University of Utah

ME EN 5210/6210 & CH EN 5203/6203
State-Space Control Systems
Spring 2016

Meeting time: Tuesday & Thursday 9:10-10:30, WEB 1250; Office Hours: TBD

Instructor:
Dr. Jake Abbott, office: MEK 2016, e-mail: jake.abbott@utah.edu, phone: (801) 585-6672

Course Objectives:
In State-Space Control Systems, we will learn how to analyze and design systems expressed as coupled linear first-order differential equations. As an alternative to Classical Control Systems (ME EN 5200/6200), which makes use of the Laplace transform to analyze and design single-input/single-output systems, state-space methods enable us to analyze and design multi-input/multi-output systems in time domain. We will consider both continuous-time and discrete-time equations. 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, that 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.), for example ME EN 3210 or ME EN 5200/6200. 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.telerobotics.utah.edu/index.php/StateSpaceControl

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.

Homework:
There will be a homework assignment most weeks, typically assigned on Friday and typically due the following Friday, at the 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, 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 a good effort). **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 not do any homework assignments. I suggest that you attempt at 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. Groups of students who work together have the right to ask a fellow student to leave their study groups if that student does not contribute to their group.

Labs:
There will be a few hands-on labs to demonstrate the methods we learn on a real system. These labs will be discussed in more detail throughout the semester. Labs can be done on the students' time. Make sure to leave the lab clean, and report any problems with the lab to the instructor.

Exams:
There will be two midterm exams during the semester and one 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 10% penalty. Students have two weeks after receiving an exam score to contest the exam grade. After that time, no changes will be made.

Accommodations will be arranged if a student has a special requirement due to a disability. It is the responsibility of the student to request these accommodations and provide documentation specifying the arrangements from the University of Utah Center for Disability Services.

Grading:

Homework:	25%
Lab:	10%
Exams:	65%

Students **must pass** each individual component (Homework, Lab, and Exams) with at least a 65% 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., C-), will be given a D+ for the final course grade.

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

Method 1: 20% + 20% + 25% = 65%

Method 2: 10% + 10% + 45% = 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.

A Culture of Respect:

State-Space Control Systems 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 controls, but rather, it is to facilitate your learning. 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 (I will answer questions in the hallway outside of class for anybody who wants to stick around). Please come to office hours with specific questions. It is not reasonable to expect private lectures at office hours. If you arrive at office hours and another student is already in my office, please come in and listen to the conversation (you may get one of your questions answered before you even ask it).

If desired, questions of a personal nature and questions not regarding course material can be discussed at a meeting by appointment, outside of office hours.

COLLEGE OF ENGINEERING GUIDELINES

http://www.coe.utah.edu/wp-content/uploads/pdf/faculty/semester_guidelines.pdf **Spring Semester 2016**

Appeals Procedures

See the Code of Student Rights and Responsibilities, located in the Class Schedule or on the UofU Web site for more details

Appeals of Grades and other Academic Actions
If a student believes that an academic action is arbitrary or capricious he/she should discuss the action with the involved faculty member and attempt to resolve. If unable to resolve, the student may appeal the action in accordance with the following procedure:

1. Appeal to Department Chair (in writing) within 40 business days; chair must notify student of a decision within 15 days. If faculty member or student disagrees with decision, then,
2. Appeal to Academic Appeals Committee (see http://www.coe.utah.edu/current-undergrad/appeal.php for members of committee). See II Section D, Code of Student Rights and Responsibilities for details on Academic Appeals Committee hearings.

Americans with Disabilities Act (ADA)

The University of Utah seeks to provide equal access to its programs, services, and activities for people with disabilities. If you need accommodations in a class, reasonable prior notice needs to be given to the instructor and to the Center for Disability Services, 162 Olpin Union, 581-5020 (V/TDD) to make arrangements for accommodations. All written information in a course can be made available in alternative format with prior notification to the Center for Disability Services.

