S	Exercise
PO3	**Design/Development of solutions**: To develop Broad theoretical knowledge in Aeronautical Engineering and learn the methods of applying them to identify, formulate and solve practical problems involving Aerodynamics	H	Discussion
PO4	**Conduct investigations of complex problems**: An ability to apply the techniques of using appropriate technologies to investigate, analyze, design, simulate and/or fabricate/commission complete systems involving complex aerodynamics flow situations.	H	Exercise
PO5	**Modern tool usage**: An ability to model real life problems using different hardware and software platforms, both offline and real-time with the help of various tools along with upgraded versions.	------	------
PO6	**The engineer and society**: An Ability to design and fabricate modules, control systems and relevant processes to meet desired performance needs, within realistic constraints for social needs	S	Exercise

PO7	**Environment and sustainability**: An ability To estimate the feasibility, applicability, optimality and future scope of power networks and apparatus for design of eco-friendly with sustainability	------	------
PO8	**Ethics**: To Possess an appreciation of professional, societal, environmental and ethical issues and proper use of renewable resources	------	------
PO9	**Individual and team work**: An Ability to design schemes involving signal sensing and processing leading to decision making for real time Aeronautical systems and processes at individual and team levels.	------	------
PO10	**Communication**: an Ability to work in a team and comprehend his/her scope of work, deliverables, issues and be able to communicate both in verbal, written for effective technical presentation	------	------
PO11	**Project management and finance**: To be familiar with project management problems and basic financial principles for a multi-disciplinary work	------	-----
PO12	**Life-long learning**: An ability to align with and upgrade to higher learning and research activities along with engaging in life-long learning.	S	Prototype, Discussions

S – Supportive **H - Highly related**

VIII. HOW PROGRAM SPECIFIC OUTCOMES ARE ASSESSED

Program Specific Outcomes		Level	Proficiency assessed by
PSO:1	**Professional skills:** Able to utilize the knowledge of aeronautical/aerospace engineering in innovative, dynamic and challenging environment for design and development of new products	H	Lectures, Assignments
PSO:2	**Problem solving skills:** imparted through simulation language skills and general purpose CAE packages to solve practical, design and analysis problems of components to complete the challenge of airworthiness for flight vehicles	S	Tutorials
PSO:3	**Practical implementation and testing skills:** Providing different types of in house and training and industry practice to fabricate and test and develop the products with more innovative technologies	-----	-----
PSO:4	**Successful career and entrepreneurship:** To prepare the students with broad aerospace knowledge to design and develop systems and subsystems of aerospace and allied systems and become technocrats	-----	-----

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IX.SYLLABUS

UNIT-I

CONTROLSYSTEMS - MODELING, FEEDBACK CONTROL

Dynamical systems - input, output - process (plant) - block diagram representation. control input, noise. Function of controls regulation (hold), tracking (command) - examples. Sensitivity of output to control input, noise and system parameters - robustness. Deterministic and stochastic control. Need for stable, effective (responsive), robust control system. Modeling of dynamical systems by differential equations - system parameters. Order of the system. Single input single output systems, multiple -input -multiple - output systems - linear and nonlinear systems. Linearization of nonlinear systems - .assumptions, validity. Time invariant linear systems.

The concept of feedback- open loop control, closed loop control. Effect of feedback on input output relation, stability, robustness. Merits of feedback control. Loop gain, feedback gain- significance. System type, steady state error, error constants- overall system stability. Application of feedback in stability augmentation, control augmentation, automatic control - examples.

Composition, reduction of block diagrams of complex systems -rules and conventions. Control system components - sensors, transducers, servomotors, actuators, filters-modeling, transfer functions. Single -input - single - output systems. Multiple input- multiple output systems, matrix transfer functions-examples.

UNIT-II.

PERFORMANCE- TIME, FREQUENCY AND S-DOMAIN DESCRIPTION

Control system performance- time domain description- output response to control inputs -- impulse and indicial response- characteristic parameters -significance - relation to system parameters -examples - first and second order linear systems, higher order systems. Synthesis of response to arbitrary input functions from impulse and indicial response. Review of Laplace transforms- applications to differential equations. 'S' (Laplace) domain description of input-output relations - transfer function representation - system parameters- gain, poles and zeroes. Partial fraction decomposition of transfer functions - significance. Dominant poles. Relation of transfer functions to impulse response. Frequency domain description - frequency response - gain and phase shift - significance - representation- asymptotic (Bode) plots, polar (Nyquist) plots, frequency transfer functions. Characteristic parameters - corner frequencies, resonant frequencies, peak gain, bandwidth- significance. First and second order systems - extension to higher order systems.

