ECE 441a/541a
Automatic Control
Fall Semester 2023
Class Numbers: 40140/61686/40141/46890

Instructor: Dr. Hal Tharp
Office: ECE 523
e-mail: tharp@arizona.edu
Office Hours: Mondays & Fridays 11:00pm-12:00pm via Zoom ID: 858 7385 9167
Lectures: MWF, CAPLA 103, 2:00pm-2:50pm and Zoom ID: 859 3055 5851
Course Web-Site: d2l.arizona.edu

Course Description: Linear control system representation in time and frequency domains, feedback control system characteristics, performance analysis and stability, and design of control. Prerequisite: ECE 320A.

Justification: Automatic control is a very general subject that has wide-spread application due to its multidisciplinary nature. Relatively speaking, control is a somewhat young discipline, since most of the control activity started to appear around the time of World War II. Control theory has put a man on the moon, sent spacecraft exploring, kept satellites in orbit, enhanced terrestrial travel, increased manufacturing efficiency and capabilities, and improved everyday living via disk drive control, environmental control of buildings, and medical device applications, to only name a few applications. This course will begin your journey into this field and lay the foundation for your own contributions in control. The material is fun, yet challenging. I hope you enjoy the course!

Teaching Philosophy: I want each and every one of you to succeed in your career. One way to better prepare for success is to learn how to learn new material on your own. You can start that process by developing strategies you find effective for your learning. Everyone learns differently. But, the more problems you attempt and solve, the more likely you will be able to learn the material and succeed in this class. I try to remember your knowledge-base at this stage of your career and help you bridge the gap between your previous knowledge-base and the new material in this class. I want you to gain confidence in your ability to work and solve control-related problems in this course. This confidence should then spill over into other areas of study and follow you through your career.

Tips for Success: I will expect you to work hard in this class. In terms of time commitment, you should be prepared to spend at least 2-3 hours outside of class for every hour inside of class. You should read the appropriate sections of the textbook before coming to class. You should also review the previous lecture notes, before the next class period. The homework problems should be read and studied (for understanding) and attempted the night they are assigned. The problems are not designed to be done the night before they are due. You should attempt and turn in all of the homework assignments. To prepare for the exams, you should examine and study the homework and previous exam material days before the scheduled exam. If you have questions during the semester, you are encouraged to ask them in class or during my office hours.

Texts: (Available from "Course Resources" on D2L)

"Modern Control System Theory and Design," 2nd Edition, Stanley M. Shinners, Wiley-Interscience, Hoboken, NJ, 1998. ISBN: 0-471-24906-8. (Available as e-Book through University of Arizona library: lib.arizona.edu , Title search using: "Modern Control System Theory and Design." Permalink: https://arizona-primo.hosted.exlibrisgroup.com/permalink/f/1h28lag/TN_cdi_safari_books_v2_9780471249061)

For ECE 541a, "Feedback Control Theory," John C. Doyle, Bruce A. Francis, and Allen R. Tannenbaum, Macmillan, 1992. ISBN-10: 0-02-330011-6. (On-line: http://www.control.utoronto.ca/people/profs/francis/dft.pdf or via "Library Tools" tab on D2L course site. Permalink: https://arizona-primo.hosted.exlibrisgroup.com/permalink/f/6ljalh/01UA_ALMA51527654690003843)

Other References:

"Feedback Systems: An Introduction for Scientists and Engineers," by Karl J. Astrom and Richard M. Murray, Princeton University Press, Princeton, N.J. , 2008, ISBN: 978-0-691-13576-2. (Available as an on-line download (Second Edition or First Edition): www.cds.caltech.edu/~murray/amwiki.) The book can also be accessed via the University of Arizona Library by performing a Title search using "Feedback Systems: An Introduction for Scientists and Engineers."

Wikibook: "Control Systems," (Available as an on-line book or pdf: http://en.wikibooks.org/wiki/Control_Systems)

"Schaum's Outline Series: Feedback and Control Systems," by Joseph J. DiStefano, Allen R. Stubberub, and Ivan J. Williams. ISBN: 0070170479.

"Modern Control Systems," Thirteenth Edition by Richard C. Dorf and Robert H. Bishop, Prentice-Hall, 2017. ISBN-13: 978-0-134-40762-3.