Repeating Courses

When a College of Engineering class is taken more than once, only the grade for the second attempt is counted. Grades of **W, I, or V** on the student's record count as having taken the class. Some departments enforce these guidelines for other courses as well (e.g., calculus, physics). See an advisor or departmental handbook. Students should note that anyone who takes a required class twice and does not have a satisfactory grade the second time may not be able to graduate.

Withdrawal Procedures

See the Class Schedule or web for more details ** Please note the difference between the terms "drop" and "withdraw". Drop implies that the student will not be held financially responsible and a "W" will not be listed on the transcript. Withdraw means that a "W" will appear on the student's transcript and tuition will be charged. **

Drop Period – No Penalty

Students may DROP any class without penalty or permission during the FIRST TEN academic days of the term (Friday, January 22, 2016).

Withdrawal from Full Term Length Classes
Students may WITHDRAW from classes without permission until **Friday, March 4, 2016.** Between January 22 and March 4, a "W" will appear on the transcript AND tuition will be charged. Refer to Class Schedule, Tuition and Fees for tuition information.

Withdrawal from Session I & Session II
See the web page for details:
http://registrar.utah.edu/academic-calendars/spring2016.php

Withdrawals **after March 4** will only be granted due to **compelling, nonacademic emergencies**. A petition and supporting documentation must be submitted to the Dean's Office, 1602 Warnock Engineering Building. Petitions must be received before the last day of classes (Tuesday, April 26, 2016).

Adding Classes

Please read carefully: All classes must be added within two weeks of the beginning of the semester (deadline: Friday, January 22). Late adds will be allowed January 17-22, requiring only the instructor's signature. Any request to add a class after January 22 will require signatures from the instructor, department, and Dean, and need to be accompanied by a petition letter to the Dean's office.
A $50 FEE WILL BE ASSESSED BY THE REGISTRAR'S OFFICE FOR ADDING CLASSES AFTER January 22. ***

Wk	Date	Topic	Reading	HW
1	12-Jan	Introduction		
	14-Jan	Continuous-time LTI Systems	1, 2.1-2.6	
2	19-Jan	Forming state-space models (a review)	2.5-2.7	
	21-Jan	Discrete-time LTI systems	2.8-2.9	
3	26-Jan	Linear Algebra Basics	3.1-3.3	
	28-Jan	Similarity Transformations	3.4	HW1 Due
4	2-Feb	Jordan Form	3.5	
	4-Feb	Linear Algebra Advanced Topics	3.6-3.11	HW2 Due
5	9-Feb	Solutions of continuous-time equations	4.1-4.2.0	
	11-Feb	Solutions of discrete-time equations	4.2.1-4.3	HW3 Due
6	16-Feb	Equivalent state-space equations	4.4	
	18-Feb	Realizations	4.5	HW4 Due
7	23-Feb	Input-output stability	5.1-5.3	
	25-Feb	Internal stability	5.4,5.5*	HW5 Due
8	1-Mar	Controllability	6.1-6.2	
	3-Mar	**Midterm Exam 1 (Chapters 1-4, HW 1-5)**		
9	8-Mar	Observability	6.3	
	10-Mar	Kalman Decomposition	6.4	HW6 Due
10	15-Mar	**No class, Spring Break**		
	17-Mar	**No class, Spring Break**		
11	22-Mar	More on Controllability and Observability	6.5-6.7	
	24-Mar	Control with state feedback	8.1-8.3	HW7 Due
12	29-Mar	State estimation	8.4	
	31-Mar	Feedback from estimated states	8.5	HW8 Due
13	5-Apr	MIMO state feedback	8.6-8.8	
	7-Apr	LQR Method	handout	HW9 Due
14	12-Apr	Kalman Filter (discrete-time)	handout	
	14-Apr	**Midterm Exam 2 (Chapters 5-8, HW 5-9)**		
15	19-Apr	Kalman Filter (continuous-time)	handout*	
	21-Apr	**No class, Design Day**		HW10 Due
16	26-Apr	Review for Final Exam		
17	4-May	**Comprehensive Final Exam: 8:00-10:00**		

Note: reading assignments with an * do not need to be completed by students enrolled at the 5000 level.