ECE441A/541: Automatic Control

§ Course Details

Instructor	Gregory Ditzler, Ph.D. (Dept. of ECE)
Instructor Email	ditzler@email.arizona.edu
Course Website	https://d2l.arizona.edu/
Lecture Times	8AM-8:50AM
Lecture Room	R. P. Harvill Bldg, Rm 204
Instructor Office Hour	ECE Bldg 556D Monday: 1PM-2PM Friday: 1PM-2PM All other times are by appointment only.

§ Description

This course provides an introduction to the fundamental concepts and mathematics of control systems engineering. Through the semester we will cover linear control system representation in time and frequency domains, feedback control system characteristics, performance analysis and stability, and design of control.

§ Textbook

- (**required; all**) *Modern Control Systems*, 12th Edition, R.C. Dorf and R.H. Bishop, Prentice Hall, Upper Saddle River, NJ, 2011.
- (**reference; graduate**) *Feedback Control Theory*, J. Doyle, B. Francis, A. Tannenbaum. http://www.control.utoronto.ca/people/profs/francis/dft.pdf

§ Software

You will be required to use Matlab[1] to work on assignments throughout the course. Matlab is available for your local computer if you install it with the University of Arizona's site license. Computer in the labs also have Matlab. *We will NOT cover "how to program in Matlab," rather, you are expected to know it or pick it up.*

§ Grading

Your final numerical grade will be computed as follows.

Homework	10 points (5 points for 541a)
In class exams	60 points
Final exam	25 points
Lab Assignments	5 points
Project	5 points (541a only)
Total	100 points

Your course letter grade will be assigned based on your final numerical grade as follows.

90	100	A
80	89	B
70	79	C
60	69	D
0	59	E

[1] http://www.mathworks.com/

The above scale represents a minimum guarantee. At my discretion, I may curve course grades up (but not down). My intent with grading is to reward fair effort with fair credit, in short, I aim to be reasonable. Exams missed by the students cannot be made up unless prior arrangements have been made with the instructor. Make-up exams are evaluated on a case-by-case basis.

§ **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 system's 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 system's 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)

§ Course Outline

- Course Description and Introduction (Chapter 1)
- System Modeling (Chapter 2)
  - Electrical & Mechanical Components (2.2), Electromechanical Systems (2.5)
  - Current-Force Analogy, Gears and Levers
  - Linearization (2.3)
- System Descriptions and Manipulation (Chapter 2 & 3)
  - Transfer Function Descriptions (2.4, 2.5, 2.6) (Assumed known from ECE320a)
  - Simulations of Systems (2.10)
  - Block Diagram Algebra (2.6)
  - System Identification and Frequency Response (Exam 1)
  - State-Space Representation (3.2, 3.3) (Assumed known from ECE320a)
  - State Transition Matrix (3.7)
  - Mason's Gain Formula (3.4, 3.5)
- Feedback System Characteristics (Chapter 4)
  - Sensitivity (4.2)
  - Initial Value Theorem (4.5) (Assumed known from ECE320a)
  - Tracking (4.5)
  - Steady-state Error (4.5, 5.7)
- System Performance (Chapter 5) and Stability (Chapter 6)
  - Specifications (rise time, overshoot, steady-state error, and settling time) (5.3)
  - Pole locations and Time Response (2nd Order Systems) (5.3)
  - Routh-Hurwitz Test (6.2) (Assumed known from ECE320a)
  - Reative Stability (6.3)
  - Time-domain Stability (6.4) (Exam 2)

- Root Locus Analysis (Chapter 7) and Controller Design (Chapter 10)
  - Root Locus Construction Rules (7.1, 7.2, 7.3)
  - Examples (7.4) (Homework 6)
  - Root Locus Phase Lead Design (10.5)
  - Root Locus Phase Lag Design (10.7)
- Bode Analysis (Chapter 8) and Controller Design (Chapter 10)
  - Bode Plot Construction Rules (8.2, 8.3) (Assumed known from ECE320a)
  - Frequency Response Measurements and Performance (8.4, 8.5)
  - Stability Margins (9.4)
  - Phase Lead Bode Design (10.4)
  - Phase Lag Bode Design (10.8)
- PID Controller Design (12.6, 12.7) (Exam 3)
- State Feedback Deign (Chapter 11)
  - Full State Feedback (11.2, 11.5)
  - Internal Model Design (11.8)
  - Observer Design and Observer-based Compensator Design (11.3, 11.6, 11.7)

§ Academic Integrity

Students are responsible for completing homework assignments by themselves, but may work on strategies to complete the assignments with other students. You are encouraged to work in teams on homework assignments, but copying a completed assignment of another student and submitting it as your own is considered a violation of academic integrity—and it will hurt you when it comes to the exams. Any take-home examinations *may not consist of any group work, even for problem strategies.*

Additional 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).

§ Accessibility and Accommodations

It is the University's goal that learning experiences be as accessible as possible. If you anticipate or experience physical or academic barriers based on disability or pregnancy, please let me know immediately so that we can discuss options. You are also welcome to contact Disability Resources (520-621-3268; http://drc.arizona.edu) to establish reasonable accommodations.