Control of Mechanical Systems

0630-417/01

Instructor Info

Ali AlSaibie

By Bookings. Office Hours: Weekdays 10:00am-11:00am

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TA Info

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Course Info

Sun Tue Thurs; 10am-11am

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Kuwait University

College of Engineering and Petroleum

Mechanical Engineering Department

Spring 2021

Course Description

This is a senior level course in the subject of control of mechanical systems. The course covers the fundamentals of feedback control, focusing on the design of control systems through the graphical techniques of Root-locus and Bode plots. The course also introduces students to control design via State-Space.

Prerequisites

1. Fundamentals of Basic Electronic Devices.
2. Basic Principles and Operations of Electric Motors and Generators.
3. Fundamentals of Fluid Mechanics.
4. Fundamentals of Thermodynamics and Heat Transfer.
5. Fundamentals of Mechanical System Dynamics.
6. Fundamentals of Measuring Devices.
7. Basic Computer Skills.

Material

Required Text

Norman S. Nise, Control Systems Engineering, 6th International Edition, John Wiley & Sons

Reference Texts

R. C. Dorf & R. H. Bishop, Modern Control Systems

G. F. Franklin, J. D. Powell & A. Emami-Naeini, Feedback Control of Mechanical Systems

K. Ogata, Modern Control Engineering

Course Objectives and Outcomes

1. To teach students analysis, design and implementation of control systems used in mechanical systems.
   - A Obtain adequate mathematical models of a physical system.
   - B Obtain linear models (state-space and transfer function) for control design.
   - C Construct, understand and simplify block diagrams and/or signal flow graphs of different systems.
   - D Specify performance objectives in time and frequency domains.
   - E Analyze linear system stability.
   - F Sketch the root locus and use it for design and analysis purposes.
   - G Sketch Bode diagrams and use frequency response for analysis and design of control systems.
   - H Design of cascade or feedback compensator to achieve a given performance objective.
2. To introduce computer-assisted design of control systems (CACSD) using time and/or frequency domain techniques.
   - A Use CACSD to simulate open loop dynamic behavior to validate linear models.
   - B Use CACSD to draw root locus, and Bode diagrams.
   - C Use CACSD to design a controller and be able to evaluate the performance of the closed loop behavior.
3. To provide opportunities for the students to practice communication and team-building skills, and to acquire a sense of professional responsibility.
   - A Work in teams effectively to complete given team assignments.
   - B Communicate effectively in written form.
   - C Recognize the need for life-long learning and acquire information not covered in the lectures.

Grading Scheme

15%	**Midterm I**
15%	**Midterm II**
20%	**Numerical Assignments**
10%	**Homework Assignments**
40%	**Final Exam**

Class Discussion and Q&A

Class discussion will be hosted on a Piazza site. There, you are encouraged to post questions regarding the course material and you are even encouraged to participate in answering your classmates questions. The Piazza forum will be moderated by the instructor and the TA.

Course Policy

Group Assignments

One of the core objectives of the course is to teach students design of control systems. The assignments are tailored to give students the opportunity to carryout an extended control systems engineering analysis and design using both analytical and numerical techniques. Without the numerical assignments, students will not be able to appreciate the value of the theoretical concepts taught.

Homework

Individual homework assignments will be given at the beginning of every part in the course, students are encouraged to review the homework problems and work through them as the part is being covered. Students are encouraged to work together in order to understand the problems and debate the solution methods. Submitted work MUST completely be ones own work. A thorough understanding of the homework problems will correlate with performance on the midterms and final.

Interactive Learning Exercises

There will be unannounced interactive learning exercises throughout the semester.

Academic Integrity

Students are expected to abide by the university's code of ethics, and hold a high academic standard. This course has a zero-tolerance policy regarding plagiarism. A student who engages in any form of academic dishonesty is subject to disciplinary action by the College. Examples of Academic Dishonesty include: cheating, plagiarism, fabrication, aiding or abetting dishonesty, falsification of records and official documents, and all acts of such nature. Additionally, students are subject to all rules and regulations of the Department, College and University as specified in the official bulletins.

Plagiarizing homework assignments, including copying of code and figures from solutions or other students, is considered cheating and WILL result in a grade of F.

Plagiarizing numerical assignments, including copying from other student groups, is considered cheating and WILL result in a grade of F in the course.

Cheating on any of the midterms or final exam, WILL result in a grade of F in the course and a cheating report WILL be submitted to the college.

An engineer who fails to maintain his ethical standards academically, will fail to be a productive member of the engineering profession. Without engineering ethics, there is no value achieved by theoretical knowledge.

Online Meeting Protocol

- While it is not mandatory to turn on your camera during regular lectures, I ask that you place a photo in your profile if possible to help me identify you.
- You will be required to turn on you camera during exams and assessments.
- Participation is highly encouraged to keep the discussion interactive, but keep your microphone muted if you are not using it.
- Office hours are to be booked through the bookings tab.
- Use the raise hand feature to help queue questions as required.

Online Exam Protocol

- You are required to be present in a live meeting with your camera turned on during the full duration of the exam.
- You are responsible for ensuring you have installed and tested the software required to conduct the online exam, as per the exam instructions.
- The camera must be stationed to your side, in a manner to show your computer screen, your workdesk and your face.
- You will be given a method to submit your written solution. Your written solution answer must match the answers submitted in the online exam.
- The exam will be returned to you. To review your exam, you need to send an email to the instructor, using your KU official email. Email is the only form of communication for reviewing exam grades.

