Course Specification

(Postgraduate Programs)

Course Title:	Nonlinear Systems
Course Code:	2202-557 (EE557)
Program:	Master in Electrical Engineering
Department:	Electrical Engineering
College:	College of Engineering
Institution:	King Faisal University
Version:	2.0
Last Revision Date:	17 April 2025

Table of Contents

A. General information about the course:

1. Course Identification:

1. Credit hours: (3)				
2. Course type				
A.	☐ University	☐ College	☒ Department	☐ Track
B.	☐ Required		☒ Elective	
3. Level/year at which this course is offered: Level 3/2nd year				
4. Course General Description:				
Introduction to nonlinear systems; Local linearization and Lyapunov redesign; Describing function method and limit cycles; Phase-plane analysis; Bifurcation; Lyapunov stability; Input-output stability and small-gain Theorem; Passivity and Feedback-equivalence; Feedback linearization; Variable structure and sliding-mode control				
5. Pre-requirements for this course (if any)**:**				
2202-430: Analog Control Systems				
6. Co-requisites for this course (if any)**:**				
None				
7. Course Main Objective(s):				
To give students a sound basis of nonlinear systems theory to enable the student to undertake research on the subject, as well as be competent in design and analysis of nonlinear feedback control systems				

2. Teaching Mode: (mark all that apply)

No	Mode of Instruction	Contact Hours	Percentage
1	Traditional classroom	45	100%
2	E-learning		
3	Hybrid • Traditional classroom • E-learning		

No	Mode of Instruction	Contact Hours	Percentage
4	Distance learning		

3. Contact Hours: (based on the academic semester)

No	Activity	Contact Hours
1.	**Lectures**	45
2.	**Laboratory/Studio**	
3.	**Field**	
4.	**Tutorial**	
5.	**Others (specify)……**	
	Total	45

B. Course Learning Outcomes (CLOs), Teaching Strategies and Assessment Methods:

Code	Course Learning Outcomes	Code of PLOs aligned with the program	Teaching Strategies	Assessment Methods
1.0	**Knowledge and understanding**			
1.1	Describe nonlinear systems in state-space and recognize the conditions for existence and uniqueness of solutions with many examples	K1	Lectures	HWs, Exams
1.2	Find the linear approximation of a nonlinear system around an equilibrium point and determine the stability of the system using the first method of Lyapunov and the center-manifold theorem	K1	Lectures	HWs, Exams

Code	Course Learning Outcomes	Code of PLOs aligned with the program	Teaching Strategies	Assessment Methods
1.3	Determine the qualitative behavior of second order systems including periodic orbits (or limit cycles) using phase-plane analysis as well as the describing function method	K1	Lectures	HWs, Exams,
1.4	Assimilate the second-method of Lyapunov, its converse theorems, as well as the Invariance principle and their applications	K1	Lectures	HWs, Exams
1.5	Determine the feedback linearizability of a nonlinear system and its linear equivalent	K1	Lectures	HWs, Exams,
...				
2.0	**Skills**			
2.1	Design of nonlinear feedback control systems using the Lyapunov redesign method.	S1	Lectures	HWs, Exams
2.2	Design of nonlinear control systems using feedback linearization, sliding mode control and small gain theorem	S1	Lectures	HWs, Exams
2.3	Use passivity theorem, Positive-real lemma, KYP lemma and Feedback equivalence to a passive system to design a stable feedback control system.	S1	Lectures	HWs, Exams

Code	Course Learning Outcomes	Code of PLOs aligned with the program	Teaching Strategies	Assessment Methods
2.4	Use input-output stability, circle criterion, Popov criterion and absolute stability to design stable interconnected feedback control systems.	S1	Lectures	HWs, Exams,
2.5	Use MATLAB software for design and analysis of nonlinear control systems	S2	Lectures	HWs, Project
3.0	**Values, autonomy, and responsibility**			
3.1	Undertake advanced research in nonlinear control systems including optimal and adaptive control of such systems, and to be able to read journal papers on the subject	V2, V3	Project	Project
...				