System identification from input output measurements- importance. Experimental determination of system transfer functions by frequency response measurements. Example.

UNIT-III

SPECIFICATION OF CONTROLSYSTEM PERFORMANCE REQUIREMENTS - SYSTEM SYNTHESIS - CONTROLLERS- COMPENSATION TECHNIQUES

Control system performance requirements- transient and steady state- specification-desired input - output relation -speed of response, stability, accuracy, steady state error, robustness. Relation with system parameters. Examples of first and second order systems. Specifications in frequency domain’s domain. Conflicting requirements - need for compromise - scope for optimization. The primacy of stability.

System synthesis -need for compensation - design of controllers - active, passive- series, feed forward, feedback controllers. Proportional, integral, proportional plus derivative control- the problem with derivative control - lead, lag, lead - lag, wash-out, notch filters / networks -properties - effect on transfer function, stability, robustness - relative merits. Adaptive control - definition, merits, and implementation - gain scheduling. Nonlinear control, merits, constraints. Feedback controllers. Significance of loop transfer function, loop gain. Stability of closed loop system- frequency response methods and root locus methods of analysis and compensation - Nyquist's criterion- stability margins - phase margin, gain margin- interpretation, significance- compensation by pole zero cancellation. Design of multiloop feed back systems.

UNIT-IV

AIRCRAFT RESPONSE TO CONTROLS - FLYING QUALITIES - STABILITY AND CONTROL AUGMENTATION - AUTO PILOT

Approximations to aircraft transfer functions, control surface actuators-review. Response of aircraft to pilot's control inputs, to atmosphere. The control task of the pilot. Flying qualities of aircraft-relation to airframe transfer function. Reversible and irreversible flight control systems. Pilot's opinion ratings. Flying quality requirements- pole-zero, frequency response and time-response specifications. Stability augmentation systems - displacement and rate feedback -determination of gains-conflict with pilot inputs- resolution-control augmentation systems- Full authority fly-by-wire control - need for automatic control.

Autopilots -purpose, functioning -inputs- hold, command, track. Displacement autopilots -pitch, yaw, bank, altitude and velocity hold -purpose, relevant simplified aircraft transfer functions, feedback signals, control actuators - operation, analysis, performance. Maneuvering autopilots - normal acceleration, turn rate, pitch rate commands - applications. Autopilot design by displacement feedback and series PID compensator - Zeigler and Nichols method. Autopilot viewed as stability augmenters. Robust control. Typical aircraft autopilots of civil and military aircraft -description, construction, operation, performance.

UNIT-V

MODERNCONTROLTHEORY-STATESPACEMODELING, ANALYSIS

Limitations of classical methods of control system modeling, analysis and design, applied to complex, multiple input multiple output systems. State space modeling of dynamical systems - state variables - definition - state equations. The output variable - the output equation - representation by vector matrix first order differential equations. General form, time invariant linear systems. Matrix transfer function. State transition matrix - matrix exponential - properties - numerical solution of state equations-illustrative examples. Canonical transformation of state equations -significance -Eigen values -real distinct, repeated, complex. Controllability and observability -definition -significance. Digital control systems -overview -advantages, disadvantages

Textbooks

1. Kuo, B.C., Automatic Control Systems, Prentice Hall India, 1992, ISBN 0-87692-133-0.
2. Stevens, B.L. and Lewis, F.L., Aircraft Control and Simulation, John Wiley, 1992, ISBN0-471- 61397-5.
3. Nelson R. C., Flight Stability and Automatic Control, 2nd edition, Tata McGraw-Hill, 2007, ISBN:0-07 066110-3.
4. Yechout, T. R. et al., Introduction to Aircraft Flight Mechanics,AIAA,2003,ISBN1-56347-577-4.