Course Regulations

- Attendance is mandatory, and will be taken during each online synchronous lecture. University rules regarding attendance will be enforced. You are allowed two unexcused absences, 1% will be deducted for additional absences. **Missing 6 hours = FA**.
- Late attendances will count toward absences. Every 3 late attendances will count toward one absence.
- You are expected to read the assigned reference material and not rely solely on the lecture material. Lecture materials are an aid, and not a complete reference.
- There are no make-up exams, one midterm exam grade will be added to the final exam grade, the final exam grade will then be 52.5%.
- An **FA** will only be given according to university regulations, a grade change to an **FA** WILL NOT be done based on a student request.

Course Schedule

The course schedule is outlined in the following section.

ME417 - Control of Mechanical Systems - Spring 2021

L	D	Date	Topic	Reading Assignment	Assignment	Submission Due
PART I: Introduction to Feedback Control						
1	Sun	Apr 04	I.1: Introduction & Birdseye View of the course	Nise: 1.1 - 1.3		
2	Tue	Apr 06	I.2: Analysis & Design	Nise: 1.4 - 1.7	NA1	
3	Thu	Apr 08	I.3: Laplace Transform & Transfer Functions Review	Nise: 2.1 - 2.3	HW1	
4	Sun	Apr 11	I.4: Mechanical Systems Transfer Functions	Nise: 2.5 - 2.7		
5	Tue	Apr 13	I.5: Electromechanical Systems Transfer Functions	Nise: 2.8		
6	Thu	Apr 15	I.6: Poles, Zeros and System Response	Nise: 4.1 - 4.4		
7	Sun	Apr 18	I.7: The General Second-Order System	Nise: 4.4 - 4.8		
8	Tue	Apr 20	I.7: The General Second-Order System	Nise: 5.1-5.3, 6.1	NA2	NA1
9	Thu	Apr 22	I.8: Introduction to Stability and Feedback Control	Nise: 5.1-5.3, 6.1	HW2	HW1
10	Sun	Apr 25	I.8: Introduction to Stability and Feedback Control	Nise: 5.1-5.3, 6.1		
11	Tue	Apr 27	I.9: PID Control via Gain Tuning			
12	Thu	Apr 29	I.10: Steady-State Errors	Nise: 7.1-7.3		
13	Sun	May 02	I.11: Unity Feedback Controller Design			
PART II: Controller Design Using Root-Locus						
14	Tue	May 04	II.1: Introduction to Root-Locus	Nise: 8.1 - 8.3	NA3	NA2
15	Thu	May 06	II.2: Sketching the Root-Locus	Nise: 8.4 - 8.6, 8.8		HW2
16	Sun	May 09	II.2: Sketching the Root-Locus	Nise: 8.4 - 8.6, 8.8		
	Mon	May 10	Midterm I			
17	Tue	May 11	II.3: Transient Response Design via Gain Adjustment	Nise: 8.7	HW3	
18	Thu	May 13	II.3: Transient Response Design via Gain Adjustment			
19	Sun	May 16	II.4: Improving Steady-State Response	Nise: 9.1 - 9.2		
20	Tue	May 18	II.4: Improving Steady-State Response	Nise: 9.1 - 9.2		
21	Thu	May 20	II.5: Improving Transient Response	Nise: 9.3		
22	Sun	May 23	II.5: Improving Transient Response	Nise: 9.4		
23	Tue	May 25	II.6: Improving Steady-State and Transient Response - PID	Nise: 9.5	NA4	NA3
24	Thu	May 27	II.6: Improving Steady-State and Transient Response - PID			HW3
PART III: Controller Design via State Space						
25	Sun	May 30	Midterm II			
26	Tue	Jun 01	III.1: State-Space Representation	Nise: 3.1-3.6		
27	Thu	Jun 03	III.1: State-Space Representation		HW4	
28	Sun	Jun 06	III.2: Stability and Steady-State Error In State-Space	Nise: 6.5, 7.8		
29	Tue	Jun 08	III.2: Stability and Steady-State Error In State-Space		NA5	NA4
30	Thu	Jun 10	III.3: State-Space Controller Representation and Design	Nise: 12.1-12.3		
31	Sun	Jun 13	III.3: State-Space Controller Representation and Design	Nise: 12.1-12.3		
32	Tue	Jun 15	III.4: Introduction to Linear Optimal Control			
33	Thu	Jun 17	III.5: State-Space Controller Design Problems	Nise: 12.8	HW5	HW4
34	Sun	Jun 20	III.5: State-Space Controller Design Problems	Nise: 12.8		
PART IV: Frequency Response Techniques						
35	Tue	Jun 22	IV.1: Introduction to Frequency Response	Nise: 10.1		NA5
36	Thu	Jun 24	IV.2: Sketching Bode Plots	Nise: 10.2		
37	Sun	Jun 27	IV.2: Sketching Bode Plots	Nise: 10.2		
38	Tue	Jun 29	IV.3: Refining Second-Order Systems Bode Plots	Nise: 10.2		
39	Thu	Jul 01	IV.4: System Identification from Frequency Response	Nise: 10.13		HW5
	Mon	Jul 07	**Comprehensive Final Exam: 08:00 - 10:00**			