University of Utah

ME EN 5210/6210 & ECE 5652/6652 & CH EN 5203/6203
Linear Systems and State-Space Control
Spring 2025

Meeting time: Tuesday & Thursday 10:45-12:05, WEB L120; Office Hours: TBD

Instructor:
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Course Objectives:
In Linear Systems and State-Space Control, we will learn how to analyze and design systems expressed as coupled linear first-order differential equations. As an alternative to Classical Control Systems, which make use of the Laplace transform to analyze and design primarily single-input/single-output systems, state-space methods enable us to analyze and design multi-input/multi-output systems directly in time domain. We will consider both continuous-time and discrete-time equations with a unified framework. Control systems are used to regulate the temperature in a room, to command a robot arm along a desired trajectory, to autopilot an airplane, and to ensure that manufacturing processes stay within specifications. A course in control systems provides a student with a common language with which to qualitatively and quantitatively discuss system performance and specifications. In addition, state-space methods are used to analyze a variety of systems that, at first, seem quite distinct from engineering systems, including economic and social models. This is not a course about forming state-space models, but rather, analyzing and controlling systems that are already described in state-space form. Other courses exist, at the undergraduate and graduate level, which focus on the topic of forming state-space models for physical systems.

Prerequisites:
Students should have been exposed to linear algebra and differential equations. Students should have also been exposed to modeling of dynamic systems (mechanical, electrical, etc.) as differential equations. If any of these prerequisites is not met, the student should speak to the instructor.

Text:
Linear System Theory and Design, Fourth Edition, Chi-Tsong Chen

Course Web Pages:
Canvas: http://utah.instructure.com
My YouTube video tutorials: http://www.youtube.com/@JJAbbottatUtah/videos

College of Engineering Guidelines (ADA, Adding, Withdrawal, Repeating, Appeals):
https://www.coe.utah.edu/semester-guidelines

Readings:
Students are expected to do the reading for a given day before coming to class. There is not enough time in the lectures to cover all of the required material, so reading is crucial for a complete understanding of the material.

Each of the lecture topics has associated tutorial videos. These videos are not required viewing, but are intended to supplement information when desired. Students might consider watching the videos before or after lectures to determine what is most effective for their learning. These videos can also be used to replace lectures when class must be missed due to illness.

Homework:
There will be a homework assignment most weeks, typically assigned on Thursday and typically due the following Thursday, but always at the data and time indicated in Canvas. Homework must be submitted as a scanned pdf to Canvas. Homework will be graded on a four-point scale as follows. Only one problem will be selected for thorough grading: that problem will receive a 3 for being perfect or close to perfect (as defined by the instructor), a 2 for a good effort but with some major error, a 1 for insufficient effort, and a 0 if it was not attempted. Additionally, the fourth point will be given if a good effort was made on the entire assignment (i.e., **all** problems were attempted with an effort that would have warranted at least a 2 if that problem had been graded). **No late homework will be accepted under any circumstances, but the lowest two homework scores will be dropped automatically.** For the sake of doing well on the exams, you cannot afford to skip any homework assignments. It is strongly suggested that you attempt all assignments (i.e., have no 0's).

Discussion of homework and teamwork are encouraged, but each student must complete each assignment individually. MATLAB will be required for many of the assignments. Figures and computer programs cannot be shared. Copying homework is unacceptable and will result in a zero homework grade for everyone involved. Utilizing solution manuals or prior-year solutions is considered a very serious ethical violation. A group of students who work together have the right to ask a fellow student to leave their study group if that student does not contribute to their group.

Labs:
There will be a hands-on lab to demonstrate the methods we learn on a real system. Labs can be done on the students' own time. Make sure to leave the lab clean, and report any problems with the lab to the instructor.

Exams:
There will be a midterm exam and a comprehensive final exam. All examinations must be taken at the scheduled time unless prior arrangements are made at least two weeks before the exam. Any exam that is rescheduled due to a nonacademic reason (to be determined by the instructor) will incur an automatic 5% penalty. Students have one week after receiving an exam score to contest the exam grade. After that time, no changes will be made.

It is the responsibility of the student to request any accommodations and provide documentation specifying the arrangements from the University of Utah Center for Disability Services.