References

1. Mc Lean, D., Automatic Flight Control Systems, Prentice Hall, 1990, ISBN: 0-13-154008-0.
2. Bryson, A.E., Control of Aircraft and Spacecraft, Princeton University Press, 1994, ISBN: 0-691-08782-
3. Collinson, R. P.G.,IntroductiontoAvionicsSystems,secondedition,Springer,2003,ISBN:978-81-8489-795-1.

X. COURSE PLAN:

The course plan is meant as a guideline. There may probably be changes.

Lecture No.	Course Learning Outcomes	Topics to be covered	Reference
1	Introduction to control systems	Dynamical systems Input, output - process (plant) - block diagram representation. control input, noise	T1:1.1
2-5	Explain the basic concepts of control systems	Function of controls regulation (hold), tracking (command) - examples. Sensitivity of output to control input, noise and system parameters - robustness. Deterministic and stochastic control. Need for stable, effective (responsive), robust control system.	T1:1.1-1.5
6	Knowledge about differential equations	Modeling of dynamical systems by differential equations - system parameters. Order of the system	T1:1.6
7	List the types of systems	Multiple -input -multiple - output systems -linear and nonlinear systems. Linearization of nonlinear systems - .assumptions, validity. Time invariant linear systems.	T1:1.1
8-10	Understand the concept of feedback	The concept of feedback- open loop control, closed loop control. Effect of feedback on input output relation, stability, robustness.	T1:2.1
11-12	Understand the concept of system type and error	Merits of feedback control. Loop gain, feedback gain-significance. System type, steady state error, error constants-overall system stability.	T1:1.2-1.4
13	Application of feedback	Application of feedback in stability augmentation, control augmentation, automatic control - examples.	T1:2.5
14	Understand the block diagrams	Composition, reduction of block diagrams of complex systems - rules and conventions.	T1:2.5-2.6
15-16	List the Control system components	Control system components - sensors, transducers, servomotors, actuators, filters-modeling, transfer functions. Single -input - single - output systems. Multiple input- multiple output systems, matrix transfer functions-examples.	T1:2.6
17-19	Explain the control system performance	**PERFORMANCE- TIME, FREQUENCY AND S-DOMAIN DESCRIPTION** Control system performance- time domain description- output response to control inputs - impulse and indicial response-characteristic parameters - significance - relation to system parameters - examples - first and second order linear systems, higher order systems.	T1:2.5-2.6
20	Describe the Synthesis of response	Synthesis of response to arbitrary input functions from impulse and indicial response.	T1:4.1

21	Understand the Review of Laplace transforms	Review of Laplace transforms - applications to differential equations. 'S' (Laplace) domain description of input-output relations - transfer function representation - system parameters-gain, poles and zeroes. Partial fraction decomposition of transfer functions - significance	T1:4.2-4.8
22	Describe the Frequency domain	Dominant poles. Relation of transfer functions to impulse response. Frequency domain description - frequency response - gain and phase shift - significance - representation- asymptotic (Bode) plots, polar (Nyquist) plots, and frequency transfer functions.	T1:4.1-4.8
23-24	Understand the characteristic parameters	Characteristic parameters - corner frequencies, resonant frequencies, peak gain, bandwidth- significance. First and second order systems - extension to higher order systems.	T1:4.1-4.8
25-26	Identify the systems	System identification from input output measurements-importance. Experimental determination of system transfer functions by frequency response measurements. Example.	T1:4.1-4.8
27- 28	Know the control system performance requirements	**SPECIFICATION OF CONTROL SYSTEM PERFORMANCE REQUIREMENTS - SYSTEM SYNTHESIS - CONTROLLERS- COMPENSATION TECHNIQUES** Control system performance requirements-transient and steady state- specification-desired input - output relation -speed of response, stability, accuracy, steady state error, robustness.	T1:4.1-4.8
29	Understand the relation with system parameters	Relation with system parameters, Examples of first and second order systems. Specifications in frequency domain’s domain.	T1: 4.1-4.8
30-32	List the conflicting requirements	Conflicting requirements - need for compromise - scope for optimization. The primacy of stability. System synthesis -need for compensation – design of controllers - active, passive- series, feed forward, feedback controllers.	T1: 4.1-4.8
33-35	List the controls and filters	Proportional, integral, proportional plus derivative control- the problem with derivative control - lead, lag, lead - lag, wash-out, notch filters / networks -properties - effect on transfer function, stability, robustness - relative merits.	T1:4.10
36	Understand the adaptive control and significance of loop transfer function	Adaptive control - definition, merits, and implementation - gain scheduling. Nonlinear control, merits, constraints. Feedback controllers. Significance of loop transfer function, loop gain.	T1: 4.1-4.8
37-39	Identify the methods for the Stability of closed loop system	Stability of closed loop system- frequency response methods and root locus methods of analysis and compensation - Nyquist's criterion- stability margins - phase margin, gain margin-interpretation, significance- compensation by pole zero cancellation. Design of multiloop feed back systems.	T1: 4.11-4.12
40-42	Explain the Aircraft response to controls	**AIRCRAFT RESPONSE TO CONTROLS - FLYING QUALITIES - STABILITY AND CONTROL AUGMENTATION - AUTO PILOT** Approximations to aircraft transfer functions, control surface actuators-review. Response of aircraft to pilot's control inputs, to atmosphere.	T1: 6.1
43	Understand the task of the pilot	The control task of the pilot. Flying qualities of aircraft-relation to airframe transfer function. Reversible and irreversible flight control systems.	T1: 6.1-6.2
44	Explain the flying quality requirements	Pilot's opinion ratings. Flying quality requirements- pole-zero, frequency response and time-response specifications.	T1: 6.3-6.4
45-46	Know the types of augmentation systems	Stability augmentation systems -displacement and rate feedback -determination of gains-conflict with pilot inputs- resolution-control augmentation systems- Full authority fly-by-wire control - need for automatic control.	T1: 6.5

