SIE 550 (Linear) Systems Theory: Spring 2021

Course Instructor, Lectures and Course Website

Instructor: Dr. Roberto Furfaro, robertof@email.arizona.edu
1. Campus Office: ENGR305, 520-621-2525
2. Cell: 520-312-7440 (texting is preferred)

Office Hours: Tue-Th 5:30pm-6:30pm (zoom personal room) or by appointment.

Teaching Assistant: Mr. Enrico Schiassi, eschiassi@email.arizona.edu,
Mr. Mario De Florio, mariodf@email.arizona.edu
Mr. Luca Ghilardi, lucaghilardi@email.arizona.edu

(OH: for TAs will be announced later)

Lectures: Tue-Th, 4:00pm - 5:15pm (zoom meetings)

Course content on D2L: www.d2l.arizona.edu

Course Description

This course is a core course for graduate students at the SIE department. Although the title is "Linear Systems Theory", the course will cover both linear and non-linear systems under a unified framework. The goal of the course is to give the students a deep understanding of the behavior of dynamical systems as well as means to analyze autonomous and non-autonomous systems employing basic and advanced mathematical techniques. The material covered in this course spans from representation and analysis of dynamical systems, Lyapunov stability theory, controllability and observability of linear systems as well as design techniques for dynamical system stabilization.

Schedule and Topics

Week 0: Jan 14

Topic: Introduction

Week 1: Jan 19 -21

Topic: Mathematical Background: Fundamentals of linear algebra

1. Vector spaces
2. Linear Operators
3. Eigenvalues and Eigenvectors
4. Diagonal Forms and Jordan Forms
5. Special Linear Operators: Symmetric and Normal/Orthogonal Operators

Week 2: Jan 26 -28

Topic: Linear and Non-Linear Dynamical Systems

1. General Dynamical Models
2. Examples of linear and non-linear models
3. Linear and non-linear phenomena

Week 3: Feb 2 – Feb 4

Topic: Solutions of Linear Differential Equations

1. Solution of Systems of linear differential Equations
2. Laplace transform and the concept of transfer function
3. Duality

Wed Feb 3 *- HW#1 due*

Week 4: Feb 9 – 11

Topic: Stability Concepts I

1. Stability of Equilibrium Points and Linearization
2. Lyapunov Stability: General Concepts
3. Lyapunov Stability for Linear Systems

Week 5: Feb 16-18

Topic: Stability Concepts II

1. Lyapunov Stability for Non-linear Systems and Linearization
2. Exponential Stability and Region of Attraction
3. Converse Lyapunov Functions and Non-Autonomous Systems

Wed Feb 17 *– HW#2 Due*

Week 6: Mar 2-4

Topic: Stability Concepts III

1. Perturbed Systems
2. BIBO Stability

Wed Mar 1 *– HW#3 Due*

Week SB (Mar 6- Mar 14): Spring Recess

Week 7: Mar 16-Feb 18

Topic: Finite Time Stability

1. Finite Time Stability: Basic Concept and Definitions
2. Finite Time Stability Conditions for Autonomous and Non-Autonomous Systems

Week RW (Review): Mar 23-25

Topic: Review and Mid-Term Exam

Wed Mar 24 *- HW#4 Due*

Tue Mar 23 *- Midterm Review*

Th Mar 25 *- Midterm Exam (Take-home)*

Week 8: Mar 30- April 1

Topic: Controllability

1. General Conditions
2. Controllability Canonical Forms

3. Time Invariant Systems
4. Output and Trajectory Controllability
5. Controllability and Stability for General Systems

Week 9: April 6-8

Topic: Observability

1. General Conditions
2. Observability Canonical Forms
3. Time Invariant Systems

Wed April 5 *- HW# 5 due*

Week 10: Apr 13-15

Topic: Canonical Forms

1. Controllability Canonical Forms
2. Observability Canonical Forms
3. Examples

Week 11: Apr 20-22

Topic: Systems Design and Estimation I: Linear Methods

1. Stabilization: Basic Concepts and Linearization
2. Linear Systems Design: Eigenvalues placements
3. Linear Systems Observers
4. Controller Observer Separation Theorem
5. Examples

Wed Apr 21 – HW#6 due

Week 12: Apr 27-29

Topic: Systems Design and Estimation II: Linear Methods

1. Design and Estimation examples via MATLAB
2. Linear Quadratic Regulator

Week 1: May 4

Topic: Systems Design and Estimation III: non-linear methods

1. Lyapunov-based stabilization
2. Robust stabilization and sliding control

Wed May 5 *– HW#7 due*

Final Exam: May 10, 2021 (Take-home)

Grading

A regular grade (A, B, C, D, E) will assigned. The grade will be established as function of the class performance (curve). Each student will receive a numerical value according to his/her performance on the following items:

Midterm Exam	30%
Final Exam	40%
Homework	30%

Course Objectives

At the end of the course, the students are expected to be able to:

1. Analyzing of Linear and Non-Linear Dynamical Systems
2. Applying of the Lyapunov Stability Theory to Dynamical Systems
3. Understanding if a System is Controllable and Observable
4. Applying a Variety of Design Methodologies to Stabilize Dynamical Systems

Semester Assignments, Midterm and Final Examination

During the semester, students will be required to submit approximately 7 (seven) homeworks with bi-weekly frequency. Homeworks will be a combination of theoretical analysis and limited computer simulation via MATLAB. There will be one mid-term exam and one comprehensive final exam. Considering the pandemic instructions on both exams format will be announced later. Make-up exams for a valid excuse must be arranged at least 1 week before the scheduled exam date. Emergency situation should be communicated to the instructor as soon as possible to arrange for an alternative schedule. Without prior consent, there will be no make-up exams.

