Automatic Control
ECE441A-541A

Jonathan Sprinkle

Day/Time: MWF 8:00-8:50 am
Location: Harvill 302

http://www.ece.arizona.edu/~ece441/

Instructor: Jonathan Sprinkle
ECE 456N
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Office Hours: 1:00-2:00 pm, Monday
9:00-10:00 am, Wednesday
And by appointment.
Instructor may cancel office hours **without** advance email notice.

Textbook(s): *Modern Control Systems* 12th ed., R.C. Dorf and R.H. Bishop. ISBN: 978-0136024583.
Feedback Control Theory (1st Edition), J.C. Doyle, B.A. Francis, and A.R. Tannenbaum (graduates only).

Prerequisites: ECE 340, advanced standing or graduate status.

I want you to learn and respect the tremendous potential of control theory to transform problems into solutions at a societal scale. I hope to make the material fun and approachable, to encourage you to continue to pursue this topic. I want you to succeed in this course, and this syllabus will help you understand the work required to do so.

Course Description:

Linear control system representation in time and frequency domains, feedback control system characteristics, performance analysis and stability, and design of control. The set of topics and areas covered by this course, and upon which you may be tested, include:

- Modeling and Approximation: differential equations or transfer functions for dynamical systems; linearization of nonlinear dynamical systems; approximations of system step response; block diagrams for system representation.
- System Definition: state transition and system matrices; role of overshoot, settling time, steady-state error, rise-time, peak-time of transient responses; translation of design specifications into pole locations in the frequency domain.
- Analysis: steady-state error and how system parameters influence it; Routh array; stability of a closed-loop system; system sensitivity to various parameters; root locus of a transfer function; phase margin and gain margin.

- Design: analog controllers through root locus; analog PID to satisfy design specifications; analog controllers using Bode plots; full-state feedback gains to meet design specifications.

In addition to the previous topics, ECE541A students may be evaluated on the following set of topics:

- Mathematical Rigor: proofs of various design guidelines; utility of signal norms as principal characteristics of a controller.
- Robust Control: analysis techniques for controllers with plant or other uncertainty.
- Project: analysis and design on a relevant *novel* control systems topic, using rigorous mathematics to prove properties of the system or to validate design goals, presented in the form of a conference paper. Project ideas may be developed with the instructor or graduate advisor.

Students with Disabilities:

Most students learn in this course through direct lecture on the board, and through completion of homework assignments. This year I am also adding limited online videos of worked problems, and derivations that will be skipped in class, in favor of examples to be performed in class.

If you anticipate issues related to the format or requirements of this course, please meet with the instructor to discuss ways to ensure your full participation in the course. If disability-related accommodations are important for your learning in this course, it is very important that you be registered with the Disability Resource Center (621-3268; http://drc.arizona.edu) and afterward notify the instructor of your eligibility for reasonable accommodations. Only after that point can we plan how to best coordinate any accommodations.

Important Dates:

T 9/3	Last day to add classes for credit from zero units
Su 9/22	Last day to drop courses resulting in deletion of course enrollment from record
Su 10/20	Last day to drop a class with a grade of "W" (if passing) or to change to or from audit grading; the instructor's signature on a Change of Schedule form is required
W 12/11	Last day of classes and laboratory sessions
W 12/18	8:00–10:00 am, Final Examination

Course Outline:

The listing of weekly course lecture topics may be found on the webpage, and is subject to change without notice due to class progress. In the event of class cancellation, advance notice *via email* will be given, but any homework due that day will still be due unless otherwise notified via email.

Grade Policy:

ECE441A		Grade Demarcation	
Homework:	10%	[90 – 100]	A
Examinations:	75%	[80 – 90)	B
Attendance/Participation/Pop Quizzes:	5%	[70 – 80)	C
Lab Experiments	10%	[60 – 70)	D
		[0 – 60)	E

ECE541A		Grade Demarcation	
Homework:	10%	[90 – 100]	A
Examinations:	75%	[80 – 90)	B
Attendance/Participation/Pop Quizzes:	5%	[70 – 80)	C
Lab Experiments	5%	[60 – 70)	D
Project	5%	[0 – 60)	E

Examination breakdown is 15% (each) for three term exams, and 30% for the final exam. Assignment of grades is done according to a "modified-contract" method. The above scale represents a minimum guarantee. However, the instructor reserves the right to "upward curve" the final grade of the entire class, or of one or more individuals whose objective performance improves as the term progresses.