C. Course Content:

No	List of Topics	Contact Hours
1.	Introduction to Nonlinear Models and Nonlinear Phenomenon	3
2.	Second-Order Systems	3
3.	Fundamental Properties and Mathematical Preliminaries	3
4.	Lyapunov Stability	6
5.	Input-Output Stability	3
6.	Passivity	3
7.	Frequency Domain Analysis of Feedback Systems	3
8.	Advanced Stability Analysis	3
9.	Feedback Control	6
10.	Feedback Linearization	6
11.	Nonlinear Design Tools	6
Total		**45**

D. Students Assessment Activities:

No	Assessment Activities *	Assessment timing (in week no)	Percentage of Total Assessment Score
1.	HW#1 : Topic 1 - Introduction	Week 1	0.5%
2.	HW#2 : Topic 2 – Second-Order Systems	Week 2	1%
3.	HW#3: Topic 3 – Fundamental Properties	Week 3	1%
4.	HW# 4: Topic – Lyapunov Stability	Week 4	1%
5.	Exam 1: Covering Topics 1, 2, 3 and 4 above	Week 5	20%
6.	HW# 5: Topic – Input-Output Stability	Week 7	1%
7.	HW# 6: Topic - Passivity	Week 8	1%
8.	HW#7: Topic – Frequency Domain Analysis	Week 9	1%
9.	Exam II: Covering Topics 5, 6, and 7 above	Week 10	20%
10.	Project	Week 10	20%
11.	HW#8: Topic – Advanced Stability Analysis	Week 10	1%
12.	HW#9: Topic – Feedback Control	Week 11	1%
13.	HW#10: Topic – Feedback Linearization	Week12	1%
14.	HW#11: Topic - Nonlinear Design Tools	Week14	0.5%
15.	Exam III: Covering Topics 8, 9, 10 above	Week 16	30%
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*Assessment Activities (i.e., Written test, oral test, oral presentation, group project, essay, etc.)

E. Learning Resources and Facilities:

1. References and Learning Resources:

Essential References	H. K. Khalil, Nonlinear Systems, 3rd Edition, Prentice Hall, Upper Saddle River, NJ, USA, 2002, ISBN-13: 978-0130673893
Supportive References	1. Nonlinear Systems: Analysis, Stability and Control, S. K. Sastry, Springer Verlag, NY, 1999 2. Nonlinear Systems Analysis, M. Vidyasagar, Prentice Hall, 2nd Edition, 1993
Electronic Materials	IEEE Xplore, and other Control Systems Journals
Other Learning Materials	Software: MATLAB, SIMULINK

2. Educational and Research Facilities and Equipment Required:

Items	Resources
facilities (Classrooms, laboratories, exhibition rooms, simulation rooms, etc.)	Normal Class room accommodating 36 students

Items	Resources
Technology equipment (Projector, smart board, software)	Overhead projector and multimedia interface
Other equipment (Depending on the nature of the specialty)	

F. Assessment of Course Quality:

Assessment Areas/Issues	Assessor	Assessment Methods
Effectiveness of teaching	Students	Indirect-Online Survey
Effectiveness of students' assessment	Students and Faculty	Direct and Indirect Assessment
Quality of learning resources	Students and Faculty	Indirect-Online Survey
The extent to which CLOs have been achieved	Students and Faculty	Direct and Indirect Assessment
Other	None	None

Assessor (Students, Faculty, Program Leaders, Peer Reviewer, Others (specify)

Assessment Methods (Direct, Indirect)

G. Specification Approval Data:

COUNCIL /COMMITTEE	**EE DEPARTMENT QUALITY COMMITTEE**
REFERENCE NO.	**MEETING # 10**
DATE	**APRIL 19, 2025**