Grading:

Homework:	25%
Labs:	10%
Exams:	65%

Students **must pass** each individual component (Homework, Lab, and Exams) with at least a 60% in order to pass this course. A student that does not pass each individual component, but arrives at a composite score greater than 70% (i.e., normally a C-), will be given a D+ for the final course grade.

For the composite exam score, the instructor will calculate two different sets of weightings of the two exams, and will use whichever benefits you as the student:

Method 1: 25% + 40% = 65%

Method 2: 10% + 55% = 65%

The instructor reserves the right to make changes to any course policies. Students will be notified immediately of any changes.

Cheating and Plagiarism:

Anyone found to be cheating on an exam or quiz, copying homework from solutions manuals, plagiarizing reports or papers of any kind will receive an E for the class. Keep your eyes on your own work during exams and quizzes to avoid the appearance of cheating. Further, posting your homework or exam solutions online, which could facilitate the cheating of future generations of students, is considered just as serious of an ethical violation as directly cheating.

A Culture of Respect:

Linear Systems and State-Space Control is a challenging class, and it will take a lot of your time and hard work. However, you will learn a lot of valuable skills that are useful in many aspects of engineering. To get the most out of this class, we must all maintain a culture of respect and a positive attitude. Questions in class are encouraged, but we have a lot of ground to cover, and must keep moving forward at good pace. It is your responsibility to stay engaged and caught up. My job as the instructor of this course is not to teach you state-space control, but rather, it is to facilitate your learning in. I can be a valuable resource for anybody willing to utilize me.

In addition to teaching this course, I manage a large and active research group, and have a number of university and extramural service duties. I must insist that students' questions regarding course material be restricted to office hours and the time just after class has ended. Please come to office hours with specific questions. If you arrive at office hours and another student is already in my office, please come right in and listen to the conversation (you may get one of your questions answered before you even ask it). It is not reasonable to expect private lectures at office hours; that being said, I will be willing to repeat as much material as necessary to help you while also respecting the other students in attendance. Questions of a personal nature and questions not regarding course material can be discussed at a meeting by appointment, outside of office hours (or in office hours if no other students are present).

Schedule for Readings, Homework, and Exams

Wk	Date	Topic	Reading	HW
1	7-Jan	Introduction		
	9-Jan	Continuous-time LTI Systems	1, 2.1-2.6	
2	14-Jan	Forming state-space models (a review)	2.5-2.7	
	16-Jan	Forming state-space models (a review)	2.5-2.7	HW1 Due
3	21-Jan	Discrete-time LTI systems	2.8-2.9	
	23-Jan	Linear Algebra Basics	3.1-3.3	HW2 Due
4	28-Jan	Similarity Transformations	3.4	
	30-Jan	Jordan Form	3.5	HW3 Due
5	4-Feb	Functions of a Square Matrix	3.6	
	6-Feb	Functions of a Square Matrix	3.6	HW4 Due
6	11-Feb	Solutions of continuous and discrete equations	4.1-4.3	
	13-Feb	Equivalent state-space equations	4.4	HW5 Due
7	18-Feb	Realizations	4.5	
	20-Feb	Realizations	4.5	HW6 Due
8	25-Feb	Input-output stability	5.1-5.3	
	27-Feb	Internal Stability	5.4-5.5	HW7 Due
9	4-Mar	**No class, Spring Break**		
	6-Mar	**No class, Spring Break**		
10	11-Mar	Controllability and Observability	6.1-6.3	
	13-Mar	Controllability and Observability	6.4	HW8 Due
11	18-Mar	Controllability and Observability	6.5-6.7	
	20-Mar	**Midterm Exam (Chapters 1-5, Homeworks 1-8)**		Lab 1 Due
12	25-Mar	Control with state feedback	8.1-8.3	
	27-Mar	Control with state feedback	8.1-8.3	HW9 Due
13	1-Apr	State estimation and feedback	8.4-8.5	
	3-Apr	MIMO state feedback	8.6-8.8	HW10 Due
14	8-Apr	Intro to LQR Method		
	10-Apr	Intro to Kalman Filter		HW11 Due
15	15-Apr	LQG Design		
	17-Apr	**No class, Design Day**		
16	22-Apr	Review for Final Exam		
	24-Apr	**Comprehensive Final Exam: 10:30-12:30**		Lab 2 Due