Homework Companion

The homework must be submitted according to the guidelines set forth by the Homework Companion (available from the course webpage). Failure to abide by the Homework Companion may result in a failing grade on that homework, regardless of the correctness of the work.

Project Companion:

Graduate Students will perform work on a course project which will be of significant value as deemed appropriate by the instructor. The course project will be submitted via the terms of the Project Companion, which will be distributed as described in the Schedule of Weeks.

Attendance, Participation, and Pop Quizzes:

Your active participation in this class will aid in your comprehension of the topics, and set a standard for active learning the rest of your life. You are encouraged to take notes (even if the lecture notes will be available) as you will learn and remember more when you write it down.

Attendance is mandatory. Although the class roll may not be taken every day, pop quizzes *may* be given without notice. Pop quizzes may not be made up. You are expected to review previous lecture notes, as well as read assigned materials, before class. *Pop quizzes may be based on material assigned for reading, but not yet covered in class.*

Please silence your cell phone, and do not use it during the class. The use of a phone in class will adversely affect your attendance grade.

Academic Integrity:

Students are expected to do all work by themselves, except when specified by the instructor in writing. All exceptions to this policy will be plainly marked in the requirements for that exercise or project. Any violations of this policy will be dealt with to the full extent permitted by the University of Arizona, and *may result in suspension or expulsion from the university, in addition to a failing grade.* Please familiarize yourself with the Code of Academic Integrity if you have any questions (see http://deanofstudents.arizona.edu/codeofacademicintegrity).

ABET Classifications

Learning Outcomes

By the end of this course, the student will be able to:

1. model, via differential equations or transfer functions, electrical, mechanical, and electromechanical dynamical systems. (Exam 1)
2. linearize a set of nonlinear dynamical equations. (Exam 1)
3. create a second-order model from a system's step response. (Exam 1)
4. construct all-integrator block diagrams from a transfer function, a set of differential equations, or a state-space representation and vice-versa. (Exam 1)
5. construct and interpret the Routh Array. (Exam 1)
6. sketch the root locus associated with a transfer function. (Exam 2)
7. determine the stability of a closed-loop system. (Exam 2)
8. calculate the phase margin and gain margin of a system from its frequency response (Bode plots). (Exam 2)
9. compute a state transition matrix from a system matrix. (Exam 2)
10. describe in terms of percent overshoot, settling time, steady-state error, rise-time, or peak-time how the poles of a second-order continuous-time system influence the transient response. (Exam 2)
11. translate design specifications into allowable dominant pole locations in the s-plane. (Exam 2)
12. calculate a systems steady-state error and how the steady-state error can be influenced via system parameter changes. (Exam 2)
13. analyze stability using state-space techniques (Exam 3)
14. calculate a systems sensitivity with respect to different parameters.
15. design analog controllers using root locus techniques. (Exam 3)
16. design a system utilizing the observable canonical form. (Exam 3)
17. design an analog PID controller to meet design specifications. (Exam 3)
18. design analog controllers using Bode plot techniques. (Exam 3)
19. design full-state feedback gains to achieve acceptable closed-loop behavior.

Program Outcomes

The following program outcomes are satisfied by this course:

(a) an ability to apply knowledge of mathematics, science, and engineering (HIGH)

(b) an ability to design and conduct experiments, as well as to analyze and interpret data (MEDIUM)

(c) an ability to design a system, component, or process to meet desired needs (LOW)

(d) an ability to function on multi-disciplinary teams (MEDIUM)

(e) an ability to identify, formulate, and solve engineering problems (MEDIUM)

(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice (HIGH)