Generative Artificial Intelligence (AI) Policy: Use these Large Language Model based tools (ChatGPT (chat.openai.com), Bard (Bard.google.com), etc.) to help you understand challenging topics/content within the course material, or to build/refresh your foundational knowledge to help you understand more advanced concepts. Don't use AI to cheat. Use AI as a tool to help you learn. Sometimes these AI tools will be wrong or will hallucinate and produce inaccurate information. Please confirm the accuracy of the output generated from these tools. Also, you should acknowledge your use of the tools (which one(s)) and explain how the tools were used and what you learned while using these tools.

Mask Policy: Face coverings are recommended in the classroom. Please refer to the COVID-19 website for up-to-date information.

Absence and Attendance Policy: The UA's policy concerning Class Attendance, Participation, and Administrative Drops is available at: http://catalog.arizona.edu/policy/class-attendance-participation-and-administrative-drop.

The UA policy regarding absences for any sincerely held religious belief, observance or practice will be accommodated where reasonable, http://policy.arizona.edu/human-resources/religious-accommodation-policy.

Absences pre-approved by the UA Dean of Students (or Dean Designee) will be honored. See: http://deanofstudents.arizona.edu/absences

Participating in course and attending lectures and other course events are vital to the learning process. As such, attendance is required at all lectures and discussion section meetings. Students who miss class due to illness or emergency are required to bring documentation from their healthcare provider or other relevant, professional third parties. Failure to submit third-party documentation will result in unexcused absences.

Accessibility and Accommodations: Our goal in this classroom is that learning experiences be as accessible as possible. If you anticipate or experience physical or academic barriers based on disability, please let me know immediately so that we can discuss options. You are also welcome to contact Disability Resources (520-621-3268) to establish reasonable accommodations. For additional information on Disability Resources and reasonable accommodations, please visit http://drc.arizona.edu/.

If you have reasonable accommodations, please plan to meet with me by appointment or during office hours to discuss accommodations and how my course requirements and activities may impact your ability to fully participate.

Please be aware that the accessible table and chairs in this room should remain available for students who find that standard classroom seating is not usable.

Classroom Behavior Policy: To foster a positive learning environment, students and instructors have a shared responsibility. We want a safe, welcoming and inclusive environment where all of us feel comfortable with each other and where we can challenge ourselves to succeed. To that end, our focus is on the tasks at hand and not on extraneous activities (i.e. texting, chatting, reading a newspaper, making phone calls, web surfing, etc).

Students are asked to refrain from disruptive conversations with people sitting around them during lecture. Students observed engaging in disruptive activity will be asked to cease this behavior. Those who continue to disrupt the class will be asked to leave lecture or discussion and may be reported to the Dean of Students.

Threatening Behavior Policy: The UA Threatening Behavior by Students Policy prohibits threats of physical harm to any member of the University community, including to one's self. See: http://policy.arizona.edu/education-and-student-affairs/threatening-behavior-students.

Code of Academic Integrity: Students are encouraged to share intellectual views and discuss freely the principles and applications of course materials. However, graded work/exercises must be the product of independent effort unless otherwise instructed. Students are expected to adhere to the UA Code of Academic Integrity as described in the UA General Catalog. See: http://deanofstudents.arizona.edu/academic-integrity/students/academic-integrity.

The University Libraries have some excellent tips for avoiding plagiarism available at: http://new.library.arizona.edu/research/citing/plagiarism.

Selling class notes and/or other course materials to other students or to a third party for resale is not permitted without the instructor's express written consent. Violations to this and other course rules are subject to the Code of Academic Integrity and may result in course sanctions. Additionally, students who use D2L or UA email to sell or buy these copyrighted materials are subject to Code of Conduct Violations for misuse of student email addresses. This conduct may also constitute copyright infringement.

UA Nondiscrimination and Anti-harassment Policy: The University is committed to creating and maintaining an environment free of discrimination, http://policy.arizona.edu/human-resources/nondiscrimination-and-anti-harassment-policy

Our classroom is a place where everyone is encouraged to express well-formed opinions and their reasons for those opinions. We also want to create a tolerant and open environment where such opinions can be expressed without resorting to bullying or discrimination of others.

Additional Resources for Students:

UA Academic policies and procedures are available at: http://catalog.arizona.edu

Student Assistance and Advocacy information is available at:

http://deanofstudents.arizona.edu/student-assistance/students/student-assistance

Subject to Change Statement: Information contained in the course syllabus, other than the grade and absence policy, may be subject to change with advance notice, as deemed appropriate by the instructor.

Examinations: There will be three single-period examinations and one comprehensive final examination. No make-up exams will be given. A grade of zero will be given for a missed exam. Re-grading of an exam must occur within one week after the graded exam is returned. If there are any problems or questions, see the instructor. For the on-line students, the exams will be taken remotely.