Class Attendance, Participation and General Ethical Guidelines

The students are expected to regularly attend the lectures. If lectures are missed, the student should make sure you get up-to-date with the course material by reviewing the zoom recorded lectures and the material posted on the D2L course website. Students and faculty each have a responsibility for maintaining an appropriate learning environment. Those who fail to adhere to such behavioral standards may be subject to discipline. Active participation during classes (e.g. answering questions when asked by the instructor, show interest and motivation for the subject) is encouraged and it may be taken into account when establishing the final grade. While collaboration and discussion between students during homework is encouraged, plagiarism is not tolerated and may be subjected to disciplinary actions.

Textbooks

Szidarovszky and Bahill, Linear Systems Theory, Second Edition (Systems Engineering) Hardcover – November 25, 1997 (Required).

Instructor class notes and relevant material (the instructor will make them available through the D2L course website at d2l.arizona.edu)

Software

MATLAB (full version available for download to UA students)

Zoom Lectures

Lectures will be delivered via zoom – access is granted via D2L portal. Here you have the zoom invitation:

Roberto Furfaro is inviting you to a scheduled Zoom meeting.

This meeting was created in a non-BAA environment and is not intended for the discussion of healthcare, health education, or health data research.

Topic: SIE 550 SP21 001 025 110 210 410
Time: Jan 14, 2021 04:00 PM Arizona

Every week on Tue, Thu, until May 4, 2021, 32 occurrence(s)
Jan 14, 2021 04:00 PM
Jan 19, 2021 04:00 PM
Jan 21, 2021 04:00 PM
Jan 26, 2021 04:00 PM
Jan 28, 2021 04:00 PM
Feb 2, 2021 04:00 PM
Feb 4, 2021 04:00 PM
Feb 9, 2021 04:00 PM
Feb 11, 2021 04:00 PM
Feb 16, 2021 04:00 PM
Feb 18, 2021 04:00 PM
Feb 23, 2021 04:00 PM
Feb 25, 2021 04:00 PM
Mar 2, 2021 04:00 PM
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Mar 23, 2021 04:00 PM
Mar 25, 2021 04:00 PM
Mar 30, 2021 04:00 PM
Apr 1, 2021 04:00 PM
Apr 6, 2021 04:00 PM
Apr 8, 2021 04:00 PM
Apr 13, 2021 04:00 PM
Apr 15, 2021 04:00 PM
Apr 20, 2021 04:00 PM
Apr 22, 2021 04:00 PM
Apr 27, 2021 04:00 PM
Apr 29, 2021 04:00 PM
May 4, 2021 04:00 PM

Please download and import the following iCalendar (.ics) files to your calendar system.
Weekly:
https://arizona.zoom.us/meeting/tZUldO2srj0qEtKLF2pw1JWFa16MOWsuWrRL/ics?icsToken=98tyKuGppjguHtSTsBGBRpwcGojCLOjziCFfj7d2sDm3EzcCSDTQN7MUH51IA83n

Join Zoom Meeting
https://arizona.zoom.us/j/81834406086

Password: 123789

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+1 312 626 6799 US (Chicago)
+1 646 876 9923 US (New York)
+1 602 753 0140 US (Phoenix)
+1 669 900 6833 US (San Jose)
+1 253 215 8782 US (Tacoma)
+1 346 248 7799 US (Houston)

Meeting ID: 818 3440 6086
Find your local number: https://arizona.zoom.us/u/kdnwDGjuOU

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Join by H.323
162.255.37.11 (US West)
162.255.36.11 (US East)

115.114.131.7 (India Mumbai)
115.114.115.7 (India Hyderabad)
213.19.144.110 (Amsterdam Netherlands)
213.244.140.110 (Germany)
103.122.166.55 (Australia)
149.137.40.110 (Singapore)
64.211.144.160 (Brazil)
69.174.57.160 (Canada)
207.226.132.110 (Japan)
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Password: 123789

Join by Skype for Business
https://arizona.zoom.us/skype/81834406086

Zoom Office Hours

Please access R. Furfaro personal room (Tue/Th 5:30-6:30pm) – or text for appointment:

Roberto Furfaro is inviting you to a scheduled Zoom meeting.

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Topic: Roberto Furfaro's Personal Meeting Room

Join Zoom Meeting
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