47-48	Knowledge about autopilot and its functioning	Autopilots -purpose, functioning -inputs- hold, command, track. Displacement autopilots -pitch, yaw, bank, altitude and velocity hold -purpose, relevant simplified aircraft transfer functions, feedback signals, control actuators - operation, analysis, performance	T1: 6.6-6.8
49-52	Explain Maneuvering autopilots and methods	Maneuvering autopilots - normal acceleration, turn rate, pitch rate commands - applications. Autopilot design by displacement feedback and series PID compensator - Zeigler and Nichols method.	T1: 6.9-6.10
53-55	Describe Autopilot viewed as stability augmenters	Autopilot viewed as stability augmenters. Robust control. Typical aircraft autopilots of civil and military aircraft - description, construction, operation, performance.	T1: 6.11-6.12
56-57	Understand the concept of modern control theory	**MODERN CONTROL THEORY - STATE SPACE MODELING, ANALYSIS** Limitations of classical methods of control system modeling, analysis and design, applied to complex, multiple input multiple output systems.	T1: 7.1- 7.3
58-60	Describe State space modeling of dynamical systems	State space modeling of dynamical systems - state variables - definition - state equations. The output variable - the output equation - representation by vector matrix first order differential equations. General form, time invariant linear systems.	T1: 7.5- 7.6
61-63	Solve the matrix transfer function and transformations	Matrix transfer function. State transition matrix - matrix exponential - properties - numerical solution of state equations - illustrative examples. Canonical transformation of state equations -significance -Eigen values -real distinct, repeated, complex.	T1: 7.7- 7.8
64-65	Define Controllability, observability and Digital control systems	Controllability and observability -definition -significance. Digital control systems - overview - advantages, disadvantages	T1: 7.9- 7.10

XI. MAPPING COURSE OBJECTIVES LEADING TO THE ACHIEVEMENT OF THE PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES

Course Objectives	Program Objectives												Program Specific Outcomes			
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
I	S	S	H	S		S						H	H	S		
II	H			H												
III	S		S			H										
IV		H	H	H		S							H			
V	H	S										H	H	S		

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

Course Objectives	Program Outcomes												Program Specific Outcomes			
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
1	H	S		S								S	H	S		
2	S	H		S									S	H		
3	S	H		S									S	S		

4	S	H	S										S	H		
5			H			S										
6			S										H			
7			H			S						H	S			
8			H			H						S	H	H		
9			H			S							S	S		
10			H			S						H	H	H		
11	S												S			
12				S												
13	S													S		
14	H	S														
15			S													

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Prepared by: Ms. D. Anitha, Assistant Professor

HOD, AE