Homework: Ten assignments are planned during the semester. Homework will be due by 11:59pm on its due date.

Determination of Final Grade: Your final grade in this course is based upon your rank in the class, that is, a system of *curving* is used. After each exam, the test distribution will be made available from which you can assess your performance.

(Unless an announcement is made otherwise, the examinations will be held on the following dates.)

Exam #1	(September 22)	20%
Exam #2	(October 20)	20%
Exam #3	(November 17)	20%
Homework		10% (5% for 541A)
Lab Experiments		5%
Project (ECE 541A only)		5%
Final Exam	(December 8) (1:00pm – 3:00pm)	25%

Laboratory Reports are Due:

Lab #1	System Identification and Modeling	October 2
Lab #2	System Performance	October 30
Lab #3	Controller Design	November 27

Class Cancellations:

M	September 4	Labor Day
F	November 10	Veteran's Day
F	November 24	Thanksgiving Recess

ECE Program Outcomes: ECE 441A/541A addresses the following ECE Student Outcomes.

1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics (Homework, Exams)
2. An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety and welfare, as well as global, cultural, social, environmental, and economic factors (Homework, Labs, Exams)
5. An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives (Labs)
6. An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions (Homework, Labs, Exams)
7. An ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

ECE 441A/541A Course Outcomes and Outline Fall 2023

Automatic Control 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. compute a state transition matrix from a system matrix. (Exam 2)
6. 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)
7. translate design specifications into allowable dominant pole locations in the s-plane. (Exam 2)
8. calculate a system's steady-state error and how the steady-state error can be influenced via system parameter changes. (Exam 2)
9. construct and interpret the Routh Array. (Exam 2)
10. determine the stability of a closed-loop system. (Exam 2)
11. calculate a system's sensitivity with respect to different parameters. (Exam 2)
12. sketch the root locus associated with a transfer function. (Exam 3)
13. design analog controllers using root locus techniques. (Exam 3)
14. design an analog PID controller to meet design specifications. (Exam 3)
15. calculate the phase margin and gain margin of a system from its frequency response (Bode plots). (Exam 3)
16. design analog controllers using Bode plot techniques. (Exam 3)
17. design full-state feedback gains to achieve acceptable closed-loop behavior. (after Exam 3)

ECE 441A/541A Course Outcomes and Outline Fall 2023

Course Outline:

Course Description and Introduction (Chapt. 1)

System Modeling (Chapt. 3)
- Electrical and Mechanical Components (3.2, 3.3), Electromechanical Systems (3.4)
- Current-Force Analogy, Gears and Levers -- **(Homework 1)**
- Linearization (Chapt. 19, Schaum's Outline)

System Descriptions and Manipulation (Chapt. 2)
- Transfer Function Descriptions (2.11,2.12,2.13) (Assumed known from ECE 320A)
- Simulation of Systems
- Block Diagram Algebra (2.14)
- System Identification and Frequency Response -- **(Homework 2 & Exam 1)**
- State Space Representation (2.21)
- State Transition Matrix (2.26)
- Mason's Gain Formula (2.14)
- State Diagram (2.19) -- **(Homework 3)**

Feedback System Characteristics (Chapt. 5)
- Sensitivity (5.3)
- Final Value Theorem (2.6) (Assumed known from ECE 320A)
- Tracking
- Steady-State Error (5.4) -- **(Homework 4)**

System Performance and Stability (Chapt. 5)
- Specifications (Rise time, Overshoot, Steady State Error,Settling Time)
- Pole-locations and Time Response (2nd-order System) (Chapt. 4)
- Routh-Hurwitz Test (6.3)
- Relative Stability
- Time Domain Stability (6.14) -- **(Homework 5 & Exam 2)**

Root Locus Analysis and Controller Design (6.14)
- Root Locus Construction Rules
- Examples -- **(Homework 6)**
- Root Locus Phase-lead Design
- Root Locus Phase-lag Design -- **(Homework 7)**

Bode Plot Analysis (6.7) and Controller Design (7.6)
- Bode Plot Construction Rules (Assumed known from ECE 320A)
- Frequency Response Measurements and Performance -- **(Homework 8)**
- Stability Margins
- Phase-lead Bode Plot Design
- Phase-lag Bode Plot Design

PID Controller Design (7.4) -- **(Homework 9 & Exam 3)**

State Feedback Design (Chapt. 8)
- Full State Feedback (8.2)
- Internal Model Design
- Observer Design and Observer-based Compensator Design (8.7) -- **(Homework 10)**